WORLD CLIMATE RESEARCH PROGRAMME

PROCEEDINGS OF THE INTERNATIONAL CLIVAR CONFERENCE

(Paris, France, 2-4 December 1998)

WCRP-109
WMO/TD No.954
ICPO No. 27
June 1999

ICSU WMO UNESCO

The World Climate Programme launched by the World Meteorological Organisation (WMO) includes four components:

The World Climate Data and Monitoring Programme
The World Climate Applications and Services Programme
The World Climate Impact Assessment and Response Strategies Programme
The World Climate Research Programme

The World Climate Research Programme is jointly sponsored by the WMO, the International Council of Scientific Unions and the Intergovernmental Oceanographic Commission of UNESCO.

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TABLE OF CONTENTS

COUNTRY REPORTS

REGIONAL REPORTS

APPENDIX:

PREFACE

The completion of the very successful International CLIVAR conference in Paris, December 2-4 1998, brings to fruition the intensive planning phase within CLIVAR and launches the implementation phase. At the conference, it was apparent that the CLIVAR global themes and the Principal Research Areas are of central importance to many countries around the world, as evidenced by the extent to which national plans were organised around these themes.

The interest in CLIVAR is at a high level but it will be a challenge to carry out the ambitious plans that have been laid out. The conference attendees reaffirmed their confidence that wise investments by countries in monitoring and research into the climate system will benefit their citizens and economies. A key point is to recognise the tremendous benefits that international coordination of otherwise fragmented efforts can bring to observe, model, understand and predict, to the extent possible, the climate variations that are so important to socio-economic activities and the environment. The potential is there, the prospects are exciting for scientists, and the continuing devastation that results from continuing climate events provides a constant reminder of the need.

This report provides a very useful record of the interests in CLIVAR around the world and the plans underway. However, it should be noted that a few countries with active CLIVAR programmes are not included because they were unable to send a representative to the conference and/or did not meet the publication deadline for a written report. The report can be used as a basis for seeking out other activities around the world that complement those of your own country. The International CLIVAR Project Office is charged with helping to coordinate these kinds of endeavours. It can best do so by being kept informed about the latest plans, and the Scientific Steering Group has requested the ICPO to obtain annual updates. We look forward to realising the successes of the CLIVAR programme with you.

Kevin E. Trenberth
R. Allyn Clarke
Co-chairs CLIVAR SSG

FOREWORD

International CLIVAR Conference
UNESCO, Paris, 2-4 December 1998

It is my distinct pleasure and privilege to introduce this report of the International CLIVAR Conference, held at UNESCO, Paris, 2-4 December 1998.

CLIVAR is a major component of the World Climate Research Programme (WCRP), which is co-sponsored by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC) of UNESCO and the International Council of Science (ICSU). It focuses on the role of the coupled ocean and atmosphere within the overall climate system, with emphasis on variability, especially within the oceans, on seasonal to centennial time-scales. In particular, CLIVAR aims to explore predictability and how to improve predictions of climate variability and climate change, using observational data, coupled atmosphere-ocean models, and palaeoclimate records. A major milestone in the development of CLIVAR was the publication in June 1998 of its Initial Implementation Plan, which was the main preparatory document and justification for the subsequent International Conference.

In the letter of invitation to attend this Conference, the Organising Committee set seven main objectives for the Conference. In brief, these were: to present CLIVAR objectives to delegates; to explain the project to potential supporters, including potential funders; to highlight to national delegations the benefits of international collaboration that CLIVAR will foster; to receive national expressions of interest; to provide guidance to the Joint Scientific Committee (JSC) of the WCRP and, in particular, to the CLIVAR Scientific Steering Group; to consider intergovernmental mechanisms to facilitate the implementation of CLIVAR; and, to identify national and other contacts. In closing the Conference, I was pleased to note that all seven objectives had been addressed during the meeting, and nearly all had been achieved, although with varying degrees of success.

Our first notable achievement was that the Conference attracted 250 participants from 63 countries. These constituted a good geographical spread and included both countries that stated their intention to conduct active CLIVAR research and those which expected to benefit from it. In this context, the undoubted major success was the receipt and presentation of many national statements of interest in CLIVAR. This provided a most welcome boost to those engaged directly in the lengthy and difficult development of the CLIVAR project, and was a most significant step forward. The main views and the strength of support from the delegates are evident in the Conference Statement, which was crafted and agreed in Paris.

Only one objective met with little meaningful progress, namely, the consideration of an intergovernmental mechanism to facilitate the implementation of CLIVAR. This was discussed only briefly and superficially at the Conference, and the decision was taken to refer it to the JSC of the WCRP. It remains important that this issue be given a more thorough airing in that forum, with full consideration given to the needs, in this context, of both CLIVAR and the wider WCRP.

Conferences such as this do not simply ‘happen’. Therefore, on behalf of all those who participated, I take this opportunity to express our gratitude to all those who contributed in their many and various ways to ensure that the Conference was a success. In particular, I thank our local hosts and co-sponsors, IOC and UNESCO, and our other co-sponsors, WMO and ICSU. I thank also the staff of the WCRP Office in Geneva, and at the CLIVAR Offices in both Hamburg and Southampton. Special acknowledgment must go to our Keynote speakers, whose ready acceptance of our invitation to help set the context and tone for the Conference provided timely encouragement and support to the Organising Committee. I thank also those CLIVAR scientists who came to promote the concept of CLIVAR through oral and poster presentations, and other informative contributions.

Finally, I wish to thank all the delegates who prepared, submitted and presented National Statements and entered fully into discussions and debate throughout the Conference. Your particular participation and

contributions have given a very clear and positive signal of general and widespread support to the CLIVAR Project and its Scientific Steering Group. The challenges now are to harness this support and to implement CLIVAR.

David Carson
Chairman
Conference Organising Committee

Conference Organising Committee

D. Carson (Chair) Director, NWP, UKMO

R. Davis, Scripps Institute of Oceanography, U.S.A

D. Goodrich, Executive Director, U.S. Global Change Research Programme

J. Jouzel, Laboratoire de Modelisation du Climat, France

A.D. Moura , Director, I.R.I. U.S.A.

A. Sumi, CCSR / University of Tokyo, Japan

I. Troen, SDME, 7/40 European Commission, Belgium

Ex-officio members

A. Alexiou (IOC)

R.A. Clarke (CLIVAR co-Chair)

W.J. Gould (ICPO)

K.E. Trenberth (CLIVAR co-Chair)

PROGRAMME

International CLIVAR Conference
Paris December 2-4 1998

Day 1:	***Wednesday, 2 December***
0800-0900	Registration
Session Chair	***Dr. David Carson***
0900-0945	Opening address – Deputy Secretary General of the World Meteorological Organization
	Statement by the Executive Secretary of the Intergovernmental Oceanographic Commission of UNESCO
	Statement by the Representative of the International Council for Science
0945-1015	Global environmental change and the need for international research programmes
	Dr. Bert Bolin, Sweden
1015-1045	The position of CLIVAR within the WCRP
	Dr. Hartmut Grassl, WCRP, Geneva
1045-1115	*Coffee*
Session Chair	***Prof. Akimasa Sumi***
1115-1145	Conference structure and objectives
	Dr. Allyn Clarke, CLIVAR SSG Co-Chair
1145-1230	The evolution of the CLIVAR Science
	Dr. Kevin Trenberth, CLIVAR SSG Co-Chair
1230-1400	*Lunch*
Session Chair	***Dr. Antonio Moura***
1400-1445	Seasonal-interannual prediction and predictability
	The 1997/8 El Niño/La Niña
	Dr. Ants Leetmaa, NCEP, USA
1445-1530	Seasonal-interannual prediction and predictability
	Towards the prediction of monsoon variability
	Dr. Victor Magana Rueda, UNAM, Mexico
	Dr. Peter Webster, U Colorado, USA
1530-1600	*Coffee*
Session Chair	***Dr. Dave Goodrich***
1600-1630	Decadal variability in the ocean-atmosphere system
	Dr. Jürgen Willebrand, IfM Kiel, Germany
1630-1700	Long term climate variability and the detection and attribution of anthropogenic effects
	Dr. Suki Manabe, FRSGC, Japan
1700-1815	Explanation of the CLIVAR Principal Research Areas
	G1-G4 **Dr. Edward Sarachik,** U Seattle, USA
	D1-5 **Dr. Antonio Busalacchi,** NASA, GSFC, USA
	A1-2 **Dr. John Mitchell,** Hadley Centre, UK
	CLIVAR/Pages **Dr. Jean Jouzel,** LMCE, France
	The need for a programme infrastructure
	Dr. John Gould, ICPO
1815 onwards	Opportunity to view and discuss posters that will highlight each of the PRAs and illustrate the work of CLIVAR-related programmes and organisations
1900	Cocktail reception hosted by IOC

Day 2:	***Thursday, 3 December***
0900-0915	Introduction to the days business
Session chairs	***Dr. Art Alexiou, Dr. Ib Troen, Dr. John Gould, Dr. Hartmut Grassl***
0915-1730	Presentations by national delegations These will be presented in (French) alphabetical order
Day 3:	***Friday, 4 December***
0900-1100	Panel question and answer session on CLIVAR science and organisational issues **Panel Members** Chair Dr. Lawrence Gates Dr. L Bengtsson Dr. A Clarke Dr. J Gould Dr. V Magana Dr. S Manabe Dr. N Smith Dr. K Trenberth
1100-1130	*Coffee*
1130-1300	Continuation of discussion if needed Reports on national statements from rapporteurs
1300-1415	*Lunch*
Session Chair	***Dr. Jean Jouzel***
1415-1500	Sustained observing systems for the atmosphere and ocean **Dr. Neville Smith,** BOM, Australia
1500-1545	Climate modelling and prediction - achievements and challenges **Dr. Lennart Bengtsson,** MPI, Germany
1545-1615	*Coffee*
Session Chair	***Dr. David Carson***
1615-1645	Final keynote address **Dr. Michael Hall,** NOAA, OGP, USA
1645-1715	Close

CONFERENCE STATEMENT

Preamble

Delegates from 63 countries met in Paris on 2-4 December 1998 to consider the implementation of the World Climate Research Programme (WCRP) project on Climate Variability and Predictability (CLIVAR).

Floods, droughts, storms and heat waves have brought major social and economic distress to communities around the world in recent years. In 1997-98 we experienced one of the largest El-Niño events ever recorded. There has also been an increasing and wider awareness of the importance of climate-related phenomena. 1998 is emerging as the warmest year in the instrumental record. A new assessment of the scientific evidence for global warming by the Intergovernmental Panel on Climate Change (IPCC) is now under way. Governments everywhere are focusing attention on the potential impacts of climate change and how they can be mitigated. The Framework Convention on Climate Change and the Kyoto Protocol include Articles referring to the need for research and systematic observations.

Scientific activity over the past few years has increased confidence in our ability to understand the functioning of the climate system and to make useful predictions. Recently many meteorological agencies and scientific institutions have begun to issue regular climate predictions. Improved monitoring and global models enabled scientists to predict the onset and development of the recent El Niño, thus protecting lives and livelihoods. CLIVAR will be the foremost research project in these important areas.

The Scientific Challenge

The climate of the Earth exhibits natural variability on all time scales. We need to understand, and to the extent possible, predict this variability and quantify long-term climate change. The Conference endorsed the overall scientific objectives of CLIVAR which are to:

- Describe and understand the physical processes responsible for climate variability and predictability on seasonal, interannual, decadal and centennial time scales, through the collection and analysis of observations and the development and application of models of the climate system;
- Extend the record of climate variability over the time scales of interest, through the assembly of quality-controlled palaeoclimate and instrumental data;
- Extend the range and accuracy of seasonal to interannual climate prediction through the improvement of global and regional climate models; and
- Understand and project the response of the climate system to increases of greenhouse gases and aerosols and to compare these projections with the observed climate record in order to detect any anthropogenic modification of the natural climate signal.

Commitments Required

To achieve these objectives the Conference considered that it essential that there must be:

- continuation of the collaboration of scientists around the world that led to the successful implementation of previous WCRP programmes and projects;
- full and open exchange of data (in keeping with World Meteorological Organisation Cg-XII Resolution 40) as well as of research results;
- long-term systematic climate observations, both space-based and in-situ, such as the Global Climate,
- Ocean and Terrestrial Observing Systems (GCOS/GOOS/GTOS), as are being advocated by the agencies collaborating in the Climate Agenda, complemented by the observing activities and assembly of research data sets as fostered by the WCRP;

- experimental extension of existing observing networks;
- regional and global-scale experiments including modelling, statistical studies and observations in order to understand key climate processes;
- comprehensive analysis of observations and empirical/diagnostic studies as well as expanded efforts to rehabilitate climate data sets and to document past climate variability through palaeo-studies;
- the development of improved regional and global-scale models and of computers with the power to run them;
- continuing links with programmes on the application of climate knowledge, such as the WMO Climate Information and Prediction Service (CLIPS), for government, business and public policy and decision-making;
- expanded collaboration with other international activities including relevant core projects (e.g. on Past Global Changes, PAGES) of the International Geosphere-Biosphere Programme (IGBP), and the International Human Dimensions Programme (IHDP);
- continuing links between CLIVAR and programmes for infrastructure and capacity building in developing countries, such as the Global Change System for Analysis, Research and Training (START) , so that all nations can benefit.

Conference Conclusions

The Conference reaffirmed that wise investments by countries in monitoring and research into the climate system will benefit their citizens and economies.

The Conference commended the work that had been done by the scientists involved in planning the programme and concluded that the Implementation Plan provided a solid basis for work to begin. Contributions and reports by many countries demonstrated a willingness to participate in the programme and to become full partners in its implementation. Improved seasonal to interannual prediction, and particularly for the monsoons, as well as longer-term variability, most notably in the Atlantic, can be singled out as foci for which strong support was indicated by many countries.

The Conference urged government sponsors of research, operational meteorological agencies, and satellite operators to marshal their best efforts to ensure the success of CLIVAR. In particular it called on a broad range of funding agencies to provide support for research, systematic observations, data systems and

STATEMENT AT THE OPENING OF THE CLIVAR CONFERENCE BY PROFESSOR G.O.P. OBASI, SECRETARY GENERAL, WORLD METEOROLOGICAL ORGANIZATION

Presented by M.J.P. Jarraud

It is a pleasure for me to be able to address you today at the opening of this important Conference on the World Climate Research Programme's (WCRP) newest programme: The Climate Variability and Predictability, or CLIVAR. I would like to welcome all of you to this important Conference. May I also take this opportunity to thank Dr Federico Mayor, Director-General of UNESCO as well as Prof. Patricio Bernal, Executive Secretary of the Intergovernmental Oceanographic Commission (IOC) for hosting this event and for placing such excellent facilities at the disposal of the Conference.

WMO has always enjoyed a very co-operative and fruitful working relationship with UNESCO and its IOC, and ICSU in a number of areas of concern to humanity. Indeed, I recall addressing a similar conference held here twelve years ago to mark the beginning of one of our most successful joint ventures - the Tropical Ocean Global Atmosphere Programme, or TOGA. I am confident that this Conference will lead us on the path to an equally rewarding collaboration.

There is no need for me to remind you of the importance of climate and climate change to humanity. Over the last year the media has given considerable attention to the impact of El Niño-related floods, droughts and fires, La Niña-related hurricanes and floods, and the potential impact of anthropogenic climate change. At its fourth session, the Conference of the Parties to the UN/FCCC held recently in Buenos Aires, adopted a recommendation urging nations to undertake programmes of systematic oceanic, atmospheric and terrestrial observations in support of climate monitoring, research, and prediction. The Conference further recommended the free and unrestricted exchange of meteorological data, support for capacity-building in developing countries, and the strengthening of international and intergovernmental programmes which assist countries to acquire and use climate information.

In addition, the Conference invited the agencies participating in the Climate Agenda, the integrating framework for the climate programmes of international organizations including WMO, UNESCO and its IOC, and ICSU to initiate an intergovernmental process for addressing the priorities for action to improve global observing systems for climate and for identifying options for financial support. I look forward to joint actions of our organizations to respond to this request.

These topics will be subjects of your discussions over the next three days in the context of the CLIVAR programme, as outlined in the Science and Implementation Plans of the WMO/IOC/ICSU Joint Scientific Committee. It is gratifying that the academic community is taking a lively interest in the planning of the CLIVAR programme. In this respect, it is to be recalled that the TOGA programme, perhaps the greatest climate research undertaking so far realised, owed its success to combining the monitoring, research and development resources of the Meteorological Services, as well as those of the oceanographic, and of the academic communities under the joint sponsorship of WMO, IOC and ICSU. WMO therefore attaches the highest importance to such international collaboration, and believes that the progress achieved through such a mix of expertise in the fields of meteorology, hydrology and oceanography and related geophysical sciences from Meteorological Services, universities, academic and government institutions around the world augurs well for the success of CLIVAR. WMO also welcomes the concept integrated into the CLIVAR programme that the user and applications communities must be involved from the very beginning of climate research projects in order to realise the maximum results.

In this regard, it is to be recalled that the Conference on the World Climate Research Programme: Achievements, Benefits and Challenges (Geneva, August 1997) identified, among others, priorities related to:

1. enhanced prediction of seasonal variations of the climate system;
2. improved projections of the magnitude and rate of human-induced climate change, regional variations, detection and attribution of climate change, the magnitude of sea-level rise and the impacts on eco-systems; and,
3. increased involvement of developing countries in the WCRP.

These priorities are reflected in the objectives of CLIVAR. The successful implementation of the CLIVAR programme is therefore essential in meeting the challenges to WCRP.

In this connection, the Meteorological Services have the heavy responsibility of providing meteorological information and producing timely forecasts on all possible time scales for their national communities. It is therefore part of their mission to explore the full range of possible deterministic or statistical prediction capabilities, especially on time scales of several months or season to decades which are vital for economic purposes.

In many tropical and subtropical countries, the very livelihoods of the people may depend on the distribution and the intensity of the annual rainy season or the advent of the monsoon. Insufficient rain at the right time, or failure of the monsoon, can have catastrophic consequences for food production. In higher latitudes, accurate predictions of anomalous seasons are extremely valuable for, for example, more efficient planning of energy use, and industrial and agricultural activities.

Over the past decade, the TOGA programme has significantly advanced our understanding of the links between fluctuations in atmospheric circulation and anomalous sea surface temperatures as in the case of El Niño and La Niña phenomena. Meteorological Services around the world have applied this understanding to produce greatly improved seasonal forecasts. This success has helped WMO to develop further the Climate Information and Prediction Service (CLIPS) Project for the benefit of the producers and users of these forecasts and of climate information.

WMO is therefore looking forward with great interest to the further development of implementation plans for all WCRP activities, and especially CLIVAR which will build on the success of TOGA and take up outstanding questions, so that Meteorological Services can prepare their participation in the relevant observational projects, modelling exercises and theoretical investigations.

When reviewing and analysing the initial Plan for the implementation of the CLIVAR programme, the Conference should agree on a clear and convincing statement that will not only serve to inform interested scientists, but also constitute a compelling argument for science administrators who control the national resources needed to implement this ambitious undertaking.

I wish to assure you of WMO's commitment to work closely with the partner organisations in organising the international infrastructure and systems needed to collect and make available the necessary data and promote research and applications in collaboration with users. In this context, I can already point to the steps being taken by WMO and its partner organizations in actively pursuing the implementation of the Global Climate Observing System (GCOS), whose Secretariat is located within WMO's Headquarters building. GCOS is a long-term worldwide operational system designed to meet climate information requirements. The system complements other programmes such as the Global Ocean Observing System (GOOS) for operational oceanography and the Global Terrestrial Observing System (GTOS) for land and eco-system observations. I believe that these and other developments in observational systems such as those associated with the proposed Integrated Global Observing Strategy will enable us to look forward with confidence to real progress in meeting the extremely important goals of CLIVAR.

In conclusion, I would like to thank the Director-General of UNESCO once again for making available these excellent facilities for the Conference and wish you every success in your deliberations.

WELCOME ADDRESS BY
PARTICIO A. BERNAL
ASSISTANT DIRECTOR GENERAL OF UNESCO
EXECUTIVE SECRETARY OF IOC

It gives me a great pleasure, on behalf of the Director General of UNESCO Dr. Federico Mayor, to welcome all the participants to the first International CLIVAR Conference to the headquarters of IOC, the Intergovernmental Oceanographic Commission, here in Paris.

This is a major scientific event. It provides a fitting climax, that closes a very significant and important year, The International Year of the Ocean. I am sure that 1998 will be remembered as being the public launching of CLIVAR.

Only a few years ago it would have been a very risky proposition to organise a gathering of national representatives around a goal of predicting climate. But here we are today, in the presence of some 250 delegates from more than 20 nations, doing just that, with a high degree of confidence. We are about to accept the commitments from the scientific communities of the world to configure and plan the implementation of the most ambitious climate program ever attempted, whose ultimate goal is to understand and predict climate variability over a whole range of time scales, from months to centuries.

Until; recently, science has progressed by dividing the complexity of nature, science has progressed by being analytical. However, today, due to the clear and massive impact of our civilisation upon natural systems, and the uncertainty of the outcome of the changes triggered, science is forced to face the irreducible complexity of the natural systems that sustain life on the Planet. Science has had to get out of the classical comfort of the separate disciplines and into the multi-discipline and the inter=discipline. Science is faced with the challenge to attack the complexity of our Earth's systems, to understand their behaviour and forecast their future states.

Today we are more aware of the complexities of the Climate System, its global properties, the limits to its predictability. We are increasingly conscious of the need for sustained, long-term improved observations, to provide some of the most urgent answers demanded by society about Climate Change. We need to add to the dynamical capability of our coupled models, the empirical constraints provided by real time observational systems. This is a task in which all the nations of the world can and must participate.

This is an urgent task. For example, without a record of 100 years of improved observations in time and space, we will not be able to discern important questions about climate, and associate them to the scales of variability of the ocean. To be able to do so, we need to start now. That is why in IOC we are dedicating many of our efforts to the development of the Global Ocean Observing System. We need the observations, not only to answer these crucial questions involving natural variability, but also to monitor the further change induced by societal activities. We need to monitor the ocean not only for climate purposes but also to provide stewardship for the living marine resources and the fragile coastal zones of the world ocean.

The intergovernmental apparatus of international organisations is prepared to undertake the role of transducer between societal demands and the institutions of science and vice versa. As scientists we are involved in actions that go beyond the traditional limits of the scientific endeavour. We deal with communication, we translate specialised language into policy advice, and we translate the concerns of governments and the common citizen into clear questions for the scientific community.

The IOC, the Intergovernmental Oceanography Commission of UNESCO is ready and prepared to help in the development of CLIVAR, and to contribute to this major scientific program by leading the effort to build the observational capacity we need to have for our single and unique planetary ocean.

I wish all of you success in your deliberations.

Thank you.

GLOBAL ENVIRONMENTAL CHANGE AND THE NEED FOR INTERNATIONAL RESEARCH PROGRAMMES

Bert Bolin
Past Chairman, Intergovernmental Panel on Climate Change (IPCC)

The global environment is much talked about these days and global politics is becoming increasingly concerned with the ongoing changes. The issue of a sustainable development of human activities on earth is viewed more urgently and the approaching a new millennium further highlights these issues. Most scientists find it self-evident that the information and knowledge that science can provide should be carefully considered in this context and CLIVAR, i.e. studies of climate variability and change, may be a most important project. How can then the needs of society best be met in developing and implementing CLIVAR? I will give some personal observations from my nine years as chairman of the Intergovernmental Panel on Climate Change.

It is not surprising that the issue of global climate change has been brought to the forefront in these discussions. The systematic analyses and attempts to understand the physics of the global climate issues have been subject for international co-ordination and pursuit for about twenty five years, i.e. since the discussions began as part of the Global Atmospheric Research Programme, GARP, jointly sponsored by ICSU and WMO, in the early part of the 1970's. The organisation of global efforts to understand the biogeochemistry of the environment began about ten years later, when the International Geosphere Biosphere Programme, IGBP, got under way. The human dimension of global environmental changes is being addressed by the International Human Dimensions Programme, IHDP, in more specific terms only since the beginning of this decade. We have now reached the stage when the development of global integrated models of the earth system as a whole is being considered as meaningful. As a matter of fact the global climate change issue is in that regard sort of a forerunner of Sustainable Development.

Scientific research in the field of climate change and its assessment by the IPCC has been the prime basis for political decisions so far and the issue has quickly been brought high up on the political agenda . Still, the IPCC has been very careful in its assessments not to go beyond the conclusions that have been presented in the scientific literature, on which the assessments have been based. The key has been to separate clearly between what can be said with confidence and what is still uncertain. It is important to point out that there are many uncertainties especially in projections into the future with regard to the timing, magnitude and regional patterns of climate change as emphasised by the IPCC 1992 assessment. This policy has earned the scientific community credibility in the political process and it should be a guide also in the future.

The 1995 assessment included a statement that part of the global climate change, that had occurred during the latter part of the 20th century, could be attributed to human activities, but the conclusion was formulated with great care. A key issue in this context has been the assessment of the likely magnitude of the random variations of climate, that occur without a human influence. This has recently been much clarified by the work of Mann et al., who have convincingly shown that the variations of the global mean temperature on decadal to century time scales during the last 600 years are $\pm 0.2^{\circ}$ C or less. Now one can rather ask those, who still are sceptical about a human contribution to climate change during the last 50-75 years, to explain the significantly larger global warming during recent decades. This change of the burden of proof is most essential. There may be other conclusions from the research efforts that can be reformulated in a similar manner.

However, in the presentations by heads of state both to the third (Kyoto) and fourth (Buenos Aires) Conferences of the Parties to the Convention, references were often made to ongoing and readily observed changes of weather and climate, e.g. droughts in California, Spain, Mozambique, Australia; flooding in the Mississippi river basin, Germany, China; destructive tropical hurricanes; most recently in Honduras and Nicaragua; unusual El Niño events. Media and politicians associate almost any of these with an ongoing human-induced global change of climate. The derivation of proper statistical analyses of rare and extreme phenomena in a chaotic system, such as the climate system, is, however, a complicated undertaking. A more thorough analysis would be most welcome to bring home more precisely how such observations should be interpreted. In the meantime scientists shall have to stick to the view that some of these phenomena might be associated with such an ongoing global change, but that we can usually not as yet tell to what extent this is so. The IPCC has, however, based on a number of scientific studies, pointed out that extreme events might become more frequent globally, but not been able to pinpoint particularly vulnerable regions.

How can this situation be improved? An insight might be gained by more detailed comparisons of the occurrence of extreme events in control experiments, assuming constant greenhouse gas concentrations, and in experiments with increasing greenhouse gas concentrations. Climate models with good spatial and temporal resolution are then required. Ensembles of experiments might also be desirable in order to permit more trustworthy conclusions, because different models behave differently and because of the uncertainties that arise when initialising such experiments. I realise of course that this would mean setting aside appreciable computational resources. Such efforts would, however, be of considerable scientific interest and certainly of importance for the further work by the Climate Convention. It would also be helpful for individual countries in their planning for a likely future climate change.

Agriculture and forestry at middle and high latitudes are primarily dependent on the characteristics of the summer season, while in the tropics the dry and wet seasons are decisive. Scaling down the global or regional changes that are foreseen to the variability of weather and inter-annual variations of the seasons is going to be important and the questions naturally arise: How well can this be done in the light of the rather marked regional differences between the outcomes of different global model experiments? What kind of statistics would be most informative? How could risk analyses be developed to assist in the transformation of model results on regional and local climate change and variability into information for the public, the business community and politicians? This is most important because there will never be accurate predictions of climate change.

As a matter of fact, the work by the scientific community sometimes does not adequately recognise the national political issues, nor those that are being subject for international negotiations. I accept of course that the formulation of the problems that should be given priority in the scientific pursuit must not be dictated from the outside, but sometimes more could perhaps be done to aid the political process. This is certainly much needed.

Most of the issues dealt with in Kyoto and Buenos Aires are largely short-term issues. Questions about what might happen beyond the year of 2010 were not much considered, if at all. Because of the inertia of the climate system as well as the socio-economic system, possible changes during the next several decades should, however, be carefully evaluated to aid the decisions about further measures to be taken. The years following the completion of the Third Assessment Report (TAR) by the IPCC, due in 2001, until 2005, a control year on the way towards the goals as agreed in Kyoto for the five year period 2008-2012, should be focused on such issues.

I know of course that developing countries have strongly opposed accepting obligations before developed countries have taken the lead in attempting to mitigate climate change as required by the Climate Convention. I accept that it is premature to start negotiations in the near future about longer-term commitments. It is, however, urgent to provide scientific analyses that focus on likely scenarios and their implications for, say, the years 2010-2030, assuming that the obligations for countries until 2010 as specified in the Kyoto protocol are met. I note that a continuation of the rate of emission increases by developing countries during the first six years of the 1990's until 2010, while developed countries are implementing the Kyoto Protocol would lead to about equally large emissions by developing and developed countries in 2010, i.e. about 4.1 Gt. C per year each. The rate of increase of global emissions at that time would not be much less than at present.

It would be particularly interesting to understand better how the socio-economic implications of taking specific measures depend on the rapidity of the change-over from a situation with increasing global emissions to one aiming at stabilisation of atmospheric concentrations of carbon dioxide at some alternative levels. The use of integrated models combining climate models, carbon cycle models, energy models and socio-economic models would be required. What alternative scenarios beyond 2010 might be useful under such circumstances?

The WCRP is now giving priority to the development of a next generation of integrated models. We shall certainly learn more about the complex global interplay between changes of the natural systems and society in that way. But we must not put all eggs in one basket. It will take time until such models with many more degrees of freedom will be trustworthy. There will be a need for eliminating spurious inadequacies similar to those that have shown up as a miss-match of the flux of heat between the atmosphere and the oceans, when coupling GCM's for the atmosphere and the oceans. Further, new findings about the behaviour of the earth system hundred years into the future can hardly still for quite some time be considered as more than illustrative examples of possible developments. The issue of validation will be a major difficulty when trying to use such findings in the political process.

How might regional scenarios of future changes of key climatic elements best be presented to a wider audience? In trying to answer such a question I wish to refer to some intriguing analyses that have been pursued by Tim Palmer We know that, although the climate system is chaotic, it clearly shows recurrent patterns that are well known not the least to the practising meteorologists. The El Niño in the Pacific is perhaps a phenomenon of this kind. In the 1940's Rossby coined the concept of High and Low Index of the middle latitude Westerlies of the Northern Hemisphere, essentially describing the changes between an intense and a weak westerly jet stream. The latter was characterised by blocking anticyclones in the late winter and spring, preferentially over Europe and the eastern parts of the Atlantic, and in the eastern parts of the Pacific Ocean.

The characteristics of such patterns of atmospheric motions presumably are partly determined by permanent features of the climate system such as the distribution of land and sea, mountain and ice sheet configurations, temporal and spatial distribution of solar radiation, and so on, in combination with the characteristics of the large scale dynamics of the atmosphere and the sea. The question arises: Can the changes of the global climate system that are occurring at present, and presumably more so in the future, be described by a rather limited set of some kind of eigen-functions, which catch the major features of such patterns of change? Perhaps these can be described as changes of the intensity and frequency of their occurrence. They might also reflect some quasi-stable states of motion that are equivalent to different modes of motion that appear in chaos theory and that Lorenz drew attention to already long ago. I do not know. If, however, real and of importance, they might be a useful in order to describe changes of the global climate. They would have the distinct advantage that geographical interdependence of climate changes would be better described, as compared with traditional statistical descriptions in terms of a most likely change and a range of variability.

But climate change and variability is more than physical changes of the environment. The response of the climate system to human emissions of carbon dioxide, puts biogeochemistry, and variability and change of the carbon cycle, high on the priority list for research during the next decade. Few models have as yet dealt with the mutual interplay between the carbon cycle and the climate system adequately.

For example: The temporary global cooling, that was caused by the eruption of Mount Pinatubo in the Philippines, influenced the carbon cycle. What does this mean in a more general context? We do not yet know well to what extent the capacity of the oceans as a sink for the carbon dioxide emissions due to fossil fuel burning might be modified by global warming. The stabilisation of the uppermost layers of the oceans, particularly in polar regions, might slow down the rate of uptake and therefore influence the increase of atmospheric concentrations of carbon dioxide. If so, how quickly might this occur? Within decades or rather during the latter part of next century? The role of the marine ecosystems for the CO_2 uptake might be influenced by the availability of micro-nutrients (e.g. iron). It is obviously not enough to determine the instantaneous change of the transfer into the surface layers, but the redistribution of the carbonate in the oceans may bring about secondary changes, the analysis of which will require model experiments. Ocean circulation variability may influence the carbon cycle significantly. All these responses would influence the global radiative forcing and thus the global warming.

Another set of issues arise directly from the Kyoto negotiations. Countries are allowed to deduct some of the uptake by terrestrial ecosystems within their own territory, particularly by forests, from their emissions due to fossil fuel burning. Some fear and perhaps rightly so, that the lack of more detailed knowledge about these ecosystems, especially the carbon turnover in soils, could be exploited inappropriately.

The Convention has asked the IPCC to produce a Special Report on this matter already within about a year. I don't think that there is enough analyses reported in the scientific literature to permit an evaluation of the magnitude of these sinks (or sources) with adequate accuracy and how to specify the rules to be applied in order to quantify them. The importance of variability within the terrestrial ecosystems, both in space and time, represents a major difficulty that needs to be analysed much more thoroughly. This is most crucial in order to keep the negotiations well-founded in scientific knowledge. One can already see how single papers in the scientific literature, the validity of which have not been assessed adequately yet, are exploited in the political debate. This is not the way science should be used.

Several of the remarks I have made here require the use of integrated models in order to be answered properly. I wish to emphasise, however, that there is still a major difference between models that describe the physics, chemistry and biology of the environment on one hand, and socio-economic models on the other. The former are based on fundamental knowledge about the behaviour of the natural systems, but are of course still approximate. The latter, e.g. macro-economic models that project future carbon dioxide emissions, describe the economic development assuming for example the rate of economic growth, population increase, rate of efficiency increase in industry, relative prices of primary energy supply, etceteras. The outcome of model experiments should therefore be viewed as scenarios that describe possible futures. They are not predictions. For this reason I don't think we should use the word "prediction" about results from transient experiments with climate models. When based on such emissions scenarios. In the political domain they will be interpreted as true predictions. For this very reason it is also misleading to show a single global scenario of this kind without indicating the range of uncertainty and the reasons for such uncertainties. We must keep in mind that there will never be accurate climate predictions, but scenarios can still be most useful as a basis for analysis of risks.

Anyone who has attended meetings of the Conference of Parties to the Climate Convention or any of its Subsidiary Bodies knows that the interpretation of the scientific findings by delegations are very simplified and usually address only some rather few selected issues that are politically "hot". There are many misunderstandings in the course of negotiations and a good grasp of key issues develops only gradually. The use of scientific information in the political process is not going to be successful if merely transmitting scientific findings. A continuous dialogue between politicians and the scientific community is a necessity.

There is a tendency to exaggerate or, on the other hand, ignore the knowledge base that science is providing. However, the climate change issue is obviously by many not considered to be that urgent that more stringent measures are required as yet. The outcome of the Buenos Aires meeting shows that very clearly. I doubt if this attitude will change much before new scientific findings and another assessment report by the IPCC will be available.

What we as scientists should do in the meantime is to pursue the scientific work such as now outlined in CLIVAR and in doing so also focus on matters that are politically important. Above all we must learn to summarise what we know in simple and effective terms without violating the scientific truth as we know it.

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CONFERENCE STRUCTURE AND OBJECTIVES

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As co-chair of the CLIVAR Scientific Steering Group, I would like to welcome you all to the CLIVAR Conference.

This is the third time that UNESCO has hosted a Scientific Conference in order to initiate a WCRP program. Interested nations and scientists came to the TOGA Conference in 1984 and to the WOCE Conference in 1988 and now, a decade later for the CLIVAR Conference. These International Conferences are organized to provide the scientific community an opportunity to respond both as nations and individuals to initial implementation plans that had been developed for these programs through several years of scientific meetings and workshops.

On the two earlier occasions, nations brought their own ideas and plans to these Conferences and told the international steering groups:

- what they liked about their implementation plans and what they didn't,
- where they would commit resources, where they might commit resources and where they wouldn't,
- how they were organizing nationally and regionally to contribute to the program,
- how they wanted to interact as nations with the ongoing development and implementation of these programs.

The TOGA and WOCE SSG's left their Scientific Conferences with a good idea of what nations were likely to support within their Initial Implementation Plans. From that information, they identified key gaps in support, modified their plans where that was possible, persuaded nations to fill those gaps where the gap was critical and went forward to successfully implement these large and complex climate research programs. The CLIVAR SSG hopes that nations respond to this Conference in the same spirit as your predecessors did in 1977 and 1988.

CLIVAR is the successor to TOGA and WOCE; it is particularly appropriate that we come before you, in Paris, to present our Initial Implementation Plan for your consideration and your response.

In this same building, WG1 of the IPCC is just completing their first meeting of lead authors for the third assessment of climate change. This group of scientists is assessing what new things we have learned about the climate system over the past five years. Today, the CLIVAR Conference is discussing the establishment of a new Climate Research program under the WCRP which will conduct coordinated research on these issues over the next decade and a half.

How is the Conference organised?

For the rest of today, a series of talks, will provide you with the broad scope of CLIVAR science issues and implementation strategies. One half day of talks will not adequately cover a program as broad as CLIVAR. Outside this Conference hall are posters providing greater detail on the PRA's and some of the CLIVAR's sister programs. These talks and posters will provide overviews on what is in the CLIVAR Science and Initial Implementation Plans. We hope that you will take advantage of these posters during coffee breaks as well as the reception this evening to ask questions and express your ideas on particular aspects of CLIVAR.

In your packets, you have been given a copies of the statements that nations have brought to this meeting. Tomorrow, many of these nations will be give brief presentations to you. The Conference organizing committee and the SSG has asked a number of its members and others who have been active in the planning of CLIVAR to listen to those presentations and to read these national statements so that they can provide this meeting with an initial assessment as to what parts of CLIVAR nations are prepared to come together and support now and what parts are going to require more work before nations are prepared to support them.

On Friday morning, there will be an opportunity to address questions to a number of people that have been involved in the planning of CLIVAR and its sister programs. You are asked to submit your questions in writing today or tomorrow.

Following coffee on Friday, there will be raporteur reports and you will be presented with a Conference Statement for your consideration and debate. Copies of an initial draft Conference Statement, are available at the registration desk. Dr. John Stone, Canada has agreed to lead a small working group to arrive at a final draft for presentation to the meeting on Friday morning. The members of this working group are: Dr Larry Gates, Dr Lennart Bengtsson, Dr Allyn Clarke, Dr John Gould, Dr Victor Magana, Dr Syukuro Manabe, Dr Neville Smith and Dr Kevin Trenberth.

They would appreciate receiving all comments on the statement by the end of the afternoon coffee break on Thursday. Comments (written please) can be given directly to working group members or left at the registration desk.

After lunch on Friday, three speakers will tell you of their vision of the future for global climate observations, modeling and prediction to send you away from Paris full of enthusiasm to transform your national plans and intentions to a coordinated international climate program.

I thank you all for coming to this Conference and hope that we all have an interesting and productive meeting.

THE EVOLUTION OF CLIVAR SCIENCE

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1. Introduction

1998 is the International Year of the Ocean. What better way to celebrate the end of this year than by affirming a major commitment to research on the oceans and their role in climate under CLIVAR.

The World Climate Research Program (WCRP) at the fourteenth session (March 1993) of the Joint Scientific Committee established the 15 year Climate variability and predictability (CLIVAR) program. With the successful TOGA (Tropical Oceans-Global Atmosphere) programme ended (in 1994) but yet to exploit the observing system developed for seasonal-to-interannual prediction, with the field phase of WOCE (World Ocean Circulation Experiment) over, and with the 1995 Intergovernmental Panel on Climate Change (IPCC) scientific assessment for the study of Anthropogenic Climate Change (ACC) completed, it was time to take stock and, rather than continue to do what we were doing, examine where we are going and set new directions. This meant carefully considering the outstanding scientific questions, how to address them, and assessing the scientific opportunities and readiness to seize them. In the CLIVAR scientific community, led by the Scientific Steering Group (SSG), we have done this. And so over the past three years, following the publication of the CLIVAR Science Plan, through workshops, working group and Panel meetings, the CLIVAR SSG has put together an initial implementation plan.

CLIVAR focuses on the role of the coupled ocean and atmosphere within the overall climate system, with emphasis on variability, especially within the oceans, on seasonal to centennial timescales. Consequently it addresses directly variability associated with El Niño and climate change arising from anthropogenic effects (global warming). CLIVAR intends to explore predictability and how to improve predictions of climate variability and climate change using existing, reanalysed, and new global observations, enhanced coupled ocean-atmosphere-land-ice models, and paleoclimate records. CLIVAR will promote the development of skilful regional and global predictive models and will enable a more accurate detection of anthropogenic modification of natural climate. CLIVAR will strongly support the design and implementation of global ocean and atmosphere observing systems for long-term climate research and will specifically address the variability of regional coupled ocean-atmosphere systems such as monsoons in relation to global patterns such as ENSO.

The CLIVAR objectives can be paraphrased as an overall GOAL:
To describe and understand climate variability and predictability on seasonal to centennial time scales and climate change, identify the physical processes responsible, including anthropogenic effects, and develop modelling and predictive capabilities where practicable.

The entire atmosphere, ocean, cryosphere, land surface and biosphere is interconnected. However, scientific programs need focus to be manageable. Recognizing that clouds, radiation and land surface processes are dealt with under the Global Energy and Water cycle Experiment (GEWEX) and that Arctic Climate System Study (ACSYS) covers sea ice and arctic ocean processes, CLIVAR's primary focus is the atmosphere and oceans and their interactions. Close coordination is also essential with the International Geosphere Biosphere Program (IGBP) and is already strong with the paleo community in PAGES (Past Global Changes).

2. CLIVAR research components

The CLIVAR program was initially organized into three component programs:
- *CLIVAR-GOALS: a study of seasonal-to-interannual climate variability and predictability of the Global Ocean-Atmosphere-Land System (GOALS).*
- *CLIVAR-DecCen: a study of decadal-to-centennial climate variability and predictability.*

[1] The National Center for Atmospheric Research is sponsored by the National Science Foundation.

- *CLIVAR-ACC: a study of the climate response to human-induced changes in radiatively active gases and aerosols*

As implementation of the CLIVAR program has been discussed in the science community, the shape of the CLIVAR program has evolved to blur the timescale partitioning and encourage more interaction between the natural variability and anthropogenic climate change communities. In particular, several key issues developed:

- Decadal variability of ENSO
- Effects of ACC on ENSO
- Projection of climate change onto natural modes of variability
- Observations of the dominance of similar modes (similar spatial structures) on several timescales
- Realization that projections of ACC are not credible without realistic variability, including ENSO.

Therefore the emphases that have developed are for
1) *a global framework* of global observations, dataset development, empirical and diagnostic studies, model development and numerical experimentation, and process studies; and
2) a number of focused research topics called *Principal Research Areas* (PRAs). A challenge to CLIVAR is to find the critical areas in which coordination and international infrastructure can make these research endeavours more effective and focused.

CLIVAR GOALS will extend our understanding, analytical, modelling and prediction capabilities of natural climate variability on seasonal-to-interannual time scales, building on the knowledge and experience gained in TOGA. Because GOALS has an emphasis on prediction, it will take an interest in any components of the climate system that give it a memory. Four PRAs are identified with GOALS.

CLIVAR-DecCen will focus on understanding of the physics of decadal and longer variability of the coupled climate system. Because ocean processes are very important on these timescales, and because so little is known about their role, DecCen will make a special effort to explore the role of the ocean in determining climate variability on the timescales of interest. DecCen will undertake data archaeology and paleoclimatic activities to extend the climate record to the past, support and extend climate data collection programs to continue the records into the future, and data analysis and modelling studies to describe, simulate and predict climate variability on decadal to century time scales. Five PRAs are identified for DecCen.

CLIVAR-ACC will coordinate data analysis and climate modelling studies directed at the detection, attribution and prediction of climate change due to human activity (two PRAs). All PRAs will spin off process studies and field campaigns to help achieve their objectives.

3. CLIVAR science

There is great excitement in the CLIVAR scientific community about the science to be done and the prospects for applying the results to better society. A few examples will be touched on briefly, including:

- The 1997/98 El Niño and progression into the 1998 La Niña. The observing system has proven successful but expansions may be fruitful. Dynamical models are proving useful and outdoing traditional statistical methods in predictions. Yet while predictions are improving, there is scope for doing much better. Possibilities abound!
- Monsoons affect millions with their variability. They also play a major role in the climate system through their tropical heat sources. The complexity is challenging to deal with as land surface processes are involved (bringing in collaborations with GEWEX, GCIP, GAME etc.) Many research possibilities exist for determining and exploiting predictability.
- In the extratropics, teleconnections provide hope for improved regional predictions, yet there are many issues. The predictions will be probabilistic and rely on ensembles of model runs, so a challenge is how to use and portray this information.
- Ocean variability outside the tropical Pacific is becoming documented. Patterns of Atlantic variability and

links with the North Atlantic Oscillation are promising. New tools using satellite instruments to provide global coverage of altimetry, scatterometry and ocean colour are especially encouraging. Yet satellites can not see below the surface, and so a strong ground based observing system must be developed. Going beyond XBTs and surface drifters, exciting new possibilities have emerged through the profiling floats that are deployed at various depths (such as 1500 m) and come to the surface every week or two to give soundings of temperature and salinity. Exploiting these data to produce global analyses is a task of GODAE, but the prospects for CLIVAR in improved understanding and better models for predicting aspects of decadal variability are enormous.

- Global climate models have developed so that they no longer have to be run with artificial “flux”, corrections. Yet further improvement are expected.
- Our PAGES colleagues have shown with the Greenland ice cores how abrupt climate change can be and it is vital for CLIVAR to build an understanding of this. There is a compelling need to understand and assess risk for sudden changes in climate, regionally and globally. Can global warming lead to a thermohaline circulation collapse in the Atlantic and regional cooling in Europe?
- The whole topic of global warming was highlighted last year in Kyoto. Global warming means global heating from increased greenhouse gases in the atmosphere or radiative forcing’, in IPCC parlance. It means that not only will temperatures rise but so too will evaporation and so this directly impacts precipitation and water resources. It is clear that there needs to be a solid base of science for the political decisions that still prove very thorny. The past emphasis has been on detection and attribution. Recent temperature rises, if continued, will soon make answers to those questions obvious, and attention will switch to realization that climate change is inevitable so that the climate of the future will differ from that in the past. Actual predictions of what the climate will be, not just with idealized scenarios but taking all factors (including solar radiation, land use changes, aerosol effects and biogeochemical feedbacks) into account will become top priority.

4. Implementing CLIVAR

Scientists have often been less concerned with societal needs. Nevertheless, CLIVAR science is application oriented. One major need is for more regional and local information in predictions on all time scales. Unfortunately predictability diminishes on smaller space scales. So how do we address this? Some things can be done. But often a full frontal attack is not the best approach. Rather, scientists nip at the problem around the edges by solving the problems that are ready to be solved, models are gradually improved, and we learn how to work with ensembles and the inherent probabilistic nature of the problem. It is important to recognize these things in setting priorities.

A key step in further progressing the CLIVAR implementation is the International CLIVAR Conference in Paris at UNESCO 2-4 December 1998. This will seek expressions of interest and commitments from nations, and national priorities and prospects for international collaboration and coordination will guide the CLIVAR SSG on where emphases should be placed.

CLIVAR deals with the global climate system. A global description can not be achieved without cooperation among nations. The weather and climate are inherently global, and the problems are not amenable to solution by any single nation acting alone. While many scientists just want to “get on with its”, these problems require international goodwill and collaboration. This is the role for CLIVAR. *Let us combine our resources and capabilities, share data and, while recognizing each nation’s autonomy and different emphases, do under CLIVAR the research that would not otherwise be possible.*

Acknowledgments:
CLIVAR has been planned and developed by a large number of scientists including the present and former members of the SSG, and the study group that proceeded it. Special thanks to Allyn Clarke my co-chair of the CLIVAR SSG.

THE 1997/98 EL NIÑO/LA NIÑA

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Introduction

The 1982/83 El Niño developed virtually unobserved. It wasn't until late in 1982 that it was announced that the event was going on. The expected world wide impacts were unknown and hence no possibility existed for mitigation of its impacts. The situation in 1997/98 was very different. The event was well observed and forecast, and many of the possible impacts forecast with enough leadtime that mitigation actions were taken in many countries. This was possible because in the intervening years extensive commitments were made to research, implementing an observational capability, and developing a forecasting capability. This short summary provides a retrospective view of the events that took place during the past two years and some of the insights that have been gained.

Development of the 1997/98 El Niño

A number of groups made forecasts in late 1996 that conditions in the Pacific would switch from slightly below normal temperatures in the tropical Pacific to El Niño ones the coming summer and fall. However, none of these correctly forecast the rapid growth of the event during the first part of 1997. This was a period in the equatorial regions where the intraseasonals were very active and very energetic. Suggestions are that these played a role in this rapid development. The evidence from the observations and from the forecast models by mid-1997 was convincing enough that it was announced by NOAA in June that this event would be in strength comparable to the top three of the century. Comparisons to the 1982/83 event show that it was stronger in the October to December period and comparable in amplitude in the January to March period. The fact that tropical temperatures cannot get much warmer that about 29 deg. Celsius, means that the largest that such events can get is what was observed this past year and during 1982/83. In general most of the forecasts either underestimated the rapid growth of the system, the peak amplitudes and the timing of this. Perhaps as a group they did better in estimating the start of the development of the subsequent La Niña.

Development of the global atmospheric response.

Use of atmospheric Reanalyses and a global precipitation analysis that combines satellite estimates with rain gauge measurements over land allows a global documentation of the atmospheric response and a comparison between 1982/83 and 1997/98. What is apparent from these two events is that there are dominant global patterns of response that are quite similar for the two events. Most areas of the globe are impacted indicating potential predictability even in regions not identified by previous studies. Comparison of these fields to those from weaker El Niños indicates patterns of response for the weaker events that are similar but weaker and more variable on a regional basis. This is the fundamental reason that climate forecasts need to be probabilistic. Atmospheric responses to similar El Niños of El Niños of different amplitudes are in a global sense similar but can differ in regional impacts on rainfall and temperature distributions.

Regional forecasts for temperature and rainfall variations

Using the forecasts for El Niño several groups made forecasts for global and/or regional seasonal variations in rainfall and temperature. All of these were probabilistic. Because of improved physical understanding and improved atmospheric general circulation models (AGCM), the forecasts were based both on empirical estimates of the regional impacts of El Niño and on output from ensembles of AGCM runs. As was the case for the global patterns, regionally, especially for the United States, there are dominant patterns of variations that El Niños on average produce. However, these were modified in sub-regions to incorporate what the AGCM forecast were indicating might be deviations from a canonical response. In general these forecasts showed skill, especially in areas where El Niño has been shown to have consistent impacts. In many areas of the globe local and state authorities invested million of dollars to help mitigate the impacts that were being forecast with great success. This was especially true in California in the U.S. and Peru. As indicated earlier the expected skill for weaker events will be less.

Extreme events and El Niño

Many areas of the globe experienced 100 year kinds of impacts. The physics of how this occurs varies from the tropics to midlatitudes. In midlatitudes the impacts of El Niño in the areas that received above normal rainfall were the result of an increase in the number of rain events and in their intensity. So not only does El Niño shift the seasonal means for rainfall totals but it also enhances the likelihood of extremes. Also the impacts can be of an unexpected nature such as the extreme ice storm in the northeast U.S. and the strong tornadoes in the southeast. Also there was major impact on hurricanes/tropical cyclones. In the Atlantic almost no hurricanes were observed during the heart of the season in 1997 while in 1998, when La Niña conditions were beginning to have an impact, a very active season was observed. In the eastern Pacific the number of storms was about average but the paths were much longer taking them into areas that normally didn't experience them. An unexpected occurrence was the rapid transition in the southern U.S. from excess rainfall (100 year records) during winter and early spring to 100 year type of drought conditions from late spring to early summer. This appears to be the impact of anomalously high ocean temperatures in the far eastern Pacific and their impact on the atmospheric circulation in this region. This was occurring at a time that a La Niña was starting to develop in the central Pacific.

The impending La Niña

La Niña conditions started to develop in the central eastern Pacific in mid-May 1998. Currently a moderate amplitude La Niña is in place. Many areas of the globe have already experienced La Niña impacts. Excess rainfall has been experience over much of the maritime continent. As for the El Niño global forecasts are available of next several seasons. The impacts are not expected to be as intense as those during the last El Niño. In general for El Niño the amplitude of the impacts goes up with the size of the event whereas for La Niñas this seems to be much less so.

TOWARDS THE PREDICTION OF MONSOON VARIABILITY

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A basic description of the basic processes related to monsoon variability, noting that it is a coupled oceanic-terrestrial-atmospheric phenomenon, is done. The structure of the monsoon as a function of temporal scale was examined, noting that there exists and interdependence on temporal scales.

The monsoon regions hold more than 60% of the global population. Here, the very regularity of the monsoon cycle makes agriculture susceptible to small changes in the annual cycle. A weak monsoon year generally corresponds to low crop-yields.

Rainfall variability in the monsoon regions occurs in four major regimes:

- Short-term disturbances (2-5 days)
- Medium or intraseasonal periods (10-40 days)
- Interannual variability
- Interdecadal variability

Each longer term variation tends to modulate variations occurring at higher frequencies. For instance, a strong monsoon year more or prolonged active periods. Therefore, forecasting the timing of the onset of the monsoon and the subsequent active and break periods is critical in agrarian monsoon societies.

There are several theories about why the monsoons vary from year to year:

1) The monsoon is a “slave” to external forcing of ENSO
2) The monsoon is forced to be stronger weak depending on the state of show cover or sail moisture on the Eurasian Continent during spring.
3) The main differences between the impact of ENSO on the monsoon in Africa, Asia, Australia and the Americas are a function of phase. It is known that ENSO and monsoons are related buy not precisely.
4) Interannual variability is the result of inherent coupled ocean-atmosphere instabilities on marginal seas around monsoon regions (e.g. Indian Ocean).

There are other forms of interannual variability in monsoons, such as the tropospheric biennial oscillation (TBO)

Relationships between ENSO and monsoons also show a large degree of interdecadal variability. It is clear then that monsoons posses great variability. It is less clear why the variability occurs. Quite possibly the monsoon varies by the imposition of remote forcing and by its own variability inherent in the coupled ocean-atmosphere system in some combination.

Modelling the monsoons and predicting their variability is one of the great scientific challenges. Several approaches are used for climate prediction. Some techniques are based on empirical analyses and some are based on numerical modelling.

There is some disagreement on the degree of predictability of the monsoons or whether they are predictable at all. There exists a great need for good data to evaluate and improve climate models. Process studies as JASMINE in the Indian Ocean and EPIC in the Eastern Pacific are good examples of field experiments for process studies to understand air-sea interactions and monsoons.

A comprehensive prediction system requires active interaction of the physical scientists who make the climate predictions, and the applications and human dimensions community, who use and apply the predictions. Overall, an end-to-end prediction system embodies many aspects of the physical scientific community, the social sciences, and the user community. The scheme, in essence, is interactive between all components and it evolves with time as the needs of the user community change and as scientific advances are made.

DECADAL VARIABILITY IN THE OCEAN-ATMOSPHERE SYSTEM

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1. Introduction

In comparison to seasonal and interannual climate variability, the understanding of the dynamics and the limits of predictability over decadal and centennial time scales is much less advanced. The obvious reason is of course that at these longer time scales it becomes very difficult to make observations that cover the full cycle of variability, and that the information from past observations is usually not sufficient, both in coverage as well as in quantitative accuracy. The CLIVAR Science Plan has identified a number of mechanisms which can generate natural variability at these time scales:

a) *Stochastic atmospheric forcing*
The chaotic nature of atmospheric circulation patterns can induce long-term variability of climate parameters, and in particular also of air-sea fluxes. The origin of variability is in the atmosphere, but at long time scales variability can be strongly amplified by the oceanic response, and we may expect that any predictability must come from the oceanic component. Under this mechanism, changes in ocean circulation patterns have no dynamical feedback to the atmosphere, but they can be of interest in their own right, and also may serve to monitor changes of the full system.

b) *Internal ocean variability*
Studies with ocean models have indicated several feedback processes that may cause variability of the ocean circulation which is not forced by atmospheric variations but could lead to consequences in the atmospheric circulation. Time scales for these processes range from decadal to centennial and even millenial. The mechanism seems to be most relevant in connection with long-term changes of the thermohaline circulation in the Atlantic.

c) *Coupled oscillations*
Both foregoing mechanisms are idealisations, as in reality we always have a coupled system. In contrast, however, coupled atmosphere-ocean variability arises from the interaction between ocean and atmosphere, analogous of El Niño. The processes discussed so far mainly involve interaction of the wind-driven circulation in subtropical gyres with the atmospheric circulation.

Of specific interest is the possibility that abrupt transitions between different climate states may occur. These may be caused by changes in atmospheric fluxes, by oceanic processes, or through other mechanisms (e.g., interaction with the cryosphere). Almost all processes discussed so far involve the ocean thermohaline circulation (see Rahmstorf et al. (1996) for a more complete discussion).

In the following discussion emphasis is on situation in the North Atlantic, although there are related phenomena in other parts of the globe. Note that the above list is not complete; a thorough discussion of the mechanisms capable of generating DecCen variability can be found e.g. in the review by Sarachik et al. (1996).

2. North Atlantic oscillation

A most basic mechanism for the generation of long-term variability is through atmospheric forcing fluctuations. Due to the inherent nonlinearity of the atmospheric circulation, the strong random variability at synoptic time scales can extend to very long periods. The atmospheric variability is associated with characteristic spatial patterns which seem to be only weakly dependent on time scale, and show substantial variations not only from year to year but also on decadal timescales. The temporal variability of these atmospheric variations is not unlike that of a white-noise stochastic process, although even in purely atmospheric models the energy may somewhat increase towards lower frequencies (James and James 1989). A well-known example for this mechanism is the North Atlantic Oscillation (NAO), but similar patterns exist in other regions as well. The ocean is subject to the associated air-sea fluxes, and essentially integrates the atmospheric variability, resulting in SST variability which is strongly amplified towards longer time scales compared to those of the forcing spectrum (Hasselmann 1976). There is no doubt that this process is going on at all times. The relative roles of fluctuations in heat and freshwater fluxes are not fully clear, on decadal time scales heat flux anomalies seem however to be dominant. A convenient index for the NAO is the winter surface pressure difference between Iceland and Lisbon for which an instrumental record exists since 1864 (Hurrell 1995). The 1980's and early 90's were characterized by a high index, i.e. high pressure difference. During this time the westerlies were stronger than normal, and brought more rain and mild temperatures to western and northern Europe, but cold conditions (polar air) over eastern N-America. As a consequence, corresponding changes occurred in the ocean (Dickson et al. 1999), as e.g. a stronger North Atlantic current and a stronger inflow of warm Atlantic surface waters into the Norwegian Sea-Arctic ocean, the absence of deep convection in Greenland Sea but strong convection in Labrador Sea, to mention but a few. Conversely, during the low-index phase in the 60's and 70's, weak westerlies prevailed, with more frequent cold and dry conditions in western/northern Europe, more precipitation over Mediterranean, and mild conditions over eastern N-America. In the ocean the North Atlantic current was weaker by 15 Megatons per second (a considerable amount by oceanographic standards), inflow into Norwegian Sea-Arctic ocean was weaker, and deep convection was strong in the Greenland Sea but absent from the Labrador Sea. Evaluation of the NAO-index from model calculation (A.Hense, 1999, pers.comm.) suggests a preference for high index values in a greenhouse warming scenario in the next century. This study is insofar interesting, as the reason for the climate change in this model is clearly anthropogenic (greenhouse forcing), but the response manifests itself through a natural mode of the system.

It is also possible to look into the more distant past with help of the NAO-Index. Stockton and Glueck (1998, pers.comm.) have reconstructed the NAO-Index from 1429 - 1983 with annual resolution, by using tree ring data from Morocco (which reflect cool season precipitation) and Finland, and most important oxygen isotopes from the GISP2 ice core. These proxies were calibrated with the instrumental record. Interestingly, this reconstruction showed decadal variability (maximum energy at 25-30 years) but little centennial variations.

3. Thermohaline circulation and internal ocean variability

The thermohaline circulation (THC) in the Atlantic is frequently viewed as part of a global 'conveyor' circulation. The THC is responsible for most of the oceanic heat transport, its variations are therefore potentially of great relevance for climate change. While variations of the THC during the last decades, and likely also during the last 10,000 years, have probably been minor, the paleo record indicates that the THC may have stopped during the last glacial on time scale of a few decades, accompanied by significant changes in climate conditions.

The principal dynamical characteristic of the THC is its strongly nonlinear behaviour. That nonlinearity is connected to several feedback processes (see Marotzke, 1996), and is relevant for most aspects of DecCen variability involving the THC. Of particular interest is the hysteresis behaviour which implies that transitions between different climate states of the thermohaline circulation are possible. Model results indicate that a transition between those states could occur in less than 10 years (Doescher & Redler, 1997). As a consequence, the gradual but substantial reduction of the thermohaline circulation which is suggested in several greenhouse scenario calculations (e.g. Manabe & Stouffer, 1993) may ultimately lead to a persistent state without a significant Atlantic overturning, even if the forcing anomaly should cease. While there is little evidence that the present state of the thermohaline circulation is near a critical transition point, the conditions under which a rapid breakdown of the thermohaline circulation is dynamically possible need further investigation.

Model studies have indicated that variability of the ocean circulation may exist independently of the atmosphere but could lead to consequences in the atmospheric circulation. Conceptually, one may distinguish between two principal ways in which instabilities within the ocean can operate. The destabilising positive feedbacks which are responsible for the existence of multiple equilibrium states can also lead to oscillations between those states, provided that some process is active which prevents the system to permanently stay in those states. The time scale is often related to the strength of external fluxes, with stronger forcing corresponding to shorter time scales. The other possible instability mechanism does only need a negative feedback (of which any system has plenty). Its crucial ingredient which also sets its time scale is a delay which may come about e.g. through advection or wave processes in the ocean. In complex models different mechanisms can interact, and it is not always easy to attribute variability to a single cause.

Experiments with 3-d ocean models with idealized basin geometry have confirmed that thermohaline variability can indeed exist even in the presence of constant atmospheric forcing, and a considerable number of studies has resulted in oscillations at decadal, centennial and millenial time scales. Suffice it to mention the deep decoupling oscillation (Winton and Sarachik 1993) which has been found in ocean models with idealized geometry and somewhat simplified dynamics. It involves an oscillation between two near-equilibrium states, one where the THC is strong (the coupled phase), and one where the THC is weak (the decoupled phase). During the strong phase the THC is gradually reduced due to the freshwater forcing. Ultimately, the high-latitude conditions become such that the convection breaks down, similar to a polar halocline catastrophy, and the THC becomes very weak. Subsequently, the deep ocean is diffusively heated over a time of order 1,000 years (depending on the strength of diapycnal mixing), until finally static instability at high latitudes occurs. Then all heat is released in a spectacular flush lasting for about a decade. The THC which can exceed 100 Sv during the flush is then re-established, and the cycle starts again. The details of the oscillation can vary; see Sarachik et al. (1996) for a thorough discussion. The deep decoupling oscillation can occur if the freshwater forcing is sufficiently strong so that the state with strong THC cannot reach equilibrium, but not so strong so that a substantial THC is prevented at all times. It is not clear whether such conditions ever existed in the real climate system, but there is some evidence from the paleo-record that rapid events (Dansgaard-Oeschger-Oscillations) involving the Atlantic THC have actually occurred (Sakai and Peltier, 1997). Note also that the time scales for both the convective breakdown as well as the flush are clearly decadal, although the overall period of this oscillation is millennial.

The results from ocean-only models must however be taken with considerable caution as the reaction of the atmospheric circulation to changes in the ocean is not fully included. It is e.g. rather obvious that the atmosphere would show a dramatic response to a basin-averaged heating of more than 100 W/m2 which is associated with a flush. This remark also applies to other forms of ocean variability where the atmospheric response may be less dramatic but nevertheless important.

4. Coupled oscillations

Decadal variability patterns in the North Atlantic have been identified which appear to be true oscillations of the coupled ocean-atmosphere system, at least in the context of some coupled models. The extent to which the ocean circulation has a significant dynamical feedback to the atmosphere on longer time scales is however not well known. Variability at long time scales can be amplified by the oceanic response, and any predictability must come from the oceanic component. Moreover, patterns of oceanic variability can be of interest in their own right, and also may serve to monitor changes of the full system.

A well-analysed 50-year oscillation in the North Atlantic occurs in the coupled global model of Delworth et al. (1993). Reduced heat transport of thermohaline circulation leads to formation of a cold dense pool in the central North Atlantic, and the resulting cyclonic circulation around the pool enhances the salt transport into the convection region, thereby strengthening the thermohaline circulation. Overall, the oceanic influence on the atmosphere appears to be weak, and very similar atmospheric patterns were obtained with a atmospheric model coupled to a simple mixed-layer ocean (Griffies and Tziperman 1995). Timmermann et al. (1998) find a somewhat stronger oceanic influence on the NAO, leading to a pronounced oscillation with a period of 30-40 years which in some aspects agrees with observed structures of variability.

Another cautionary remarks that applies to all models mentioned above concerns the coarse resolution of these models which are clearly unable to properly represent the flows through narrow straits and passages which typically have spatial scales of a few tens of kilometres and play a substantial role for the THC. Sensitivity experiments with high-resolution models (Doescher & Redler 1997) indicate that the presence of a deep overflow over the Greenland-Iceland-Scotland ridge make the Atlantic THC less sensitive to changes in the near-surface buoyancy field, and therefore may critically influence an important process for DecCen variability in most coarse-resolution models.

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LONG TERM CLIMATE VARIABILITY AND THE DETECTION AND ATTRIBUTION OF ANTHROPOGENIC EFFECTS

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Despite its simplicity and low computational resolution, the coupled ocean-atmosphere-land surface model developed at GFDL simulates reasonably well the decadal variability of local and global mean surface temperature. It appears that, with the exception of oceanic regions of high latitudes, coastal boundaries and tropical Pacific, both observed and simulated variabilities of surface temperature over the globe essentially follow the so-called linear stochastic theory as proposed by Hasselmann 1996. Comparison of the observed and simulated variability of global mean surface air temperature suggest that the warming trend sustained during the 20th century has not been generated internally through the interaction among the atmosphere, ocean and land surface. Instead, it appears to have been forced by natural and/or anthropogenic radiative forcings (Manabe and Stouffer, 1997). Similar inference could also be drawn from coupled models that have been developed at the Hadley Centre of U.K., and the Max Plank Institute at Hamburg, Germany.

It is highly likely that greenhouse gases in the atmosphere are the major contributors to global warming observed during this century. However, recent coupled model simulations of the warming trend suggest that other anthropogenic radiative forcings alter the trend substantially. Unfortunately, we know very little about the magnitude and distribution of these radiative forcings (see IPCC95 report, for example). Major emphasis should therefore be placed upon the long term monitoring of radiative forcings not only by greenhouse gases but also by various types of aerosols as well as by solar irradiance. Such monitoring is indispensable for evaluating the sensitivity of a coupled model and reliably projecting the future change of climate.

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INTRODUCTION TO THE GOALS COMPONENTS OF CLIVAR

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Background

The Global Ocean Atmosphere Land System (GOALS) component of CLIVAR was established to study global seasonal-to-interannual variations of climate. It followed on a previous program of the World Climate Research Program, the Tropical Ocean Global Atmosphere Program (TOGA). The TOGA program was designed to describe seasonal-to-interannual variations in order to assess its predictability; to model the coupled system in order to predict its variations; and to design an observing system for operational prediction should predictability be proven. It existed from 1985 to 1995 and upon its demise, the CLIVAR Programme began to be contemplated.

The TOGA program accomplished its objectives by:

- Contributing greatly to the understanding of ENSO by formulating theories of ENSO and investigating processes that were essential to these theories;
- Demonstrating the predictability of SST variations in the Tropical Pacific and investigating the consequent global effects;
- Building an observing system for monitoring surface and subsurface variations in the Tropical Pacific and useful for initializing predictions;
- Encouraging the creation of the International Research Institute (IRI) for climate prediction to demonstrate the application of predictive information.

While these accomplishments were indeed impressive, they took place only in tropical Pacific so that TOGA did not meet its global objectives: other seasonal-to-interannual phenomena in other parts of the world were left unexplored. The question naturally arose whether or not such progress was possible elsewhere throughout the globe. The GOALS component of CLIVAR was designed to answer this question.

Objectives

The GOALS component of CLIVAR was formulated with the following objectives:

- Developing observational capabilities to describe seasonal and interannual climate variability, including continuation of the toga observing system;
- Further developing models and predictive skill for SST and other climate variables on seasonal to inter-annual time scales around the entire global tropics;
- Building understanding and predictive capabilities of the interaction of monsoons with the Indian ocean, ENSO and land surface processes;
- Understanding climate variability and predictability arising from the interaction between the tropics and extra-tropics;
- Exploring the predictability of extratropical seasonal to interannual climate variability induced by the interaction of the atmosphere with oceans, land surface processes, and sea-ice processes and developing means to exploit any such predictability.

Principal research areas

In order to address these objectives, four principal research areas (PRAs) were developed and presented in great detail in the First CLIVAR Implementation Plan. These are:

G1: ENSO: Continuation and Expansion of TOGA Activities in the Tropical Pacific.

Among these activities are continued monitoring of the surface and subsurface tropical Pacific by the TAO-Triton Array; continued prediction of SST in the tropical Pacific and global climate variations connected to these SST variations; continued research in climate applications including the demonstration projects planned by the IRI. Expanded topics for study will be the decadal variability of ENSO and its connection to the PDO (PRA D4).

G2: Variability of the Asian Australian Monsoon system

This is a study of the interannual variability of the Asian Australian Monsoon, both in its summer and winter manifestations. The idea is to identify the connections with ENSO, to understand the mechanisms of variability (including the role of land) and to examine the predictability of the monsoon. There are already programs in place that address this PRA:

GAME (GEWEX Asian Monsoon Experiment) designed to study the role of land and hydrologic processes in the South Asian Region and

SCMEX (South China Sea Monsoon Experiment) to understand the physical processes responsible for the onset, maintenance and variability of the monsoon over Southeast Asia and Southern China leading to improved predictions.

G3: Variability of American Monsoon System (VAMOS)

This is a study of the Pan American Monsoon over both North and South America to understand the mean and seasonal aspects of the American monsoon system, to understand the predictability, and to design and prepare societally useful products. Programs already in place to address these problems are:

PACS (Pan American Climate Studies) to investigate the role of the eastern Pacific atmosphere-ocean complex in influencing the American Monsoon;

LBA (Large Scale Biosphere-Atmosphere Experiment in Amazonia) in designed to create the new knowledge needed to understand the climatological, ecological, biogeochemical, and hydrological functioning of Amazonia, the impact of land use change on these functions, and the interactions between Amazonia and the Earth system; and

PIRATA (Pilot Research Moored Array in the Tropical Atlantic) is a project designed to study ocean-atmosphere interactions in the tropical Atlantic that are relevant to regional climate variability on seasonal, interannual and longer time scales.

G4: The African Climate Variability

Designed to study the monsoon system over Africa; the physical factors that influence its year to year variability and the predictability of the monsoon in this vulnerable region. While there is much study by individual investigators, there are no programs yet in place for this PRA.

The implementation of all the PRAs of GOALS, indeed of all the PRAs of CLIVAR ,will be through a closely interacting mix of observations (both process oriented and sustained), modelling, and process studies. The closeness and intensity of the interaction among these three elements, both in articulation and in execution, will determine the ultimate success of the CLIVAR/GOALS Programme.

Linkages

Because CLIVAR forms the natural home for oceanographic research, much of the oceanography in GOALS will be accomplished within the CLIVAR/GOALS framework. Other components of the climate system contribute to seasonal-to-interannual variability, in particular the land and the cryosphere.

CLIVAR/GOALS, in particular, looks to GEWEX for research on land processes and hydrologic processes over land.

GOALS links to other PRAs scientifically. In particular, the decadal variability of ENSO (part of D4) links to G1 and to the extent ENSO contributes to, or confuses, the record of, anthropogenic climate change, forms a natural link with the Anthropogenic Climate Change component of CLIVAR. The seasonal-to-interannual variability of monsoons has decadal modulations and therefore links to the DecCen component of CLIVAR.

GOALS will link to other national or international programmes as opportunities and needs arise.

Expectations

As a result of a successful GOALS Programme, we expect:

- a better understanding of seasonal-to-interannual variability and predictability throughout the globe;
- the outline of a design for sustained observations in support of predictions where predictability is shown;
- in place contributions to a global observing system; and
- better global predictions and better applications of climate information for the benefit of societies and economies.

The CLIVAR/GOALS Program will help unravel the nature of seasonal-to-interannual variations in the world's climate system; will tell us where the variations are predictable and where not; will help us develop the prediction systems needed to make useful forecasts where the variations have been demonstrated to be predictable; and will help us learn to actually apply these forecasts to a variety of sectors in a variety of regions. When all is said and done, we will be able to peer just a little bit more into the future and use

AN INTRODUCTION TO THE CLIVAR DECCEN PRINCIPAL RESEARCH AREAS

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The scientific objectives of CLIVAR DecCen are to describe and understand decadal to centennial climate variability and predictability through the analysis of observations and the modelling of the coupled climate system, to extend the record to decadal to centennial variability through paleoclimatic studies, data archeology, reanalysis of atmospheric and oceanic data, and to develop and implement appropriate observing, computing, and data archiving and dissemination programs needed to understand the mechanisms of decadal to centennial climate variability and predictability in cooperation with other relevant climate research and observing programs. The principal research areas of CLIVAR DecCen include the Pacific and Indian Oceans Decadal Variability, Tropical Atlantic Variability, the North Atlantic Oscillation, the Atlantic Thermohaline Circulation, and Southern Ocean Climate Variability.

The CLIVAR DecCen principal research area on the Pacific and Indian Oceans Decadal Variability (D4) provides the major link with the CLIVAR GOALS objectives on seasonal to interannual climate variability. On decadal time scales, climate variations in the Pacific and Indian Oceans involve all latitudes. They include a modulation of ENSO, lower frequency variations, and possible trends in the coupled climate system. It has been noted that there are distinctly different patterns for interannual and longer term variability in global sea surface temperature. For example, the North Pacific Ocean SST anomaly is stronger for the pattern of decadal and longer term variability than for the interannual which is dominated by ENSO. Regression analyses for Pacific Ocean sea surface temperature and 500 mb pressure indicate that the decadal mode contains the strong variability of North Pacific SST that correlates most strongly with the PNA teleconnection pattern while the interannual variability of SST characteristic of ENSO correlates with a more zonal atmospheric pattern. Western boundary currents such as the Kuroshio are also of special interest because they transport large amounts of mass and heat poleward relatively rapidly, and therefore provide a critical feedback mechanism in some theories of decadal modes of coupled ocean atmosphere interaction. In contrast to the Pacific Ocean, the database in the Indian Ocean is poor; therefore, knowledge of decadal variability in and around the Indian Ocean is poor as well.

A major emphasis of this principal research area is an interdecadal Pacific climate mode that extends over the whole of the Pacific Ocean in a fairly simple spatial pattern that may modulate ENSO on decadal time scales. A current hypothesis for its maintenance that CLIVAR will investigate include subtropical gyre feedbacks on the atmosphere, tropical/subtropical interactions through both the atmosphere and the ocean, and a null hypothesis regarding the excitation of a basic mode of the atmosphere which is imprinted on the ocean. The evaluation and generation of new hypotheses will require focused process experiments and a commitment to the global survey and monitoring of the Pacific. The proposed processes that will need to be investigated with respect to an interdecadal Pacific climate mode include investigation of the upper ocean variability through the thermocline, feedbacks with the atmosphere, mixed layer formation and maintenance, connection from the mixed layer to the interior via subduction, and the subsurface advection of thermal anomalies.

Much of the CLIVAR DecCen focus is centred in the Atlantic Ocean basin. With respect to Tropical Atlantic Variability (D2), extensive research in the last 30 years has indicated a strong link between various climate related impacts occurring in countries surrounding the tropical Atlantic basin and sea surface temperature anomalies in the tropical Atlantic Ocean. For example, the well-known droughts of northeast Brazil have been shown to be closely related to anomalously warm/cold sea surface temperature anomalies in the tropical north/south Atlantic. Droughts in sub-Saharan Africa are often found to be associated with a broad band of negative/positive sea surface temperature across tropical north/south Atlantic. Rainfall variability in the central American/Caribbean region also appears to be related to tropical North Atlantic sea surface temperature fluctuations. Of particular importance to the rainfall in northeast Brazil, and to a lesser extent in the Sahara region of Africa, is the variation of the interhemispheric sea surface temperature gradient. Empirical analyses indicate the sea surface temperature anomaly pattern in the tropical Atlantic Ocean exhibits a “dipole” with opposite values on either side of the thermal equator.

Two competing hypotheses have been put forward to explain the variability of the cross equatorial sea surface temperature gradient. One hypothesis is that decadal variations of the interhemispheric sea surface temperature gradient stem from regional ocean/atmosphere positive feedbacks involving primarily sea surface temperature and wind induced latent heat flux. Under this scenario when there is warm sea surface temperature north of the equator there is a corresponding low sea level pressure and weakened northeast trade winds. This results in a northward cross-equatorial wind anomaly. Coincident with this, low sea surface temperature, high sea level pressure, and strengthened southeast tradewinds exist south of the equator. Although this air-sea interaction hypothesis assumes that the circulations on both sides of the equator are related, it does not require that sea surface temperature changes in each hemisphere be simultaneous as in a perfect SST dipole. What is fundamentally important is the variability of the interhemispheric SST gradient. Correlation and empirical analyses also suggest that the sea surface temperature in the tropical North Atlantic may also be under the external influence of ENSO variability from the Pacific Ocean, and as will be discussed later, the influence of the North Atlantic Oscillation from higher latitudes.

The other hypothesis for tropical Atlantic variability views the development of SST anomalies on either side of the equator as being dynamically independent and controlled by processes in each hemisphere. If SST anomalies occur independently on either side of the equator, the variation of interhemispheric SST gradient may not have preferred time scales. This hypothesis postulates that variability of the cross equatorial SST gradient is largely stochastic or preferentially controlled by one hemisphere over the other.

Similar to the situation in the Indian Ocean, the lack of a sufficient observation data base has hampered progress in elucidating these scientific questions in the tropical Atlantic. This will be partially addressed by a newly initiated observational program, the Pilot Research Moored Array in the Tropical Atlantic (PIRATA). PIRATA is intended to run from 1997-2000 with the full array being in place in the later part of 1999. This moored array is an extension of the TAO Array in the tropical Pacific Ocean. It will consist of 12 moorings including one zonal mooring section along the equator and two meridional mooring sections, one along 38°W between 4°N - 15°N, and the other along 10°W between 10°S - 2°N. This array will provide well resolved time series measurements of surface heat and moisture fluxes, SST and salinity, and subsurface thermal and current structures down to 500m.

At higher latitudes in the Atlantic Ocean, the North Atlantic Oscillation (D1) is a principal research area of study. The NAO is a large scale alternation of atmospheric mass with centres of action near the Icelandic Low and Azores High. The high index phase of the NAO is characterized by an intense Icelandic Low with a strong pressure ridge to the south and is associated with strong mid-latitude westerlies. The converse is true for the low index phase of the NAO. Time series analysis of the NAO index indicates that this oscillation is broad band in frequency with spectral peaks at periods of 24, 8, and 2-3 years, as well as multi-decadal energy. At long periods the NAO index indicates a decadal alternation in the amplitude since the late 19th century with low-index extrema during the 1960's and high-index extrema from 1900-1930 and in the 1990's. There is also evidence that the multi-decadal signal has been amplifying with time. Multivariate, linear regression analyses between the NAO index and Northern Hemisphere surface temperature indicate that 50% of the December-March temperature variance is accounted for by a combination of the NAO and Southern Oscillation variability, of which one-third of this signal is attributed to the NAO. Taken together these modes of variability account for the majority of the warming in the past 20 years. Hence, a major goal of CLIVAR D1 is to study the extent to which these interannual to decadal changes in the NAO index are predictable.

As the dominant mode of the atmospheric behaviour in the North Atlantic sector, the NAO is associated with large systematic amplitude patterns in anomalies of precipitation, wind speed, latent heat, sensible heat, and SST over much of the extratropical north Atlantic. These include changes in the Atlantic storm track fluctuations, the number of winter storms, the strength of the mid-latitude westerlies, and their impact on significant wave height within the ocean. Changes in ocean circulation related to the NAO include temperature and salinity fluctuations in the Greenland-Labrador Sea, the convection strength of Labrador Sea water, and sea ice discharge out from the Arctic Ocean.

A key unresolved question with respect to the NAO is whether observed anomalies in oceanic conditions represent a passive response to decadal changes in the atmospheric circulation, or whether they feed back to force decadal and longer period oscillations in the NAO. For example, the low phase of the NAO is associated with warming of sub-polar SST in the north Atlantic, and conversely cooler SSTs during the high phase of the NAO. It has also been noted that the oceanic transport of the Gulf Stream and North Atlantic Current appears to lag the NAO index by approximately 4 to 5 years. Thus, the modelling and prediction studies of the NAO are geared toward determining whether the variability simulated in models is fundamentally coupled, whether one component of the climate system drives variability in another, whether simulated variability modes are related to observed variations and whether modes of variability once identified are predictable. The complimentary field program for the NAO in CLIVAR is largely determined by the need to confirm and quantify the factors which redistribute, protract or amplify the SST anomaly field of the North Atlantic sector such as the variability of North Atlantic heat fluxes and storage, water mass conversion processes in the sub-polar north Atlantic, and the Arctic response to NAO forcing.

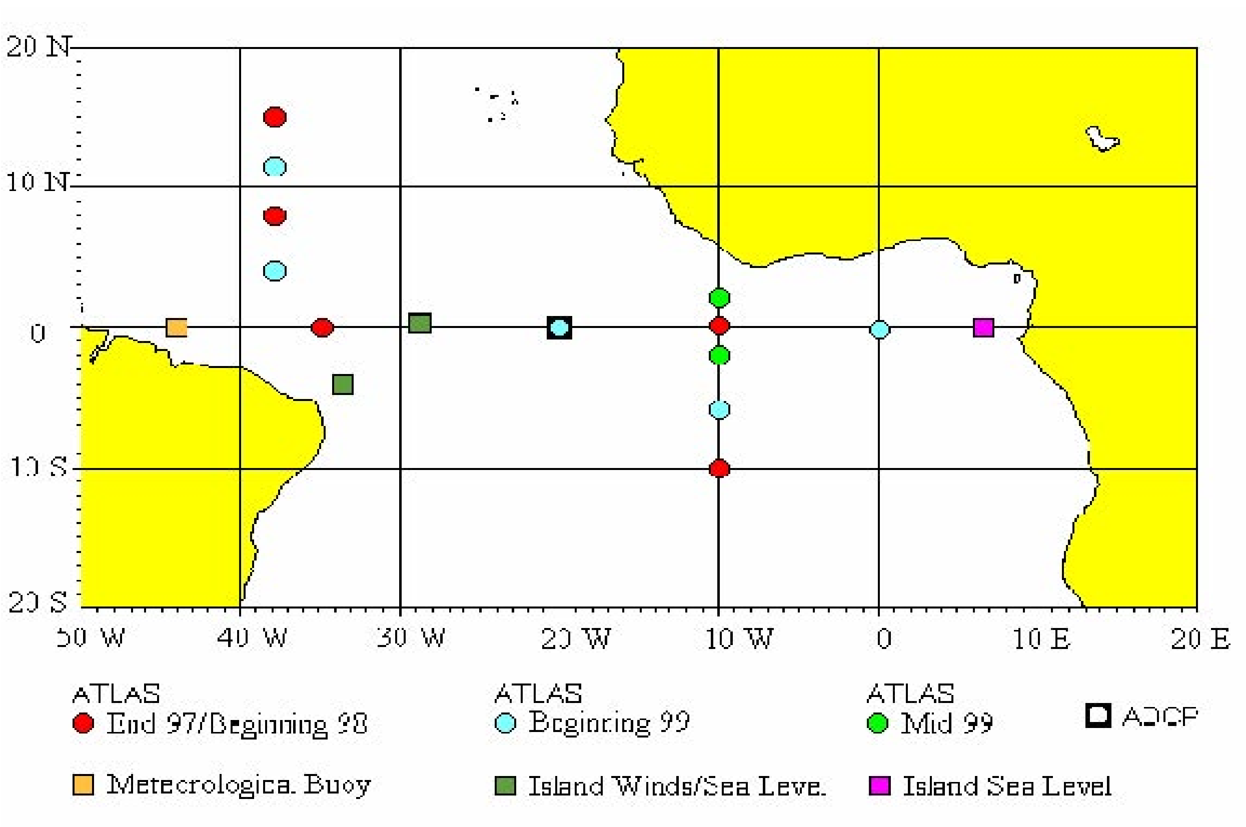
In addition to the North Atlantic Oscillation, study of the North Atlantic thermohaline circulation (D3) is another principal research area of CLIVAR. Research on this topic is needed because the oceanic heat transport in the Atlantic Ocean has an obvious and well-known impact on climate. This is of direct interest to CLIVAR DecCen to the extent that variations of the thermohaline circulation on decadal to centennial time scales lead to changes in SST and ocean heat transports. Observations have shown that the water mass distributions in the sub-polar North Atlantic change on decadal time scales. In particular, convection activity in the source regions for the deep thermohaline circulation has been observed to undergo substantial changes on decadal time scales. In the late 1960s, for example, intense convection down to 3,500 m occurred in the Greenland Sea. In contrast, the Labrador Sea convection was tightly capped by a lense of fresh water that had built up at the surface. At lower latitudes there was intense production of 18o water in the Sargasso Sea region. Twenty five years later during the early 1990s an opposite scenario was operant. At this time there was minimal convection in the Greenland Sea down to 1,000 m, whereas convection was at record intensity in the Labrador Sea down to 2,300m and penetrated the North Atlantic Deep Water sublayer. At lower latitudes there was minimal production of 18° water within the Sargasso Sea.

Paleooceanographic data show that climate changes have occurred sometimes very rapidly in the geological past and were associated with changes in the thermohaline circulation such as the formation of North Atlantic Deep Water. Model results suggest that a collapse of the thermohaline circulation within less than 10 years is dynamically possible and can be triggered by changes in surface conditions leading to fresher and/or warmer SST in high latitudes. In response to such a "polar halocline catastrophe" strong cooling has been simulated over the North Atlantic (basin averaged 2°C, regionally 5°C in European regions). In addition to sudden changes, coupled models indicate that multi-decadal thermohaline circulation variations of moderate amplitude have a feedback on atmospheric climate. These oscillations with a time scale of approximately 40 to 60 years involve large scale interactions between Arctic fresh water and ice export, the intensity of the East Greenland Current, and fluctuations of the intensity of the thermohaline circulation in the North Atlantic. In such studies, the intensity of the thermohaline circulation has been shown to lag anomalous sea surface temperature in the Greenland Sea by 10 years. On these time scales simulated surface fresh water anomalies propagate into the Labrador Sea via the East Greenland Current and inhibit convective overturning.

Moving to the Southern Hemisphere, the Southern Ocean provides the only deep ocean link between major ocean basins. As such, it helps to shape the global ocean stratification, it plays a unique role in coupling the ocean to the atmosphere and cryosphere, and it plays a central role in global sea level. Specific aspects of the CLIVAR research on Southern Ocean Climate Variability (D5) include the Antarctic Circumpolar Current (ACC) that connects the major ocean basins permitting a global-scale thermohaline circulation and providing an inter-ocean communication route for heat and freshwater climate anomalies. Upwelling of Circumpolar Deep Water poleward of the ACC provides the site of major venting of deep oceanic heat into the atmosphere and associated cryosphere. The Southern Ocean also couples the ocean and atmosphere within the subantarctic belt and its polar-extrapolar communication of heat, freshwater and CO_2 through the production of Antarctic Intermediate Water and Subantarctic Mode Water, which spread northward inject-ing cool low salinity water into and along the base of the main thermocline helping close the hydrological cycle. Yet even deeper, the production of very cold dense Antarctic Bottom Water dominates the lower two kilometres of the global ocean to an average temperature well below the coolest temperatures possible from the North Atlantic Deep Water. At the surface, the Antarctic sea ice fields represent a highly mobile and variable surface property whose distribution and characteristics may play a major role in the global radiative budget and thus global climate. Lastly, the large-scale coherent variability of the atmospheric circulation over the Southern Ocean and the mechanisms of these variations and their geographic communication, are directly involved in the propagation of anomalies across the various climate zones of interest to CLIVAR.

For practical considerations not all of the Southern Ocean climate related issues can be covered by CLIVAR. Rather, CLIVAR D5 will be focused on addressing variability in the Antarctic Circumpolar Current, variability of Subantarctic Mode Water and Antarctic Intermediate Water, coupled variability of deep water formation, sea ice and the atmosphere, the formation mechanism of Antarctic Bottom Water, and the variability in the Antarctic Circumpolar Current. For example, the variability in the Antarctic Circumpolar Current is a key area of interest for studies of the Southern Ocean thermohaline circulation. The best documented large scale pattern displaying coherent variability over a variety of time scales is the Antarctic Circumpolar Wave which manifests itself as an eastward propagating anomaly in sea ice extent, sea surface temperature, sea level pressure, and meridional wind stress. Whether or not this represents a physical mode of the coupled climate system will require additional data analysis, observations (sea-ice extent, ice thickness, vertical profiles of temperature and salinity), model verification and process studies of these recently discovered patterns. Such studies will be needed to establish if there are indeed formal modes, to establish the spatial extent and connectivity in the ocean, atmosphere, and sea-ice, to determine their dominate/controlling physical mechanisms, and to determine if the surface signal penetrates to the intermediate or deep layers in the ocean.

Figure 1 The PIRATA Array



ANTHROPOGENIC CLIMATE CHANGE - CLIVAR ACC

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1. Introduction

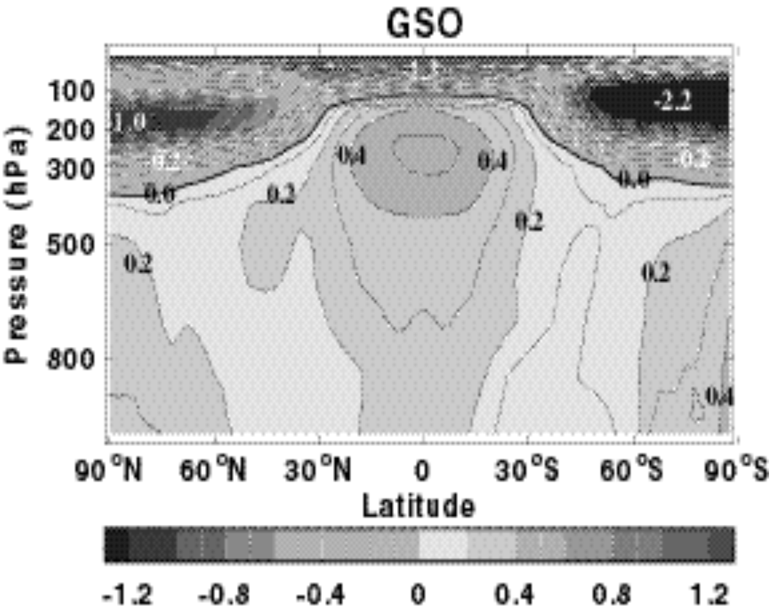
In the last few decades, the possibility that mankind may be influencing climate through increasing the concentrations of greenhouse gases has received increasing attention. In a recent IPCC report, Santer et al. (1996) concluded that there was " a discernible human influence on climate". In the same report Kattenburg et al. (1996) presented model projections of global mean temperature increases of a few degrees Celsius by the end of the twenty first century. However the claim of attribution of climate change to human activity remain controversial, and the prediction of future changes is beset by many uncertainties. It is important that we are able to confirm (or disprove) that there is an existing human influence on climate. It is also crucial that we increase confidence in model projections of the future. These are needed in order to plan adaptation to future changes, and to guide policy makers in possible amelioration of future changes through greenhouse gas emission policies. In this paper, we consider areas in which CLIVAR can reduce uncertainties in both the detection and prediction of climate change. CLIVAR ACC has two components. The first A1, climate change prediction, seeks to answer the question " What effect will future emission scenarios have on future climate?". The second, A2, detection and attribution, addresses the issue "Can we detect and quantify a human influence on climate?".

There is considerable overlap in the issues addressed by the two components. Both require the use of climate models. These are needed to convert emissions of greenhouse gases, sulphur and other anthropogenic emissions into concentrations, to calculate the consequent changes in radiative heating and hence the accompanying changes in climate. In the case of detection, the historical emissions are used to estimate the anthropogenic effect on climate. These are compared with simulations in which only natural factors are taken into account, and with observations of past climate. For prediction, scenarios of future emissions are used to projections of future climate. It is important to distinguish between changes which are due to the human influence and those which arise from the natural internal fluctuations of climate. With both attribution and prediction, it is important to evaluate models against observations to show that they produce a credible representation of processes governing climate and climate change.

The rest of this paper considers four key topics. First, we consider the need for observations which are crucial for attribution as well as model evaluation. Next, we outline some model developments which are needed to consider the full range of factors influencing climate. Thirdly, we look at what needs to be done reduce uncertainty in modelling the climatic response to changes in external factors. Fourthly, consider the type of numerical experiments that are needed in the future and the implications for computing power. Finally we conclude with some general comments on how CLIVAR ACC needs to link with other programmes.

2. Observations

One of the most convincing pieces evidence for an anthropogenic influence on climate is the change in the vertical profile of atmospheric temperature.



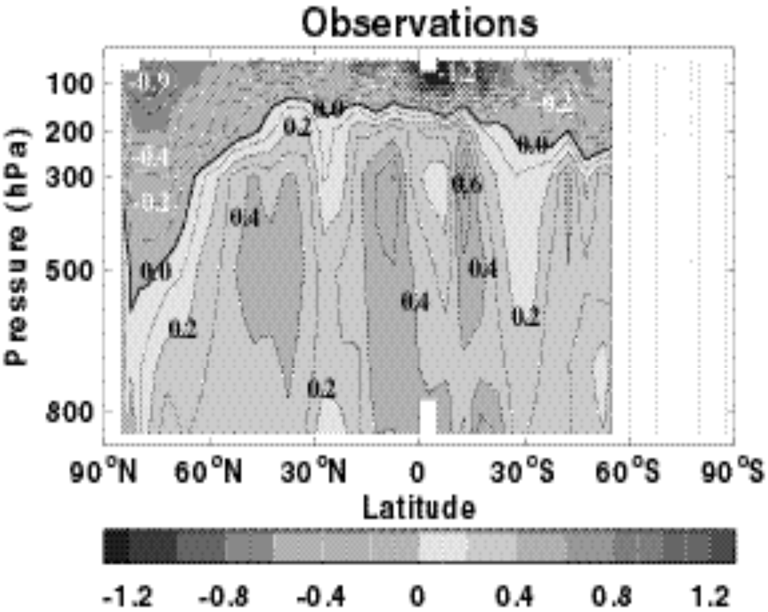


Figure 1. Simulated and observed zonal mean temperatures changes.

Top panel: Model run HadCM2 (Hadley Centre) with greenhouse forcing (sulphate aerosols) stratospheric ozone;

Second panel: Observations. All signals are defined to be the difference between the decadal mean from 1986 through 1995 and the 20-year mean from 1961 through 1980 (Tett et al, 1996)

The stratosphere has cooled, particularly in high latitudes, and the troposphere has warmed. Model simulations (lower panel) show that the stratospheric cooling can be explained by the increases in carbon dioxide, enhanced near the poles by reductions in stratospheric ozone. The increases in carbon dioxide (and other greenhouse gases) account for the tropospheric warming. It would be very difficult to explain these changes in terms of natural factor. Solar variations cannot account for the stratospheric cooling. The recent increase in volcanic eruptions would lead to a warming rather than a cooling of the stratosphere. There remains the possibility that the observed trend is due to a long term internal variation of the climate system. The observational record of atmospheric temperatures goes back only forty years or so. A longer record is needed to provide more definitive evidence of climate change.

The observations used to derive the upper panel are derived from radio sondes. The coverage of radio sonde observations over the oceans and parts of the continents is only marginally sufficient for attribution of climate change. Despite their fundamental importance for monitoring climate change, the global coverage of radio sonde observations is decreasing (D. E. Parker, personal communication).

Surface observation of temperature are available over the last 130 years or so. There are still areas of the globe where the distribution of surface observations is inadequate. Hence one of the most important tasks for CLIVAR is to ensure that systematic long term observations necessary for monitoring and detecting climate change continue to be made, and are extended where necessary. This is both important and urgent- we cannot make observations in retrospect.

There are ways in which we can extend the historical record of surface temperatures. Many surface observations have not yet been included in climatological data sets. These need to be quality controlled and corrected for known biases before they can be used for climate monitoring. This is a highly skilled but very cost effective way of extending the climate record, but one for which funding agencies seem reluctant to support. Palaeoclimatic reconstruction of climatological data can allow the extension of the climatic record further back in time, albeit with questions of accuracy. This latter approach is our only hope of estimating long term natural climate variability without relying on climate models. This will involve ongoing collaboration with PAGES, the programme on Past Global Changes

3. Climate forcing

In order to understand past changes in climate, and predict future changes in climate, we need to first quantify the factors influencing climate. Increases in well mixed greenhouse gases are the main anthropogenic factor influencing climate over the last hundred years. However, there are other factors which are believed to have had a smaller but possibly significant effect on recent climate. These include changes in the atmospheric concentrations of ozone, sulphate aerosols, biogenic aerosols and soot. Aerosols have a much shorter lifetime than most greenhouse gases, and so tend to be concentrated locally rather than spread evenly over the globe. They have the potential to produce distinct patterns of climate change which may it may be possible to detect. They are also likely to influence regional climate change in the future. Unfortunately, there are large uncertainties in estimating the strength of many of these factors (Shine et al., 1996). For example, in the case of sulphate aerosols, there direct effect on solar radiation is uncertain by a factor of two or so, and the uncertainty due to their secondary effects through alteration of cloud properties is even larger. Reducing these uncertainties requires an improved understanding of atmospheric chemistry. These processes, where appropriate, should be included in global climate models.

The major greenhouse gases including carbon dioxide and methane have natural life cycles. Thus, for example, in estimating the effect of future increases in emissions of atmospheric carbon dioxide through human activity, one has to take into account the accompanying changes in the natural carbon cycle. This will include changes in the uptake of carbon dioxide in the oceans and by vegetation, and through respiration in soils. Since these processes are also sensitive to changes in climate, they should also eventually be included in climate models.

The improved representation of chemical and biological processes in climate will require close collaboration be CLIVAR and the International Geosphere-Biosphere Programme (IGBP).

4. Model development and validation

Even if we were able to predict and quantify the anthropogenic factors influencing climate exactly, there would still be considerable uncertainty in predicting the climate response using our current models. This is one area where there has been very little progress. In 1990, Mitchell et al. (1990) showed a factor of three uncertainty in the equilibrium global mean temperature response to doubling atmospheric carbon dioxide. There was a similar uncertainty in the change in global mean precipitation. Le Treut and McAvaney (personal communication), found a similar range of uncertainty with present day models. Most of this uncertainty arises from differences in modelling cloud and related processes. There are also marked differences in the patterns of response of global models. This must be borne in mind when looking at predictions from regional models. Although increased detail in regional models may be alluring, it is to no avail if the larger scale changes are in error. The evidence above suggests that we can have little confidence in the regional detail from global models. "New science" such as including new chemical and biological processes in a model is relatively attractive to funding agencies. Finding support for improving processes already included in a model such as those associated with cloud precipitation is more difficult. This is understandable, as there is more likely to be a short time payoff with "new science", but it is also short-sighted. For example, the modelling of vegetation in a model is very sensitive to the simulated precipitation, and as we have seen above, the magnitude of the response is dominated by uncertainties in cloud and related processes. We will not improve the usefulness of climate predictions until we reduce the uncertainty due to modelling cloud and related processes. This will require close collaboration between CLIVAR- ACC and GEWEX (the Global Energy and Water budget Experiment). CLIVAR can help identify those mechanisms that are important for climate change, GEWEX through carefully focused model data intercomparisons can guide the development of more realistic parametrizations of cloud and related processes. Although this I believe is the most crucial area for model improvement, the success of CLIVAR ACC depends on the improved representation of physical processes in ocean-atmosphere models in general.

5. Computing requirements

Over the last few years, the demand for computing time for numerical studies of climate change have increased dramatically. There are a number of reasons this

i. Increased resolution.

Increased horizontal resolution over land will produce a much more accurate representation of orographic effects which are especially important for precipitation. There is also a demand for more regional detail for impact studies, though as noted above, regional detail will be worthless if there are still substantial errors in the simulation of the larger scale climatic features. Increased resolution in the ocean will enable a more accurate representation of sills and channels and hence of ocean circulation. Current climate models do not resolve mesoscale eddies in the ocean, though it is not clear at present whether or not these features are important for climate change. The ocean grid of current models would be need to be reduced by a factor of six or so to resolve ocean eddies. As a halving of the horizontal grid spacing leads to approximately an eightfold increase in computing time, at least a hundredfold increase in computing power would be needed to model these phenomena.

ii. The need for ensembles of simulations.

The climate system produces its own internal variability regardless of the presence or otherwise of external factors. Any two predictions starting from slightly different initial conditions will diverge because the internal variations will evolve differently. This is a consequence of the non-linearity of the climate. By running an ensemble of simulations, each from slightly different initial conditions, one can use estimate the most likely change, and the range of possible changes in future climate. To date, the size of ensembles derived from fully coupled ocean atmosphere models have ranged from 2 to 10. For long range weather prediction, ensembles of thirty are often used. Ensembles are more important for regional climate change than global mean changes as these tend to have a lower signal-to-noise ratio. The signal-to-noise ratio is generally much higher for temperature than for other variables. It is likely that many impact studies using decadal means of changes in precipitation over subcontinental regions have assessed the impact of climate noise rather than climate change. The use of ensembles is particularly important in estimating the patterns of response for climate change detection and attribution, as the signal-to-noise ratio for historical changes in climate is low.

iii. Multiple scenarios.

The level of future greenhouse gas emissions depends on the future changes in population, economic growth, technology and so forth. Since each of these is subject to considerable uncertainty, economists have tried to span the range of possible future emissions by a number of emission scenarios. In principle, ensembles of simulations should be run for each scenario if the regional impacts are to be investigated systematically. To estimate the full range of uncertainty, this should be done with several climate models (see section 4 above)

iv. Long simulations.

There is an increasing interest in the long term effects of increases in greenhouse gases. Even if we could stabilise the concentration of greenhouse gases now, the increase in sea level due to thermal expansion would continue for centuries. Thus, very long simulations are required to evaluate the long term effect of stabilisation scenarios. Model simulations are used to estimate natural climate variability for detection and attribution studies. A ten thousand year long control simulation would be required to provide a sample of one hundred century time scale trends needed to estimate the significance of the observed changes over the last century. Even longer control simulations are needed if part of the control is to be used to determine the optimal space for detection and attribution.

6. Concluding remarks

CLIVAR-ACC is primarily a modelling programme. It depends on links with other programmes within the WCRP. This is particularly true if it is to reduce uncertainties in predictions of climate change. Some of the key links are illustrated schematically in Figure 2.

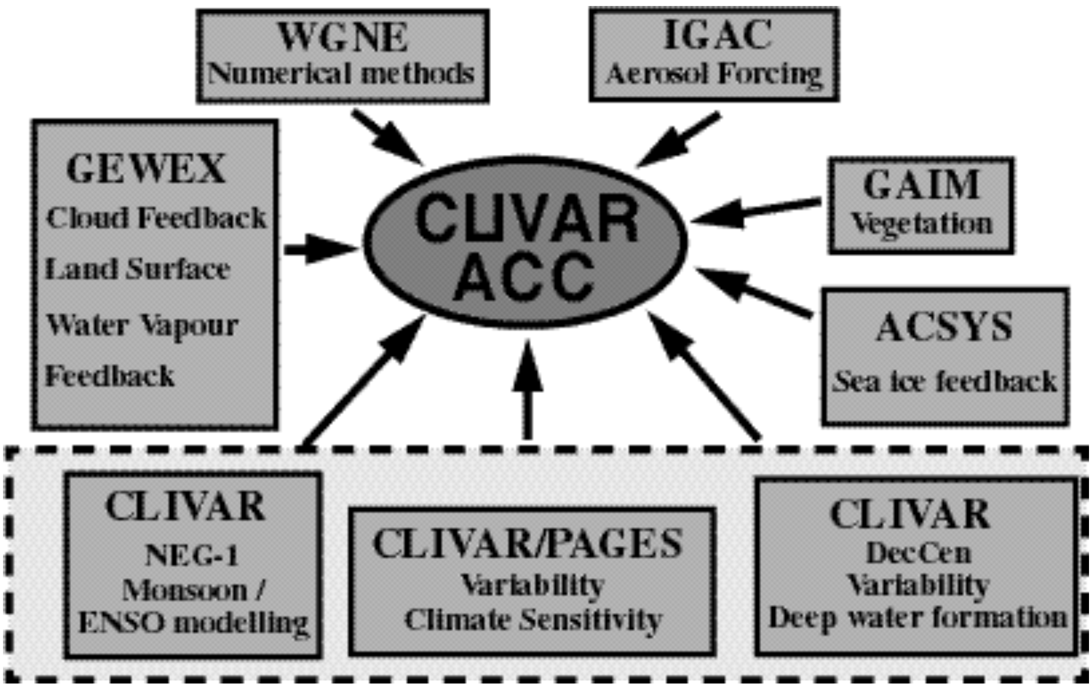


Figure 2. Schematic diagram of the linkages between CLIVAR ACC and other programmes.

Most of these links are concerned with the improved understanding of physical and dynamical processes and their inclusion in models. The most important part of this figure is the arrows which represent the interaction between the different programmes. It involves close collaboration between different communities of scientists who very often attract funding from different agencies. Without this interaction progress in reducing uncertainty will be severely limited, and confidence in model simulations will remain low. With this interaction, suitably encouraged by funding across different disciplines, CLIVAR-ACC will in a good position to reduce the uncertainties in predictions of climate change.

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PAGES/CLIVAR INTERSECTION

Keith Alverson[1], Jean Claude Duplessy[2], Jean Jouzel[3] and Jonathan Overpeck[4]

The four principal areas of paleoclimate research relevant to CLIVAR goals are:

- Extending the instrumental climate record back in time with quantitative proxy data
- Documenting and understanding rapid climate change events
- Documenting and understanding natural climate variability during the Holocene and other, relatively warm, interglacial periods with background climatic states similar to those of today.
- Testing the ability of climate models to capture known past climate variability.

At the International CLIVAR conference material from each of these areas of research was presented as part of numerous national presentations. In addition, an oral presentation by Jean Jouzel and two posters coordinated by Keith Alverson specifically highlighted the PAGES/CLIVAR intersection by presenting a few individual examples of successes to date, as well as plans for the future. This statement summarizes the content of these presentations (for a more complete representation of the PAGES/CLIVAR Intersection please refer to the publications listed on the website html://www.pagesclivar.unibe.ch/).

Extending the instrumental record

The instrumental record of climate change is too short to capture the full range of climatic variability on decadal and century timescales. However, numerous proxy records of climate variability exist, often with annual resolution, during the period prior to the beginnings of instrumental records. These records have been combined to produce hemispheric and global average temperature records extending back several centuries. Recently published reconstructions include high latitude, northern hemisphere, tree ring measurements showing the importance of volcanic events as aerosol climate forcing (Figure 1. Briffa et. al., 1998a). The same reconstruction also indicates a change in high latitude tree growth characteristics during recent decades, perhaps due to CO_2 increases, which is visible as an apparent cooling signal (Figure 1. Briffa et. al., 1998b). Multiproxy, high Arctic temperature reconstructions show a rapid warming in recent decades, unparalleled in at least the past four centuries (Figure 1. Overpeck et. al., 1997). These records are of particular interest, in part due to modelling studies suggesting high latitude sensitivity to greenhouse gas forcing. Finally, several independent, single and multiproxy northern hemisphere and global average temperature reconstructions show the recent warming trend, known from instrumental data, within the context of records extending back as early as 1100 AD (Figure 1. Jones et. al., 1998, Mann et. al., 1998, Pollack et al., 1998)

In addition to individual climatic variables, major dynamical phenomena are captured by proxy records and can therefore be reconstructed. Examples include a 350 year record of the North Atlantic Oscillation recorded in Greenland ice cores (Figure 2. Appenzeller et. al., 1998) and a dendroclimatic reconstruction of the Southern Oscillation Index beginning in 1706 (Figure 2. Stahle et. al., 1998). Proxy data also provide a record of past changes in climatic forcings. Greenhouse gas levels, for example, are measured from air pockets trapped in ice cores. Such records can provide clear evidence of the phasing of natural temperature and greenhouse gas changes in the past. Since both properties are measured in the same material any phase lags can be discerned. Proxy records of insolation variation are also available, for example from measurements of Be10 in paleoclimate archives. Finally, as mentioned above, records of volcanic eruptions, and their climatic influence, have also been compiled.

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Figure 1: Several recent large scale spatial average temperature reconstructions placed on a uniform scale. Synthesizing these efforts is one major goal of the upcoming PAGES/CLIVAR Intersection workshop in November 1999.

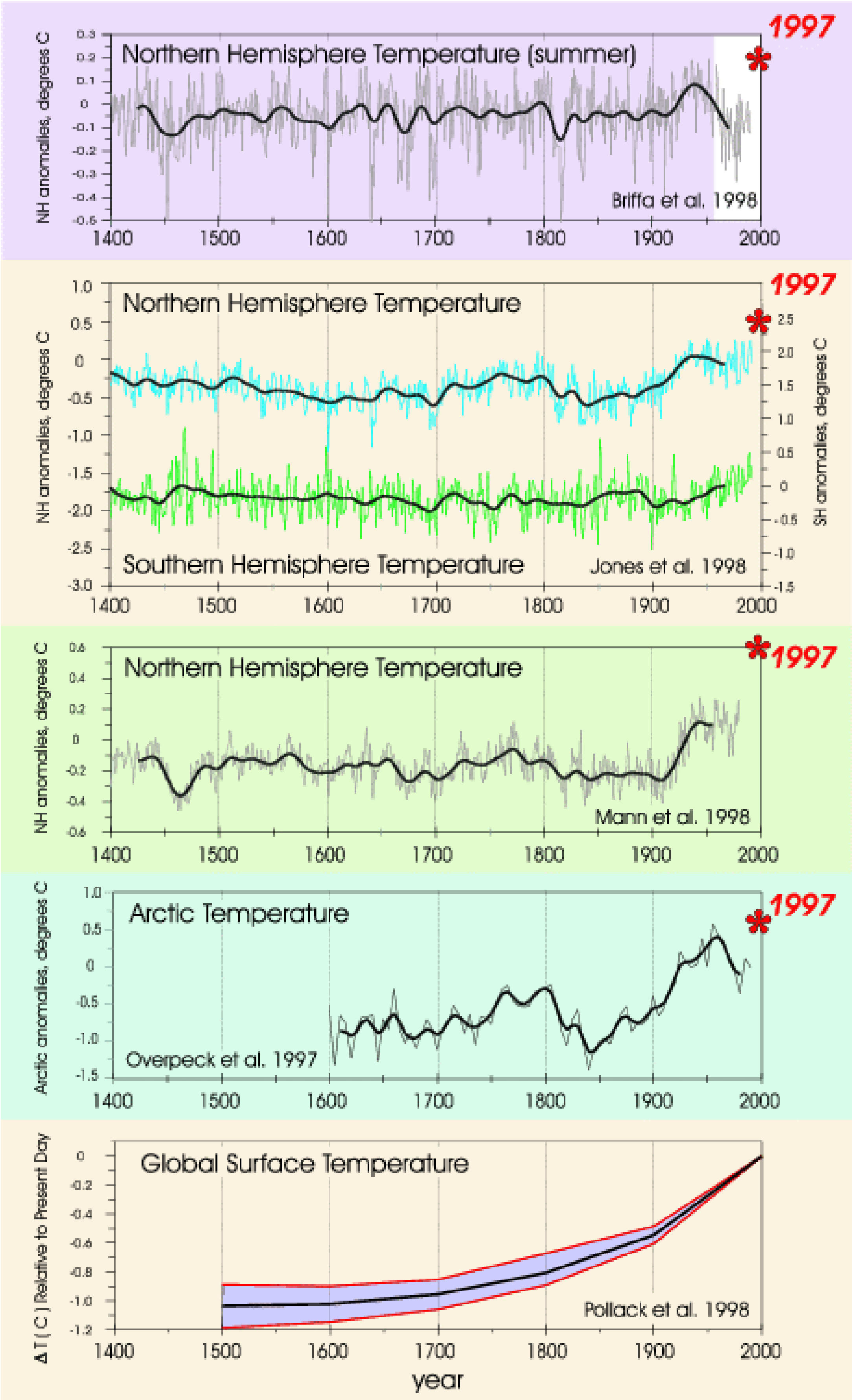
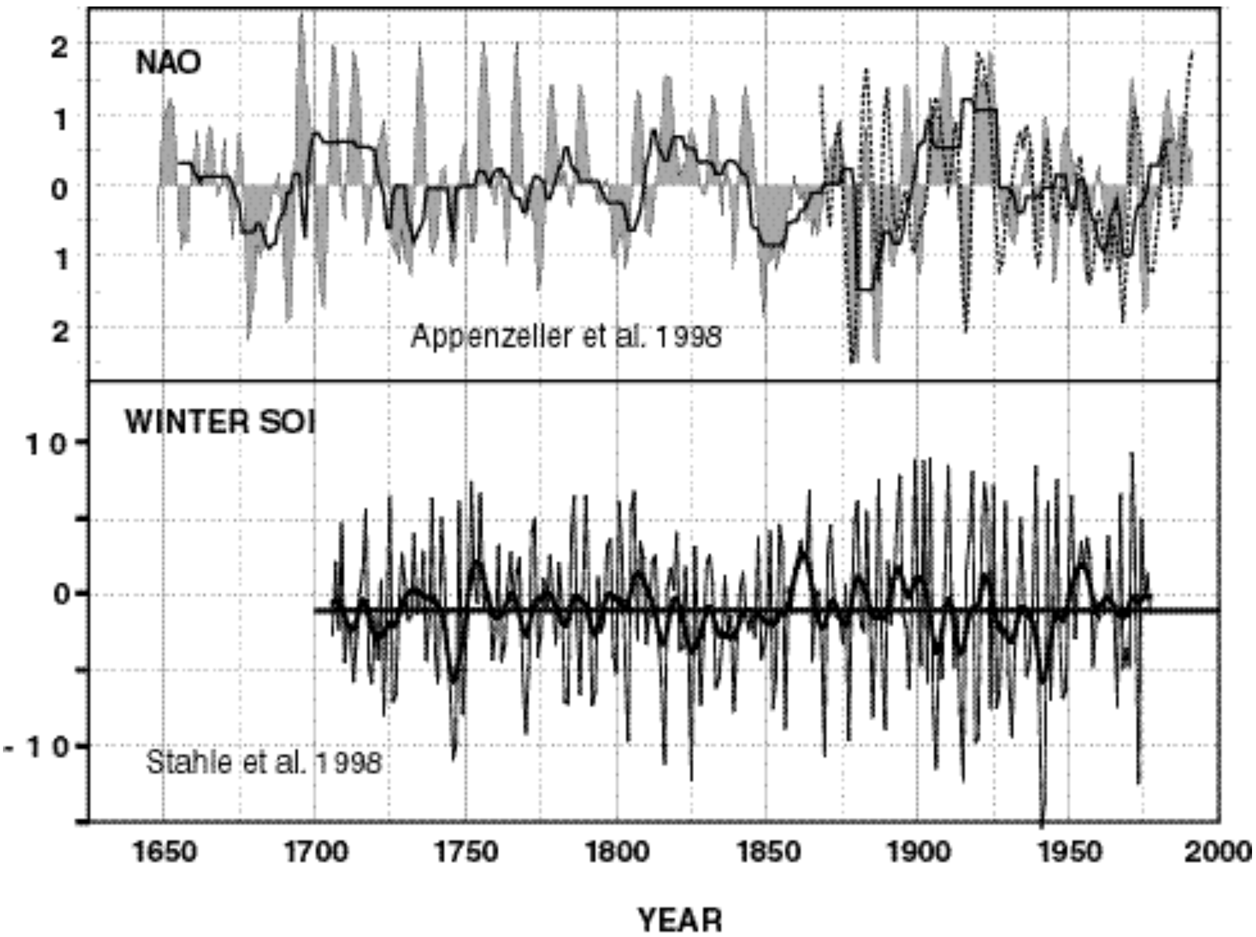


Figure 2: Some examples of dynamical phenomena reconstructed from paleorecords. Above is a record of the North Atlantic Oscillation index taken from Greenland Ice cores and below a tree ring based reconstruction of the Winter Southern Oscillation index.



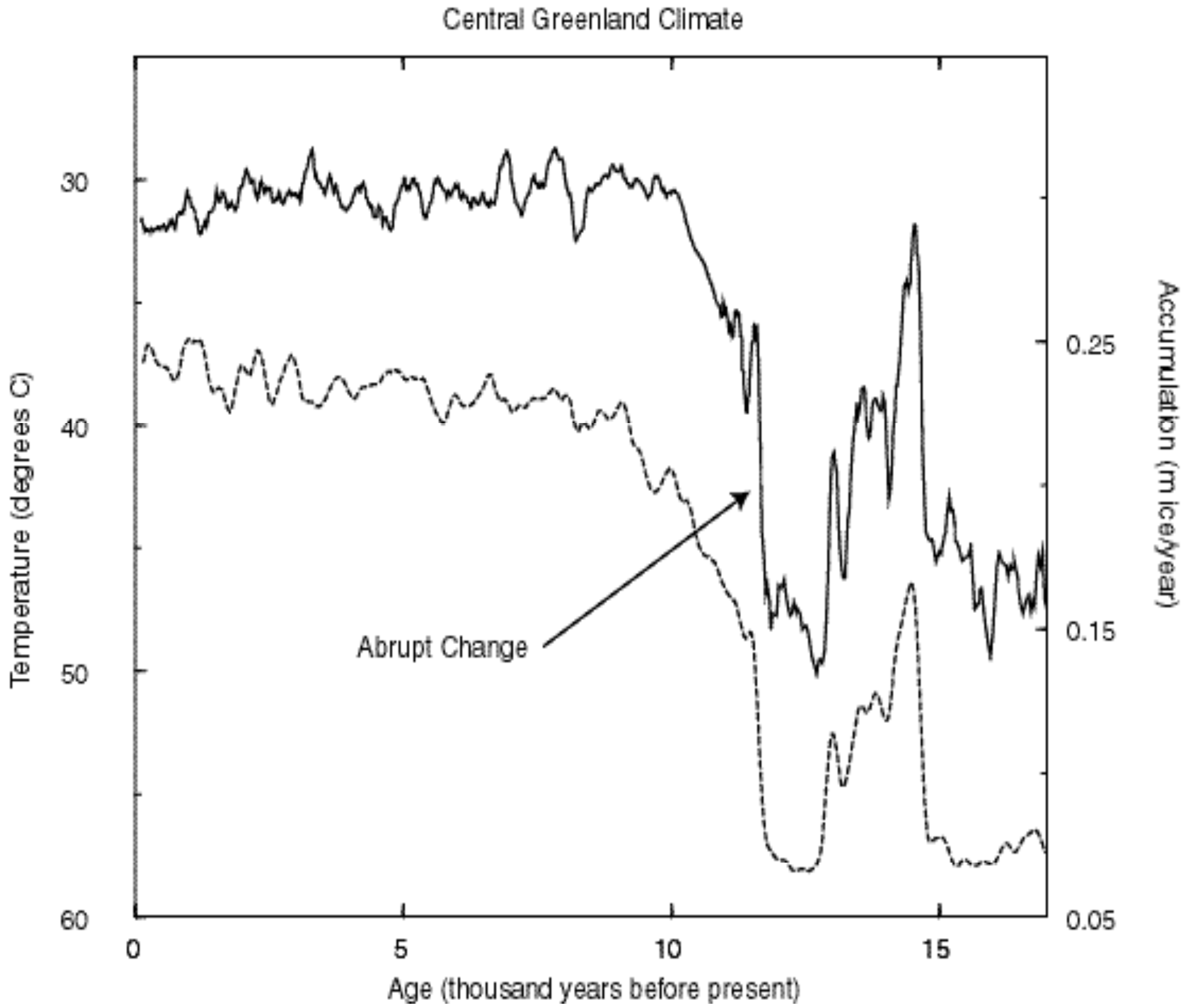
Warm Climate Variability

There are numerous examples of climate change on societally relevant timescales during the relative warmth of the Holocene (roughly the past 10 millennia). Understanding climate variability during warm interglacials is of particular importance for improving predictive climate models which are initiated from modern, warm, background climate conditions. For example, century scale variations in hydrologic balance reconstructed for two widely separated lakes in tropical Africa imply dramatic shifts in the precipitation/evaporation balance much greater than any to be found in the modern instrumental record (Gasse and Van Campo, 1994). Lake level records in the Central USA (Laird et. al., 1996) also reveal periods of intense, multidecadal drought which far outweigh even the severest events in the historical record. Looking further back in time, there are signs from several high resolution archives, for example ice core records and Chinese loess, that at least one major interruption occurred during prevailing warmth of the last interglacial (some 115 - 125k years ago).

Rapid climate shifts

The proxy record is replete with examples of rapid climate change. Such events indicate that strong non-linearity exists in the dynamics of the climate system and present particularly vexing problems for predictability. One well known example is the termination of the Younger Dryas cold event, some 11.6k years ago, an abrupt climatic shift with a probable global signature, albeit with different phasing in different locations (Kudrass et al 1991, Blunier et al, 1997, Steig et al., 1998, Thompson et al 1998). In the record from Central Greenland, this abrupt shift is manifested as a warming of around 15˚C, accompanied by a doubling in annual precipitation volume, occurring in less than a decade (figure 3, Alley et al.,, 1993). The Younger Dryas is not a unique event. During the last glacial period, a series of rapid and large climatic shifts occurred which are well documented in a variety of proxy indicators around the world. At present perhaps the most widely accepted explanation for these climatic instabilities is based on thermohaline circulation changes induced by fresh water pulses into the northern North Atlantic due to continental ice sheet instabilities.

Figure 3: The warming after the Younger Dryas cold event, shown here in the temperature and precipitation records from central Greenland, is one of many rapid, large climatic shifts with probable global signature seen in the paleorecord.



However, climatic instabilities do not depend on the presence of large ice sheets, as they are not limited to glacial times. Accumulation and temperature records in the Greenland GISP2 ice core and temperature records derived from oxygen 18 measurements on ostracod tests in the sediments of Ammersee, southern Germany, both show a climatic instability event which occurred around 8200 years BP, during the Holocene. The event was large both in magnitude, as reflected by a temperature signal in Greenland of order 5°C, and in its geographical extent, as indicated by the close correlation of the signal in these two locations (Von Grafenstein et. al., 1998). As a final example, the drought history for the continental USA shows a large abrupt change in drought variability around AD 1200 (Woodhouse and Overpeck, 1998). Before that time, the high plains were characterized by much more regular and persistent droughts than at present. The mechanisms for rapid shifts such as that seen in these examples are poorly understood, and have yet to be simulated by the current generation of numerical models being used for climate prediction.

Paleoclimate modelling

As part of the task of evaluating models used to simulate climate under changed future boundary conditions, paleodata provides real scenarios against which to test the performance of climate models run under past boundary conditions different from those that prevail at the present day. For example, a first-stage comparison has been performed between numerous model simulations and lake level data for the period. Despite reasonable agreement between models over the Sahara/Sahel region of Africa, all fail to simulate the strong positive hydrological balance demonstrated by the paleo-data (Duplessy and Overpeck 1994). Recognition of this initial mismatch has led to a fruitful interaction between data and modelling communities out of which is emerging a better understanding of the sensitivity of models, and of the climate systems which they represent, to changes in vegetation, land cover and surface moisture.

As part of the PAGES Paleoclimate Modelling Intercomparison Project (PMIP), numerous models have been run under identical boundary conditions (i.e. ice sheets, atmospheric CO2 concentration, sea surface temperature and sea ice extent, as well as changes in the Earth's orbital parameters) relevant to the conditions at several time slices including the Last Glacial Maximum and the so called "Holocene Optimum" when global average temperatures are believed to have been warmer than today. Paleoclimate modellers have also begun to employ simplified models capable of on creating long timeseries to compare with the proxy record.

Future Plans

Interaction between PAGES and CLIVAR is driven by the overlapping interests of the paleoclimate and climate prediction research communities. Paleoscientists rely on modern instrumental records in order to calibrate and validate their proxy climate reconstructions while climate prediction relies on the information about decadal and century scale variability which long, high resolution, multi-proxy paleorecords provide. Project-driven interactions of this nature have led to significant scientific advances. However, the tremendous range of proxy material needs to be harmonized and made readily available to the wider climate research community. The task of coordinating this effort is central to the PAGES/CLIVAR Intersection. Following on from the initial success of the first PAGES/CLIVAR Intersection meeting (Duplessy and Overpeck, 1994), and riding the momentum from the CLIVAR International meeting, an ambitious series of PAGES/CLIVAR workshops is underway.

The first, a small data protocol workshop was held in Boulder, at the World Data Center, in January 1999. The small group of scientists present set about defining the required meta-data which must be made available as part of paleoclimate reconstructions in order to make them usable by the wider CLIVAR community. A second, larger workshop is planned for Venice in October or November, 1999. This latter workshop is envisioned as having roughly equal participation of paleoscientists and scientists from the mainstream CLIVAR disciplines. Comparing and contrasting existing reconstructions of climatic forcing factors, and the climate record itself, for the past 1000 years will be one of the primary activities at the workshop. The outcome is hoped to be a unified, state of the art, global, multiproxy climate reconstruction for the past millennium available in a format most conducive to climate model comparison and climate model forcing. Subsequent workshops specifically addressing abrupt change and climatic modes such as the North Atlantic Oscillation and ENSO are also envisioned. Altogether, this series of workshops will help to bridge PAGES/CLIVAR intersection.

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THE NEED FOR A CLIVAR INFRASTRUCTURE

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CLIVAR is a research programme with a wide-ranging scientific agenda and one that already encompasses an enormous number of researchers and will require huge resources. The very fact that over 60 countries (a record level of interest in a single WCRP project) attended the Paris conference is a clear and positive sign that CLIVAR is an important undertaking. The commitments that we will be made will amount to hundred's of millions of dollars - and that large expenditure on research is entirely appropriate, since the phenomena that CLIVAR will study over the next 15 years have impacts on the global economy that run into tens, if not hundreds of <u>billions</u> of dollars.

The component projects of WCRP present an object lesson in scientific partnership. They have no significant central international resources for observations or for modelling. The projects achieve their objectives through a level of international collaboration and cooperation that is staggeringly successful.

But if course this does not happen by chance. Firstly the international community of scientists needs an agreed plan, and CLIVAR has one, an Initial CLIVAR Implementation Plan, that is the end-product of numerous planning workshops over the past 2 years. It is an **Initial** plan. It will evolve as priorities change, as our knowledge improves and as we identify new critical areas that require study in order to unravel the climate puzzle that is so fascinating and that brought us to Paris.

Just as the planning of CLIVAR required international coordination so there is an even greater need to oversee and assist the implementation of that plan. This is where any project (and CLIVAR in particular because of its breadth) needs an effective, responsive international oversight structure of committees and working groups.

The oversight structure of a project like CLIVAR will, and must, evolve as CLIVAR matures and passes from planning to implementation. Working Groups must address particular problems into which CLIVAR needs improved insight. Panels will provide a means to coordinate activities and this is particularly relevant to observations. (see Figure 1)

There is however an aspect of CLIVAR infrastructure that is just developing. That is the system that CLIVAR needs to manage and store its data and to ensure that those data (and derived products) are delivered to CLIVAR (and the wider community of researchers) in a timely and straightforward manner while maintaining high data quality and comprehensiveness of metadata.

CLIVAR faces particular data challenges because of the wide range of timescales it spans - from seasonal prediction, in which real time data delivery may mean "within a day", through decadal - where speed of delivery is secondary to data accuracy and in which a delay of a year may be entirely acceptable - to anthropogenic change where again there are delays of years between (proxy) data collection and the availability of the interpretation of that data

CLIVAR also requires access to data from virtually all elements of the physical climate system - Atmosphere (over land and sea), Hydrosphere (oceans, rivers, lakes), Cryosphere (sea and land ice) and lithosphere (vulcanism).

CLIVAR faces an added difficulty (but maybe it will ultimately be a strength) in that many elements of the data system that CLIVAR will need, already exist. They have been developed to provide access to the data from equatorial Pacific TAO Array, to handle oceanographic data from the WCRP's World Ocean Circulation Experiment (WOCE) and to provide meteorological and oceanographic data for the operational meteorological services. Not all of these existing systems will exactly match CLIVAR's research requirements (which have yet to be established in detail) but, rather than inventing new systems, we must, wherever possible, adapt and influence existing systems to meet CLIVAR's needs.

Steps are already underway to define those needs and adapt those systems. A CLIVAR Data Task Team has been established to address these issues.

Finally we have an International CLIVAR Project Office. The scientists who give their valuable time to sit on CLIVAR Panels and Working Groups do so on a part-time basis, but any major project requires full-time oversight to try to ensure that things get done. That is the role of the International Project Office. The Office was established in Hamburg at the start of the project and moved at the beginning of 1999 to Southampton, UK, where it will be located alongside the project office for WOCE.

The ICPO's functions are:

- To be the executive arm of CLIVAR Scientific Steering Group
- To advise the SSG and its co-chairs
- To coordinate national research contributions to the international project
- To provide secretariat support to CLIVAR meetings and to publish meeting reports
- To publish a CLIVAR newsletter "Exchanges"
- To publicise the CLIVAR project and its achievements
- To liaise with WCRP Joint Planning Staff in Geneva

The staff that will carry out this task is presently small (3 staff) but will have to increase to match the tasks placed upon it. The ICPO is supported by staff secondments and financial contributions from Australia, Germany, Japan, UK and USA and of course the contributions to CLIVAR support from the JCRF.

CLIVARl needs an enhanced, and evolving infrastructure that can be summarised as :

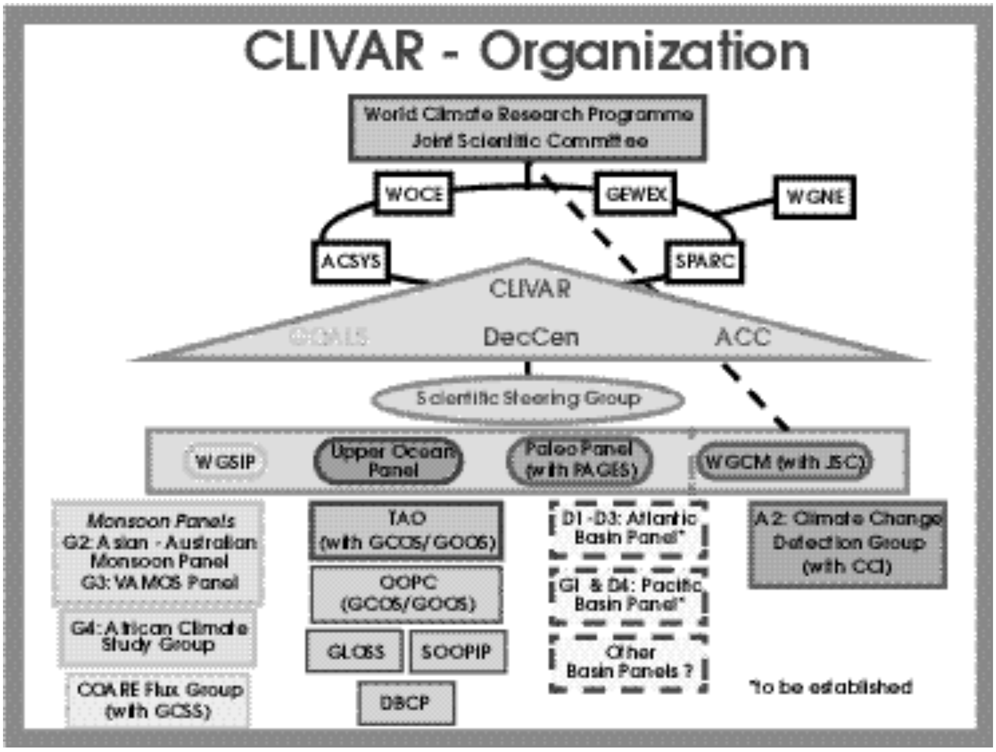
- An effective, well-staffed and well-funded ICPO
- Effective data/information management system
- Scientists willing to serve on WGs and Panels

These needs will primarily be met by countries through their national commitments to CLIVAR in the form of:

- Financial support of, and staff secondments to the ICPO
- Willingness to host and fund elements of data system
- Commitment to the free and open exchange of data
- Support for scientists on participate in CLIVAR Panels and WGs

CLIVAR will, over its 15 year lifetime involve the worldwide expenditure of thousands of millions of dollars. The effectiveness of that expenditure will be greatly enhanced by the commitment of a small fraction of that sum towards the provision of an appropriate project infrastructure.

Figure 1: A schematic diagram summarising the current structure of CLIVAR



SUSTAINED OBSERVING SYSTEMS FOR THE ATMOSPHERE AND OCEAN

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1. The importance of sustained observations for CLIVAR

Observations are a critical element of the World Climate Research Program's (WCRP) Climate Variability and Predictability Programme (CLIVAR) research agenda. In elementary terms, we can state that it is not possible to learn and understand in the absence of relevant observations. The phenomena of interest to CLIVAR scientists have time scales stretching from those of weather out to centuries. There is a similar range in spatial scales. Such a broad research program depends upon an equally broad and comprehensive observing system, sustained over the lifetime of CLIVAR and over all the relevant spatial scales. However, resources are limited, so care must be taken to build upon and exploit existing capabilities and to target enhancements so that they have maximum effect for CLIVAR research.

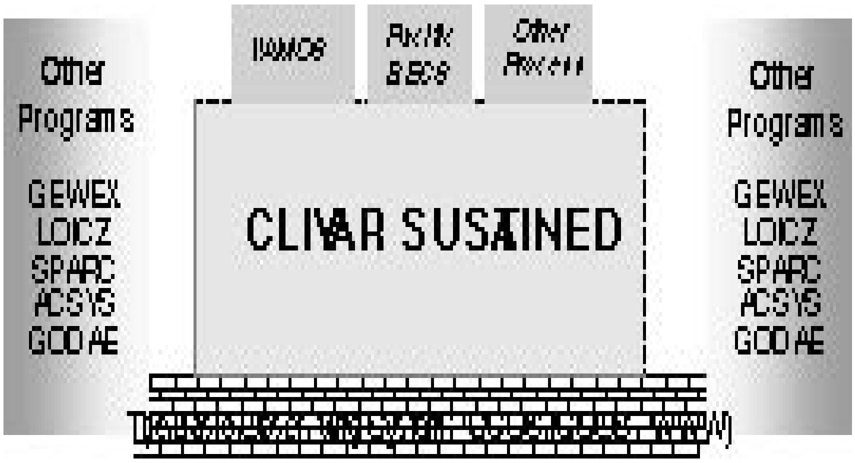

Figure 1. A schematic of the elements contributing to the CLIVAR observing system. The "Basic Observing System" is primarily the responsibility of existing entities like the Global Climate Observing System (GCOS) and the World Weather Watch (WWW). There are important contributions from related programs like the Global Energy and Water Exchange Experiment (GEWEX) and the Global Ocean Data Assimilation Experiment (GODAE). The CLIVAR sustained observing is implemented and maintained primarily for CLIVAR research. There are also various contributions tied to specific process/intensive efforts.

Figure 1 is a schematic of the CLIVAR observing system, with sustained observations for CLIVAR at the core. CLIVAR will benefit directly from observational efforts maintained by others, or for other purposes. Of course, other programs will also draw benefit from CLIVAR observations, an important aspect of efficiency. Specific process and/or regional studies in turn build from the basis of the (global) sustained observing system.

The CLIVAR Implementation Plan notes the importance of a globally distributed set of observations within its global (cross-cutting) framework. For CLIVAR, they provide important contextual information for regional, more focussed studies. Indeed, when one considers the over-whelming importance of global-scale mechanisms in the CLIVAR Principal Research Areas (PRAs), it follows that the global aspects of the sustained observing system must be given very high priority. It is not possible, or practical to implement the observing system PRA by PRA since this would introduce unacceptable redundancy and wastefulness. It is more efficient to implement a satisfactory global foundation and then seek PRA- or region-specific enhancements.

2. Data and information management

A successful and efficient data and information management strategy is critical for CLIVAR. It is likely that many of the CLIVAR signals (signatures of processes/mechanisms) will be small in amplitude, particularly at time scales longer than the interannual. Diligence and care will be needed for processing and analysing both past and newly gathered data sets. The development of a data management plan is perhaps the most pressing concern for CLIVAR at this time.

The following points are likely to be prominent in the plan:

- Swift assembly and distribution of CLIVAR data (real-time), ready availability, and free access;
- Data sets and products that are comprehensive in terms of the CLIVAR variables, with emphasis on global and temporal homogeneity;
- Encourage exploitation of historical and paleao data sets;
- Encourage processing methods that eliminate or minimize the introduction of spurious signals;
- Ensure that adequate and timely data are available for the initialization and validation of climate forecast systems;
- Maximize the utility of the sustained observing system for various process and/or intensive studies; and
- Work with GOOS/GCOS, World Weather Watch (WWW) and Global Atmospheric Watch (GAW) in the development and implementation of the strategy.

There are many different players, so strong cooperation will be needed. For atmospheric data, the systems of the WWW and GAW, and the various activities associated with the Commission for Climatology will be relevant, as will the plans of the GCOS. The new Joint Technical Commission for Oceanography and Marine Meteorology (see Section 5) will provide significant assistance for oceanography data.

In some cases, existing systems and/or practices may need to be renovated for CLIVAR purposes. In other cases, the practices of programs like the Tropical Ocean-Global Atmosphere (TOGA) and World Ocean Circulation Experiment (WOCE) Experimentsa can be adapted to suit CLIVAR objectives. In yet other cases, CLIVAR will have to be prepared to develop new systems and standards.

3. Atmospheric observations

Atmospheric observations will come mainly from existing measurement systems, both remote and surface based. The World Weather Watch and the Global Atmospheric Watch are clearly two important contributors to CLIVAR. They key is to help these networks and associated processing systems work for CLIVAR. These systems are in the first instance not operated for CLIVAR, nor does the research community associated with CLIVAR resource them. They are nevertheless remarkably effective for climate and the best strategy is quite clearly to work with these systems to ensure the necessary data sets are available. Similar comments pertain to the processing mechanisms, particularly those used for numerical weather prediction. The inhomogeneity of the data streams (e.g., the increasingly heavy reliance on satellite data compared with several decades ago) and the ever-changing models and assimilation methods tend to compromise the small, long-period signals of interest to CLIVAR. Various reanalysis efforts have attempted to address the issues associated with changing methods and models but they still remain marginal in terms of longer period changes.

GCOS has defined two networks as a way of maintaining essential baseline data. The GCOS Surface Network (GSN) (figure 2) comprises around 1000 high-quality land surface sites. It is a minimal requirement. Further efforts are needed in data sparse regions. The GCOS Upper Air Network (GUAN) is a fundamental element of the WWW. GUAN is a subset comprising around 150 stations, with the distribution distorted toward the Northern Hemisphere. Many are not fully operational and the numbers are in decline. The GUAN is a needed element of the climate baseline.

The GCOS/WCRP Atmospheric Observations Panel for Climate concluded that the climate community (GCOS and CLIVAR) should be more explicitly involved in the assembly and processing of historical and

present data to ensure the processing, and the final product, meet climate standards. Several centres have already been identified to undertake these tasks.
GEWEX is an important partner, particularly for precipitation and radiation fields. Relevant GEWEX activities include:

- The global streamflow/runoff database;
- The baseline surface radiation network, comprising around 24 stations collecting accurate radiative flux measurements;
- The Global Precipitation Climatology Project for monthly global estimates of area-averaged precipitation; and
- Surface radiation budget, a 10-year global data set of the Earth's surface radiation budget.

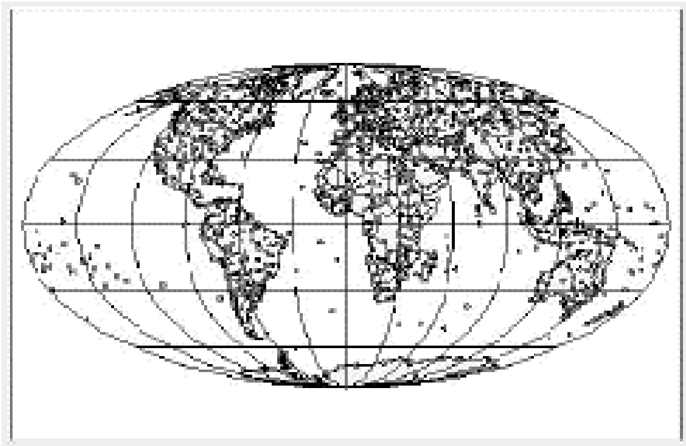

Figure 2. The GCOS surface network (courtesy of the GCOS Project Office)

4. A sustained ocean observing system

TOGA and WOCE provide valuable guidance for CLIVAR. The Ocean Observing System Development Panel (1995) used this basis in developing their recommendations for a GOOS/GCOS ocean climate observing system, in essence the "basic" part shown in Figure 1. CLIVAR is however a research program and so the sustained ocean observing component requires a mix of "operational" and "experimental elements. The emphases implied by the PRAs dictate that certain enhancements will be required. It should be recognized from the outset that there is no strict delineation between "sustained CLIVAR" and GCOS/GOOS ocean observations. The commonalties far outweigh the distinctions, and strong cooperation will be required for implementation. Equally, there is no strict delineation between the sustained and PRA-specific (or process) observations (the two top levels of Figure 1). In this paper (and in the Implementation Plan) the sustained part is aligned with global and cross-PRA contributions.

4.1 Fundamental requirements

The CLIVAR Implementation Plan suggests several elements are fundamental, that is, without these elements the whole of the CLIVAR research program would be severely compromised. In terms of remote sensing, (i) global sea surface temperature (SST), (ii) precision altimetry and (iii) NSCAT-class scatterometer winds (or their equivalent) are considered essential. The need for high quality global SST measurements is clear. The emphasis on small, long-period signals, and the consequent requirements in terms of precision and accuracy (around 0.1°C), perhaps distinguishes the new era from those of the past. This requirement will only be met with appropriate attention to continuity and quality of satellite data and the implementation of an adequate surface-based measurement network. Care is also required when dealing with sea-ice data and the methods used to infer SSTs.

The Topex/Poseidon mission has provided convincing evidence that such a capability must be a part of the sustained observing system. It will contribute across many of the PRAs, from seasonal prediction to monitoring climate change. Precision altimetry is also vital for many applications outside CLIVAR, perhaps best epitomized by the Global Ocean Data Assimilation Experiment (GODAE). The all-too-brief Adeos NSCAT mission provided a glimpse of the potential of scatterometry for estimating global surface wind stress. The "glimpse" was too brief to be able to *prove* such capabilities are essential for further progress but the accumulated evidence is very strong.

The real issues are to do with *how many* rather than "if", for all three approaches. For high temporal and spatial resolution the present polar orbiting satellites are limited in terms of SST. It seems that enhanced geostationary capabilities and/or improved alternative sensors (e.g., microwave) may be needed. For altimetry, the consensus is that at least one high precision and one high resolution (i.e., ERS class) scatterometer are needed. There are good arguments for further capabilities of either class but just which is preferred is not certain at the moment. For wind stress, a similar quandary arises, complicated by the fact that numerical weather prediction is providing ever-improving estimates.

There is also general agreement (e.g., the reports of the CLIVAR Upper Ocean Panel) that certain direct methods are essential. These include:

- The TAO/TRITON arrays in the equatorial Pacific for surface wind, SST and subsurface temperature;
- Drifting buoy and merchant ship measurements of SST, mean sea level pressure and wind;
- A global array of in situ sea level gauges; and
- A global array of profiling floats for measuring temperature and salinity in the upper 2000m.

There are many other important contributions but the above might be considered an absolute minimum. The following sub-section expands a little on some of the detail and enhancements. This is not a comprehensive account and the reader is referred to the CLIVAR Implementation Plan for further detail.

4.2 Surface measurements

For SST the availability of high-quality direct measurements, both from merchant vessels and buoys, is essential. CLIVAR also needs to pay particular attention to sea-ice concentration data and the way it is handled for producing monthly and long-term mean analyses. Good surface samples also remain essential for surface wind stress. For El Nino monitoring and prediction, the TAO array remains one of the most potent sources of information. Even in the presence of a powerful scatterometer it would seem TAO winds should retain high priority.

Surface heat flux estimation remains a difficult task. Operational centers are providing ever-improving products but they generally fall below the standard required for CLIVAR. TOGA showed that it was possible to estimate surface fluxes to high precision with high quality instrumentation, to better than 10 W/m^2. These improvements in modelling and in direct estimation have prompted a proposal to maintain a number of reference sites with the primary purpose of providing on-going, routine flux data for validation of operational products and coupled models. Figure 3 shows one proposal for such a global array, in several cases also maintaining subsurface time-series as well.

Remote sensing of sea-ice concentration and surface radiation are also important elements of the observing system, again with good quality direct measurements being an essential complementary approach. Surface salinity has been given a strong emphasis in the Implementation Plan, first because of its relevance to seasonal-to-interannual prediction, but also because of its importance in following longer-period thermohaline variability. In the absence of a remote sensing capability at this time, emphasis has been given to improving both merchant vessel and drifting buoy sampling.

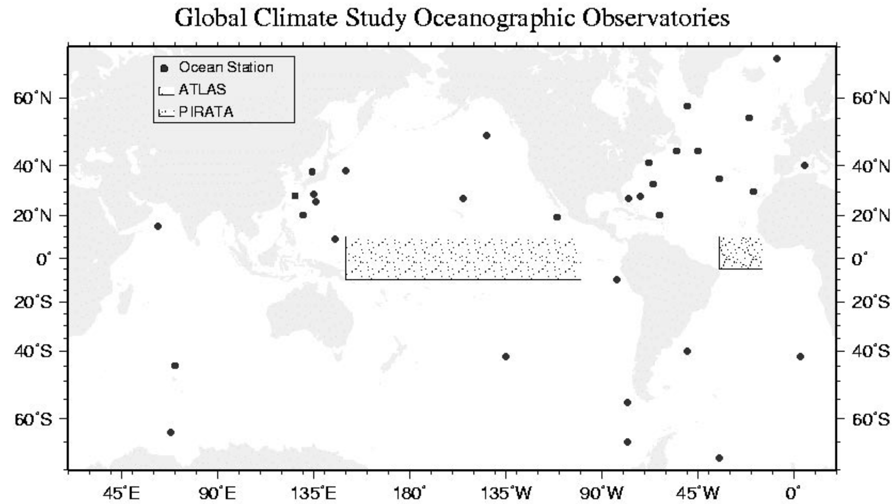

Figure 3. Proposed sites for references stations. They will provide surface reference data for validating surface flux estimates from satellites and atmospheric models. They will also provide time-series data in selected locations, following the mode of the former Ocean Weather Ships, but employing new technologies.

4.3 Upper ocean measurements

The majority of the CLIVAR research areas have a strong requirement for good quality subsurface temperature and salinity data, ranging from seasonal-to-interannual prediction through to climate change detection and attribution. The TAO array and the ship-of-opportunity program were developed in TOGA and remain a key contribution to the observing system. WOCE extended the ship-of-opportunity network globally but it remains limited by the coverage provided by the merchant fleet, the XBT probe depth, and the lack of a cost-effective salinity probe.

A neutrally buoyant float was developed in WOCE to provide estimates of the absolute circulation at depth. In recent years the vertical cycling of the float has been exploited to gather measurements of temperature and, lately, salinity. Figure 4 is a schematic of the cycle of a profiling float. It is feasible to measure temperature and salinity over 2000 m about once every 10-14 days, transmitting the data via satellite to ground stations/labs. A lifetime of around 3-4 years is now feasible. The all-up cost per profile would be order \$100. GODAE and CLIVAR are cooperating in a project called *Argo* to deploy around 3000 such devices through the global ocean. The salinity measurements are a key factor for CLIVAR.

Other approaches are also being considered. Time-series stations (observatories; see Figure 3) and acoustic methods (e.g., thermometry) are likely to be considered.

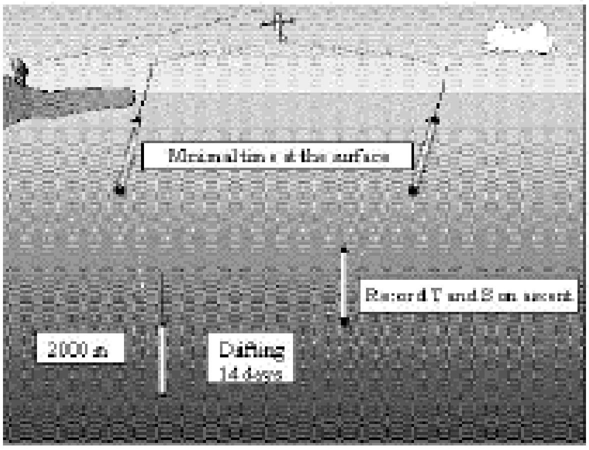

Figure 4. Schematic of the operation of profiling floats (courtesy B. Owens). The float is programmed to seek a certain depth and to "float" there for a certain length of time. It then surfaces measuring temperature and salinity on ascent. At the surface these data are transmitted via satellites to assembly centres/labs. With planned communication systems, the timing of the ascent will be synchronized with the passage of the satellite and two-way communications will be used to tell the float to submerge once data has been received thus minimizing transmission time (and energy).

4.4 Sea level, circulation and the deep ocean

Sea level is clearly an important measurement for CLIVAR. For shorter time scales, it is now recognized as an important contribution to initializing seasonal prediction models. Sea level records constitute one of the few baseline data sets for the ocean and are thus important for interannual and decadal research. At longer time scales, sea level is given special attention because of the potential impact of sea level rise. The preferred strategy is to combine remote and direct measurements so that the benefits of the historical record can be maintained as well as those from global altimetric measurements.

The altimeter is also a powerful, indirect method for inferring ocean circulation; surface topography can be used to estimate surface geostrophic currents. It is this multi-purpose attribute of altimetry that makes it such a powerful contributor to CLIVAR. Floats and surface drifters provide other valuable data for studies of ocean circulation and its role in climate.

Top-to-bottom measurements of the ocean are prominent in most of the DecCen PRAs. Repeat hydrography and trans-basin sections are an important strategy for following the deep thermohaline circulation of the world's oceans. Time-series stations are also an important component. At this time, a comprehensive, integrated strategy for deep measurements has yet to be defined for CLIVAR.

4.5 The Global Ocean Data Assimilation Experiment (GODAE)

The GODAE project was born outside CLIVAR and after the scientific plan had been defined. It does however have many strong links with CLIVAR, not least because of common interests in the observing system. The primary objectives of GODAE are:

(i) The application of state-of-the-art ocean models and assimilation methods for short-range open-ocean forecasts, for boundary conditions to extend predictability of coastal and regional subsystems, and for initial conditions of climate forecast models.

(ii) To provide global ocean analyses and re-analyses for developing improved understanding of the oceans, improved assessments of the predictability of ocean systems, and as a basis for improving the design and effectiveness of the global ocean observing system.

The principal applications include:

- Extended predictability (BCs) for coastal forecasts systems
- Initial conditions for climate forecasts
- Short-range ocean forecasts
- Ocean reanalyses
- Support for the global ocean observing system

GODAE is now entering its pre-operational phase (1999-2002). The development of *Argo* is one of the activities through this period. The intensive phase of GODAE is scheduled for 2003-2005 during which it is hoped that the viability and practicality of global ocean observing systems and forecasts will be demonstrated.

5. The path to implementation

5.1 A Unified Implementation Structure

A new structure is being created within WMO and IOC to support the implementation and maintenance of ocean observing systems. It is to be called the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM; Figure. 5). It will function in a way similar to the technical commissions of WMO which are instrumental in establishing and maintaining the standards associated with atmospheric observations. Its main focus will be on the basic (GOOS/GCOS) elements but it will also provide a mechanism for implementing and maintaining the sustained observations of CLIVAR.

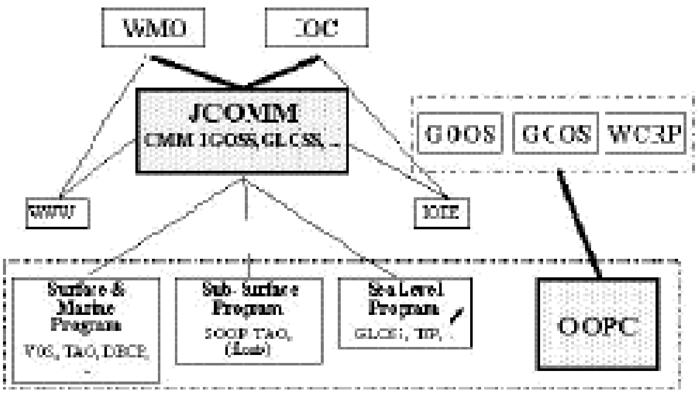

Figure 5. The structure of the proposed Joint (IOC/WMO) Technical Commission for Oceanography and Marine Meteorology (JCOMM). It will absorb the functions of the Integrated Global Observing System Strategy Programme (IGOSS) and the Commission for Marine Meteorology (CMM).

5.2 The Conference of the Parties

The Conference of the Parties to the Framework Convention on Climate Change (COP) recently considered a report on the Adequacy of Global Observing Systems. At the fourth meeting of COP in Beunos Aries in November several resolutions were passed which strongly supported concerted action to improve the observing system for climate. These included:

- A mandate to initiate an intergovernmental process for action (probably via GCOS and friends).
- Identify funding processes within the United Nations and and other mechanisms.
- Parties urged to support the implementation of atmospheric, oceanographic and terrestrial systems and to develop and report national observing plans.

- Supported the principle of free and unrestricted exchange of data.

These resolutions provide unprecedented support for the implementation and maintenance of observing systems in support of climate.

5.3 Conference on Ocean Observations for Climate

With respect to ocean observations for climate, we have now reached a point where we have a good idea of what sort of system we would like to see implemented. The 1995 Report of the GCOS/GOOS/WCRP Ocean Observing System Development Panel, the various reports of the CLIVAR Upper Ocean Panel, and the work of the Ocean Observations Panel for Climate provide a solid basis. The emergence of JCOMM and the resolutions from COP IV also give us the intergovernmental and international means to implement these plans.

The Upper Ocean Panel for CLIVAR and the Oceans Observations Panel for Climate concluded that the best path forward was to convene a conference of all interested parties to obtain community consensus on the scientific rationale and the mix of methods that should be part of the sustained and "operational" systems. The conference will include:

- both operational and sustained research
- scientists and practitioners
- infrastructure and management
- product-driven foci, not technology
- consensus and confidence building
- sharpen priorities but retain balance
- coherent, integrated, broadly supported systems
- remote, direct and indirect methods

This Conference will be held over 18-22 October 1999 in Saint Raphael, France.

6. Conclusions

For CLIVAR research, a global network of sustained observations is mandatory. There are many common requirements among the PRAs so it is sensible to seek an observing system that is multi-purpose. The sustained observing system will provide a basis upon which more specific, process-oriented components can be implemented. The sustained observing system will be implemented in cooperation with others, including GCOS and GOOS.

With few exceptions, we *know* how to gather the information for CLIVAR. The requirements dictate a balance of remote and direct measurements. The requirements are many times greater than any single nation can manage so international and intergovernmental cooperation will be needed. The requirements are several times greater than what CLIVAR itself can do so it must learn to work with others.

At this time, the momentum is with the climate community. The "political" (people) support for global observing systems for climate is presently strong. Our responsibility is to ensure that we use the opportunity wisely.

CLIMATE MODELLING AND PREDICTION
- ACHIEVEMENTS AND CHALLENGES -

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1. Introduction

The climate system is inherently dominated by non-linear processes and there is no simple relation between an external forcing effect, e.g. greenhouse gases or solar irradiation, and the climate system response. Furthermore, certain aspects of climate are unpredictable, and only with considerable efforts can one separate a climate change signal from the natural variability. A particular problem is that the forced and unforced modes are determined by the same mechanisms and feedbacks. To understand and analyse such mechanisms advanced modelling is required.

Three-dimensional atmospheric modelling is now a main component in weather prediction. The recent tremendous improvement in weather prediction (e.g. Bengtsson, 1999), with global useful forecast skill from a day or two to more than a week is a result of such models. A key question is if the same approach will be equally successful for climate modelling and prediction. Such a question must be carefully considered. Firstly, chaotic atmospheric processes limit useful predictive skill to at most a few weeks. Secondly, climate modelling requires integration of atmospheric, oceanic and land surface processes as well as interactions with chemical and biogeochemical processes. Thirdly, external processes, both natural and anthropogenic, add further complexity. Clivar considers time-scales from seasons to centuries so as to allow astronomical forcing such as the Milankoviç cycles to be disregarded. Unfortunately, since humans have significantly influenced climate over the last 100 years, these influences have to be considered.

We are now progressing towards comprehensive modelling of the full climate system but most achievements so far are in the modelling of the atmosphere. Simulation of the general circulation of the atmosphere has benefited from the synergy with numerical weather prediction, NWP, from reliable, accurate atmospheric observations and systematically analysed global data sets. Over the last decade some 30 modelling groups have undertaken decadal and longer simulations of the atmospheric general circulation forced by the same sea surface temperature (Gates, 1992). Although there are deviations from observed atmospheric data, such as upper troposphere temperatures, the agreement with observed atmospheric circulation is remarkably good. This also holds for the characteristic natural variability on different time scales, Table 1. Ensemble experiments show that the three-dimensional atmospheric circulation in the tropics is well constrained by the surface boundary conditions, while at higher latitudes the observed variability is dominated by atmospheric dynamics (Bengtsson et al., 1996). These results are consistent with experience in ENSO prediction.

ECMWF obs	stationary pattern			high frequency (2.5 - 6 days)			low frequency (10 - 90 days)		
SEASON	1000 hPa	500 hPa	200 hPa	1000 hPa	500 hPa	200 hPa	1000 hPa	500 hPa	200 hPa
DJF	0.90	0.91	0.93	0.97	0.95	0.94	0.97	0.93	0.90
MAM	0.84	0.87	0.89	0.96	0.96	0.95	0.96	0.96	0.98
JJA	0.88	0.75	0.69	0.92	0.92	0.95	0.94	0.96	0.95
SON	0.92	0.95	0.95	0.98	0.98	0.99	0.95	0.94	0.96

Table 1 Correlation between observed (ECMWF) and simulated pattern of variability by the ECHAM3-T42 for the Northern Hemisphere (30-year average) (from Perlwitz, 1997).

Name	Forcing due to changing atmospheric concentrations of	Years
GHG	CO_2 and otherwell mixed greenhouse gases	1860-2100
GSD	GHG plus sulfate aerosols (direct effect onlyh)	1860-2050
GSDIO	GHG plus sulfate awrosols (direct and inderect effect) plus tropospheric ozone	1860-2050
CTL	Unforced control experiment	300

Table 2 List of climate change experiments. After Roeckner det al. (1999)

The hydrological cycle is also well simulated. Figure 1 shows the simulation of the global water cycle by the MPI Hamburg's ECHAM4 model forced by observed 1979-1988 SST data. The agreement with the best empirical estimates is within the accuracy of these data. It is interesting that the model can accurately reproduce the secondary water circulation over land areas since precipitation over land is some three times larger then the net transport of water from the oceans. Over some limited regions the models reproduce the large scale water cycle quite well. The simulated hydrological cycle (Figure 2) for the same period but for the Baltic Sea region including the total run-off area is in broad agreement with observational estimates including the interannual variations (not shown). However, a detailed evaluation indicates deviations in the annual cycle and that the model simulates more precipitation in winter and too little during the summer.

Notable progress has taken place in coupled modelling over the last decade and coupled ocean atmosphere models are now routinely used in seasonal and interannual prediction such as for the El Niño events. Land surface modelling has similarly undergone major improvements including the capability to predict hydrological flow and the incorporation of realistic vegetation or biomes which can change with season and interact dynamically with meteorological parameters.

Three examples will be given of recent achievements and associated problems in climate modelling.

2. Seasonal and interannual prediction

Following the success of the TOGA programme, seasonal and interannual prediction is now operational and is thus in a similar situation to NWP in the 1950s and 1960s. We anticipate that efforts will go towards building a comprehensive forecasting system including advanced data-assimilation.

As so elegantly demonstrated by Lorenz (1963), the Earth´s atmosphere is a chaotic system where observational errors and model imperfections prohibit accurate forecasts of the day to day weather beyond a week or so. However, there are two reasons why useful predictions can be extended well beyond this limit. Firstly, the tropical atmosphere does not really conform with the Lorenz definition of chaos. Tropical circulation and precipitation are strongly controlled by sea surface temperature and are rather insensitive to initial conditions of the atmosphere (Shukla, 1998). Secondly, the slowly varying tropical SSTs exercise a steady influence on the large scale global circulation and thereby influence the probability distribution of weather regimes at middle and high latitudes. Thus average meteorological conditions over a month or a season change when influenced by surface boundary conditions predominantly from tropical areas. As demonstrated by Lau (1985) and Bengtsson et al. (1996), typical climate anomalies during a pronounced El Niño event are reasonably well reproduced by atmospheric models when forced by observed SSTs. Figure 3 shows that, when averaged over many cases, an ENSO signal can even be identified over Europe, although in individual cases the noise dominates the signal (May and Bengtsson, 1998).

Experimental predictions by coupled models are now being done on an operational basis (see contribution by Leetma in this volume). A recent experiment by Oberhuber et al. (1998) was interesting in that the prediction was carried out from a coupled general circulation model run (Roeckner et al., 1996) coming from a climate change study to be discussed in section 4. However this model was found to predict ENSO events surprisingly well by making use of a very simple initialization procedure.

The initialization was carried out by just replacing the model's simulated SST anomalies with the observed SST anomalies for the period January 1982 to October 1997. The time scale for the adjustment or nudging was 2 days at the equator and 3.5 days at 30° latitude. The time scale of adjustment increased with latitude to reach 1 month at 60°. Poleward of 60° no SST adjustment was undertaken so that the ocean and the sea ice could evolve freely by interaction with the atmospheric circulation. During the SST assimilation process predictions were carried out. A detailed study was carried out of the El Niño event 1997/98. Figure 4 shows the evolution of ocean temperature anomalies in cross-sections along the equatorial Pacific from the data assimilation experiment. The model is able to realistically capture the downward displacement of the thermocline in the West Pacific for the pre-El Niño phase as well as the eastward propagation during the El Niño phase towards the coast of South America as seen by the TOGA-TAO array (McPhaden, 1995). In April 1997 thermal anomaly reaches the surface and spreads westward until July. At the same time a cold anomaly starts to develop in the West Pacific, intensifies until October and propagates eastward. This feature, confirmed by the TOGA-TAO array, is a first indication of the 1998 La Niña.

A series of forecasts was carried out between January 1996 and October 1997 starting from the assimilated data set and initialized at the beginning of every quarter of the year. Figure 5 shows the NINO-3 SST anomalies as prescribed in the assimilated observations and as predicted by the model from the initial states from January 1997. All the experiments predict an El Niño event in 1997, although with a reduced amplitude, and also the following La Niña. Prediction experiments starting in October 1996 and earlier did not predict the 1997 El Niño event nor did they predict an erroneous event in 1996. Independent studies (Roeckner, pers. comm.) also indicate that the atmospheric response to the SST anomalies was realistic and agreed with meteorological observations in areas where El Niño effects are normally found.

The following conclusions can be drawn from this study, namely:

1) Comprehensive coupled climate models are now capable of realistically reproducing the El Niño and La Niña phenomena confirming other studies that well developed El Niño phenomena are predictable beyond 12 months.

2) Realistic coupled model are needed for ocean data-assimilation. It appears possible to realistically *infer* the temperature structure of the upper tropical ocean without any ocean temperature measurements *below the surface* (see Figure 4).

3) Accurate tropical SST data in space and *time* are crucial.

4) As with atmospheric modelling and NWP the observational requirements and their optimization for ENSO modelling and prediction should not be determined without the use of suitable data-assimilation systems.

3. Decadal prediction

Observations, even when averaged over large domains, are characterized by decadal and longer variations. For the present century where the mean temperature shows a rise until 1940, thereafter a falling trend for some 30 years and then a marked warming. Superimposed on this pattern are shorter, decadal, fluctuations. These are more marked over land than sea and stronger in winter than summer.

What physical mechanisms gives rise to these fluctuations? Stochastic forcing, Hasselmann (1976), is one possibility. The atmosphere is constantly in motion and, while probably not decadal in nature, can readily induce decadal and longer motions in the more slowly varying systems (such as the ocean) that are coupled to the atmosphere. Sarachik et al. (1996) have suggested the analogue of tossing of a coin which generates arbitrary long fluctuations depending on the number of tossing. In a coupled system the arbitrary long time scales are prevented by damping mechanisms. Interannual forcing of irregularly occurring El Niño events can similarly generate ultra-low frequency fluctuations in the coupled system. We share the view of Wunsch (1992), who proposed that stochastic forcing could be considered as a null hypothesis for decadal to centennial variability unless proven otherwise.

A specific application of a low frequency fluctuation in the climate system is the fluctuations of the water level of the Caspian Sea. The Sea is a closed water reservoir with an area of just under 400.000 km^2. The total river catchment is about 3 million km^2. The discharge from the Volga river averages 240 km^3/year or 80% of the total water supply. While the water level only underwent minor fluctuations during the first 100 years or so after 1837, a major drop of occurred in the 1930s, followed by a slower decrease until 1977 – a total drop of almost 3 m. A further fall seemed inevitable due to the increasing water consumption in the Caspian basin. However, quite unexpectedly the level started to rise in 1978 and has now practically returned to the pre-1930s value. The rise in the 1970s and 1980s is comparable to the catastrophic drop in the 1930s and caused even more environmental disasters (Cazenave et al., 1997).

Can the change in the water level be simulated by a GCM? What are the main reasons to the change? Can the future change in the water level be predicted?

Following a preliminary investigation over the period 1979-1988 undertaken within AMIP (Golitsyn et al., 1995, Meleshko et al., 1998), a more extensive study (Arpe et al., 1999) for the period 1903-1994 has been made. The first experiment along the same lines as the AMIP study used observed SSTs and sea ice boundaries according to Rayner et al. (1996). The two major factors that affect Caspian water levels are river discharges and evaporation. While the model can easily simulate the river discharge, determination of evaporation from the sea is very unreliable since the SST data set is not realistic. Fortunately, the correlation between the annual river discharges and the water level changes is 0.82 so river discharge has been used as a proxy for water level changes. Model data from the GCM ECHAM4 (Roeckner et al., 1999) shows (Figure 6) the observed and modelled river run off. The agreement is remarkably good and leads one to conclude that present models can simulate the variations in river discharges and hence variations in Caspian Sea levels.

What are then the possible reasons to the changes? Figure 7 from Arpe et al. (1999) shows a map of cross-correlations between the annual mean SSTs (1903-1994) and the precipitation over the Volga basin. The correlation patterns for both observed and modelled precipitation are practically identical with the strongest correlation in the eastern tropical Pacific. Since the variation in the river discharge of Volga varies with the precipitation, it appears that the main cause is likely to be related to processes coupled to temperature anomalies in the eastern tropical Pacific. Arpe et al. (1999) also found that the correlation pattern between the SST anomalies and the river discharge is very similar to the correlation pattern in Figure 7. Positive anomalies (high SSTs) are coupled to higher than normal precipitation in the Volga catchment area and vice-versa.

The atmospheric equivalent of El Niño is the Southern Oscillation, SO. Observational data as well as model simulations have demonstrated the strong coupling between the two. The Southern Oscillation is normally expressed as the pressure difference between Darwin and Tahiti and is positive when eastern Pacific SST is anomalously warm. Arpe et al. (1999) have shown that an index consisting of the successive time integrations of the SO can be suitably related to the Volga river discharge and hence the Caspian Sea level. Longer periods when cold anomalies dominate in the tropical Pacific reduce the value of the integrated SO and periods of warm anomalies increase the value. (Figure 8). The integrated SO leads the change in Caspian Sea level. It appears therefore that the main cause of Caspian Sea levels is variations in the probability distribution of ENSO events. Periods of dominating warm events generate more precipitation in the Volga catchment basin and vice versa and hence influence discharge to the Caspian Sea.

The third question may then be coupled to any possible changes in the probability distribution of El Niño. We believe, as indicated from long model simulations, that El Niño is likely to vary in a chaotic way at least in a long term perspective, and thus without any climate change we may anticipate the low frequency variation to continue. However, this may not be the case under a scenario of climate change where generally the precipitation, in particular over land, is projected to increase. Such an increase in precipitation may then likely be superimposed on the type of natural variations discussed above.

4. Anthropogenic climate change

An area where coupled modelling has been active is the study of anthropogenic climate change. IPCC has over the last years proposed a series of scenarios concerning the likely future emission of CO_2 and other greenhouse gases. An issue which may have been somewhat overlooked in recent years is the general question of the response of climate models to a prescribed forcing. The JSC working group of climate modelling (WGCM) has recently arranged a series of climate model studies to explore model response to a prescribed forcing. In order to obtain a climate equilibrium state the experiments were carried out with an atmospheric model coupled to a shallow mixed layer model. The forcing consisted of a doubling of CO_2. What happens when suddenly the CO_2 concentration is doubled?

The immediate response is a reduction in the outgoing long wave radiation at the tropopause of about 3.1 Wm^{-2} and an increase in the downward emission from the stratosphere by about 1.3 Wm^{-2}.The sum of the two 4.4 Wm^{-2} is the net instantaneous forcing at the tropopause.

Following this immediate shock the stratosphere cools. The increased CO_2 in the stratosphere enhances the CO_2 emission. Because the stratospheric temperature increases with altitude this has the effect that the cooling to space is larger than the absorption from layers below. This is in fact the fundamental reason for the CO_2-induced cooling in the stratosphere. Following the stratospheric cooling a new radiative equilibrium with the new doubled CO_2 concentration occurs, which reduces the increased downward emission at the tropopause by about 0.2Wm^{-2}, and the tropopause forcing is adjusted accordingly.

The surface-troposphere system will continue to warm until the entire system reaches a new equilibrium. This may take a considerable time due to the very high heat capacity of the ocean and it will certainly last several decades before an equilibrium is reached, if at all. In a mixed layer model an integration length of some 20 years is normally sufficient. Due to different feedbacks in the climate system, mainly through water vapour and clouds, the initial forcing is considerably enhanced but in a way which is strongly model dependent. Figure 9 from LeTreut and McAvaney (1999) shows the response changes in the global average temperature and precipitation by 11 different models to a doubling of CO_2. The surface warming ranges between 2.1°C and 4.8°C and the global precipitation increases between 1 and 10%. The increase in precipitation is considerably less than calculated from the Clausius-Clapeyron equation. The reason is that the surface net forcing is not increasing proportionally to the surface temperature, since the atmosphere is getting less transparent at higher greenhouse gas concentration.

The relation between forcing and response to forcing is even more pronounced when we study its geographical distribution. We will discuss this in relation to recent transient climate change experiments by Roeckner et al. (1999). Roeckner et al. undertook three specific climate change experiment as summarized in Table 2.

The experiments start in 1860. Observed concentration of greenhouse gases and sulphate aerosols have been used until 1990 and thereafter changed according to the IPCC scenario IS92a. Tropospheric ozone changes have been calculated from precursor gases.

In the first experiment, GHG, the concentrations of CO_2, CH_4, N_2O as well as a series of industrial gases including CFCs and HCFCs were prescribed as a function of time:. The absorptive properties of each gas have been calculated separately. Furthermore, the radiative forcing is practically identical to the narrow band calculations. This meant here an increase in the radiative forcing by some 10% compared to the actual broad band calculation in the radiation code of the model.

In the second experiment, GSD, the greenhouse gases are treated as in GHG but with the additional incorporation of the tropospheric sulphur cycle as due to anthropogenic sources only. Natural biogenic and volcanic sulphur emissions are neglected, and the aerosol radiative forcing is generated through the anthropogenic part of the sulphur cycle only. The space/time evolution in the sulphur emissions has been derived from actual emission records. The full anthropogenic sulphur cycle has been integrated into the atmospheric model including the actual geographical emission of SO_2, chemical transformation to sulphate, semi-Lagrangian transport of the sulphate aerosols and finally the dry and wet disposition of sulphate particles from the atmosphere.

In the third simulation, GSDIO, the indirect aerosol effect on cloud albedo was added. The tropospheric ozone distribution was also changed as a result of the prescribed anthropogenic emission of precursor gases. Figure 10 shows an attempt to validate the deposition of sulphate in the wet and dry deposition in ice core measurements at the Dye 3 on Greenland. Figure 10 a shows the measured concentration of sulphate in ng g^{-1} according to Legrand (1995), Figure 10 b the result from the corresponding control integration and from the GSDIO experiment. The agreement between the calculated deposition is in broad agreement with the measurements.

The global annual mean temperature change from the three experiments, is shown in Figure 11. As expected, the long term warming is largest in GHG and smallest in GSDIO. Until 1980 or so the simulated temperatures are more or less within the range of natural variability of the control integration (not shown). However, the simulated temperature patterns undergo large low frequency variations on a multi-decadal time scale in broad agreement with the estimated observed temperature pattern. In the model simulations there are pronounced ultra-low fluctuations at higher latitudes of the Southern Hemisphere, but it is not possible to say whether these fluctuations are simply an artefact of the coupled model.

We will next investigate the geographical relation between the forcing and response in the three transient experiments. This is done by comparing the meridional profiles of zonally averaged forcing for the period 2040-2050 to the corresponding meridional profile of the surface temperature, Figure 12 and Figure 13, respectively. The experiment with greenhouse gases only, GHG, has a maximum forcing at around 20°N, decreasing both towards the equator and higher latitudes. The other experiments have a reduced forcing increasing towards middle latitudes at the Northern Hemisphere due to the emission of SO_2 in these regions. The meridional profile of response to forcing looks very different to that of the forcing with the maximum warming taking place at high latitudes of the Northern Hemisphere in the region where at least the experiments GSD and GSDIO have the smallest forcing! What can be the reason to this?

We believe that the warming pattern is generated following a series of complex feedbacks in the model. Due to the complexity of the model and the long time-scales involved an analysis at this time can only be tentative. Most models respond to the initial greenhouse warming in the troposphere by increasing the amount of water vapour (most models more or less conserve relative humidity). The altered water vapour enhances the greenhouse effect and a positive feedback takes place. The effect is likely to operate in areas where the moisture content is high, such as in the tropical rainbands and the extratropical stormtracks. Warming over land areas is larger than over oceans due to the large ocean heat capacity which delays the warming considerably.

The delayed warming is particularly strong in the southernmost oceans with its strong oceanic vertical heat exchange. Finally, in the climate warming experiments the storm tracks are moved slightly polewards, particularly over the Northern Hemisphere. The feedback at high latitude land areas is also enhanced through albedo feedback due to reduced snow cover on the ground in the climate change experiments. We thus anticipate that complex feedbacks like these are the probable reason for the distribution of the warming. Many of the feedback processes are model dependent and the probable cause of the large model variability as that shown in Figure 9.

With these complex feedbacks at work will it all be possible to realistically improve the accuracy of simulations and to predict regional climate change? It is clear that we have to improve the coupled models and better understand the feedback mechanisms. Model improvements require better observations and a better understanding of processes. This can only be accomplished if CLIVAR works very closely with the process-oriented programmes of WCRP and IGBP.

We must also note that most climate change experiments undertaken so far are perturbation experiments and different empirical corrections have been applied to assure that the coupled models, when forced with present data, remain within the range of the present climate. Because of systematic model errors a more or less slight drift towards another quasi-equilibrium occurs. Normally this is corrected by assuring that the mean fluxes of water and heat between the atmosphere and the oceans are empirically geographically adjusted (so called flux adjustment) to avoid a drift away from the present climate. However, due to recent model improvements model errors are now so low level that they have become tolerable. Nevertheless, the general result with and without flux adjustment is practically identical.

5. Concluding remarks

The central objective of CLIVAR is climate prediction and simulation and, as we have tried to demonstrate, we anticipate that numerical modelling will constitute a central part of the future research programme. However, to achieve success, very demanding and significant computing resources will be needed. The climate system is only partially predictive and special techniques will have to be developed to handle this in a systematic way. The ensemble technique presently being used in medium range prediction is one such way which should be explored. Another issue is the coupling of the different components of the climate system into an integrated system including, when required, four-dimensional data-assimilation. To do this requires special institutional resources including advanced technical staff of the type which presently only exist at the large forecasting centres such as ECMWF.

An area where major scientific efforts are needed is climate change modelling. So far only the global aspects of climate change have been addressed, while the practical value and thus the interest for society concerns the regional and local changes. In that respect possible changes in extreme climate events are probably the most important deliverables. As is indicated in this lecture this is not an issue which can be addressed by high resolution modelling but must in the first hand depend on a better understanding of the feedback processes in the climate system.

A particularly important question not yet properly modelled is the integration of biogeochemical cycles in the climate models. It is to expected that changes in the temperature and water cycle will change the uptake of carbon cycle in the biosphere. Preliminary studies (P. Friedlingstein, pers. comm.) suggest that a fully integrated system may affect the carbon cycle significantly and thus change the atmospheric concentration more than previously assumed. The JSC WGCM and the IGBP GAIM committee have agreed

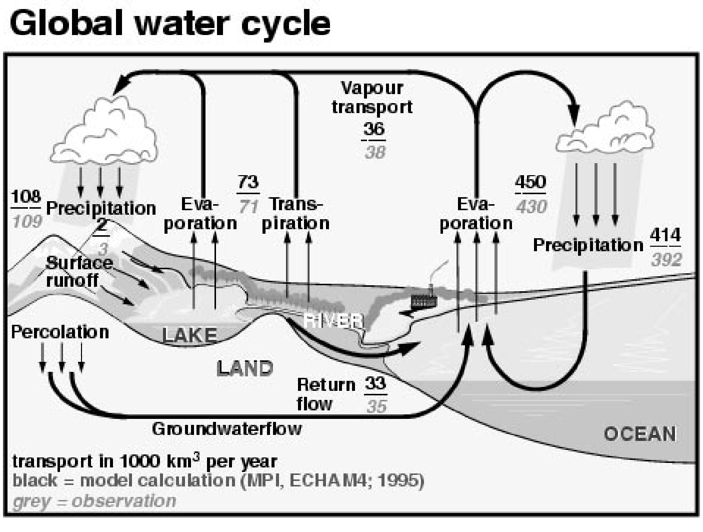
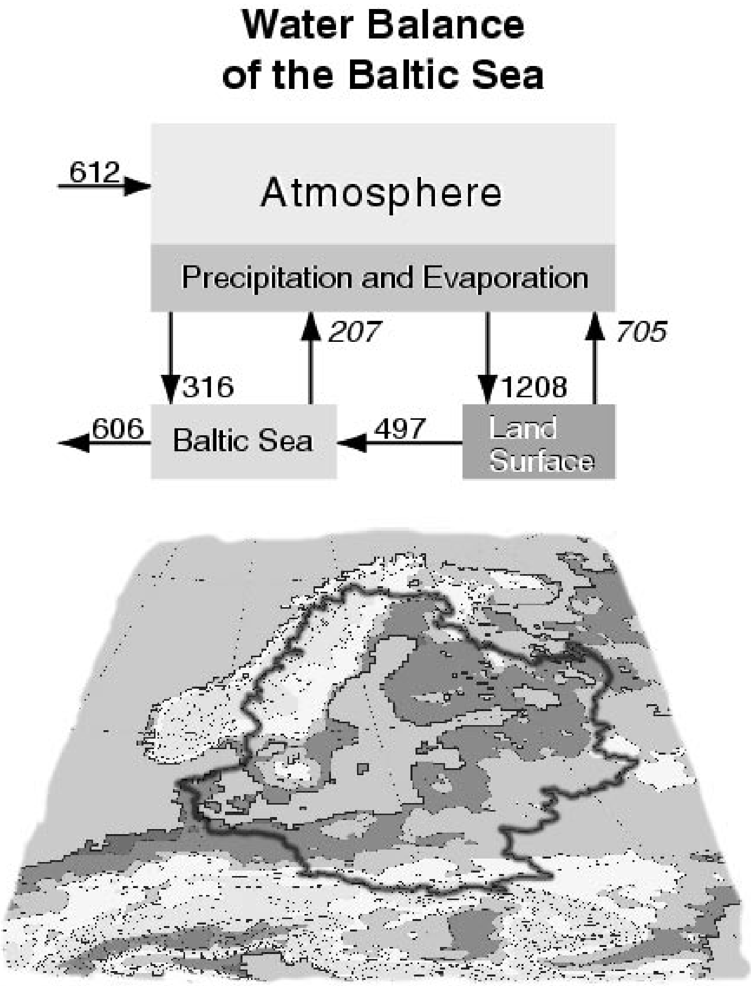


Figure 1: Global annual mean hydrological cycle for the marine and continental areas, respectively. Upper figures show model calculations with the ECHAM4 model and lower figures are empirical estimates (averages result from Baumgartner and Reichel (1975) and Chahine (1992)). Snow fall according to Bromwich (1990). Units are given in 10^3 km^3 yr^{-1}.

Figure 2: Model simulation of the hydrological cycle in the Baltic Sea drainage basin with the ECHAM4 model (10-year average). Precipitation over land and sea is indicated by downward directed arrows and the evaporation by upward arrows. The river run-off from land and the net run-off into the North



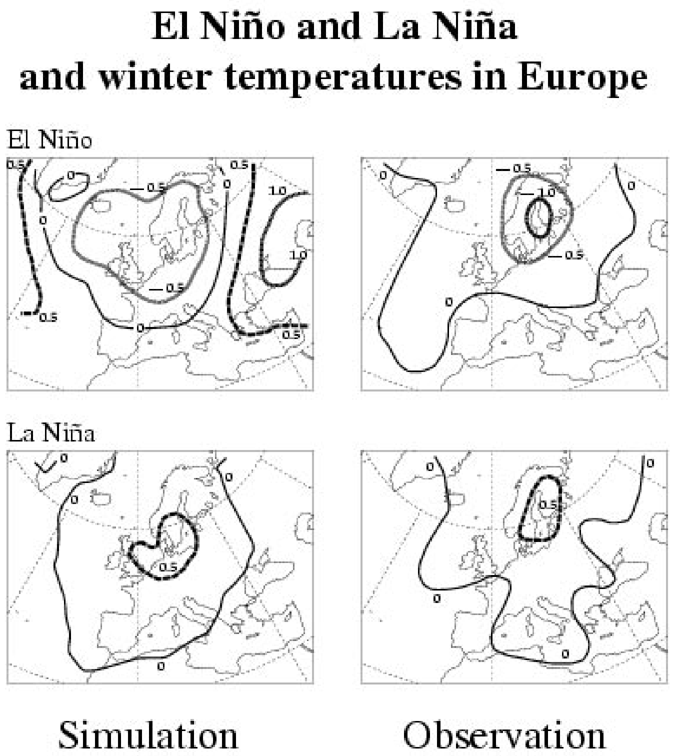
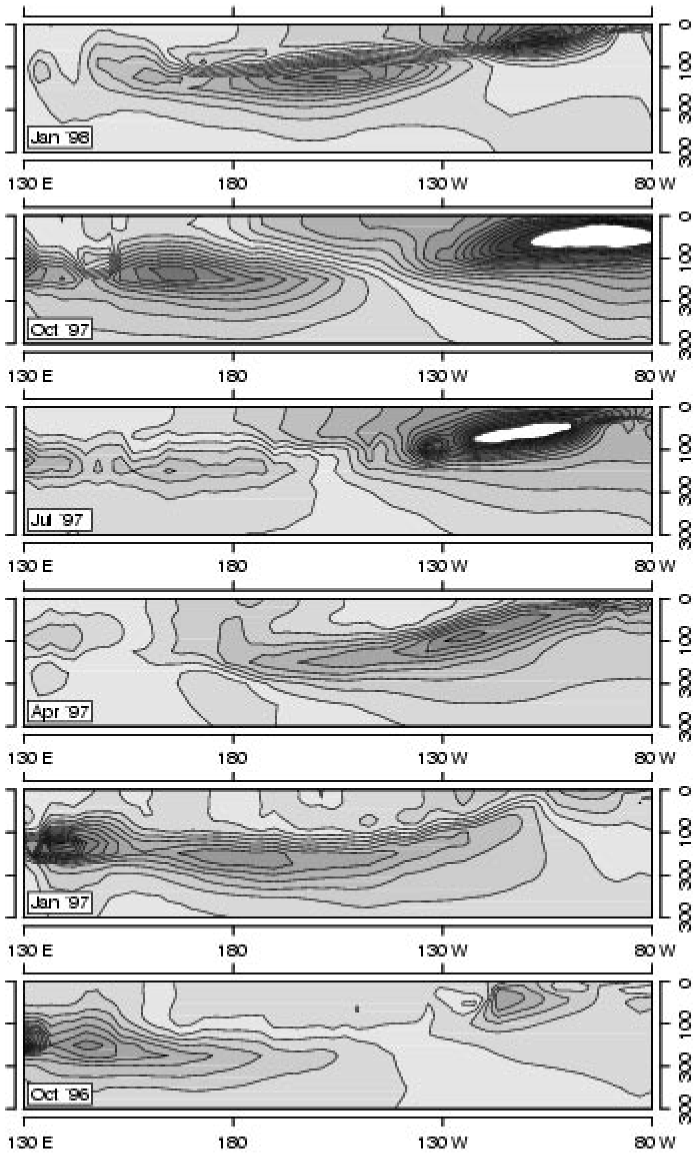


Figure 3: Simulated temperature at 850 hPa (left) and observed surface temperature (right) for the ENSO signal for the European area. Observations according to Fraedrich and Müller (1992). Unit K.

Figure 4: Vertical cross section of the ocean temperature anomaly at the equator as derived from the averaged modelled seasonal cycle for October 96 to January 98. The first five fields are assimilated results and the last field (January 98) predicted from October 97. Increments are given in units of 0.5 K. Full lines are warmer than 0.25 K and dashed lines colder than -0.25 K. After Oberhuber et al. (1998).



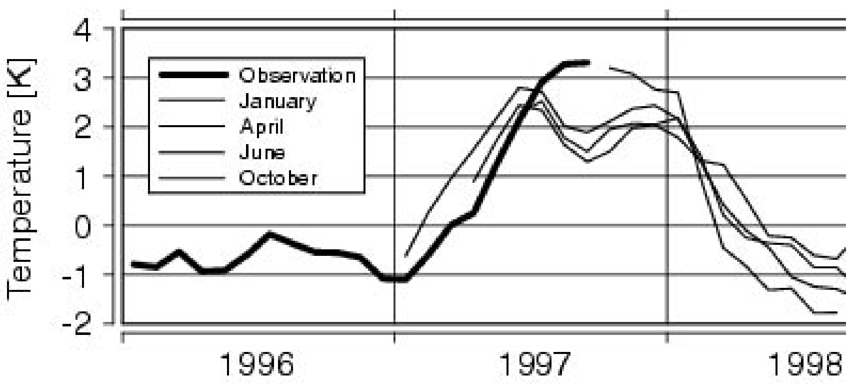


Figure 5: NINO-3 averaged sea surface temperature anomaly for the observations (heavy full line) and for the predictions initialized in January, April, June and October 1997. Full line, dashed line, dotted line and dash-dotted line, resprectively. Temperature units in K.

to set up a joint study to explore this issue in depth.

Figure 6: Observed and model calculated river runo-off to the Caspian Sea from 1900-1995. The units are expressed in cm yr^{-1} of sea level change. For further information see text.

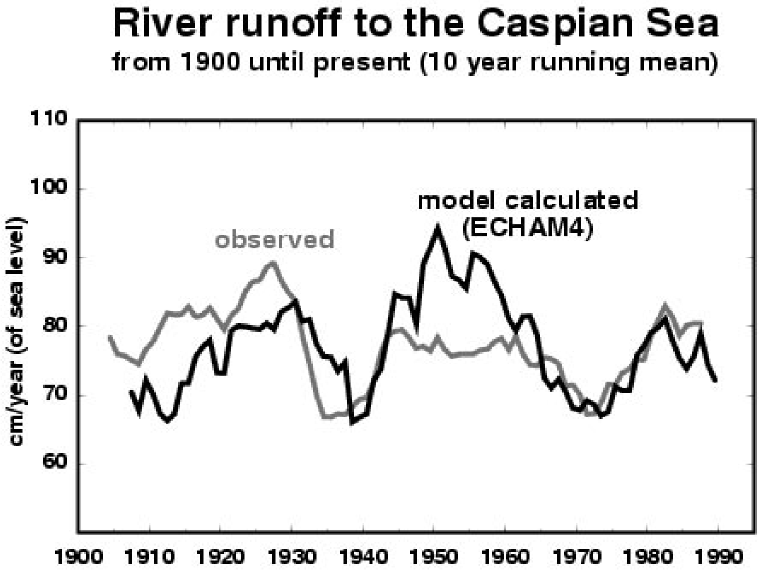
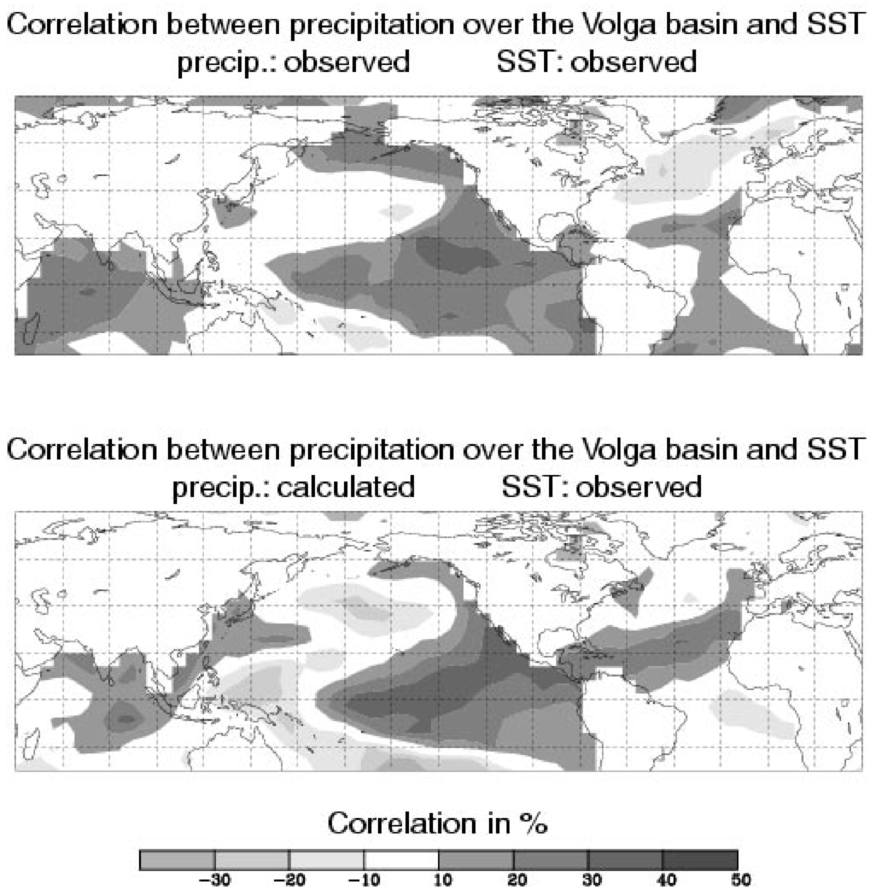
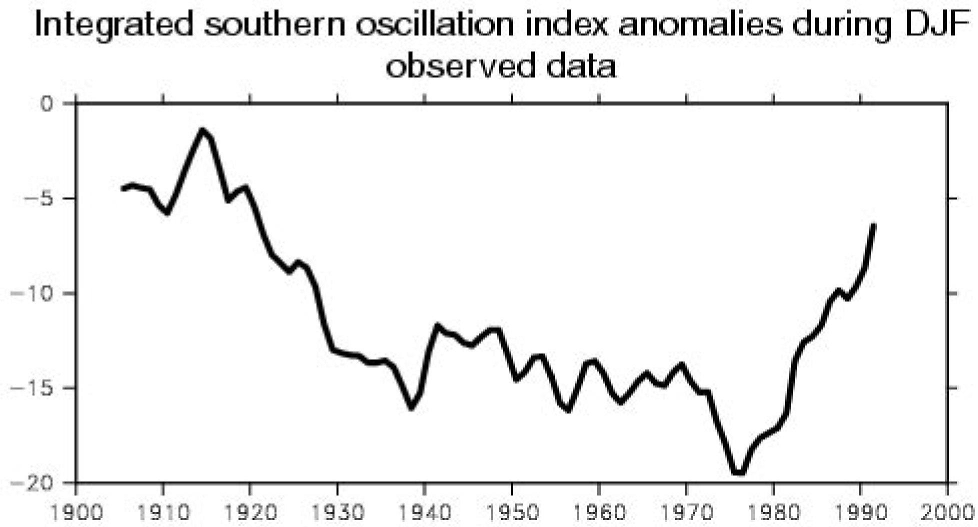


Figure 7: Correlation between precipitation over the Volga basin and sea surface temperature. Annual means between 1950 and 1995. Above: Between observed precipitation and observed SST. Below: Between model calculated precipitation and observed SST. An ensemble of four integrations has been used. After Arpe et al. (1999).





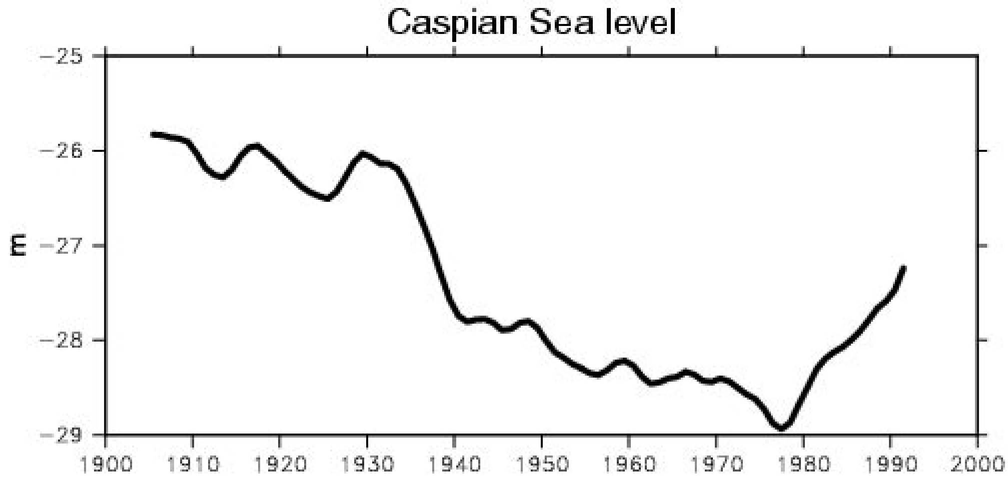


Figure 8: Above: Time integrated Southern Oscillation index anomalies during DJF. Arbitrary unit. Below: Variation of the Caspian Sea l;eve. Unit m. After Arpe edt al. (1999)

Figure 9: Equilibrium response to 2 x CO_2 for eleven GCM coupled to a mixed layer ocean. For further information see text. After Le Treut and McAvaney (1999)

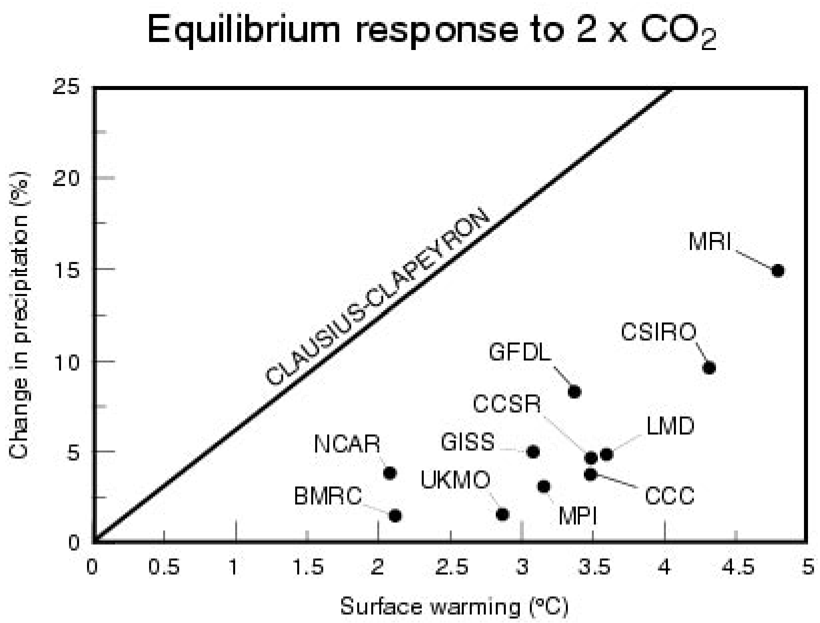


Figure 10: Evolution of the annual sulphate content in snow/ice at the Dye 3 site in southern Greenland (65°N, 43°W)
a) observed (Legrand 1995)
b) GSDIO simulations for the nearest grid point with prescribed natural sulphur emissions only (gray line) and total emission (natural plus anthropogenic [dash line]). After Roeckner et al. (1999).

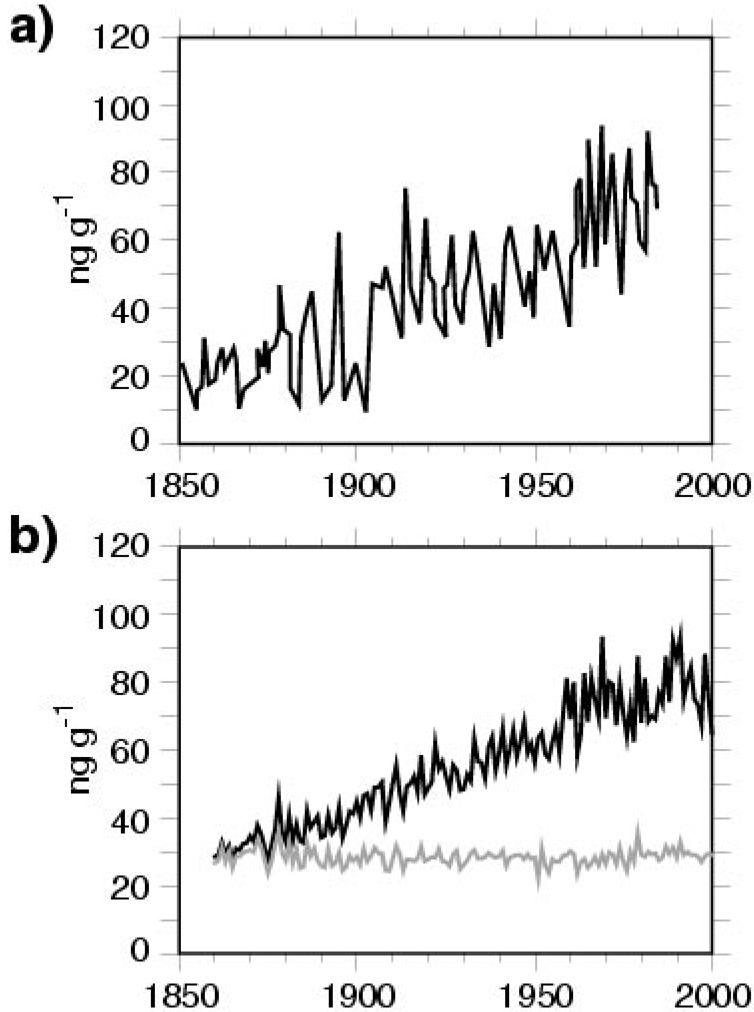


Figure 11: Evolution of changes in annual global mean surface air temperatures compared to a control integration (for the experients, GHG, full thin line, GSD light gray thin line, and GSDIO, gray thin line). Observational data from 1860 until present is shown by a heavy dark line. A 5-year running mean is applied. After Roeckner et al (1999).

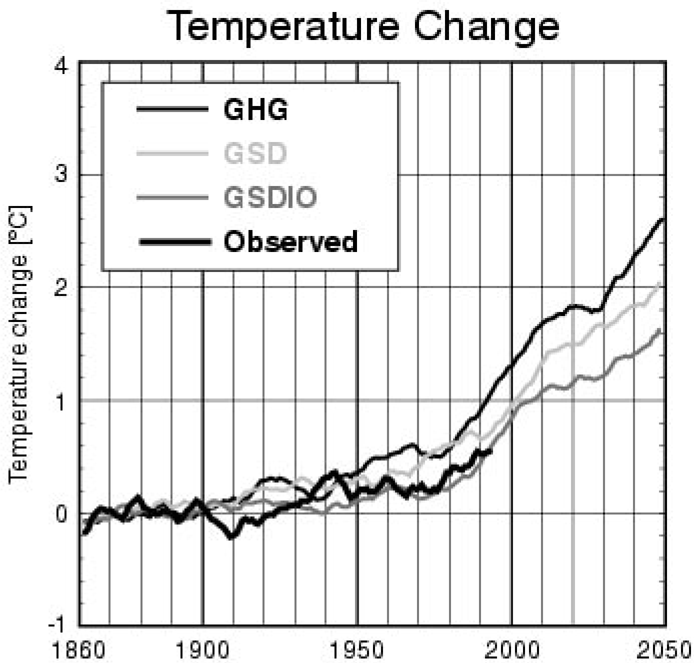


Figure 12: Annual mean radiative forcing at the top of the tropopause in the three experiments GHG, GSD and GSDIO as well as the individual forcing due to O_3 (Troposphere only), SO_4 (Direct effects) and SO_4 (indirect effects as calculated from experiments GSDIO). The figure shows the meridional profiles of zonal averages for the period 2040-2050. After Roeckner et al (1999).

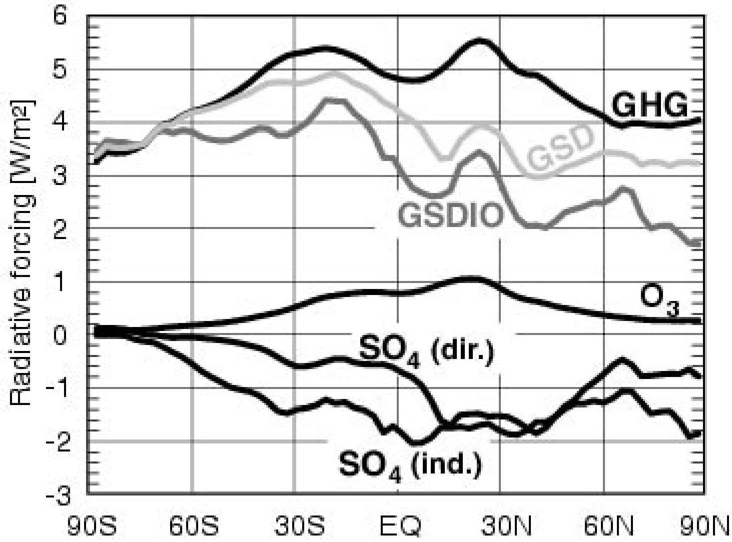
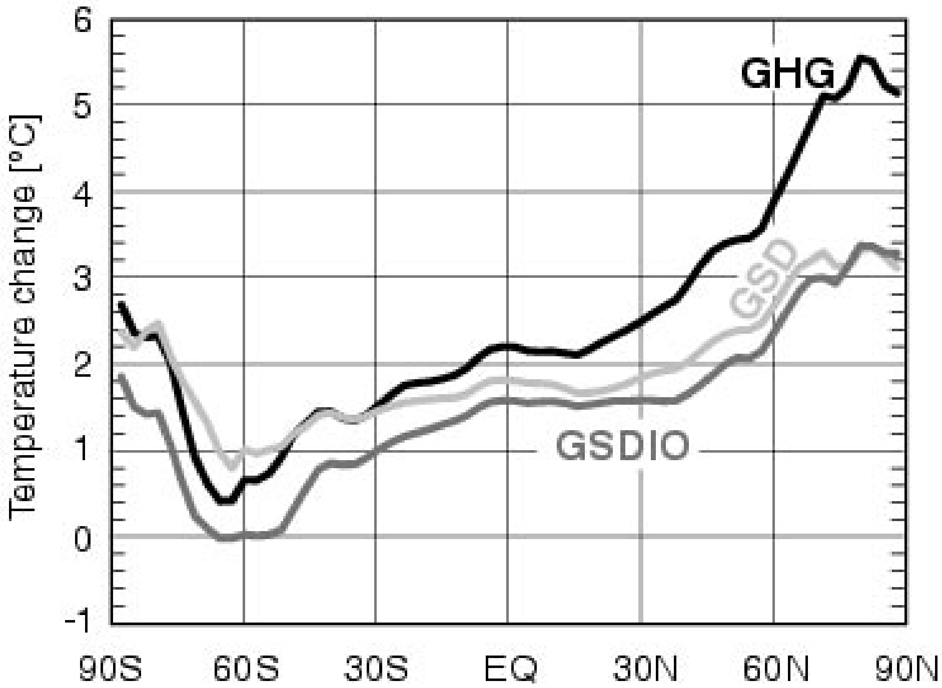


Figure 13: Meridional profiles of changes in the annual zonal mean surface air temperatures for the period 2030-2050. After Roeckner et al (1999).



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CLIVAR - REALIZING THE VISION

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The organizers of this conference asked that I provide some informal comments at the end of the meeting, in part as a potential CLIVAR sponsor. How does CLIVAR planning thus far look to potential sponsors? Speaking for the US agencies represented here today, I am pleased to say that these comments are more accurately those of an actual sponsor. We believe CLIVAR is on the right track and is articulating a vision which will prove to be responsive to the interests of sponsoring nations but also of leading scientists, decision-makers and the public. My personal comments today are centred around a few suggestions for how you might realize your vision, and a view of what is at stake in your succeeding in this enterprise.

A useful place to start is the changing world context in which you are planning your program. While it is certain that you address a critical set of research problems the larger context will turn out to be very relevant to the magnitude and the success of your program. I believe that the very nature of the social contract between research and society is changing. The cold war played a critical role in energizing the sciences for 50 years. But the cold war is over. The question now is which societal interests will sustain the research effort in the future? We must pay close attention to what that broad reconsideration of research motives means to our enterprise. At a minimum, the societal aspects of the climate problem and the need for a comprehensive, integrated scientific perspective, will force us to consider the limits of the scientific reductionism with which we have become so comfortable.

We are now experiencing both intellectual and practical demands for inquiry into "the whole" of climate system behaviour as it relates to social policy. Although we have succeeded greatly over the past twenty years by decomposing our research into an ocean problem and an atmosphere problem, and by experimenting with dynamic coupling of these important sub-systems, we are not yet able to treat a host of practical problems for which the assembly of an even larger whole is necessary. Beginning to address the scientific "whole" is where CLIVAR comes into the picture. If you can accomplish true intellectual integration in the implementation of CLIVAR, you will have found the key to achieving scientific insight into one of the most important issues of our time. Such a program will naturally draw major support from a diverse group of stakeholders in the climate problem.

Undoubtedly, the implementation of a fully integrated enterprise will be more difficult than the global scale research projects we have previously undertaken. So when you hear talk about implementing mechanisms which are a little more elaborate than you have seen before, don't recoil; management of an effort of this breadth is going to be a formidable challenge. Your effort thus far has been remarkably successful. CLIVAR has achieved the level of scientific planning that is critical to this task. There are already numerous national documents, a very good scientific plan and a promising implementing plan on the table. You have rationalized a very complex research agenda that even a few years ago seemed impossible. In addition, you've given us a vocabulary to use in weighing the gravity of one scientific challenge against another. The fact that CLIVAR is said to be all over the map is actually high praise — for your task is a global one. CLIVAR is in the process of assembling the unifying intellectual construct, the elusive dynamical centroid of the whole climate problem.

A further implication of the evolving social contract and its importance for science is the imperative to make connections with IHDP (the human dimensions program) and with social scientists more generally. Consider, for example, the recent Science paper suggesting that carbon sinks are regional in character and may be as large as carbon emissions on a comparable scale. The paper suggests also that these sinks may well have something to do with human land use activity. Not only does this illustrate the increasing importance of links with social scientists, but it exemplifies the fact that the way you do your science and the way you communicate results can change the world.

A third element of the social contract that I want to emphasize has to do with diagnostics and prediction. You are in the process of creating the intellectual underpinning of a routine climate information service. The tendency among scientists to keep results close to the vest until certainty is quite high presents a major challenge in getting the information into the hands of decision-makers in a timely way. Communicating what we know about decadal trends and incorporating them into our seasonal to interannual forecasting, for example, will be an essential feature in building a reliable and relied-upon information service. Our ability to meet the challenge of the new social contract depends upon our commitment to keep working at this task.

My final suggestions have to do with program management. First, capture and sustain the momentum of this meeting. That may sound trivial, but its importance cannot be overstated. Next, recognize that you are trying to design an efficient and self-sustaining program culture. I really believe that whether CLIVAR is a great program or merely a good program is going to be a function of the ability to sustain the kind of enthusiasm we see here today in governments worldwide - and that's a matter of sustaining enthusiasm in people. Give the sponsors a place at the table with all that implies: physical presence, a chance to hear your discussions, and a chance to be heard. And bring players into the system who may not be initially major contributors but who have much to gain through active participation in the research program.

I'd like to close with some thoughts about the integration of your program. I hope you will pursue the notion of a central unifying climate dynamic which ties together all the disparate elements of your program. Every time a new dimension of that central question raises itself somewhere in the world, create a project to address it and ask that your sponsors move resources to the problem. One key element of this dynamical construct is the multiple time scale behaviour which you have successfully captured in your planning. Another element is whether the greenhouse expresses itself principally or perhaps entirely through established modes of spatial and temporal variability — modes that are natural in their fundamental character. The possibility of rapid change in climate is an integral part of the same problem. Infusing these "whole system" ideas into your implementing plans will be a real challenge.

Another important integrating theme has to do with societal vulnerabilities to climate variability and change. We are now providing regional warming scenarios to social scientists to ascertain the importance of anthropogenic climate change. Is there "perhaps" greater value in understanding how societal vulnerability would change were the thermohaline circulation in the North Atlantic to cease. The answer is that we don't know and we are not really working on the problem. The social sciences need best guesses from you about what rapid climatic change might look like. Similarly, a new map of the world that reflects human land use practices and related societal vulnerability is needed to prepare societies for climate variability and change. Such a map can be an important prognostic tool in itself, suggesting where the next disaster is likely to occur.

If moving from diagnostics to prognostics in CLIVAR creates some unease, contemplate the following. In the early days of the TOGA scientists faced a similar dilemma. It took the same courage then as is required of you now to consider a real time prognostic experiments on decadal time scales. TOGA scientists set up something called ENSO.INFO. It existed only in the research domain, and they used it primarily to chat among themselves. Little by little, the chatter crept out of the research domain and became what we now call experimental forecasting. Ants Leetmaa, an operational forecaster, told you that he's using decadal- centennial trends in his analysis. The trends he's using are poorly defined, poorly understood, and poorly documented. You could in principle provide better trend information even now. Understanding that you can share information of uncertain quality is a matter of understanding your social contract with users and decision-makers and your relationship to social scientists. I believe a closer proximity by scientists to the decision- making process will provide the world with a new perspective on the uses of "uncertain" information.

I'd like to close with a quote from E.O. Wilson's book, Consilience: "Thanks to science and technology, access to factual knowledge...is destined to become global and democratic...What then? The answer is clear: synthesis. We are drowning in information, while starving for wisdom. The world henceforth will be run by...people able to put together the right information at the right time, think critically about it and make important choices wisely."

We have to organize to generate wisdom, not just knowledge. Make discovering the dynamical centroid of the whole climate system your challenge. Place it squarely on your shoulders and say, "we're going to do this." If you do, you can turn CLIVAR into the giant that it can be.

REPORT OF ARGENTINE DELEGATION
TO THE INTERNATIONAL CLIVAR CONFERENCE
Paris, 2-4 December 1998

1 Climate variability over Argentina: Highlights

The Argentinean territory extends from 20°S to 55°S, i.e. from subtropical to subpolar regions. The subtropical region is essentially a large plain (Gran Chaco and the pampas) that rises gradually from east to west, interspersed by the pampas sierras and sheltered from the influence of the Pacific Ocean by the Andes. The southern portion of the country shows a typical plateau landscape known as Patagonia that extends from the Andes to the Atlantic Ocean. The dominant climatic characteristic of the subtropical eastern (maritime) part is its high degree of moisture content, whereas in the remaining regions air is markedly dry (except in the southern cordillera).

More than half of Argentinean's exports come from agriculture and cattle activities mainly performed over central and eastern Argentina. Summer wheat, for example, is one of Argentina's largest income-producing exports. The mean yield is 15 million (metric) tons, but this can significantly decrease in a bad year. As irrigation is virtually non-existent, production is closely linked to the vagaries of weather and climate. Climate variability is not necessarily unique to a single region or country; consequences are often felt on a near-continental scale. Argentina conforms with Brazil, Paraguay and Uruguay; a common market referred to as MERCOSUR. The MERCOSUR region is home to more than 200 million people. This population is profoundly affected by both short- and long-term climate variability. In the short term, floods and droughts result in deaths, displacement, and agricultural catastrophes (with economic consequences). Long term variability can cause impacts on agricultural production and its associated economies. In particular, systematic changes in the moisture and heat fluxes in the region due to anthropogenic effects or to natural climate variability could affect the regional agriculture as well as the availability of water resources for energy production, among other impacts. Fifty percent of Argentinean electricity generation is produced through hydraulic generation.

In Subtropical Argentina, the rainfall mean annual cycle shows a minimum in winter, which is more pronounced in the west, with dry conditions prevailing from May to September. In the eastern portion of the country, the annual cycle is less conspicuous being significant only south of 30°S. One of the most studied non-periodic large-scale phenomena affecting southern South America is el Niño-Southern Oscillation (ENSO). Precipitation anomalies over northeastern Argentina, Uruguay and part of Southern Brazil are consistently positive from November of the warm event year through February of the following year. In addition, in a vast region, east of the Andes, strongest positive rainfall anomalies are found in the spring (0). Furthermore, during cold event years, there are consistent negative precipitation anomalies from July through December. However, a relatively low coherence for the Southeastern South America region regarding rainfall anomalies during ENSO events has been found. Precipitation anomaly changes along the El Niño cycle present different timing throughout the region and thus more detailed analyses are required. Many important questions such as the identification of the processes relating ENSO to the atmospheric anomalies in southeastern South American region remain unresolved. Also the influence of other potential forcing mechanisms such as the Atlantic Ocean SST variations, should be further explored.

Significant interdecadal rainfall variations have also been reported in a greater part of South America. In Argentina, precipitation changes have been positive since 1916 and became greater after the late fifties. The observed precipitation increase between 1956 and 1991 reached 30% in several localities, and encompasses almost the entire region between 20 °S and 35° S east of the Andes. In addition, interdecadal variations of the precipitation annual regime have been detected. It can be pointed out that the positive precipitation changes between 1956 and 1991 lead to an increment of the lands used for agriculture activities in more than 100.000 km^2. Although some studies relate interdedacadal rainfall variations to changes in the Southern Hemisphere meridional temperature gradient at low-levels, the source of this interdecadal variability and the associated processes are not yet completely understood.

In addition to these long-term climate fluctuations, significant intraseasonal variations occur over subtropical Argentina during summer. It is generally recognized that the South Atlantic Convergence Zone (SACZ) is an important feature of the summer season. A seesaw pattern on the SACZ with amplitude reversal in approximately 10 days was documented. Strong convective activity events over SACZ are associated with rainfall deficits over the subtropical plains of South America. In contrast when SACZ weakens, precipitation over these plains is abundant and there is a strong influx of moisture from the Tropics into central Argentina and southern Brazil. A strong low-level jet east of the Andes enhances this moisture influx. Some results demonstrate that the compensating subsidence associated with SACZ takes place to the southwest of its position. Thus, precipitation deficits in Northern Argentina and Paraguay may be associated to periods of enhanced SACZ activity. There are some indications that anomalies in the South Pacific Convergence Zone would propagate in the form of a 30-60 day oscillation and affect SACZ. In addition, it seems that the Andes barrier is not the dominant effect on the establishment of the upper level trough associated with SACZ during summer, although it seems to be important for the deflection of the low level flow. However, the source of this seesaw pattern and the relative roles of orography, local and remote heat sources are not completely understood. Also the modulation of the intraseasonal activity by lower frequency variability needs to be further explored.

2 The Western South Atlantic Ocean

Argentina considers that the South Atlantic Ocean has received minor attention by CLIVAR. The oceanic circulation in the Western South Atlantic (WSA) plays an important role in the regional climate and marine resources, and thus in the economies of Argentina, Uruguay and Brazil. Recent results, among others, showed that during winter, warm WSA SST anomalies might have a more direct impact on rainfall anomalies over Uruguay and Southern Brazil on interannual time scales than the corresponding SST anomalies in the Pacific Ocean. Also, positive precipitation anomalies over subtropical eastern Argentina during summer are strongly correlated with warm WSA SST anomalies. In addition, the WSA holds significant fisheries. Between 20°S and 50°S catches are known to be strongly influenced by inter-annual variations of environmental characteristics associated to water mass properties and circulation. While it is obvious that these issues are most relevant to communities in South America, such climate anomalies are also an inextricable part of variations in the global climate system.

On the global scale, WSA is one of the major conduits for inter-ocean water mass exchanges. In the Argentine Basin, Circumpolar Deep Waters, which have circulated around the entire Southern Ocean and which have components from all three major basins and the subpolar gyres, start their complicated northward passages to the North Atlantic. At densities intermediate to the circumpolar deep waters is the North Atlantic deep water (NADW) southward flow into the subpolar domain which subsequently gets into the Indian and Pacific oceans. Above the least dense of the Circumpolar Deep Waters is the Antarctic Intermediate water (AAIW) which spreads northward into the North Atlantic. AAIW may be a significant component of the upper ocean northward flow required to balance the Atlantic NADW export. In the upper levels, the South Atlantic subtropical gyre is where warm and saline Agulhas waters and tropical waters are converted to subtropical modes and are subsequently advected into the subpolar domain at the western boundary at the confluence of the southward Brazil (BC) and northward Malvinas (MC) currents, near 38°S. The Brazil-Malvinas Confluence Zone (BMCZ) contains one of the world's most intense oceanic fronts and complex SST fields, surface jets can often exceed 1m/s. Water masses with vastly different properties derived from numerous, distant sources are brought into close proximity there, thus setting the stage for globally-significant heat and freshwater exchange. The configuration and latitude of separation from the continental slope of the Confluence Zone is thought to depend upon the relative strengths of BC and MC. The boundaries of both currents are usually associated with strong horizontal gradients in surface temperatures that are in turn linked to the temperature fields of the upper 1000-m of the water column. These SST gradients have a significant impact on cyclone evolution off the coast of Uruguay and south of Brazil that is a preferred region for the occurrences of cyclogenesis during austral winter. The collision of these two opposing and intense currents spawns a highly complex regional SST pattern that couples to atmospheric wind and to fluxes of heat and moisture. Variations in the circulation and SST in the WSA occur over time scales ranging from subseasonal to seasonal and interannual. These variations are influenced to a large extent by interactions between the opposing flows of the BC and the MC which are affected by the basin scale wind field and (probably) by the absorption of the Agulhas rings. On subseasonal time scales the production of transient cold-core eddies from the MC and warm-core eddies for the BC serve to make the BMCZ one of the most energetic regions of the World Ocean. On longer time scales, annual and semi-annual variations of SST and circulation have been detected and associated with wind forcing. However, several other factors can modify these signals to produce interannual variability.

A multi-disciplinary international (Argentina, Brazil, Uruguay and the US) effort called South Atlantic Climate Program (SACC) has been conceived under the sponsorship of the Inter-American Institute (IAI) for Global Change Research, the NSF and other local funding agencies of the involved countries. The goal of SACC is to understand the variability of oceanic circulation in the WSA region, the forcing mechanisms causing it, the evolution of the associated SST and the interactive relationship of the WSA SST and the larger scale climate behavior. Argentinean scientists (including meteorologists, oceanographers and biologists) and related institutions have a strong participation in SACC and Argentina expects that this Program to be considered as a contribution to CLIVAR in the Atlantic Ocean.

3 The South American Low-level jet field experiment

Global analyses suggest the existence of a southward low-level jet (SALLJ) to the east of the central Andes that plays an important role in the: i) Transport of heat, moisture and chemical contaminants from low to high latitudes of South America, ii) Forcing and modulation of the convective activity over subtropical and tropical South America. iii) The hydrological cycle of both Amazon and de la Plata Basins. In particular, the de la Plata Basin, although not as large as the Mississippi basin in North America, does contain a nearly equivalent amount of fresh water. Therefore, processes that govern variability in this region are also extremely important to better understand the South American Monsoon System. Although there is a generalized idea that the SALLJ structure is similar to its North American counterpart, there is a lack of observational evidences to support this because of the low density of the South America observing system and because of its sub-synoptic dimension. We need to document the location, timing, cross-stream and vertical scales of the low-level jet and its structure variability. Therefore, Argentina has strongly recommended that VAMOS/CLIVAR Panel endorses the realization of a field program on the South American low-level jet (endorsement decided in VPM-1). Such experiment will provide coverage to the low-level circulation as it emerges from the tropical Amazonia to quantify vertically integrated water vapor meridional transport. In that sense, by middle 1998, a Planning Committee for the SALLJ program was established under the initiative of the University of Buenos Aires (Argentina). At this stage, this Committee involves representatives from institutions of Argentina, Brazil, Chile and Paraguay that have already confirmed their participation in the LLJ field Program. Also, this Committee plans to incorporate institutions from Bolivia and the U. S.

The field experiment will be based upon current rawinsonde network, improving the frequency at some sites of this network. Also deploying rawinsonde and/or pilot balloon sounding sites and moving portable units in order to increase spatial distribution of the observational network over the region where the low level jet has been detected: Bolivia, Paraguay, Brazil and northern Argentina. The field experiment will start tentatively during the austral summer of 2001 and it will be conducted in coordination with Land Biosphere Atmosphere Program (LBA). Argentina expects that VAMOS/CLIVAR Panel endorse the proposed initiative as a VAMOS Program.

The proposed initiative would establish an important precedent in the assessment of the role of the low level jet as a component of the South American Monsoon System and also would contribute to: i) calibrate numerical analyses and judge uncertainties in wind analyses, and possible discrepancies of moisture flux divergence computed from gridded analyses. ii) Verify the capability of models to correctly reproduce the mean state and variability of the tropospheric flow over the region. Understanding this LLJ could hold the key to improve the prediction of precipitation in subtropical South America on seasonal time scales. Also an improvement of precipitation prediction would lead to increase our confidence in the simulations of different scenarios of regional climate change over South America. iii) Provide guidance to improve radiosounding network over the region through the evaluation of the enriched initial-analyses impact upon forecasts.

4 About research activities on climate variability in Argentina and its relationship with CLIVAR.

Scientific groups related with climate variability issues are mainly concentrated at the Department of Atmospheric Sciences of the University of Buenos Aires and at CIMA (Centro de Investigaciones del Mar y la Atmósfera), both located in Buenos Aires, the capital city of Argentina while other few groups are dispersed throughout the country. Most of them perform empirical and diagnostic studies with a few amount of scientists devoted to modeling. Although there is in Argentina a long tradition in global and regional oceanic and atmospheric modeling, this area has not been fully developed due to the limited computational resources available. For this reason and provided that Argentina does not and, in a short term, will not perform operational numerical climate predictions, modeling activities are mainly concentrated on the improvement of the regional models to be used for downscaling the broad-scale climate predictions produced by other countries over Argentina region. It should be pointed out that during the last years a strong interaction between Argentinean groups and Brazilian Universities and Centers (such as CPTEC/INPE and USP) has been started, which results in a significant progress of atmospheric and oceanographic research activities in the region. In that sense, a regional program (PROSUR) with the participation of institutions of Argentina, Brazil, Uruguay, Paraguay and some scientists of the U. S. have begun in 1999, to advance in the knowledge of regional climate variability and change, their prediction and impacts over southeastern South America.

Argentinean participation at CLIVAR began with the creation of the VAMOS Panel. Although, Dr. Carolina Vera is the only Argentinean member in all the CLIVAR Panels, other local scientists have strong and active participation in VAMOS activities. In fact, the next VAMOS Panel meeting (VPM-2) will be held at the University of Buenos Aires and will certainly contribute to enhance the relationship between CLIVAR and Argentinean scientific community.

5 About CLIVAR and the Argentinean Secretary of Science and Technology.

The Argentine government clearly realized the importance of the studies associated to climate and its variations. By Decree of October 1991, the President of the Nation created the National Commission on Global Change within the domain of the Secretariat of Science and Technology. This inter-ministerial commission has gathered the Argentine scientific community and the governmental organizations dealing with the support and formulation of policies associated to Global Change. Since its creation the Commission has supported and fostered several national and international programs and the organization of various scientific meetings associated to global change, coordinating the action of different scientific and technological sectors. The Commission holds the mandate to represent the Argentine government before different international organizations related to climate change. In particular, it has taken an active part in the development of the Inter-American Institute for Global Change Research (IAI). Argentina has been one of the thirteen American countries, Founding Parties, which signed the Agreement for the Creation of the IAI in May 1992, in Montevideo, Uruguay, and presently it holds the Chair of its Executive Council.

Last June, an Agreement was signed between Argentina's National Agency for Scientific and Technological Promotion and the IAI, providing for the joint financing of research projects related to Global Change. The Agreement provides for the realization of joint Agency-IAI yearly calls in order to perform pre-qualifications of scientific and technological research projects oriented to the subject of global change. From the selected projects, the Argentine Agency will contribute 75% of the grant requested by the research group or groups from participant Argentine institutions.

We believe that it is possible to steer an active cooperation with CLIVAR through arrangements such as the one we have just described, in order to achieve an actual support for the studies of climate variability in South America.

INVESTIGATION OF CLIMATE VARIABILITY IN ARMENIA

H.Melkonyan, Z.Zoryan, K. Hayrapetyan

The Republic of Armenia is situated in the South of the Caucasus and occupies 29,800 km^2. Armenia is a typical mountainous country. About 90% of all territory has height more than 1000m above see level and 40% of territory has more than 2000m above see level. The average level of territory is 1830m, the maximum height amount 4090m, the minimum about 350m.

The geographical location of Armenia, complicated mountainous relief and presence of different climatic zones have conditioned the diversity of natural conditions of the territory. The territory of Armenia has six main climatic zones from dry subtropical to rigorous high mountainous. In June-August average air temperature in low-levels as high as +24/26°C and in high mountainous regions temperature less than 10°C. In January the average air temperature is dependent on the height and peculiarity of relief and fluctuates from +1°C to -13°C. The absolute maximum and minimum of temperature is +41°C and the -42°C accordingly. Armenia has droughty climate with the average annual precipitation about 570mm.

Hydrometeorological observations in Armenia have been realized since 1885. At present the observing network include 46 meteorological and 3 climatic stations. Since 1992 Armenia has been a member of WMO and collaborated with world and regional centers and national hydrometeorological services.

Global increase of temperature in the earth will create new physical-geographic climate system. Temperature change in Armenia is brought about by total effect of global climate change and change of inner microclimatic conditions and further will be proposed the problem to assess of possible change of regional climate. Based on these changes various scenarios are being developed which will be applied for assessing sensitivity and vulnerability of different ecosystems towards climate change.

The observation data of air temperature were processed in 46 meteorological stations and we have received the trends of anomaly for 1930-1998 period. Here, as well as in the calculating of anomaly of remaining meteorological elements, as climatic basis was accepted the standard period of 1961-90 confirmed by WMO. Studies were carried out for variation of anomaly in separate stations, for average temperature of all stations, for seasonal temperature and mean annual temperature.

The full observations in Armenia have been carried out since 1930 till 1998. Since 1992 till 1998 data of only 25 reliable stations were analyzed. Linear and unliniar trends are used for assessment of temperature.

Calculating of temperature using linear trends is dependent on number of observations. In the following are given the results of growth of anomalies temperature (Æt), calculating by linear trend for different period of time (Æt) for all territory of Armenia.

Æt, year	1930-96	1930-90	1935-90	1944-90	1964-90	1964-96
Æt°C	0.07	0.1	-0.08	0.27	0.4	0.32

It should to pay the attention on observation data of metostation "Yerevan" which has a positive trend for all period of time (1930-1998). On the fig. 1 (a) are submitted the temperature anomalies in Yerevan in the period of 1894-1998. Growth of temperature calculating by linear trend amount + 0,78°C. Analogous results for precipitation are given on fig. 1(b). For observing period sum of annual precipitation decrease on 90mm according to trend. Yerevan is the large industrial conglomerate, so it has great impact on climate change.

Observing data of meteostation "Aragats" (3230m above see level) are analyzed specially. By reason of its location meteostation is separated from impact of antropogenic factors and can be used as a ground indicator of global climate change . On the fig. 1(c, d) are submitted the deviations from temperature and precipitation standards and their linear trends in the period of 1935-1996 of meteostation "Aragats". Since

1996 this meteostation is not working.

Re-equipment of meteostation "Aragats" in framework of CLIVAR programme will have been permitted to create a basis station in Armenia for complex work. We made comparison between the results of average monthly temperature and precipitation for 1998 (using data of 25 meteostation) and the results of 1960-1990 as its norms.

On the fig. 2 (a, b) are given distribution of average monthly value of temperature and precipitation for 1998 and for standard period. Since March of 1998 temperature is more its norm, for some stations gradient of temperature amount about 2°C, and for several month gradient of temperature as high as 5°C.

Analysis of annual move of precipitation is showed that amount of precipitation for
May and July of 1988 is above its norm, in spite of strong decrease of total annual precipitation. Lack of precipitation in period of August-December 1998 will bring to unfavorable conditions for water resources store and formation of agricultural harvest in 1999.

For detail investigations of climatic elements on territory of Armenia was worked out numerical carts with horizontal step 1 km and should be determined their values by point of irregular observations. These results can be used as justified initial data in regional and global climatic models; as data of microclimatic characteristics using for investigation of a territory.

As it is shown in [1] temperature increase on 1.5°C and precipitation decrease on 10% will bring
to decrease of soil moisture on 10-30%;

- lack of soil moisture amount about 25-50mm;
- to decrease of harvest of agriculture on 7-14%;
- to decrease of water resources on 15-20%
- in 1999.

Reference:

Melkonyan H., Zoryan Z., Hayrapetyan K. Estimation of Global Climate Change in the Republic of Armenia and assessment of vulnerability of ecosystem. 2nd European Conference on Applied Climatology 19 to 23 October 1998. Central Institute for Meteorology and Geodynamics, Vienna, Austria, N 19.

Fig. 1: Annual mean temperature (a,c) and precipitation (b,d) for Yerevan (a, b) and Aragatys (c, d)

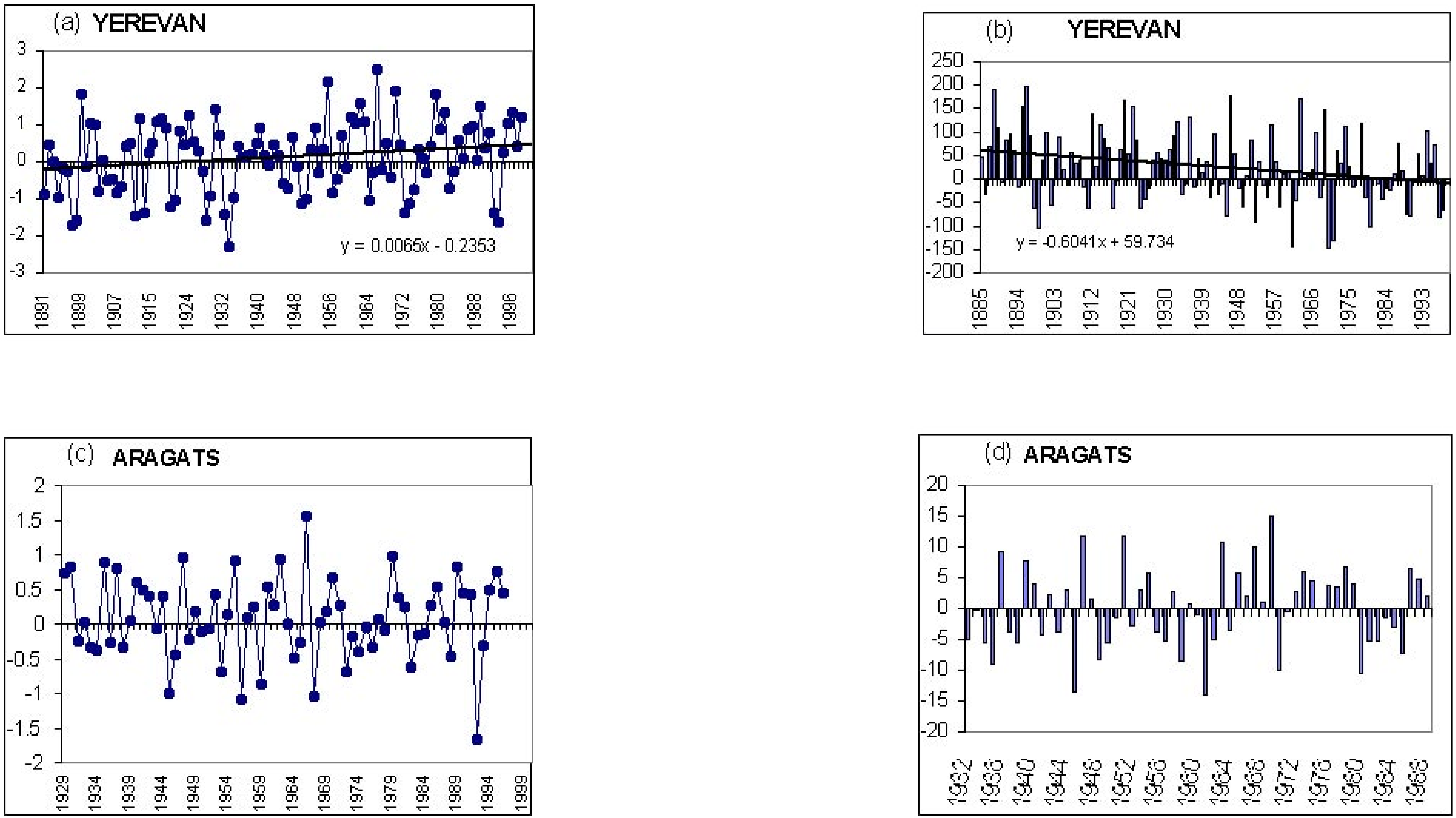
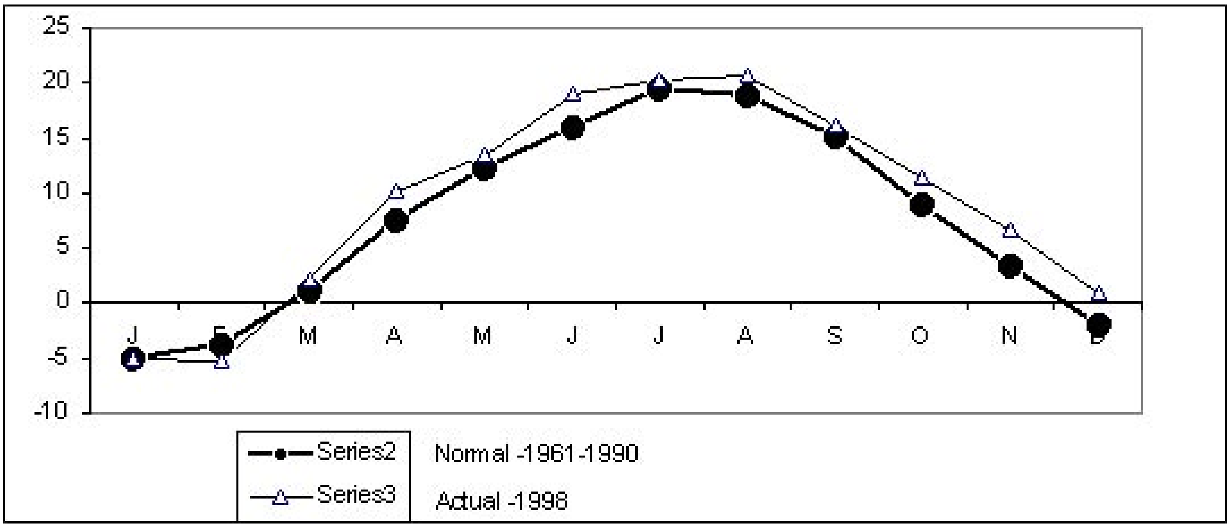
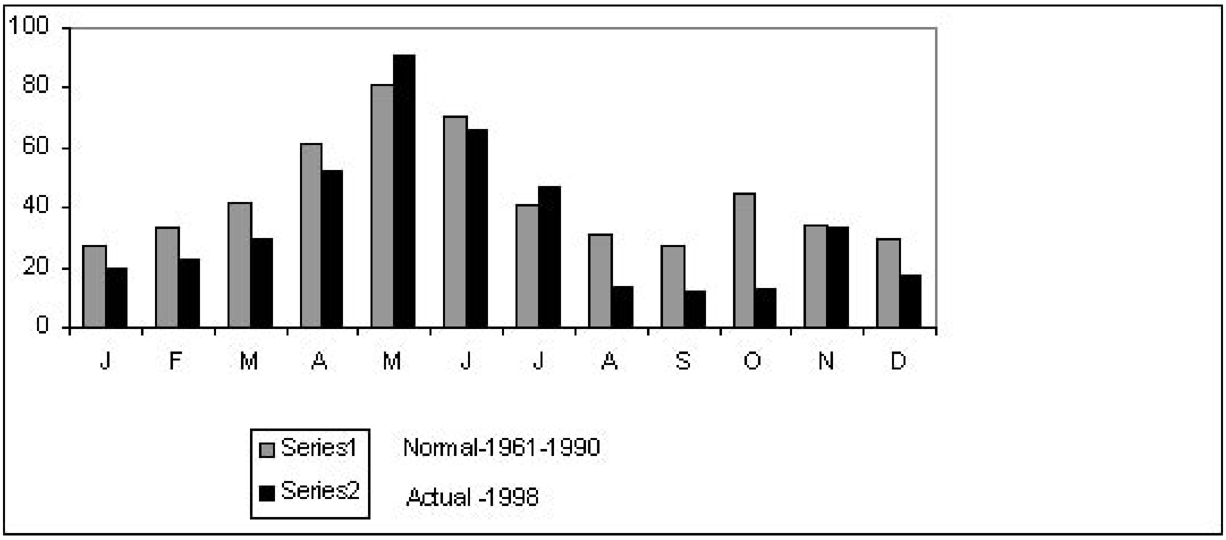


Fig 2: Monthly areal average temperature (a) and precipitation (b) in Armenia





AUSTRALIAN CLIVAR ACTIVITIES

M.J. Manton
Chair, CLIVAR Sub-Committee
National Committee for Climate and Global Change

Background

Compared with most other regions of the world, Australia has a climate with very high year-to-year variability. The nature of this variability and its causes have been studied by Australian scientists for over a hundred years, and so there is a long tradition of climate research in Australia. In particular, Australia has been a significant contributor to the activities of the World Climate Research Programme (WCRP) since it was established in 1980.

The Tropical Oceans and Global Atmosphere (TOGA) program, the predecessor of CLIVAR, was of particular relevance to Australia, as it played a major role in bringing together the international science community to focus on the problem of seasonal prediction related to the El Niño – Southern Oscillation (ENSO). Australian scientists were active on the TOGA Scientific Steering Group and the TOGA working groups for numerical experimentation and data management.

The Coupled Ocean Atmosphere Response Experiment (COARE) was a significant milestone in the TOGA program, leading to an improved understanding of the air-sea-interface processes affecting the behaviour of the westerly wind bursts that are associated with developing ENSO events in the western Pacific region. Australia had several research institutions directly involved in TOGA COARE, and the operations centre for the observational phase of the project was located in Townsville in northern Queensland.

With a history of involvement in programs such as TOGA, it is natural for Australia to consider active participation in the CLIVAR program which aims to provide an international framework for nationally-relevant climate research.

Institutional arrangements

Climate research is conducted by a number of institutions in Australia. The Bureau of Meteorology Research Centre (BMRC) provides a focus for research in the national meteorological service, and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) has a major sector of research on climate that spans across Divisions. The Australian Institute for Marine Science (AIMS) and the Australian Nuclear Science and Technology Organisation (ANSTO) have programs on paleo-climate research. A number of universities conduct climate research, and the Commonwealth Government program of Co-operative Research Centres has also supported climate research, particularly at Monash University and the University of Tasmania.

Co-ordination of the national effort on climate research is promoted through the National Committee for Climate and Global Change (NCCGC), which is hosted by the Australian Academy of Science and jointly sponsored with the Bureau of Meteorology and the Heads of Marine Agencies. These three bodies are the national links to the International Council for Science (ICSU), the World Meteorological Organization (WMO) and the Intergovernmental Oceanographic Commission (IOC), the three international sponsors of the World Climate Research Programme.

The NCCGC has established a CLIVAR sub-committee to coordinate Australian planning for and participation in the international CLIVAR program. The sub-committee involves 13 scientists from a range of national research organisations associated with climate research. The initial task of the CLIVAR sub-committee was to prepare a science and implementation plan for Australian CLIVAR activities. The initial national plan was published in October 1998, and it can be found on the WWW at:

http://www.science.org.au/internat/natcomm/pubs.htm.

Australian CLIVAR plan

Regional focus

The Australian CLIVAR plan provides for clear links with the international CLIVAR activities. However, it has a regional focus on phenomena that directly affect Australian climate.

The El Niño – Southern Oscillation (ENSO) represents the largest interannual signal in the climate system. While ENSO leads to global scale modulations of climate, it has a particularly large influence on Australian climate and it tends to be associated with widespread drought. The potential for the Southern Oscillation Index (SOI) to be used for seasonal climate prediction in parts of Australia has been recognised for many decades, and it was the basis of the first seasonal outlooks issued by the Bureau of Meteorology in 1989. Since the SOI can explain only about 30% of the total variance in seasonal rainfall, there remains a need to understand better the links between ENSO and the overall climate variability of Australia.

There is strong interaction between ENSO and the Asian-Australian monsoon, which is the major factor in the seasonal variations of northern Australia. Delays in the onset of the monsoon wet season can limit the availability of water across the region. The interannual variability of the monsoon is largely determined by the nature of intra-seasonal fluctuations, associated with the 30-60 day Madden-Julian Oscillation. Much work remains to be done to improve our capability to understand and predict the behaviour of these fluctuations.

Although the Southern Oscillation in the Pacific Ocean explains much of the variability and predictability of Australian climate, there are significant influences from other ocean basins. Both statistical and modelling studies demonstrate a relationship between large-scale patterns in the sea-surface temperature (SST) in the Indian Ocean and winter rainfall across south-east and central Australia. The extent of the influence of the Indian Ocean on Australian climate and the links between the Indian and Pacific Ocean effects need to be clarified.

The Antarctic continent and the Southern Ocean have major impacts on the climate of the southern hemisphere. The permanent snow and ice cover of the continent affect the overall energy balance. Variations in the extent and thickness of sea ice and its covering snow lead to large seasonal and interannual variations in air-sea fluxes at high latitudes.

Most of the weather across southern Australia has its origins in the Southern Ocean. Moreover intraseaonal climate variations in tropical Australia are influenced by mid-latitude weather patterns. There is a need to document and understand better the relationships between the circulation of the Southern Ocean and Australian climate.

Scope of Australian CLIVAR

The initial Australian CLIVAR plan was prepared in order to focus existing research projects and to promote new projects required to achieve the aims of CLIVAR for the benefit of the Australian community. The plan outlines a broad scope of activities to include empirical studies, modelling and process studies as well as logistical activities for data management and communications.

Australian support for CLIVAR

Following its historical support for WCRP activities, Australia is expected to continue to participate actively in CLIVAR. The benefits of international collaboration are well recognised in a country with a low population density and surrounded by vast oceans. In participating in CLIVAR, the Australian focus will be on regional phenomena that impact on our climate. However, these phenomena, such as ENSO and the monsoon, have global significance, and so the national activity should link closely with the international aims of CLIVAR.

Australian scientists have played a large role in the planning process for CLIVAR, and this involvement is expected to continue as the program matures and promotes substantial international projects. Australian research organisations are continuing to invest in infrastructure that will support CLIVAR activities.

Modelling will remain an important component of the national research effort on climate. The establishment of the joint Bureau of Meteorology – CSIRO High Performance Computing and Communications Centre in Melbourne demonstrates a national commitment to modelling of the atmosphere and ocean.

Because of the extent of its geographical region of interest, Australia has always maintained appropriate infrastructure to observe and monitor the atmosphere and ocean. A major national research facility for airborne research has been established at Flinders University, and there is a long history of achievements from aircraft-based measurements in CSIRO. A miniature robotic aircraft, the Aerosonde, is also being developed to support atmospheric research, especially in remote areas. In addition to aircraft, Australia has a number of ground-based research sites extending from the tropics to Antarctica which support both process studies and longer-term observing projects.

A significant component of national support of oceanographic research is the RV Franklin, owned by CSIRO and operated as a national facility. The research vessels of CSIRO and the Australian Antarctic Division support deep-water oceanographic research, with a focus on the links between the ocean and climate on all time scales. Australia will continue to contribute to international long-term observing programs of the ocean, and is playing a significant role in the Global Ocean Data Assimilation Experiment (GODAE).

The primary commitment that Australia makes to CLIVAR and other international research programs is through the contributions of individual scientists, who devote their time and intellect to problems of international significance. The benefits of this commitment are clear. By contributing to CLIVAR, Australian scientists are able to draw on the international knowledge base, to influence the direction of international studies, and to ensure that international best practice is maintained.

BELGIUM'S CONTRIBUTION TO CLIVAR

The Belgian OSTC research programmes

CLIVAR's implementation will be closely co-ordinated with- and build on- national programmes. A lot of the ongoing CLIVAR-related research in Belgium is embedded in the federal research programme Global Change and Sustainable Development (1996-2000), and to a minor extent in the Belgian research programme The Antarctic - phase IV, in particular in the area on the Southern Ocean dynamics.

The research programme Global Change and Sustainable Development (1996-2000) is one of the five thematic programmes of the "Scientific Support Plan for a Sustainable Development Policy". This plan was approved by the Council of Ministers on 7 March 1996. The research programme is planned to cover a period of 4 years, from 1 December 1996 to 30 November 2000, with a total budget of about 16 MECU.

The programme comprises two components:
sub-programme 1: "reducing uncertainties" and
sub- programme 2: "scientific support for Belgian policy on climate change".

Sub-programme 1: reducing uncertainties aims to improve understanding the state and the evolution of the environmental system interacting with socio-economic activities in a context of climate change. Studies are being both descriptive (experimentation) and predictive (modelling). They focus on the priorities assigned (arbitrary) to 4 sections:
- Atmospheric processes
- Hydrological cycles
- Terrestrial ecosystems
- The climate system

Sub-programme 2: CLIVAR-related research is situated in the section on the climate system. The objectives of this section are to develop models that explain the fundamental processes of the climate system and make projections of the evolution of the climate in our regions (Europe - Belgium). Because climate models are constructed according to the laws of physics or factual data, the key scientific challenge is to couple these two approaches.
The priorities are:

- Belgian research financed by other funding agencies
  Some of the Belgian research teams participate in CLIVAR relevant research in the framework of the European Commissions Environment and Climate Programme (1994-1998). The universities themselves and the Fund for Scientific Research supports as well CLIVAR-related research. In particular, the Fund for Scientific Research Flanders supports the following international projects with a participation of Flemish teams: the European Ice Sheet Modelling Initiative (EISMINT), and the Consortium for Ocean Drilling (ECOD).

- Overview of ongoing CLIVAR-related research
  Hereafter follows an overview of the ongoing research classified according the relevant CLIVAR areas.

Clivar Goals

African climate variability (G4)

The Royal Museum for Central Africa, MRAC, Tervuren), the University Catholique de Louvain, (UCL,Louvain-la-Neuve) and the Universities Gent (RUG) are investigating the ENSO impact on the interannual variability of the climate, agriculture, and fisheries in the Lake Tanganyika area (East Africa) and the recording of a paleoclimatic signal, possibly ENSO related, in its sediments.

For the recent ENSO study, a multi-disciplinary database (climate, agriculture, fisheries data...) is built (recent instrumental period) at the MRAC while remote-sensing data (1981-1994) are analysed at the Laboratoire de Detection of the UCL. In the remote-sensing approach, the 15 most recent years are analysed using the NOAA-AVHRR Pathfinder Land database. Low-resolution time series are used to detect the ENSO signal in the land cover fluctuations of the Tanganyika region. Monthly maximum value composites of the Normalised Difference Vegetation Index (NDVI) and land-surface temperature (Ts) are utilised. High-resolution data are used to study fluctuations of lake surface temperature in a typical ENSO and non-ENSO year. The resulting time series (NDVI and Ts anomalies, climatic data, agricultural and fisheries data records) are compared to the Pacific Ocean data (ENSO) in a teleconnection approach. The results of the lagged correlation analysis are spatially analysed in a geographical information system. The preliminary results show that air temperature, atmospheric pressure, rainfall, NDVI anomalies, and fisheries are correlated with ENSO in the Lake Tanganyika area. Air temperature and monsoonal winds influence widely the lake surface temperature, its hydrodynamics, and the nutrients mixing in surface water. The aim of this study is to characterise extreme ENSO events in this area and the effect of those climatic conditions on crop yields and fisheries. The objectives are:

- to build a preliminary model linking ENSO and the East African environment, useful for yield forecasting in agriculture and fisheries and
- to determine the possible effect of small interannual climatic changes on the limnology of Lake Tanganyika in order to test hypothesis useful for the paleoclimatic reconstruction.

For the paleo-ENSO period, sediments of Lake Tanganyika are studied in a collaborative effort between UCL and RUG. The past 1000 years will be analysed on an annual basis. As Lake Tanganyika is one of the oldest lakes in the world and very sensible to climate variability, its sediments might prove to be real archives of paleoclimatic variability, sea-surface temperature, and monsoonal changes in Africa. A set of laminated cores has been sampled recently in the south of Lake Tanganyika. They will be described using standardised protocols and image analysis. Thin sections will be prepared and analysed by electron microscope. Organic carbon content and neoformed minerals in the sediment will be analysed and 14C and 210Pb datations used. Diatom and chrysophyte cysts analysis will be effectuated on the thin sections. Spectral analysis will be applied to the results in order to detect periodical patterns. Present day plankton communities are also analysed. The recent signal as compared to the older sediments may contribute to a better understanding of the possible human impact on the recent climate change. The presence of a tick layer of sediments preserved in anoxic conditions is favourable for a possibly much longer paleoreconstruction. If the ENSO signal may be well understood from this study, its possible recording in this 20 millions years old lake could constitute a proxy of world interest. The methods developed in Lake Tanganyika could also be applied in Lake Malawi where favourable paleoclimatic conditions are also present.

Decadal-to-Centennial Climate Variability (DecCen)

Atlantic Thermohaline Circulation (D3)

Over the last few years, the Institut d' Astronomie et de Geophysique G. Lemaitre of the UCL (ASTR-UCL) has gained a good experience in the study of the Atlantic thermohaline circulation (THC) with 2.5-D and 3-D global ocean models. The study has a particular focus on the reconstruction of the circulation changes that occurred at selected times in the past, such as the last glacial maximum. In the near future, we intend to investigate the sensitivity of the Atlantic THC to changes in the North Atlantic precipitation regime, river runoff, or iceberg discharge. The stability of the THC and the possible occurrence of sudden transitions induced by these perturbations will be analysed thoroughly. The comparison of model results with reconstructions made from proxies for times when the freshwater budget of the North Atlantic significantly differed from today (for instance, during Dansgaard/Oeschger oscillations, Heinrich events, or the Younger Dryas) would allow to determine to what degree the model sensitivity is realistic. A reconstruction of the Atlantic circulation changes throughout the whole Holocene is also planned. To perform these studies both 2.5-D and 3-D global ocean models will be utilised, alone or coupled to atmospheric models of moderate complexity

Southern Ocean Climate Variability (D5)

The ASTR-UCL 3-D ocean/sea-ice model has been widely used in the past to assess the influence of ocean/sea-ice interactions on the general circulation of the whole World Ocean. Sensitivity experiments carried out with this model have demonstrated the crucial role played by these interactions in determining the properties of the Southern Ocean water masses, particularly the Antarctic Bottom Water (AABW). The study of the mechanisms responsible for the AABW renewal in the model will be pursued in the future, with a special emphasis on the role of ice formation and on the way the salty shelf waters are exported towards the deep ocean. Furthermore, the model, coupled to the intermediate-complexity atmospheric model of the Koninklijk Nederlands Meteorologisch Instituut (De Bilt), will be employed to investigate the decadal and centennial variability of the sea-ice cover in the Southern Ocean and its impact on bottom-water formation. It will be particularly interesting to see, if the coupled model is capable of simulating open-ocean-convection events, such as the one observed during the occurrence of the Weddell Polynya, under which conditions those events are possible, if they are periodic or totally irregular, and what is their influence on the global ocean circulation.

The Southern Ocean is characterised by specific oceanographic processes. More precisely, the Weddell Sea has been identified, together with the Greenland Sea in the Northern Hemisphere, as one of the main locations of deep-water formation. This dense water, generated by complex processes related to the presence of ice pack, to meteorological forcing as well as to the resulting heat and salt fluxes, spreads into the World Ocean. With the aim of understanding these processes, the Management Unit of the North-Sea Mathematical Model (MUMM, Brussels) is building a coupled ocean/ice model at the regional scale of the Weddell Sea, with a particular attention to the zones around the Filchner-Ronne Ice Shelf and the Maud Rise, which are renowned, the first for contributing to the production of AABW (Antarctic Bottom Water), the latter, for undergoing vertical movement (upwelling) of relatively warmer water. An ice formation model based on Semtnerís approach and a 3-D ocean circulation model have already been satisfactorily applied to this zone. At this stage of the project, MUMM is implementing a k-(turbulent closure as well as an appropriate parameterisation of the subgrid-scale phenomena. The coupling of the ice formation and ocean circulation models through the heat and salt fluxes and the surface stress between ice and water will be achieved within few months.

Anthropogenic Climate Change (ACC)

Climate-Change Prediction (A1)

Currently, ASTR-UCL is developing a coupled atmosphere/ocean general circulation model (AOGCM) suitable for investigating the climate response to increasing greenhouse-gas concentrations and other anthropogenic influences. This model is made up of the atmospheric general circulation model of the Laboratoire de Meteorology Dynamique (Paris) and of the ASTR-UCL 3-D ocean/sea-ice model. A series of process studies have been conducted with the first version of the coupled model with the aim of identifying the causes of the model drift. In the future, the physics of each component will be improved to stay in line with the latest advances of the climate science. In addition, the model will be coupled to a three-dimensional thermo-mechanical model of the Greenland ice sheet (GISM). This work will be done in close collaboration with the Geografisch Instituut of the Vrije Universiteit Brussel (GI-VUB, Brussels), which has built the GISM (see below). A limited number of simulations beginning in the recent past and ending by the end of the next century will be carried out with the AOGCM and coupled AOGCM/GISM. These simulations will use standardised historical forcings for the past and standard forcing scenarios for the future. A particular attention will be paid to the model response in the North Atlantic area and in both polar regions. The influence of the iceberg calving and melt water flow from the Greenland ice sheet on the World Ocean's THC and sea-level rise will be assessed. In the distant future, the inclusion of new processes (notably biological and chemical feedbacks) in the climate model will be envisaged.

ASTR-UCL has also at its disposal a regional atmospheric model (RegAM). This model has been extensively tested over the last few years. In particular, it has been used to study mesoscale atmospheric processes occurring in the Antarctic region and over Greenland, like the genesis of mesocyclones or the sudden onset and decay of katabatic winds. Recently, it has been adapted to Western Europe. In order to validate this model version, it has been nested in the European Centre for Medium Range Weather Forecasts

(ECMWF) re-analyses. In the near future, several periods characterised by intense drought or precipitation will be simulated with the model, and the results will be thoroughly compared to observations. We will particularly focus on the model performance over Belgium. Once validated, the RegAM will be nested in the AOGCM/GISM with the purpose of refining the climate-change projections performed with this model over Western Europe. The nesting technique will be tested for present climate conditions. Then, time-slice experiments lasting roughly one seasonal cycle will be conducted for various time periods in the future by using as boundary conditions the output of the transient runs carried out with the global climate model. The analysis of the results will provide some insight of the climatic conditions (including extreme events) that might prevail in Western Europe, and especially in Belgium, in the next century.

In parallel to this work, the ASTR-UCL 2.5-D climate model, which includes explicit representations of the atmosphere, ocean, sea-ice, and ice-sheet dynamics, will be utilised to investigate the evolution of climate over the last and next 2000 years in response to natural and anthropogenic forcings. The histories of the various forcing factors (solar output, volcanic aerosol load, greenhouse-gas concentrations,...) will be built from measurements for the recent past and proxies for the distant past, while plausible forcing scenarios will be set up for the future. A series of model integration will be conducted to evaluate the influence of each type of forcing on the long-term evolution of climate. These long experiments should provide guidance on the natural variability present in the climate system, information on the causes of observed climate variations, and a first guess of the long-term impact of human activities on climate. Note that this research work is also relevant to the principal research area “Climate-Change Detection and Attribution” (A2) of the CLIVAR Initial Implementation Plan.

During the last decade, the Geografisch Instituut of the Vrije Universiteit Brussel (GI-VUB) has gained a substantial expertise in the study of ice and climate interactions with numerical ice-flow models of glaciers and ice sheets, coupled to climate, mass-balance, and bedrock models of variable complexity. The main tool is a 3-D thermo-mechanical ice-sheet model, which is being used to investigate the ice sheets of Antarctica and Greenland, and those that covered the Northern Hemisphere continents during the ice ages. Flowline models have been developed to study Alpine and polar outlet glaciers. Time scales of interest range from Tertiary ice-sheet inception to glacial/interglacial cycles and future anthropogenic warming

The ice-dynamics models are first of all widely used to better constrain the present evolution of ice-sheets and glaciers. Their current evolution is determined by past environmental changes dating back to the last glacial-interglacial transition because of the long response time scales associated with continental ice-sheet dynamics (thermo-mechanical coupling, isostatic adjustment,...). Efforts are undertaken to link model results to a variety of field data (satellite altimetry, gravity, GPS ground surveys,...) to better determine the present contribution of the polar ice sheets to global sea-level change apart from anthropogenic forcing. Recent work involved the coupling of the Greenland ice-sheet model with a self-gravitating visco-elastic isostasy model to investigate uplift patterns and gravity anomaly trends in Greenland.

The 3-D Greenland and Antarctic models are furthermore extensively used to investigate the response of these ice sheets to future anthropogenic warming. They are being forced by prescribed climatic change scenarios to obtain sea-level predictions during the next century and beyond. This has taken place within the framework of the IPCC95 report, within the ESF network of EISMINT, and more recently as part of the Global Change and Sustainable Development programme, where the Greenland model will be coupled with the AOGCM of ASTR-UCL. The ice-sheet modelling work is furthermore embedded in the EU Framework IV project “Climate Change and Sea Level”. It is envisaged that these ice-sheet models will also take part in the next IPCC sea-level projections, in which efforts will be undertaken to obtain the climatic forcing from available GCM output.

The glacier model applied to Glacier d’Argentière (French Alps) was recently used to make predictions about glacier melt and glacier volume up to the year 2100 for a set of prescribed climate change scenarios. This was done within a larger international effort co-ordinated by EISMINT involving 12 glaciers and ice caps worldwide.

The Climatology Department of the Royal Meteorological Institute of Belgium (RMI-CD, Brussels) is working on the production of a regional climatic database for Belgium. The goal is to characterise the recent Belgian climate and its variability at the regional scale. The climatological archives of RMI-CD over the last three or four decades are the main sources of the information, and the raw data are examined for heterogeneities in the series. This work will significantly improve the data given for Belgium in the climatic European database built up by the Climatic Research Unit of the University of East Anglia. The database will also help to validate the present climate simulated by the regional climate model developed at ASTR-UCL.

In parallel to this work, two other research activities of RMI-CD have to be mentioned. First, the daily precipitation recorded at about ten stations spread over the country allows the study of the precipitation evolution since the end of last century. In particular, the extreme precipitation events are important as they can be related to flood risk assessment. The number of these long records could be extended in the future. In addition, RMI-CD is also trying to reconstruct local and regional thermometric series at century time scale. Up to now, only the long-term series for station Brussels/Uccle-Ukkel has been studied in detail, but an heat island effect cannot be disregarded on the long-term. A set of rural stations dispersed in the land will be selected after scrutiny for heterogeneities. These research activities will allow a reconstruction of the regional climatic evolution in Belgium during the last century. This will also put the past climatic variability observed in the country in perspective with the future climatic changes simulated by the ASTR-UCL climate model at the regional scale.

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**STATEMENT OF THE BRAZILIAN DELEGATION
TO THE INTERNATIONAL CLIVAR CONFERENCE**

Paris, 2-4 December 1998

Brazil is a large country of 8.5 million km^2, extending from 5° N to 30° S and encompassing many different climates, including the tropical humid Amazon region, the drought-prone semi-arid region of Northeast Brazil, savannas in the central part and the subtropical to midlatitude transitional climate in southern areas. These regions are all subject to climate variability on seasonal to longer time scales, which causes severe impacts to the country's economy and society. Brazil has a relatively large population of about 160 million inhabitants living predominantly along the Atlantic coast and a sizeable fraction of its agriculture is rainfed.

To better understand the climate and its variability over Brazil, several institutions in the country have been involved for many years in climate research, with a noticeable progress being achieved during the last two decades. At the present, it is well known the important role played by the tropical Pacific and Atlantic sea surface temperature variations on the climate of several regions of the country, in particular Amazonia and Northeast Brazil. However, there is relatively little effort aiming at the consolidation and synthesis on how the various phenomena affect the climate of Brazil. Also, at present, it is well recognized that there is yet much to understand on the climate variability of the Atlantic Ocean and of the southern and southeastern parts of Brazil.

The Brazilian Government is aware that the climate and its variability play a crucial role for the country's activities. For that reason alone there has been a number of infrastructure improvements. The acquisition of an additional supercomputer by the Center for Numerical Weather Forecasting and Climate Studies of the National Institute for Space Research (CPTEC-INPE), is just an example of the Brazilian Government resolve to give great importance to climate issues. This has rendered possible a more effective participation of Brazil in the international efforts towards the understanding and interpretation of the results from numerical models. There has also been a continuing effort to promote operational training and scientific studies in the country. Contrary to the worldwide trend of declining operational observational systems, Brazil is spending about US 60 million to enhance and modernize its meteorological observational infrastructure in Amazonia. From a handful of stations now, the Brazilian Air Force's SIVAM Project will deploy 15 new sounding stations, 200 automatic surface stations, and 10 Doppler weather radars in the timeframe 1999-2001. Oceanographic observations are envisioned to increase using oceanographic ships, moored and drifting buoys. In addition, the successful Brazilian participation in international experiments such as the Anglo-Brazilian Amazon Climate Observational Study - ABRACOS, as well as the Brazilian participation in the World Ocean Circulation Experiment (WOCE) and in the Pilot Research Moored Array in the Tropical Atlantic (PIRATA), enables the country to participate in similar programs.

The Brazilian Government considers the CLIVAR Programme a very important international effort to the understanding of climate variability. Furthermore, the Brazilian Government recognizes that CLIVAR is instrumental in understanding the climatic variability of Brazil. As a result of that, Brazil would like to join other countries and take an active role in this endeavour. To accomplish this expectation, the Brazilian scientific community is launching a "National Research Program" akin to CLIVAR focusing on the problems of predictability and variability of the climate with emphasis on the Brazilian continental area. This program known as CLIVAR/BRAZIL will include aspects of importance to the national economy and wellbeing of the population. It is deemed to be a coordinated effort from both the meteorological and oceanographic communities to analyse the existing data and plan future modelling and field experiments oriented towards an effective participation of the country in CLIVAR. The Brazilian Government believes that joint action among the several Research Institutes and Universities is instrumental in identifying the adequate strategies to reach successfully the goals of the CLIVAR/BRAZIL.

The main objectives of the CLIVAR/BRAZIL are:

1 To understand the physical processes responsible for the variability of the climate of Brazil on intraseasonal, seasonal, interannual, decadal and longer time scales, and its connection to the variability of the

oceans (in particular the Pacific and Atlantic Oceans) and the coupled atmosphere-ocean-land system. Emphasis will be placed on the study of the role of the Atlantic ocean on regional climate variability in South America from seasonal to decadal time scales

2 To study the climate predictability on all time scales over Brazil;

3 To study the climate changes due to natural and anthropogenic causes, including land use change; and

4 To study the connections between the climate variability and critical resources, such as agricultural productivity, to minimize the impacts of adverse climate, mainly in regions like Northeast Brazil.

The CLIVAR/BRAZIL Program is conceived to be closely linked with other similar international and national programs, such as:

a) Variability Of The American Monsoon System (VAMOS)
VAMOS is one of the principal components of CLIVAR-GOALS. The study of the monsoon system of South America is of great relevance to the climate of Brazil. The success of VAMOS is of great importance to Brazil and the CLIVAR/BRAZIL will make the best effort to contribute decisively with VAMOS, including participation in VAMOS field campaigns such as the planned field observations of the Low Level Jet east of the Andes in conjunction with Argentina, Bolivia, Paraguay, Chile and United States.

b) Large Scale Biosphere-atmosphere Experiment In Amazonia (LBA)
LBA, one of the GEWEX Continental Scale Experiments, is an international research program led by Brazil and involving the amazonian countries, United States, United Kingdom, Germany, Holland, France and Italy. Its main objective is to generate a new body of knowledge necessary to understand the climatological, ecological, biogeochemical and hydrological functioning of Amazonia; the impact of changes in land use and the interaction between this region and the Earth System. The CLIVAR/BRAZIL will support LBA's efforts. The physical climate component of LBA is directly relevant to CLIVAR/BRAZIL goals. It will document the diurnal, seasonal and interannual variability of the Amazon atmospheric heat source. LBA is being funded by Brazilian, US and European funding agencies. Its field phase will happen from 1998 through 2003. There are close links between LBA and VAMOS. There are also close links between LBA and CLIVAR Anthropogenic Climate Change on that. LBA will reduce uncertainties in the quantification of the carbon cycle of Amazonia.

c) South Atlantic Climate Change (SACC)
The SACC program is an international initiative involving Argentina, Brazil, Uruguay and the United States, aiming at the study of the effects of the global climate changes on regions adjacent to the western part of the Atlantic Ocean. The main goal of this program is to understand the interactive relations between the Southern Atlantic SST's and the large-scale climate behaviour and its impacts over South America. The current CLIVAR Implementation Plan lacks research focus on the South Atlantic. SACC plus planned research on the eastern South Atlantic by South African scientists could form the basis for a South Atlantic study in CLIVAR.

d) Pilot Research Moored Array in the Tropical Atlantic (PIRATA)
PIRATA is a multinational effort involving Brazil, France and the Unites States. It is conceived as a three-year pilot project (1997-2000) that will extend the Pacific Ocean TAO (Tropical Atmosphere-Ocean) moored buoy array into the Atlantic Ocean. It will provide time series of surface heat fluxes, surface and subsurface temperature and salinity in key regions of the tropical Atlantic. CLIVAR/BRAZIL is fully committed to supporting the enhancement of the PIRATA array.

It is hoped that, following the example of the TAO array in the Pacific, that has led to the remarkable progress in Tropical Pacific SST prediction, PIRATA will play an equivalent role for the Tropical Atlantic SST predictions. The result inevitably will be improved seasonal to interannual climate predictions for Tropical South America.

The PIRATA program will also promote the interaction between the GCIP and LBA researchers, furnishing the necessary information from the tropical Atlantic Ocean to allow a better understanding of the moisture fluxes into the monsoon system of the Americas.

e) Global Ocean Observing System - Brazil (GOOS/BRAZIL)
This program is sponsored by the Brazilian Interministerial Commission for the Resources of the Sea (CIRM) and its implementation is being charged to the Brazilian Navy's Directorate of Hydrography and Navigation (DHN). The climate module of GOOS/BRAZIL will serve directly CLIVAR/BRAZIL since its objectives are to increase the observational data base on the oceans with long term systematic measurements and to advance ocean modelling.

Activities currently underway include:

i) sea level monitoring (nine tide gauges are part of the GLOSS Program);
ii) support the transition of PIRATA towards an operational array after 2000; establishment a data base to facilitate assimilation of ocean data in climate models; and maintaining a National Buoy Program (PN-BOIA): drifting and moored buoys in the Tropical and South Western Atlantic Ocean.

Linkages with IRI

IRI is providing postdoctoral research opportunities to Brazilian scientists. Brazil is contributing routine forecast products to IRI. Plans are being drawn for the joint development of end-to-end applications of climate forecasts.

REPORT FROM BURKINA FASO
FOR THE INTERNATIONAL CLIVAR CONFERENCE

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Variability and predictability of climate in Burkina Faso

For several decades, the physical environment of Burkina Faso has been subjected to climate change and to a strong anthropogenic pressure. The droughts observed, in particular in the past decades, have revealed the weakness and vulnerability of the ecosystems but above all, of the methods used for agricultural production. A generalized awareness at the national and regional levels, resulted in initiatives more or less coordinated, that were aimed at a better understanding of the climate phenomena in order to be able to take those into account when planning and managing the environment natural resources. At the national level, the variability and predictability of climate are major concerns for farmers, stock breeders, and life in general, as well as for the scientists and the decision-makers. On one hand, these concerns resulted in some climate variability studies, and on the other hand, in some institutional arrangements which have been made to deal with these concerns in a better organized framework.

Preliminary evaluations of the research on variability and predictability of climate in BURKINA FASO

The first climatological observations in Burkina Faso date back to 1902. Since then, the climatological data collecting network has filled out gradually and has now led to a significant database which stems from:

- Ten stations for synoptic observations which have all been operating for over fifty years;
- Twenty stations for climatological and agrometeorological observations, most of which have been operating for over sixty years;
- One hundred and fifty rain data stations, some of which have been giving continuous data for over eighty years;
- One observational station in altitude which has been generating data for over 25 years.

This database has allowed many research scientists, from Burkina Faso and abroad, to carry out research studies on the country's climate.

Several studies about the variability of temperature and rainfall have been undertaken. The analysis of temperatures shows that they tend to stay high all year round. They can vary between 23°C and 30°C in Gaoua in the southern part of the country and between 22°C and 33°C in Dori in the northern part. The lowest temperatures rarely go below 15°C. However, the changes in temperatures show a tendency to a warming up of the atmosphere due in part to the development of urban areas. Rainfall also shows a strong spatio-temporal variability, both within the same rainy season and when compared over different years. The annual mean varies from 400 mm in the North to over 1200 mm in the South.

Several teams of research scientists have worked on climate predictability, using the starting dates of the rainy season and trying to calculate the volume of rainfall for the next rainy seasons. The starting dates of the rainy season have been evaluated mostly through statistics, but this method does not allow to predict the precise date of the start of the rainy season of any given year. Various studies have showed the influence of El Niño/La Niña and especially the influence of sea surface temperatures on rainfall. These results show in particular that the links with the ocean can explain 60% of the seasonal rainfall variability.

National Initiatives Concerning The Evaluation Of The Variability And Predictability Of Climate

In Burkina Faso, the activities related to agricultural production employ more than 80% of the working population and are heavily dependent on rainfall. These past few years, some farmers have tried to adapt to the strong changes in climate by sowing cereals (such as millet, corn or sorghum) earlier in the year in the lower layers of the ground, in order to be able to take advantage of the best ground humidity conditions as long as possible. But this practice is often risky, and it shows again the urgent need to improve the current knowledge about climate variability.

Information on the onset of the rainy season allows the farmers to plant with the cycle corresponding best to the predicted season.

In the same way, knowledge (long in advance) of the expected rainfall for a given season, allows a better use of the lower layers of the ground, by sowing either rice, in case of a normal (or in excess) rainfall prediction, or other cereals (such as mil, sorgho or corn) in case of a very low rainfall prediction. It is therefore necessary to continue research in these fields.

For all these reasons, various initiatives have been undertaken at the national level, sometimes in collaboration with foreign partners in order to strengthen the knowledge already acquired, or to extend the scope of investigations. From this point of view, we can mention (among others) the following initiatives:

- to carry on climate data collection for the meteorological service in order to give scientists continuous and reliable series of data;
- to set climate analysis as a national priority within the strategic plan of scientific research adopted by the Government in 1995;
- to establish various research programmes in this field, among which it is worth mentioning the following:
  - the Desert Margin Programme dealing with the management of natural resources in countries adjacent to the desert;
  - studies on the vulnerability and adaptation to climate changes;
  - the PRESAO programme (Seasonal Prediction in West Africa) managed in partnership with several national and sub-regional institutions such as ACMAD, AGRHYMET, etc.);
  - the research project on climate and food security, managed by the Universities of Ouagadougou and Wageningen with the National Meteorological Service;
  - the pilot research project on the opportunities and constraints when using rainfall predictions to improve the security of stock and agricultural production systems in the Soudano-Sahelian region, managed by the University of Georgia in collaboration with the National Meteorological Service;

However, in order to carry on these programmes, the country will need the following:

- some support, mostly in the form of measuring equipment for climate data collection;
- some support also in the form of research grants as well as small equipment necessary for the training of the country's scientists;
- some scientific support to facilitate the implementation of international programmes on the national level.

For the time being, collaboration with the CLIVAR programme has not been developed. However, considering the objectives of this programme, the research teams in Burkina Faso are showing interest in

CANADIAN ACTIVITIES RELATED TO CLIVAR

Current state of Canadian Climate Research

In 1998, the Canadian Climate Board was restructured and established new Science and Impacts/ Adaptation Committees. We expect that a national CLIVAR committee will be established during 1999 to broaden the community represented in this document by making links with Canadian paleoclimate researchers, develop a formal Canadian plan and seek out funding opportunities. This document discusses current CLIVAR related activities with some suggestion of how those activities might evolve in the future.

Canada is developing its plans for climate and ocean observations as a signatory to the Climate Change Convention and in response to GCOS and GOOS. New funds have been made available to support climate studies in Canada. A national GCOS workshop is planned for February, 1999: a second workshop on Climate and the Arctic is being planned for the same time frame.

Environment Canada's Atmospheric Environment Service presently supports the Canadian Climate Research Network; a network of nine research nodes directed toward the improvement of the prediction of climate variability and climate change. These nodes involve both university and government scientists; their activities are highlighted in the following sections.

Climate Models and Predictions

Global Models

Global climate modelling is carried out by the Canadian Centre for Climate Modelling and Analysis (CCCma), Atmospheric Environment Service located at the University of Victoria. Their research is focused primarily on climate change and variability on a range of temporal and spatial scales. This involves both model simulations of historical and projected climate and analysis of various kinds of observations.

The CCCma has developed and operated a global coupled climate model which has been used to conduct multi-century simulations of past, present and projected climate. These include a completed 1000 year control simulation and an ensemble of historical and projected climate change simulations covering the period 1900 to 2100. Selected results have been made available to the IPCC data centre, and these data are also available on the Internet. Initial analysis has focused on changes in variability, the role of sulfate aerosols, detectability of climate change, extremes in temperature, precipitation and cyclonic storms, predictability at interannual to centennial time scales, the role of sea-ice in climate variability, and the role of other climate forcings like solar variability.

Development of a new coupled model is nearing completion, and will replace the current version. This new model includes higher spatial resolution, improved parameterizations of numerous physical processes (radiation, clouds, convection, ocean mixing, sea-ice, etc.), and will allow simulations aimed at assessing the role of individual greenhouse gases and the indirect effects of sulfate aerosols.

Diagnostic studies of both the observed and simulated climate system are also an integral component of CCCma's work. The Centre has developed an extensive climate diagnostics package that is fully integrated into CCCma's modelling environment. The diagnostics package is used by a number of groups within the Atmospheric Environment Service, in the Climate Research Network and in the Canadian university community, and has been emulated elsewhere.

CCCma participates in a broad range of international studies and programs, including intercomparison projects such as AMIP, the Coupled Model Intercomparison Project (CMIP), the Paleo Model Intercomparison Project (PMIP) and TRANSCOM (a chemical tracer modelling intercomparison project). CCCma members contribute to WGCM, ACSYS, SPARC and other committees and working groups. CCCma contributed to 1990 and 1995 IPCC reports. As well as contributing to the global modelling thrust of CLIVAR, the activities of the CCCma will contribute to the PRA's: **A1, A2** and to a lesser extent to **G1, D1 and D3**.

Regional Climate Models

A Canadian Climate Research Network node lead by René Laprise, University of Quebec at Montreal is developing and exploiting a Canadian Regional Climate Model (CRCM) — that is a limited-area, nested numerical climate model capable of achieving higher spatial resolution than is feasible with global climate models. Preliminary results obtained with the CRCM thus far have aroused great interest (and expectations) from application and impacts model data users. The CRCM is computationally efficient with physical parameterization fully consistent with the GCM within which it is nested.

Current objectives in this project are:
1. to validate the ability of the nesting approach to reproduce mesoscale features and to assess the realism of these features, with a special attention to hydrological processes and surface exchanges,
2. to use this model to perform more extensive high-resolution studies of both current and altered climate scenarios, and
3. to further improve the current version of CRCM on the basis of findings made in (1) and (2) above.

This activity contributes to the downscaling problems identified in the CLIVAR Initial Implementation Plan.

Regional Ocean Models

A Climate Research Network node led by Richard Greatbatch, Dalhousie University and Dan Wright, Bedford Institute of Oceanography has been developing a high resolution circulation model of the North Atlantic that can be run on powerful modelling workstations. The project goals are:
1. to develop a realistic model of the North Atlantic,
2. to use the regional model to motivate and test conceptual ideas regarding the controlling factors for the circulation and water mass properties in the model and in the real world,
3. to identify key model weaknesses through comparisons with observations, develop and implement modification to correct these problems where possible, and
4. to use the model outputs to improve interpretations of existing data sets and to assist in the development of future field programs.

This North Atlantic model will contribute directly to PRA's **D1 and D3** as well as contributing to an improved understanding of the problems associated with coarser scale ocean models within the coupled ocean-atmosphere climate models.

Climate Variability (seasonal to decadal)

This Climate Research Network node led by Jacques Derome, McGill University, has been studying the dynamics of climate variability on time scales ranging from seasons to decades. The research is aimed at determining the relative importance of the lower boundary conditions and the internal dynamics in generating and maintaining the atmospheric fluctuations on the above time scales. It will also help determine what part of the observed fluctuations might be predictable. Currently the research project is focused on:
1. the dynamics of the North Atlantic Oscillation (NAO), and
2. the predictability of seasonal and longer time scales.

This project is a strong contribution toward understanding the North Atlantic Oscillation, PRA **D1**. In its project elements dealing with seasonal predictability, the node will also contribute to an understanding of the extended effects of ENSO, PRA **G1.**

Seasonal to Interannual Forecasting (ENSO)

The Climate Prediction Group, University of British Columbia (led by William Hsieh), is focused on climate prediction at seasonal to interannual time scales using statistical or hybrid statistical/dynamical modelling approaches. This group has concentrated primarily on neural network techniques to analyze large-scale, low-frequency climate variability and to develop improved ENSO forecasting schemes. A joint project with Ken Denman, IOS, Pat Bay, has modelled the climate regime shift in the N. Pacific Ocean with an ocean general circulation model. This group will contribute to both **G1 and D4**.

Climate Variability (decadal and longer)

The Climate Modelling Group, University of Victoria (Andrew Weaver) is focused on processes involved in climate variability, primarily at decadal and longer time scales. The principal tool in this research is a coupled energy-moisture balance atmosphere model coupled to an ocean general circulation model. The simplifications inherent in the atmospheric component of this model allow efficient multi-century simulations to be conducted, without explicit flux adjustments. There is ongoing collaboration between this group and the CCCma in areas such as ocean modelling, Arctic climate, NAO variability, and climate extremes. Research underway or planned which contributes directly to CLIVAR objectives includes:

- The role of the Arctic (in particular its freshwater export) in climate change and variability including the understanding of the observed warming of subsurface water in the Arctic. (**D3)**
- Decadal-interdecadal variability in the Pacific Ocean. Special emphasis will be placed on understanding the role of oceanic and atmospheric teleconnections between the tropical and extratropical Pacific. (**D4)**
- Changes in precipitation over Canada. Historical Canadian station data will be analyzed for trends and extreme events over the past 100 years and connections between Canadian precipitation and climate indices such as ENSO and NAO will be examined.**(G1, D1)**

Variability in the Northwest Atlantic and Labrador Sea

Bedford Institute of Oceanography, Fisheries and Oceans has been observing, documenting and modeling inter-annual variability in the waters and the sea ice distribution of the Northwest Atlantic. They presently occupy WOCE repeat section AR7W early each summer, set ice drifters on the Labrador ice pack, collect temperature and salinity profiles across the Labrador shelf also during the winter months, collect, process and analyse satellite magery (AVHRR and ocean colour) and collect, analyse and archive oceanographic data from the eastern Canadian shelves.

Climatological data bases of quality controlled ocean and sea ice data provide a record of ocean variability over the past four decades that will be the foundation of their work with the high resolution North Atlantic model. Their sea ice modelling are focussing on ice formation and decay, and the interactions with the atmosphere, upper ocean and the shelf / slope frontal structures.

Dr. Kent Moore, University of Toronto, has been working on the problems related to intense cyclogenisis in these mid and high latitude waters and the role that these intense storm systems play in redistributing fresh water (and hence buoyancy) within the Labrador Sea.

The Labrador Sea is an area where ventilation of the deep ocean occurs, hence the Canadian program includes strong biological and geo-chemical components devoted to the carbon cycle. The group plans to continue to occupy AR7W annually in the early summer and will be looking for funding or partners to maintain a mooring at the old OWS Bravo location. These activities are direct contributions to both **D1 and D3**.

Pacific Decadal Variability

Institute of Ocean Sciences, Pat Bay (Fisheries and Oceans) has maintained ocean observations on Line-P / Station-P since the 1950's. IOS has also been analyzing Topex / Poseidon data and plans to assimilate these data sets into North Pacific circulation models. The continuation of line P / Station P observations and their assimilation into basin scale oceanic models will be a continuing focus. Funding is being sought to include regular occupation of line Z north from Station P to Alaska as well as several shorter sections across the continental slope along the British Columbian coastline from Strait of Juan de Fuca to Hecate Strait. IOS is also developing a proposal to participate in the North Pacific PALACE deployments and data assimilation activities for GODAE. These activities will contribute to PRA **D4.**

Variability associated with the Arctic Ocean

Many Canadian research groups are interested in the role of the Arctic in climate variability / change. While some of the necessary research activity has been included within ACSYS, the interaction of the Arctic with the rest of the climate system needs to be part of CLIVAR.

Canadian groups have constructed several ocean circulation models of the Arctic Ocean and its ice cover. We are presently constructing a high resolution Arctic Ocean that will include the North Pacific and the North Atlantic oceans. Since this model will deal with the connections between the Arctic and the global ocean, it will form the basis of projects looking at the Arctic Ocean's role in the observed variability in both the Atlantic and Pacific.

This work will contribute to the PRA's: **D1, D3 and D4.**

Effects of snow cover and ice on seasonal variability

As a high latitude nation, Canada has a special interest in snow, ice and frozen soils. Snow cover and frozen ponds, lakes and rivers and frozen soils provide different heat and water fluxes to the atmosphere than do their unfrozen equivalents. At these high latitudes, so much of the annual input of solar energy arrives in spring and early summer when the snow and ice cover results in high albedo and reflection of this energy back out to space. Canadian climate scientists are interested in understanding the relationships between variations in snow cover and frozen inland waters and seasonal variations of climate on a regional or larger scale. As the basis of this activity, Canada is developing better descriptions of the interannual variation of these parameters and this work is coordinated through an NASA Interdisciplinary Science Investigation on the Use of the Cryospheric System (CRYSYS) to Monitor Global Change. Dr. Barry Goodison is the principal investigator. This area of work will contribute to the issue of climate change detection, **A2.**

CLIVAR / PAGES activities

Canada has a number of researchers in universities and government departments who have collected and analyzed paleoclimatic data from tree rings, lake and coastal inlet sediments, ice cores and bore holes to reconstruct climatic conditions over much of the Canadian territory. Many of these researchers are also involved in similar activities in different parts of the globe.

Canadian climate modellers have developed lower order coupled atmosphere - ocean climate models in order to investigate the dynamics associated with paleo-climate events. The work on the large climate signals associated with changes between glacial and inter-glacial changes has focused attention on the relationships between fresh water transports, exchanges between the Pacific and Atlantic through the Arctic and the stability of the oceanic thermohaline circulation system. This work is continuing and will contribute to primarily to D3 and A1.

CLIVAR infrastructure

Canada, primarily through Environment Canada and Fisheries and Oceans, will continue to ensure that Canadian ocean and atmospheric data is delivered to the appropriate international data systems. At present the Marine Environmental Data Service, Ottawa provides international data management services with respect to ocean surface drifters and upper ocean thermal data. It is Canada's present intention to continue to support these services. Canada will participate in the planning processes currently underway that are seeking to evolve the international ocean data management structure into a structure that will better serve the needs of CLIVAR, GOOS and GCOS for more timely access to ocean data.

Canada also recognizes the need to support CLIVAR's international infrastructure. Canada will maintain climate research travel budgets out of which it will try to pay the travel and living costs of all Canadian scientists who are involved on international CLIVAR committees. Canada will also look for other opportunities to support the activities of international CLIVAR within the funding proposals that will be prepared over the next year.

Summary of Activities by Canadian groups:

Activity or PRA	**Contributing Canadian Groups**
Global Coupled Modelling	CCCma, UVic
Global and Regional Analysis	CCCma, McGill
Regional Modelling	UQAM
Ocean Modelling	BIO, DAL, IOS, McGill, UVic
Sustained Observations	AES, BIO, DFO, IOS, MEDS
G1	UBC
D1	BIO, CCCma, DAL, McGill, UBC, UofT, UVic
D3	BIO, DAL, UofT
D4	IOS, UBC
A1	CCCma
A2	CCCma

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A STATEMENT ON THE CHILEAN CONTRIBUTIONS
TO THE CLIVAR RESEARCH PROGRAMME

Prepared by Chilean National Oceanographic Committee CONA

S. E. Pacific Ocean Sustained Observations

The following CLIVAR PRAs are relevant

- G1: Advancing understanding and observations of climate variability associated with El Niño–Southern Oscillation (ENSO) and global teleconnections to improve prediction and applications.
- G3 Pacific Ocean: Developing better understanding of the Pan American monsoon, its interannual variations and links to the Pacific Ocean.
- D4 Pacific Ocean: Improving the description and understanding of the decadal variability and its predictability in the Pacific Ocean basin, and its relationship with ENSO and teleconnections.

Introduction

Chile is located along the south eastern boundary of the Pacific Ocean, between latitudes 18°S and 56°S, with a length of 4100 kilometres and an average width of 220 kilometres. It has three well defined climatic regions: Desert, Subtropical and Temperate Oceanic. The desert region is one of the earth's driest, with areas that receive less than one millimetre of rainfall per year, with no particular seasonal cycle. The Subtropical region has a climate with four well defined seasons and most of the precipitation (around 450 millimetres per year) during fall and winter. Further south, the Temperate Oceanic region is characterised by year-round precipitation that keeps the landscape green but limits farming to the growing of more traditional grains and pasturing animals. All of them are affected by «El Niño Southern Oscillation» (ENSO) or by oceanographic and meteorological anomalies associated with ENSO.

Research activities

The research activities of CLIVAR are of great interest to Chile. Understanding the physical processes responsible for climate variability and the mitigation and prediction of the impacts of this variability on the socio-economic activities is a high priority among the Chilean Government and its scientific community. Chile welcomes the establishment of CLIVAR and expects to join and help on its development.

CLIVAR relevant research activities in Chile are focused on the following areas :

- ENSO: Extending and Improving Predictions (G1): Advancing understanding and observations of climate variability associated with El Niño–Southern Oscillation (ENSO) and global teleconnections to improve prediction and applications.
- Variability of the American monsoon in the Pacific Ocean (G3): Developing better understanding of the Pan American monsoon, its interannual variations and links to the Pacific Ocean.
- Pacific Ocean Decadal Variability (D4): Improving the description and understanding of the decadal variability and its predictability in the Pacific Ocean basin, and its relationship with ENSO and teleconnections.

Chilean CLIVAR working group

In Chile a national CLIVAR working group was established in 1997, hosted by the National Oceanographic Committee (Comité Oceanográfico Nacional - CONA). The Chilean contributions to CLIVAR consist of ongoing research at six Universities, at the National Meteorological Service (Dirección Meteorológica de Chile - DMC), at the Hydrographic and Oceanographic Service of the Navy (SHOA) and at the Fisheries Research Institute (Instituto de Fomento Pesquero - IFOP), all these projects are funded by the National Research Funding Agency. The Navy through SHOA has several funded projects that are being executed in co-operation and in support of the ongoing research.

Ongoing research activities

Humboldt Current System HCS (Peru Current System) (US$ 1.8 x 10^6)

"Circulation and physical-biological interactions in the HCS and their impact upon regional biogeochemical cycling", is focused on the following scientific objective:

the characterisation and evaluation of the influence of remote and local physical forcing and of low oxygen conditions upon:

i) the structure and dynamics of coastal benthic and pelagic systems, and

ii) biologically mediated carbon and nitrogen fluxes in the HCS off Chile.

The following characteristics in the HCS off Chile constitute the fundamental components of these studies:

- the occurrence of coastal upwelling along extensive areas, most commonly involving low oxygen waters, associated with an oxygen minimum layer;
- the occurrence, mainly off northern Chile, of a secondary fluorescence peak and nitrite maximum, and the occurrence of high levels of denitrification in the water column, in association with a comparatively shallow upper boundary of the oxygen minimum layer;
- the propagation of remote forced coastal trapped waves (CTWs) along the whole of the HCS off Chile and their likely dissipation at the wider shelf off Concepción (latitude 38ºS), possibly acting as an additional forcing on biological production;
- the usually assumed high primary productivity in the HCS and short pathways through the pelagic and benthic systems; and
- the co-existence of massive and extensive prokaryotic mats (mainly of Thioploca spp.) with a sparsely structured eukaryotic benthic community; these mats may have a role in habitat detoxification and in mediating nitrogen flux between benthic and pelagic systems.

The combination of these characteristics makes the HCS off Chile, both at the national and the international levels, a most interesting area and subject of oceanographic research. Here, the traditional and most recent paradigms, hypotheses and/or system models about coastal upwelling ecosystems, the extent of biologically mediated carbon/nitrogen cycling, the influence of physical forcing and chemical conditions upon variability in biological production, the variability in the structure and dynamics of benthic and pelagic systems, and the degree of coupling between these two systems, can be tested.

Based on the above aspects, which have been the subject of most recent multidisciplinary projects or programs, with the participation of national and international groups, the present project is seeking to sustain and strengthen two main and interlinked lines of advanced research:

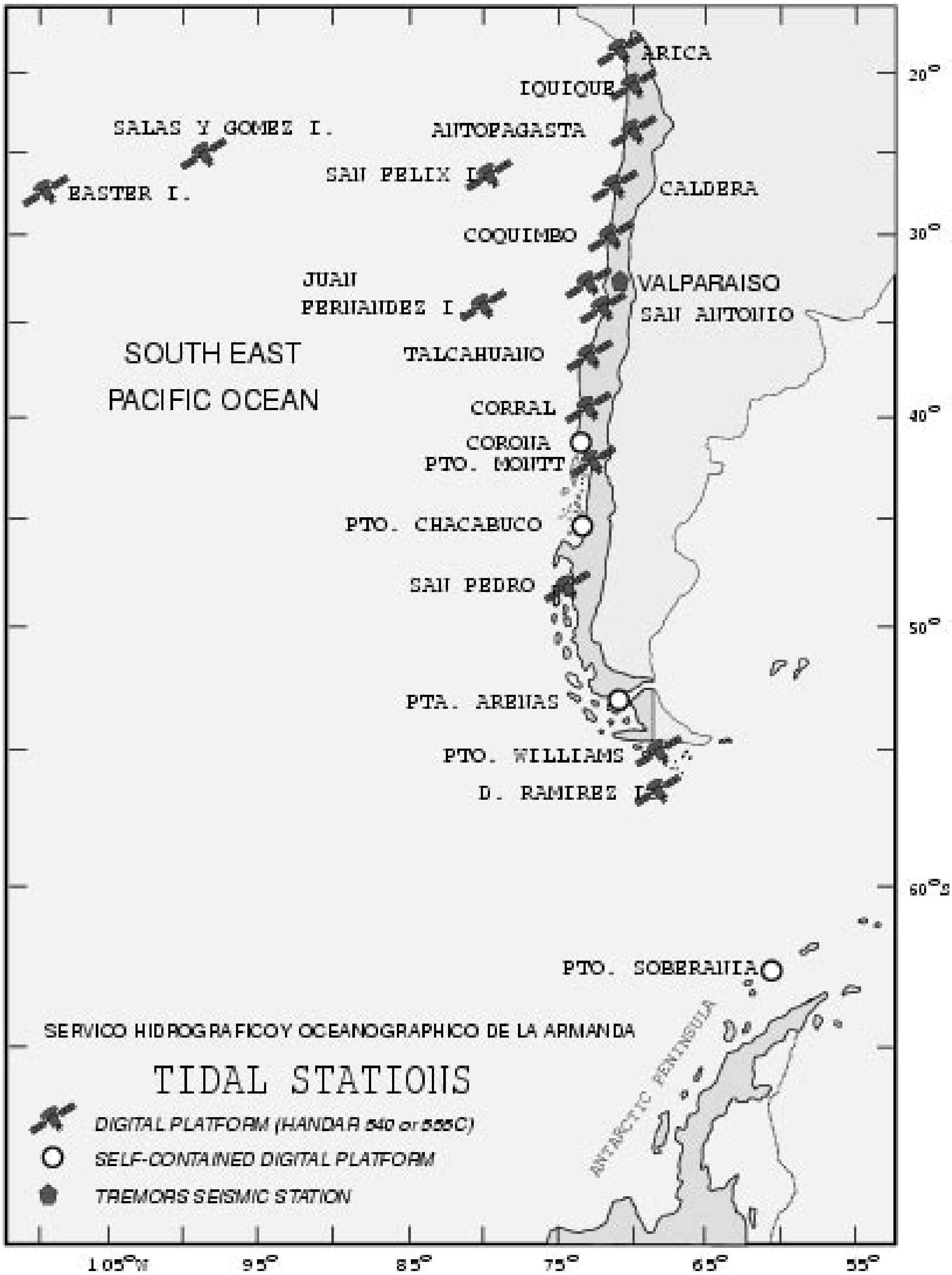
- the effects of remote and local physical forcing upon high productivity and their impact upon carbon fluxes within the pelagic and between the pelagic and benthic systems, and
- the influence of low oxygen conditions upon the structure and dynamics of benthic and pelagic systems, and their impact upon the biologically-mediated fluxes of carbon within and between these systems, in the HCS off Chile.

Near Real-Time Tidal Network (US$ 250 x 10^3).

Chile has a coast line that extends for almost 4100 kilometres from north to south. The Hydrographic and Oceanographic Service of the navy operates a tidal network that has eighteen stations. The network has several types of tidal gauges, including bubbler (metercraft), acoustic Doppler (Sutron) and pressure sensors (Handar 540). An upgraded network consisting of eighteen Handar 555C Data Collecting Platforms (DCPs) and three Aanderaa tidal gauges will be installed during the first semester of 1999 (see attached figure). Sometime during the year 2000, the three Aanderaa tidal gauges will be replaced by Handar 555C. The DCP's will measured air temperature, air pressure, water temperature and sealevel (pressure sensor). All eighteen DCP's will be connected to SHOA and University of Hawaii Sea Level Center (UHSLC) using GOES-East satellite. The data will be available on a near real-time basis to the scientific community. Another three digital self-contained tidal gauges will be installed at Faro Corona, Puerto Chacabuco and Punta Arenas (open dots in attached figure). These self-contained tidal gauges will measured sealevel and water temperature. This data will be made available through the National Oceanographic Data Center (Centro Nacional de Datos Oceanográficos – CENDOC).

The high quality sealevel (and other variables measured) will be used to support the ongoing research on the Humboldt Current System and other national and international projects, such as products published by the National Meteorological Center of USA (NMC) and the climate bulletin of the South Pacific Permanent

Commission (Comisión Permanente del Pacífico Sur – CPPS).



Hydrographic Cruises

IFOP cruises (US$ 450 x 10^3)

The Fisheries Research Institute (IFOP) has a monitoring programme for the northern part of Chile (between 18ºS and 26ºS) that consists of periodic Hydrographic cruises every other month to measure basic biological and physical oceanographic parameters, such as salinity, oxygen, temperature and others. The cruises consist of transects done at three different locations and cover an area of up to 200 miles off the coast.

SHOA ENSO cruises (US$ 105 x 10^3)

The Hydrographic and Oceanographic Service of the Navy will start an ENSO monitoring programme during May of 1999. This programme is planned to last, at least, until the year 2002. The programme includes two transects per year (May and November/December) at latitude 33ºS from the coast to 200 miles off the coast. The cruises will measured physical oceanographic parameters using a rosette sampler (temperature, salinity, oxygen), meteorological parameters using a continuous recording met station (air pressure, air temperature, true wind direction and intensity) and surface salinity and temperature along the transect (continuous thermosalinometer).

CPPS ENSO Chilean cruises (US$ 231 x 10^3)

On May 1999 the four countries of the South Pacific Permanent Commission (CPPS) Chile, Colombia, Ecuador y Peru will do several simultaneous cruises within their E.E.Z., as part of the ENSO monitoring activities co-ordinated by CPPS. This activity was started in 1998 and as a result of these cruises an excellent snapshot of the ENSO 1997/1998 along the South American coast was obtained for the first time.

Future research activities

Oceanic South East Pacific Array (OSEPA) (US$ 15 x 10^6)

The South East Pacific Ocean is one of the areas of the planet that has no systematic meteorological and oceanographic information. Only the coastal stations and a few islands (Easter island, Juan Fernandez island, San Felix island and Salas y Gomez island) provide information on the sea surface temperature and sealevel. The actual knowledge on the oceanographic conditions of the area does not help understand the ocean phenomena occurring along the coast zone, such as the upwelling processes and continental shelf wave propagation which impact fishing and coastal climate. The initial economical impact of ENSO 1997/1998 in Chile was close to US$ 655 millions.

Chile is proposing to install an array of buoys that combined with the new upgraded tidal network that will be completed by June 1999, to monitor the evolution of ENSO and to provide inputs for the Regional Models presently being develop to mitigate the impacts on the phenomenon in the coastal area.

This array will consist of 16 buoys (similar to the ATLAS buoys used by the TOGA/TAO array) and 12 currentmeter arrays installed at 3, 20, 100 and 1000 miles of shore at 20ºS, 30ºS, 40ºS and 45ºS. The data collected with this array could be used by Chile, Peru and Argentina, as part of an advanced meteorological warning and monitoring system. All data collected by this array and by the coastal stations will be freely shared among the scientific community to prevent and mitigate the social and economical impacts caused by El Niño in the Southeast Pacific Ocean.

Chilean national contact points for CLIVAR

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Chinese Contribution for CLIVAR

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Outline of CLIVAR Research Programme in China

Climate variabilities and change are closely associated with the disasters and environmental problems and become more and more serious concern of the society in China. Thus, study of climate variabilities and change have been emphasized in China from the early 1980's. Under the supports by the Ministry of National Science and Technology of China, the National Natural Science Foundation of China, Chinese Meteorological Administration and Chinese Academy of Sciences, some important research programs on climate variabilities and change, especially on the Asian monsoon variabilities and their simulation and prediction, have been implemented and are being implemented.

In this paper, the scientific background and objectives of the China CLIVAR Research Programme and the ongoing research programs associated with the CLIVAR Research Programme in China are simply reviewed. Moreover, a brief outline of the Chinese CLIVAR Research Programme under planning and the contributions to CLIVAR will be introduced.

1. Scientific Background and Objectives

(i) Scientific Background

In order to study the climate variability and its predictability in China, Chinese meteorologists have paid much efforts to reconstruct the historical sequences of climatic change for the last 1000 years including the temperature and rainfall in China by using the climate change information recorded in our vast accumulation of ancient literature and in oceans, geology, glaciers, deserts, water level of rivers and so on, especially to reconstruct the classes of droughts and floods occurred in the last 500 years.

The climate change during recent 100 years in China has been analysed by using the instrumented observation. The analysed results show that since the Asian monsoon activity and anomaly, the interdecadal interannual and intraseasonal variability of climate and the climate change in China are very significant and complex, the prolonged droughts and heavy rainfall/ floods have been brought in China, especially in the summers of 1997 and 1998. These severe droughts and floods have caused huge economic losses in China. Therefore, Chinese meteorologists have paid and are paying much efforts to the studies on climate variabilities and the East Asian monsoon and their predictabilities.

Many studies on the physical mechanism of the Asian monsoon variabilities have been made in China during recent years. Particularly the effects of ENSO cycle, the western Pacific warm pool, the Tibetan Plateau and the land-surface processes on the variabilities of the Asian monsoon are systematically investigated. Moreover the research progresses in planetary-wave dynamics, the dynamical mechanism of atmospheric intraseasonal oscillation in the tropics and extratropics, the dynamical mechanism of ENSO cycle, the theory of stantwise vorticity development (SVD) are also significant in China, and these theories have been used to understand the climate variabilities, particularly the Asian monsoon variability.

Seasonal and extra-seasonal prediction experiments on the summer monsoon rainfall, especially summer drought and flood distributions, have been continuously made in China for 10 years by using GCMs and coupled climate models.

Due to the complexity of Asian monsoon variability, the regularity and causes of intraseasonal, interannual and interdecadal variabilities and long-term climate change, especially the causes of heavy droughts and floods, are not very clear so far. Moreover, the physical processes of the East Asian monsoon, such as the influences of the tropical air-sea interaction, the Tibetan Plateau and the air-land interaction in the arid and semi-arid regions on the Asian monsoon, the simulation and predictability of the East Asian monsoon variability and anomalies need to be investigated further from observed data diagnoses, theoretical analyses and modelling. Besides, although the prediction methods with empirical and statistical features have been widely applied to the seasonal and interannual predictions of summer monsoon rainfall in China, but the forecasting accuracies by these methods are unstable, especially the prediction of droughts and floods. Therefore, it still is an important issue to study the effective seasonal and interannual prediction methods with dynamical and numerical models.

(ii) Scientific Objectives

Due to the above-mentioned reasons, the main scientific objectives of China CLIVAR Research Programme are as follows:

(1) To understand the regularities and causes of climate variabilities and anomalies and climate change in China, especially, persistent drought, flood and cooling summer.
(2) To reveal the physical processes and mechanism of the short-term evolution of climate system in East Asia.
(3) To monitor the impact of the western Pacific warm pool the Tibetan Plateau, ENSO cycle and the land-surface processes on climate in China.
(4) To detect strong signals of the climate anomalies in East Asia.
(5) To develop the new global model and regional model of climate with high-resolution, to improve the skill for monthly and seasonal predictions of climate anomalies in China and to develop the interannual prediction of climate in China.

2. Ongoing Research Programs Associated with CLIVAR Programme

In order to understand deeply the physical processes of the Asian monsoon variabilities and to design a complex air-land-sea coupled climate model with high-resolution so that to improve the current prediction skill of climate and monsoon anomalies in China, the following research programs associated with CLIVAR Programme are implemented in China for 5 years from 1996.

2.1) Integrated Field Experiments Associated with the Physical Processes of the Monsoon Variabilities and Climate in East Asia

The air-sea and air-land interactions and the energy and water cycle play an important role in the Asian climate variabilities. In order to understand the air-sea and air-land interactions and the energy and water cycle in the East Asian monsoon region, the following four integrated field experiments are being performed:

a. The Huai River Basin Experiment on Energy and Water Cycle (GAME/HUBEX)

The scientific objective of this experiment is to understand the interaction processes between large-scale system and meso-and small-scale systems in the Meiyu front, the characteristics of cloud and radiation and their interaction, the land-surface process and air-land interaction and the energy and water cycle in the Huai River basin in China.

b. The South China Sea Monsoon Experiment (SCSMEX)

The scientific objective of this experiment is to provide a better understand of the key physical processes responsible for the onset, maintenance and variability of the monsoon over the South China Sea and southern China leading to improve predictions of the monsoon over southern China and the South China Sea.

c. Field Experiment and Study on the Physical Processes of Air-Land Interaction over the Tibetan Plateau and Its Impact on Global Climate and Disastrous Weather in East Asia (TIPEX)

The scientific objective of this experiment is that by observing the physical processes of air-land interaction over the Tibetan Plateau, a better understand of the physical processes in the surface of the Tibetan Plateau may be achieved so that to identify the influence of the physical processes over the Tibetan Plateau on global atmospheric circulation and climate, especially on the disastrous climate anomalies in East Asia.

d. The Inner Mongolia Grassland-Atmosphere-Surface Study (IMGRASS)

The scientific objective is to monitor grassland atmospheric and ecological parameters and the terrestrial water budget; to develop and validate l-D soil-vegetation-atmosphere transfer model with assessing the microscale variability and a comprehensive meso-scale model for simulating the cloud and precipitation cycle in the typical Inner Mongolia grassland area and to assess the feedback effects between ecosystem and climate change.

The joint IOP of the above-mentioned four field experiments have been performed in the Huai River basin, the Tibetan Plateau, the South China Sea and its surrounding areas and Inner Mongolia during the summer of 1998, respectively. Since a particular strong monsoon rainfall occurred in the Yangtze River basin during the summer of 1998, the observed data during the IOP of these field experiments will help to achieve the goals of CLIVAR Research Programme.

2.2) Research Programs Associated with Climate Variabilities and Their Prediction

In order to reveal the physical processes and mechanism of climate variabilities and to promote the study on dynamics and prediction theory of monsoon and seasonal climate anomalies in East Asia, the following two national key research projects are being performed in China.

a. Study on Climate Dynamics and Climate Prediction Theory

The scientific goals of this project are to analyse the general behaviours and dynamics of climate and persistent anomalies of general atmospheric circulation in East Asia and Asian Monsoon with the observed data and dynamical theories; to reveal the physical processes governing climate variabilities with analyses, diagnostics and simulations; to improve numerical modelling of climate and Asian monsoon through the experiments on the response of climate and monsoon to external forcing and to make the seasonal and extra-seasonal prediction experiments on climate and East Asian monsoon anomalies with climate models.

b. Study on Short-Term Climate Prediction System in China

The goals of this project are as follows: according to a set of physically sounded short-term climate monitoring, the monthly and seasonal climate prediction system as well as the assessment system of the impact of climate anomalies on economy in China are set up and will be developed in the National Climate Centre of China. The key objective of this research program is to develop a new and advanced composite short-term climate prediction technique, which is focused on the dynamical climate models and statistical methods. Through the studies of this program, the more accurate climate prediction of monthly, seasonal precipitation and air temperature and their anomalies will be issued for various provinces and corresponding department of national economy of China.

In addition to these two national key projects, under the support by the National Natural Science Foundation of China, five important research projects are being implemented which are as follows:

a. The interaction between Asian Monsoon and ENSO cycle:
b. Physical Mechanism of the Variability of the Western Pacific Subtropical High
c. Seasonal Variability of the Atmospheric Circulation
d. Interdecadal Variability of Climate in China during the 20th Century
e. Regional Climate Variability in China

3. Outline of China CLIVAR Research Programme (CCRP) under Planning

In order to respond to the International CLIVAR Programme. a proposal of China CLIVAR Research Programme has been drawn up in the China Committee for WCRP. The main scientific objective of the programme is to extend the studies on climate variabilities including their physical processes and their simulation and predictability from monthly and seasonal time-scales to interannual time-scale.

3.1) Research Programs

Under the support by the Ministry of Science and Technology of China, a national key project- “Study on the Interannual Variability of Climate System and Interannual Predictabilities of Heavy Climate Dis-

asters in China" will be performed as the most important one of the research projects of CCRP for 5 years from 1999 and may be continued for 10-15 years. This is due to that heavy disasters of droughts and floods frequently occurred in China, and these disasters have brought huge economic losses in China.
The main scientific topics of this project are as follows:

i To analyse and study the physical processes of air-land-sea interactions in the Asian monsoon region
ii To monitor the occurring signal of ENSO event and to reveal the physical mechanism of ENSO cycle
iii To study the interaction between the Asian monsoon and ENSO cycle and to analyse the impact of ENSO cycle on Asian monsoon and heavy climate disasters in China
iv To analyse the interannual and seasonal variabilities of the Asian monsoon system and the Meiyu in East Asia and to put forward the interannual and seasonal prediction theory and method of heavy drought and flood in China during summer
v To study the dynamical and thermal effects of the Tibetan Plateau on the interannual climate anomalies in China and to understand the energy and water cycles in the arid and semi-arid regions in China
vi To design a advanced air-sea-land coupling climate model with high-resolution, to assess the interannual and seasonal predictabilities of the East Asian summer monsoon with climate models and to improve the monthly and seasonal climate prediction system.

3.2) Observational and Theoretical Research Programs Associated with Climate Variability in China

Under the supports by National Natural Science Foundation, Chinese Academy of Sciences and China Meteorological Administration, some observational and theoretical research programs on the interdecadal variability of climate in China, the interaction between the East Asian monsoon and ENSO cycle, the effect of the western Pacific warm pool on the Asian monsoon, the air-land interaction processes in different climate regions including the monsoon region and the arid and semi-arid regions of China and regional climate in China may be proposed as a part of CLIVAR Research Programs in China.

3.3) Construction of Climate Observing System in China

In order to realize the objectives of CCRP, first of all, the real-time and achieved data sources provided by existing operational observing systems are very important. CCRP will strengthen the construction of the operational and quasi-operational climate monitoring systems so that to better monitor the climate variability and change in China. Moreover, the observational experiments on the air-sea interaction processes in the western Pacific warm pool and the South China Sea and the air-land interaction processes over the Tibetan Plateau and in the arid and semi-arid regions in China will be made.

The CLIVAR Research Programme has been proposed and will be proceeded for 15 years. As a part of International CLIVAR Research Programme, China CLIVAR Research Programme will be performed for 10-15 years. It can be believed that through the implementation of China CLIVAR Research Programme, great progresses in the studies on the climate variabilities, anomalies and predictability in East Asia, especially on the East Asian summer monsoon, can be obtained, and this Programme will be also an important contribution to the International CLIVAR Programme.

CLIMATE MONITORING AND RESEARCH ACTIVITIES IN CROATIA

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Introduction

Croatia is located in the South-Eastern Europe between latitudes 42°N-46°N and longitudes 13°E-20°E. Although it is rather small in area, it covers an area with at least three climate types: Mediterranean, Pannonian and mountainous. As a country with rather developed tourism and agriculture, its government is very interested in monitoring and research of climate over its territory. Great part of these activities is concentrated within Meteorological and Hydrological Service (MHS) of Croatia although there are some of activities at the universities, environmental agencies and research institutes. Thus, this review will be mainly devoted to the MHS's activities.

Observations and climatological data base

More than one hundred climatological stations are active in Croatia nowadays. One third of them are with professional staff and the others operate on a half- professional basis (with volunteer observers). Yet the professional criteria are the same for all stations. This arises from a long tradition of observations in Croatia. The first stations have been established in fifties of the nineteenth century.

The data are monthly stored and controlled subjectively and automatically by computer. Thus, controlled data are available on computer media for all active stations for the period 1981-1997. There are available secular time series for six stations at the same media which can be used for climate research activities. For example, Zagreb[2] station data are available for the period 1861-1997.

Scientific projects

Between the MHS and the Croatian Ministry of Science and Technology (MST) an agreement about long-term joint support of scientific projects of societal interest has been signed. Some of them treat climate change issue. One of them is the project "Croatian Climate Monitoring Within the Global Climate Changes". realised in the period 1991-1995. The second is in realisation titled "Long-Range Weather- Climate Forecasting along Adriatic-Pannonian Profile". A relationship between regional meteorological (hydrological) fields and large-scale circulation parameters has been considered within the projects. For example, it was indicated that there was a significant relationship between the monthly large-scale sea level pressure anomalies and the regional (those over Croatian territory) monthly temperature, precipitation or discharge anomalies. The results were published in the international scientific journals like: International Journal of Climatology, Theoretical and Applied Climatology and others. Some of them made an international success.

An internal the MHS's booklet titled "Croatian Climate Programme Project Review 1991-2000" has been published. It was prepared according to the World Climate Research Programme (WCRP) also with an emphasis on the regional scale. The programme covers topics like: climate data and monitoring, agrometeorological applications, energy aspects of planing and designing buildings and settlements, socio-economic consequences of climate changes etc.

Two projects: "Implications of Expected Climatic Changes for the Kastela Bay Region of Croatia" and "Implications of Expected Climatic Changes for the Cres-Losinj Islands" were realised under the United Nations Environment Programme - Coordinating Unit for the Mediterranean Action Plan. The results were published in the book "Climatic Changes and Mediterranean" by L J. Jeftic, S. Keckes and J.C. Pernetta (1996).

[1] On behalf of the National Delegation for Croatia

[2] Croatian capital with co-ordinates: latitude (j=45° 49'N), longitude (l=15° 59'E) and altitude (H=157m).

In addition to the mentioned international co-operation, a visiting project was realised with the United Kingdom Meteorological Office by the end of 1994. Some co-operation with experts from Slovenia, Hungary, Greece and India has been realised including exchange of climatological data.

International conventions

The MHS, i.e. Croatia, has also been involved, from the very beginning, in a number of international projects trying to determine the amount and paths of pollutants across international borders as: MEDPOL (Mediterranean Pollution Monitoring and Research Programme), EMEP (Operative Programme of Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe), GAW (Global Atmospheric Watch) and others. One of the oldest conventions is LRTAP (Long Range Transport Air Pollutants) convention for reduction of the global pollution of the atmosphere. The most recent one is the “Convention on Climatic Changes” signed by Croatian government in Rio de Janeiro (1992) and ratified 1994. A national report on climatic change is in preparation, in which the environmental aspect of the issue will be considered.

Conclusion

The WCRP, as one of the most important WMO (World Meteorological Organization) programmes, has been seriously accepted in Croatia even before it became independent. Main role in that process takes the HMS in co-operation with the MST. Although, the mentioned activities have not been directly included into the CLIVAR (CLImate VARiability) programme, it is clear that many of them can be also treated as a part of this programme. Croatian experts and institutions will try to contribute to the realisation of the CLIVAR programme making their intellectual and material resources available for the project purposes in spite of possible real difficulties.

Statement of the Czech Republic

Presented by Dr Ladislav Metelka
Czech Hydrometeorological Institute, Dvory, Czech Republic

On behalf of the Czech Republic's agencies that operate in climatology, I would like to express here the great interest of these agencies in participating in CLIVAR project.

According to the demand of CLIVAR conference organizers, 5 agencies that operate in climatology and related sciences within the Czech Republic were asked to express their interest in participating in CLIVAR project as well as their possible contribution to the project. These agencies were:

- Czech Hydrometeorological Institute (as a national weather service)
- Charles University, Faculty of Mathematics and Physics, Department of Meteorology and Environmental Protection
- Masaryk University, Faculty of Science, Department of Geography
- Academy of Sciences of the Czech Republic, Institute of Atmospheric Physics
- Academy of Sciences of the Czech Republic, Institute of Geology

The representatives of all of these agencies expressed their interest in the project. Moreover an overview of the research activities that are under way in these agencies and that correspond to CLIVAR project intention was made up. It was found that many of the recent research activities of the Czech climatology correspond well to some parts of the CLIVAR project. The main corresponding topics are:

1. Studies of validity of GCMs at the Czech Republic territory, based on both monthly and daily data. These studies started about 5 years ago and the Czech climatologists have got significant experience and important results concerning the GCMs validation in central Europe. The studies based on monthly data were used mostly for validation of the mean values within the framework of Country Studies whereas the daily data are presently used for studies of variability and some extreme phenomena occurence.

2. Studies of impacts of expected climate changes, especially in agriculture, forestry, water management and energy supplies. There is also a several year experience in impact studies, including the application of the artifical weather generator that has been built in the Czech Republic. This weather generator turned out to be very useful tool for impact studies.

3. Statistical downscaling of GCM outputs within the central Europe and constructing of site-specific climate change scenarios. These studies were based on 500 hPa heights, 1000/500 hPa relative topography and 850 hPa temperatures over Europe from ECHAM3 model. Statistical methods, as for instance Multiple Regression, Canonical Correlation Analysis and Singular Value Decomposition were applied to fit the relation between model outputs and measured temperature series from the Czech Republic, Slovakia, Germany, Austria, Switzerland and Belgium, both for ECHAM3 control run and 2xCO_2 run.

4. Empirical studies of climate variability and of statistical properties of the observed time series. These studies are based especially on the processing of secular time series originating from the Czech Republic territory as well as from other mid-European countries. Studies are focused especially on the time-dependent evolution of variability and the autocorrelation structure of time series. Advanced statistical methods, including spectral analysis and autoregressive models are used for this purpose.

5. Objective classification of circulation patterns in European area, especially by the means of rotated Principal Component Analysis.

6. Methods of empirical seasonal climate forecasting in mid-European area. This activity has recently started. From the methodological viewpoint it is based on the utilization of advanced statistical methods as for instance principal component analysis, canonical correlations and factor analysis. Great attention is given to the utilization of artificial intelligence systems (especially neural networks) in the analysis of climate system behavior and predictability studies.

7. Studies of statistical properties of extreme phenomena occurence with respect to the relation between the projected climate change and the corresponding changes in extreme phenomena occurence and severity.

8. Reconstruction of climate within the last thousand years on the basis of written sources and studies of long-term climate variability. This effort is under way for many years in the Czech Republic and has significantly contributed to the knowledge of the behavior of time series at the Czech Republic territory and of time-dependent changes within these time series.

9. Reconstruction of climate within the last 10 thousand years with respect to paleotemperature data and important dry spells.

10. Glacial cycle courses.

All these activities should serve as a good basis for the Czech Republic's contribution to CLIVAR project.

Concerning the topics where CLIVAR project could help to the Czech climatology, one of them is recently very important for us. Our access to GCMs outputs is not as good as we need to be able to intensify our effort on GCMs validation and downscaling and also on impact, variability and predictability studies. We would also like to help to the enhancement of the exchange of data sets, results and experience within climatological community.

As for the possible Czech Republic support to the CLIVAR project and its infrastructure, presently the financial support would be rather difficult for us because the budget of all the agencies mentioned before, is strictly restricted. Our possible future financial support to CLIVAR project is dependent on the results of the future negotiations between the agencies involved in the project, Czech National Climate Programme and the government authorities. Despite this fact, the Czech Republic agencies are able to support the CLIVAR project. First of all, these agencies can offer some research capacities for the project needs. Moreover, a supercomputer has been set into operation in the Czech Hydrometeorological Institute this year. This supercomputer is being used for the procesing of the weather limited area model ALADIN within the framework of central European LACE center, that is located in Prague. The ALADIN model has been built in Meteo-France by an international team in which the scientists from the Czech Hydrometeorological Institute and Faculty of Mathematics and Physics, Charles University, Prague, played a significant role. Besides the further development and utilization of ALADIN model, we would like to cooperate on further development and utilization of ARPEGE-CLIMAT and ALADIN-CLIMAT models in cooperation with Meteo-France.

The decision was made at the Czech Hydrometeorological Institute a few weeks ago that some computation time and data-storage capacities of this supercomputer could be reserved for the CLIVAR project needs. Our experiences in both building and routine operation of the ALADIN model could serve as a good base for instance for climatological limited area modeling and studies or for the improvement of dynamical downscaling methods in complex terrain.

Ladies and gentleman, Czech Republic is a small country with rather low number of climatologists. Moreover, our financial budgets are strictly restricted. Despite these facts, we are convinced that we are able to become a member of CLIVAR society and contribute to the progress of CLIVAR project.

Democratic People's Republic of Korea
Proposal for Participation in the CLIVAR

DPRK is a peninsular country in the east of Asian continent surrounded by the sea on the 3 sides.

The land is affected by evident regional climate characteristics of continental and maritime climate and Asia-Australia Monsoon.

With regard to the recent climate of the country, a systematic and abrupt climate change in diverse patterns due to such global and regional-scale climate changes as global warming, solar activity and El-Niño events drives a continuous natural disasters like steady drought, high temperature, cold and flood to give a tremendous impact on the development of national economy including agriculture.

In the country climate study is attracting a great social interest by helping the development of national economy with the priority of agriculture.

The subjects of climate investigation are paleoclimate data development, normal climate value determination and improvement, regional climate model development, identification of relationships between the statistical climate change characteristics of the global and our country, and statistical prediction of climate change and other fields.

The institutions studying climate change are the Central Forecast Research Institute, the Hydrometeorological Research Institute, Oceanographic Research Institutes, Fishery Research Institutes and other institutes including University Research Institutes.

We are sure that the CLIVAR programme implementation will properly contribute to the understanding of human being on the global hydrological and meteorological environment and raising the creative capacity of human being to control it.

Acknowledging the noble goal and scientific content of CLIVAR we shall take a sincere part in the CLIVAR IIP implementation in the standpoint of a member of the globe.

Our proposal participation in CLIVAR in accordance with the CLIVAR IIP is as follows:

No:	Work to be undertaken by DPRK	Item corresponding to CLIVAR IIP	Remarks
1	Global Modelling and Prediction • Development of regional climate model of our country • Study for use of global atmosphere-ocean coupled model products in the regional small scale of our country (downscale)	II. 2,5	
2	Development of Paleoclimate Data • Development of paleoclimate data (air temperature, precipitation) for the past 2000 years • Analysis of the past climate change characteristics	II5,3 or II 2,7	

3	Global Sustained Observations Establishment and operation of standard climate station available to the implementation of CLIVAR Project	II4,2,3 or II 2,6,3	Station equipments and instruments need outside provision
4	Global-scale Empirical, Analytic and Diagnostic Studies • Empirical predictablity of such abnormal events as El Niño • Short-time downscale empirical prediction modelling • Seasonal to interannual timescale empirical predictability		

Danish Contribution to the CLIVAR Conference in Paris 1-4 Dec. 1998.

Danish Centre for Earth System Science

The Danish Centre for Earth System Science, supported by a five-year grant from the Danish National Research Foundation, was established in December 1997. The Centre is housed at the Niels Bohr Institute for Astronomy, Physics and Geophysics, University of Copenhagen, and at the Biological Institute, University of Odense. The Director is Prof. Gary Shaffer and the Associate Directors are Prof. Ray Bates and Prof. Don Canfield. The Centre will employ over thirty people, including scientists, Ph.D. students, technicians and administrative personnel.

The Centre will focus on three research themes:
1. Climate System Stability
2. Role of the ocean in the climate system
3. Chemical and biological evolution of the atmosphere and oceans.

The research will be pursued using climate and biogeochemical models, ranging in complexity from simple conceptual models to coupled atmosphere-ocean GCMs. The models will be used to investigate mechanisms and feedback's in the climate system and to analyse meteorological, oceanographic and geochemical data sets. The modelling work will be complemented by oceanographic field work in the southeast Pacific and by geochemical field studies. Interdisciplinary research linking the three research themes will be a central focus of the Centre.

Danish Meteorological Institute (DMI)

DMI contributes to all three CLIVAR Programs: "GOALS", "DecCen" and "ACC". Its activities are concentrated in the Danish Climate Centre (DCC) which unites the science and modelling at DMI related to climate variability and change.

Seasonal to inter-annual variability and predictability are key activities. DMI is currently involved in two EU-supported projects, PROVOST and POTENTIALS, both focusing on seasonal prediction of climate. While PROVOST uses a classical coupled as well as uncoupled dynamical modelling approach, POTENTIALS, investigates if an (a-priori) empirical correction of the governing differential equations in atmospheric models can reduce their systematic errors and thus improve the energy dispersion characteristics and potential seasonal predictive skill. DMI has recently started an operational seasonal prediction activity.

So far, DMI has mainly been involved in "DecCen" from an observational point of view. This has been e.g. through studies identifying statistical relationships between different measures of solar activity and climate on earth and via the WASA project where a study of storm activity in the North Atlantic region in the last hundred years was been performed (see figure above). It is planned to start coupled atmosphere ocean modelling in the near future aiming at understanding and eventually predicting decadal variability.

"ACC" is a main theme within the DCC and DMI has been and is participating in several international research projects studying the climatic impact of enhanced concentrations of greenhouse gases and ozone depletion. DCC is involved in development and improvement of dynamical models used for climate process studies and climate change studies. The models include the regional climate model HIRHAM and two global GCMs (ECHAM4/T106 and ARPEGE/T42).

On the observational side DMI has actively participated in the BALTEX by designing a regional reanalysis system. Regional reanalyses constitutes valuable data sets for verification/improvement of NWP systems and regional climate models as well as for regional climate studies. Using variational assimilation techniques a new set of re-analyses will be made for the BALTEX/BRIDGE intensive observation period using many ‘unconventional’ observational data types such as radar winds, GPS-estimated vertical humidity integral, etc.

DMI is also involved in oceanic studies and measurement cruises on atmosphere-ocean carbon (CO_2) interactions. This includes three cruises to the Greenland Sea. Furthermore DMI is responsible for monitoring the oceanographic conditions off West Greenland which is related to the North Atlantic Oscillation in the atmosphere. Finally DMI is actively involved in EuroGOOS - the European component of the Global OceanObserving System - which will cooperate closely with CLIVAR.

Geological Survey for Denmark and Greenland.

The department carries out research, gives advice and educates PhD students on long-term variation in the marine and terrestrial environments. Areas of special expertise include late-Pleistocene and Holocene climatic change at the north Atlantic margin, late-Quaternary palaeoceanography, near shore sedimentation processes and pollutants, quantitative palaeoecology, landscape development, nutrient status of lakes, vegetation history, human impact and natural forest dynamics.

Glaciology

The glaciology section at Niels Bohr Institute for Astronomy, Physics and Geophysics, University of Copenhagen has during 30 years specialized in ice core drilling (mainly at the Greenland Ice Cap) and analysis of the ice. The analyses include physical and chemical measurements as well as computer modelling of the behaviour of the ice. All elements contribute to our understanding of the climate conditions back in time.

n the period 1989-1993 an ice core was drilled from surface to bedrock at Summit, the highest point of the ice cap. The result of the european GReenland Ice core Project (GRIP) was an ice core of more thanI 3000 m length. This core, has given a climate history about 200.000 years back in time! This means information from even before the last warm period, the Eemian, at 113-125 ka BP.

Unfortunately the ice from the interglacial Eemian period was slightly disturbed by bedrock topography. To obtain a more undisturbed and detailed record from this period, which is interesting because it can be compared with our current warm period, the Holocene, a new deep drilling project started in North Central Greenland in 1996 (North GRIP).

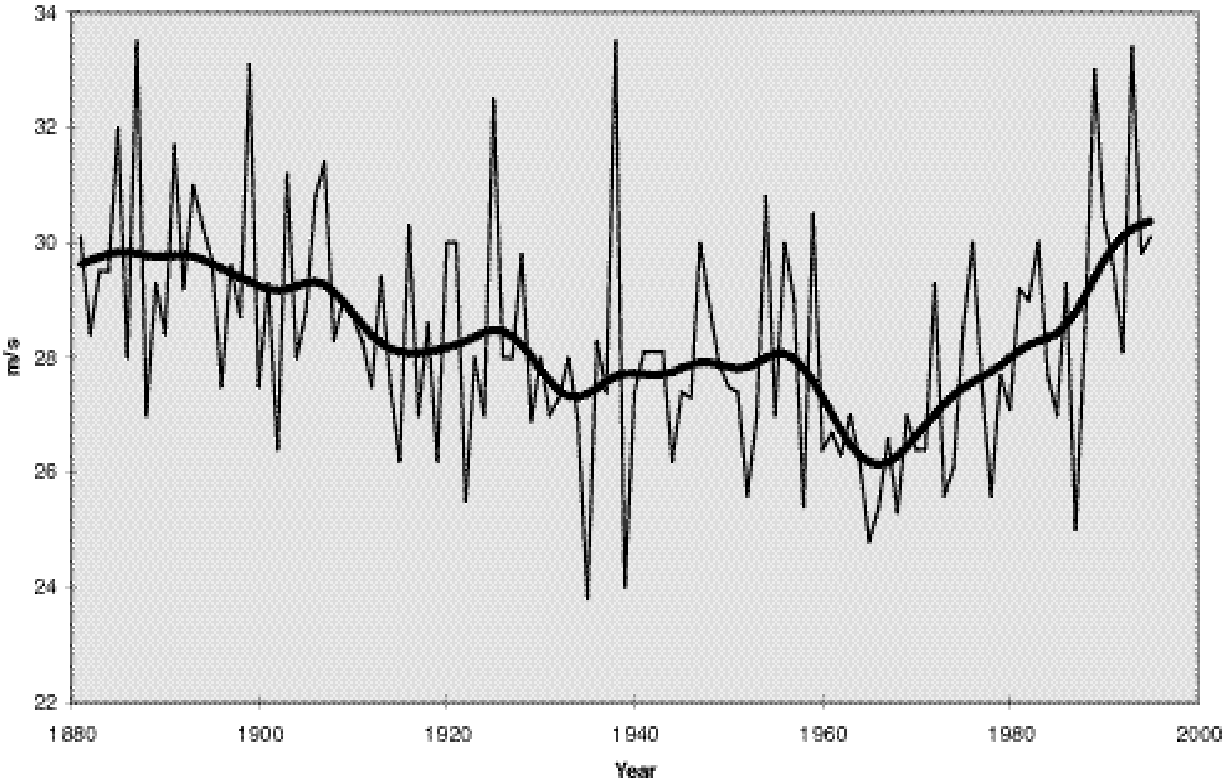

Figure 1 - Varying storm activity in the period 1880-1995 estimated as the annual 99% fractile of the geostrophic wind between Torshavn (Faroe Islands), Bergen (Norway) and Aberdeen (Scotland). Only winter data are used. The thick curve shows the result after low-pass filtering the annual values.

DOMINICAN REPUBLIC NATIONAL INTEREST IN CLIVAR

Lic. Mercedes I. Mejía
Director of the General Meteorology Department of
National Meteorological Office, Dominican Republic

In connection with the International CLIVAR conference (Paris, 1-4 December 1998), in discussions concerning the possibility of participating in CLIVAR project we would like to express our great interest of the national community in the matters and issues related to the climate, its variability and their effects on the economic and social activities and is planning to take active part in the implementation of the CLIVAR Programme and pretends to attract the interest of our scientists to this project.

Agree that natural disasters are of global concern, and have their most severe impacts on vulnerable communities, as well as economic and social infrastructures in the developing world, and can therefore contribute to increased poverty if no concrete action is taken towards integrated preventive strategies.

In spite of three dimensional monitoring of global climate system with highly advanced tools such as satellite and weather radar, etc. it is not an easy task to predict the future climate, but now CLIVAR aims at the monitoring and prediction of the climate variation.

Last decades, the needs in climatological information have increased from the Policy and Decision makers and to respond to these request our national scientists community needs to improve substantialy studies in some areas.

Several research institutions like the National Meteorological Office, Sub-secretariat of Natural Resources under the auspices of the Ministry of Agricultural and a Working Group of Meteorologists Associated is planning to participate in all three CLIVAR principal research areas those which are focused on:

- Predictability at long range scale (monthly, seasonal,..) mainly for rainfall
- Mangement of extreme event and teleconnexion with know phenomenon like El Niño and La Niña episodes and its impact on the Dominican Republic rainfall distribution.
- Climate Change and its socio-economical influence on the Dominican Republic.

Dominican Republic manifests its interest in participating in CLIVAR Program in its Principal Research Area and hopes full success to all the work to be done under its framework.

Several research institutions like the National Meteorological Office, Natural Resources under the auspices of the Ministry of Agricultural and a Working Group of Meteorologists Associated is planning to participate in all three CLIVAR principal research areas those which are focused on the:

- Anthropogenic Climate Change (A1)
- The North Atlantic Oscillation (D1)
- Extending and Improving Predictions ENSO (G1)
- Tropical Atlantic Variability

Dominican Republic main contribution to Clivar would consist in the fields of observation network and data base to meet CLIVAR needs, research activities by the Working Group Associated in relation with performing empirical predictability studies in connection with large scale oscillation (ENSO) and Atlantic depressional systems trajectories besides in the form of normal operational and research activities by the National Meteorological Office (Onamet).

We are looking forward to increase opportunities for participation in the major CLIVAR initiatives and to be able in sharing international collaboration on problems of mutual interest.
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Santo Domingo, D.N.
Dominican Republic

EGYPT PRESENTATION TO INTERNATIONAL CLIVAR CONFERENCE

Dr. A. M. El-Asrag
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This report gives a concise summary of Egypt activity and possible participation in CLIVAR plan for the coming century. Also, it depicts Egypt needs and proposals to expedite and to involve developing countries in this important project.

1 Program of Research and Observing System in Egypt

The Egyptian Meteorological Authority (EMA) is one of the African and Arab countries that have long meteorological observation. Over 100-surface - meteorological stations and 4 upper air stations have been established since more than 50 year ago. Also, total amounts of ozone have been measured on daily bases at three locations in Egypt since 1974. Besides, surface ozone and GHG measurements are taken at 5 locations.

EMA has over 200 meteorologists that are specialized in most branches of meteorology. Among these 200 meteorologists, 25 of them are working in research fields of Climatology, NWP, and Agrometeorology.

A part of research plan in EMA is devoted to study climate change and variability over North Africa. Numerical ETA model is running now in a routine basis. In addition to normal products of ETA model, it is developed to study sand / dust storms and flash floods over Egypt.

Nile River is the main source of fresh water for Egypt and for many other African countries. So, it is very important to study Nile River basin from climatological and historical views. This suggested study might include the following points:

a) Rainfall that causes Nile River flood.
b) Relation between Nile floods and climate change in the past.
c) And using GCM, Regional Climatic Models, and other statistical Models to forecast Nile discharge as well as rainfall over Africa.

These three mentioned points might be included in CLIVAR program through its research area of interannual variability of the African climate system (G4). However, a complete plan of implementing this project can be discussed with CLIVAR panel.

2 Possible contribution of Egypt to CLIVAR

Egypt has fair capacity in both research domain and database of climatic data. Through research domain, Egyptian researchers can contribute in CLIVAR program. They can take responsibility to execute a part of CLIVAR project especially that part of G4 that investigate climate variability and change over Africa as well as Nile River study. Also, study of climate change over the Sahara could be a part of G4 with the aid of remote sensing techniques. This may give us more understanding of climate system. Like oceans, conventional meteorological measurements in the Sahara are rare and have to be replenished by remote sensing technique. In short, Egypt contribution in CLIVAR may be summarized in the following three tasks:

- Studying Nile River flood and its link to past, present, and future of climate change as well as Nile Discharge predictability.
- Supply the infrastructure of one of CLIVAR Subsidiary Centre to collect data related to research area G4 and to make the appropriate research on it.
- Study the climate change and variability in the Sahara.

3 What can CLIVAR provide to Egypt?

The proposed participation of Egypt is in need of some technical assistance from CLIVAR. This technical assistance could be summarized as follow:

- Supplying Egypt of hardware and software required for the suggested Subsidiary Centre of CLIVAR in Cairo.
- Training Egyptian Meteorologists on advanced techniques of Regional Climatic Models, and NWP as well as on GCM. This will increase capacity building of researchers who will be responsible for the suggested CLIVAR Subsidiary Centre in Cairo. In addition, this centre may be regarded as a training centre to African and Arab trainees in the future with cooperation with ACMAD.

4 General suggestion to CLIVAR

To expand and to intense CLIVAR program it is recommended that:

- Many Subsidiary Centres have to be erected in many parts of the world. Every Subsidiary Centre has a defined function in CLIVAR program. The infrastructure of any Subsidiary Centre has to be
- supplied by the WMO member that wants this Subsidiary Centre be erected on its own land. The proposed Subsidiary Centres have to be under supervision of national meteorological service.
- The methods of operating Subsidiary Centres have to be unified with some regulation of WMO and the Joint Scientific Committee of WCRP.
- All Subsidiary Centres are coordinated and controlled by the main CLIVAR centre.
- A training program has to be implemented to increase capacity building of developing countries in climate variability and forecasting.
- The training programs may include advanced mathematical and statistical tools that are required in developing recent Regional Climatic Models, NWP Models, and GCM as well as advanced methods of assessing and investigating climate change.
- As conventional meteorological measurements have to be replaced completely by remote sensing measurements, intensive courses in satellite technology have to be included in CLIVAR program for the 21^{ST} century.
- The volcanic eruptions inside ocean may by included in CLIVAR program to detect their effect on SST and on Thermohaline circulation.
- The Monuments in Egypt and those in other countries can be included in CLIVAR program research areas as aid source of paleo-climatic data.

CLIVAR RELATED ACTIVITIES IN FINLAND

Presented by Prof. Mikko Alestalo,
Finnish Meteorological Institute, Helsinki, Finland

Organization of climate activities

Climate related activities in Finland are carried out at the Finnish Meteorological Institute, the national meteorological service of Finland, representing both operational and research activities in climatology. The Department of Meteorology at the University of Helsinki also carries out climate research, in addition to meteorological and climatological education.

The Academy of Finland, the leading institution to finance research in Finland, coordinates the national climate programs and the Finnish participation in the international programs. In addition, national committees coordinate activities in Finland in relation to the Intergovernmental Panel on Climate Change (IPCC) and global change studies. A special national Global Change research programme is being launched for the years 1999-2001.

CLIVAR related activities in Finland

The main contribution to the CLIVAR is provided in the form of normal operational and research activities by the national weather service, Finnish Meteorological Institute (FMI).

In research on climate changes and their detection, jointly with other European countries, Finland has taken part in the North Atlantic and Nordic climate projects aiming at the best possible long-term climatological data records for the study, monitoring and detection of past and future climatic changes in the North Atlantic and adjacent land areas. In this work, the reliability and homogeneity of the data records and the station records (metadata) are in a key role. Finland has also taken part in WMO and GCOS activities through the Commission for Climatology and various working groups on climate data management and climate change detection.

At the FMI, the main aim in CLIVAR related research is to cooperate with various international climate-modelling centres in order to have an access to the newest developments in climate scenarios to be applied in various application and impact areas in Finland. Special emphasis has been directed to the road and sea traffic sector.

CLIVAR related research is also being carried out in the University of Helsinki. At the Department of Meteorology several tools are being used to study stationary and quasistationary large-scale waves in the real atmosphere as well as in the atmospheric general circulation models. The basic question concerns the role of various forcing mechanisms in the excitation and maintenance of these waves in the present and future climate.

In addition, Finnish Institute of Marine Research (FIMR) is making research on ocean circulation and polar ice and Karelian Institute at University of Joensuu on dendrochronology.

CONTRIBUTION FROM THE FRENCH RESEARCH FOR CLIVAR

Introduction

Many scientists in France have expressed a deep interest in the objectives of CLIVAR and wish to bring some contributions to different questions addressed by the CLIVAR Programme. France already participated to WOCE and TOGA and helped to collect the necessary data, to perform their interpretation and to get a better understanding of the climate system through analysis and numerical modelling. The french research programme is particularly interested to study the predictability in tropical regions, specifically in the tropical Atlantic and the African continent, to investigate the long-term variability in the North Atlantic with specific references to the abrupt variability observed in different climatic contexts, to explore the variability in the southern latitudes and to contribute to reduce the uncertainties in the prediction of the climate of the next century, by developing comprehensive models of the earth system (the incorporation of relevant biogeochemical processes in global models will be discussed in coordination with IGBP-GAIM; a first task will be to consider the coupling with the carbon cycle). To carry on these studies, French researchers propose to contribute to the network of sustained observations of CLIVAR, to intensify their numerical modelling effort, particularly in the representation of the oceanic circulation and in the development of comprehensive models, and to carry on specific process studies in PRA (Principal Research Areas).

Climate research is covered by several agencies which are coordinating their efforts through a national program called PNEDC (Programme National d'Etude de la Dynamique du Climat). The present document has been prepared by the Scientific Committee of the PNEDC and discussed in several coordination meetings of the agencies. The development of the contribution for CLIVAR has also been discussed through European collaborations, in the framework of EUROCLIVAR. The document will present the following issues :

1 The contribution to the sustained observations
2 The global climate and its variability
3 Principal Research Areas
3a The North Atlantic oscillation (D1) and the thermohaline circulation (D3)
3b The southern Indian ocean and the Antarctic climate (D5)
3c Coupled interaction and predictability (G1)
3d The tropical Atlantic and the African climate (G4 and D2)
4 Anthropogenic climate change
5 Participation, data and computer facilities

1 Contribution to the sustained observations

Observations from space

Through its participation to different space agencies (EUMETSAT, ESA, CNES), France is strongly involved in observing programmes from space. It supports the recommended meteorological satellites (METOP, ENVISAT).

Some specific requirements of the CLIVAR programme concern the long-term observations of the following variables : the wind stress at the ocean surface and the ocean surface elevation. The wind stress at the ocean surface has been observed through the successive ERS1 and 2 scatterometers (8 years of continuous observations are now available) and the effort will continue with ENVISAT, in european collaboration.
France has taken the engagement to maintain its support to the observation of the global sea-level, at a centimetric accuracy, in collaboration with US. TOPEX-POSEIDON will be followed by JASON, assuring a continuous time series of sea level for more than a decade. The pursuit of this programme has the highest priority.

New technological developments are studied in order to follow other interesting variables. The POLDER instrument measures the polarization, the direction and the spectral characteristics of the radiation. It could offer very interesting survey of clouds, aerosols and ocean productivity. Another developement is also the radar in P-band proposed in the project SMOS/RAMSES. This instrument has the potential to detect the sea surface salinity.

In situ measurements

Very valuable informations on the long trend climatic behaviours has been detected by the Voluntary Observing Ships selected to make specific meteorological observations and the merchant ships which contribute to observe the upper ocean. MeteoFrance (VOS ships), IRD (tropical Atlantic and tropical Pacific XBT lines) and IFRTP (Atlantic sub polar gyre sections and Tasmania/Terre Adelie section) will maintain their effort. The observations of sea level is also invaluable to get the climatic trends and to give some reference for the altimetric signal. The ROSAME programme (observation of sea level in the indian austral islands - Kerguelen/Crozet/Amsterdam) will continue this important mission.

France is also supported some observing services for the CO_2 (in the atmosphere and in the ocean-OISO). Other services are under studies like a time series station in the austral islands. An exploratory station (KERFIX) was located in a harsh environment, in the southern Ocean (60 miles sotuh of Keguelen island). The heavy cost due to the difficult logistics and the uniqueness of the obtained data sets have to be evaluated.

The moored sites in the tropical Pacific (TAO) have brought crucial informations to follow the atmospheric conditions under which develop strong air-sea instabiltities. The oceanic measurements atached to these buoys follow the signal along the equator. France maintains its interest to contribute to the logistics and maintenance of this network in the Pacific from New Caldeonia. In the tropical Atlantic, France was involved in the pilot programme PIRATA. A careful evaluation of this observing system has to be made at the end of the 3-year experiment.

New technologies are emerging to monitor the inner ocean structure and the circulation. We are working on the development of a drifter which will measure temperature and salinity profiles from 2000 m to the surface. This PROVOR instrument could bring a strong contribution to ARGO experiment and the long life of the buoys could help to reach the objectives of CLIVAR.

2 The global climate and its variability

Toward the development of a comprehensive system

The prediction of the climate for the next hundred years offers a formidable challenge. Models of increasing resolution are used to reduce the uncertainties, and sensitivity studies will try to improve the understanding of the contribution of clouds and their radiative impact, the hydrological cycle and the sea ice and its coupling to the oceanic circulation. Dynamical structures may also be sensitive to the modification of the biogeochemical environment. After studying separately the impact of the greenhouse gases on the dynamical climate, and the impact of the evolving dynamical environment on the carbon cycle, it is timely to start to work at the interactions between the dynamical system and its biogeochemical components. The complexity will be progressively increased and special care will be required to integrate biospheric processes photosynthesis, phenology, biome change...) in the system. The objective is to simulate scenarios from the beginning of the industrial period with the specification of the sources of the greenhouse gases (A1).

The detection of the anthropogenic impact relies on the improvement of the data bases for the last centuries. Efforts will be made both to develop new technologies to aquire specific time series to reconstruct the european climate of the past centuries (dendrochronology, varved sediments) and to develop reliable statistical methods to build these time series (A2).

The past climates

Past climates and their variability offer the challenge to confront our ideas on climatic adjustment and mechanisms with past records. This approach will improve our knowledge of the mechanisms of natural variability (decadal to centennial scales) and to test our models capabilities in different environments.
The mid Holocene (6000 years BP) was explored during the PMIP projetc. The efforts now will concentrate

on the last glacial maximum (21000 years BP) and its decadal to centennial variability; multiproxy approaches will help to evaluate models and times slice at high resolution will help to document the variability during this climatic extremum. Specific efforts will be made to integrate the modification of the biosphere in these simulations and necessary data will be looked for.

Observations in past climate have also shown that abrupt events could happen during the last glacial maximum and the Holocene. These periods are very useful to document the variability of the thermohaline circulation and the adjsutment of climatic conditions to these transiences. Understanding the non linearities in the climate system will be in focus.

To support these works on past climates, an intensive effort in analyses and synthesis is needed. French teams have already a strong capacity in the interpretation of ice core drilling and oceanic drilling; some progress is needed to get and intrepret continental series. Improved techniques are needed to get higher resolution. The demand for isotopic measurements at high resolution is strong.
France owns the vessel MARION-DUFRESNE, which is very well equiped to perform oceanic drillings. Its involvement in PAGES/CLIVAR is strong and this ship is opened to the international community.

The oceanic component of the climate system

One source of important uncertainty for the prediction of the climate for the next century is the ocean. Considerable efforts were deployed during the international programme WOCE to improve the basic knowledge of the present oceanic state and to develop models able to use these data. This work is still going on. To take advantage of the observing system and to reduce the uncertainty in the oceanic state, an operational oceanography project (MERCATOR) is developing. This project has the objective to give a real time description of the global ocean at high resolution, using optimal combination of models and data.Besides the survey in real time of the oceanic state, it will be possible to perform oceanic reanalyses, in order to get the consistent time series needed for climatic interpretation. MERCATOR will provide initial conditions for seasonal forecast prediction at global scale.

To get a better understanding of the initial drift in coupled experiments and to detect the processes at the origin of instability growth, an effort will be made on the development of new techniques (like the adjoint). This could be very helpful to improve the description of the oceanic state and to get quantitative estimates of the sensitivity.

3 Priority Research Areas

3-a The North Atlantic oscillation (D1) and the thermohaline circulation (D3)

Europe is directly affected by the variability of the North Atlantic Oscillation. It is thus important to understand the nature of the decadal variability on the North Atlantic and how it could evolve with the anthropogenic climate change. Sceintists have proposed to explore the physical mechanisms which triiger it off and maintain it through different anallyses of long time series, modelling experiements, and acquisition of new data.

D1 - A first task will be to identify, in data and model outputs, the time and space patterns of the NAO and its signature in the European climate. This will be done for the present climate and also for the climate of the last centuries with the help of proxies. The response of the atmosphere to specific SST patterns will be analyzed. And the ability of atmospheric to represent the observed patterns will be evaluated.

A second step will be to identify the characteristics of the decadal variability in the North Atlantic and to determine its link with atmospheric variability. Several hypothese about the origin of the decadal variability will be looked at (the possible role of the stochastic forcing from the atmosphere, the generation of decadal signal by processes internal to the ocean, the role of sea ice in the Arctic regions...). Oceanic experiments, forced by the observed atmospheric decadal variability, will help to understand the consequences of this forcing on the water mass formation.

D3 - A particular interest is to investigate the possible role that the oceanic thermohaline circulation plays in this variability. This will require the acquisition of new data to explore how the surface signal penetrates into depth and then evolves inside the ocean in the subpolar gyre circulation.

A preliminary process study is scheduled in the north Atlantic in 2001. This experiment called POMME will cover a full seasonal cycle and explore the process of subduction and its consequences on the burying of geochemical properties in the themocline. Part of the in situ instruments used in POMME could help to respond to the objectives of CLIVAR. In particular, the drifters will have a longer life than POMME itself.

To cover the ocean circulation in the subpolar gyre, its interactions with the atmosphere, and the burying in the thermocline, several operations are scheduled. The first one (already operating) is to pursue the systematic survey with merchant ships between Iceland, Newfoundland, Denmark and the west coast of Greenland.

Other measurements could be integrated in a european survey of the North Atlantic and could start in 2002. They comprise : a series of hydrological sections, the deployment of deep moorings in specific narrow paths between the Greenland sea and the subpolar gyre, the large scale monitoring of water mass by tomography and above all, the survey of the subpolar gyre circulation with profilers during several years. This last point is very interesting because it is a meeting of the interest of ARGO, MERCATOR and CLIVAR, and a significant contribution can be made by reaching the efforts in this very strategic region.

The full strategy of the involvement in the survey of the subpolar is not yet defined. Strong recommendations are expected from the modelling experiments and the partnership with other countries interested in this area is in discussion.

3-b The southern Indian ocean and the Antarctic climate (D5)

The Southern Ocean has a unic role in the oceanic circulation because it connects the three tropical basins. It redistributes the properties in the three basins, shape the meridional heat transport, and the deep and intermediate water masses. The water masses created in these southern latitudes reflect the complex intereactions between atmosphere, sea-ice and ocean. At present, little is known about the climate variability there but evidence is emerging that coherent patterns exist in the atmosphere, the ocean and the ice. The questions to which we are interested to bring some answers are :

- what are the nature and the amplitude of the exchanges between the Austral ocean, the atmosphere, the sea-ice and the continental ice and the other oceans in terms of momentum, freshwater and heat content in the present observed state
- what are the nature and the amplitude of the interannual variability of these exchanges in connection with the local variability (semi-annual cycle and Antarctic Circumpolar Wave) and also with the tropical variability

The answers to these questions will be looked for with studies with global coupled models where the different parameterizations used for sea-ice, ocean mixing, atmospheric boundary layer will be questioned. An original tool wil be to use tracers in the ocean to evaluate the water mass formation and mixing.

A key-issue will be to get the necessary observations to document the variability and to give a data basis to evaluate the coupled models. We plan :

- to encourage continental observations and support a mini-radar and a micro-meteorological mesurement system at the Dome C site
- to support the systematic oceanic observations (XBTs + SST/SSS along the line between Tasmania and Terre Adelie; the tide gauges network ROSAME; the network of hydrologiacl and geochemical rmeasurements between the islands and south of Kerguelen, OISO)

New observations have to carefully evaluated. They could be a fixed mooring in the south of Kerguelen to get time series of hydrology and geochemistry (KERFIX—CLIOKER) and the deployment of PROVOR floats.

3-c Coupled interactions and predictability (G1)

This research theme is mostly focused on ENSO and the mechanisms which control its occurence and shape its patterns. These questions will be investigated through data analysis and modelling experiments the mechanisms acting in the beginning of a coupled anomaly and its enstension to the full Pacific.
Some studies will concentrate at processes in the warm pool (westerly wind bursts, barrier layer, salinity fronts...) and how these processes could interact with the ENSO development.

Reanalyses of the ocean will be performed using in situ and satellite observations in order to get an accurate history of the recent periods and initial conditions for predictability studies. The impact of the altimetric data will be carefully examined. Some new techniques (adjoint model) will be used to test the sensitivity of the instability growth rate to oceanic physics and atmospheric patterns and help to determine the conditions under which there is some skill in prediction.

Another area of research will concern the role of ENSO in the global climate system, its connection with other oceanic regions and the atmospheric teleconnections. The exhanges between the Indian ocean and the Pacific ocean will be studied, in the context of mean state and variability; the links between the Atlantic variability and ENSO will be explored; and new tools will be adapted to quantify correctly the ventilation of the equatorial thermocline (a process which may potentially link ENSO and the decadal variability).

The observations needed to explore these questions are already included in the sustained measurements for CLIVAR. They are mostly based on the global coverage by the satellites (for SST, sea level and wind stress) and on the merchant ships and TAO moorings to get the upper ocean sturcture. Our contribution to these observations will be to maintain our current level of involvement.
TAO (logistics, 15 thermo-salinometers)
XBT (8 lines) and T/S observations

To complement these observations, a reconstruction of the ENSO variability in the last centuries will be encouraged. This will include new drillings in corals in Polynesia and New Caledonia and the acquisition of ice cores in some Andean glaciers where isotopic datation could be done.

3-d The tropical Atlantic and the African climate (G4 and D2)

Similar to the tropical Pacific, the upper tropical Atlantic shows strong variability at the seasonal, interannual and decadal time-scales. The neighbouring continents are also affected by strong climatic signals (Nordeste droughts, Sahel droughts...). The reason of these climatic hazards is not clear. Are these variability patterns connected ? What is the influnce of the local SST on the African Monsoon ? Is it connected with the Pacific El Niño ?

The objective of this research is to study the climatic variability from the seasonal to the decadal scale in the tropical Atlantic and the adjacent tropical continents, Africa and South America, and to determine its predictable components. Some specific aims have been put into focus for our studies :

- To identify the signatures of the variability and the relevant mechanisms (in the upper ocean, the atmosphere and the continental surfaces)
- To determine the predictable components
- To analyse the scale interactions.

This last point covers in fact to different questions. The first one questions about the connection between the evolution of the upper ocean and the general oceanic circulation and its variability. The second one is focused on the link between continental surfaces and atmosphere (convection, easterly waves, intra-seasonal variability...).

These studies are based on diagnostics analyses of coupled simulations, reanalyses and long time series of data. Sensitivity studies will explore the response of the atmosphere to different SST patterns and to different schemes for representing the continental surface. The interannual to decadal variability of continental convection systems will be studied. To improve the description of the upper ocean variability, we are participating to the survey by merchant ships of the tropical Atlantic (3 lines) and we are involved in the pilot experiment PIRATA in which we have taken the responsability of the moored buoys in eastern Atlantic and a tide recorder (Sao Tomé island).

To explore the connection between the surface signal and the ocean interior (surface variability and transfers between hemispheres, new data are necessary to complement the data sets in hydrology and tracers already acquired during the WOCE programme. To ge a better understanding of the inner ocean variability, we would like to repeat cross equatorial sections every four to five years. The first cruise EQUALANT is scheduled for Summer 1999. It will cover the western Atlantic till 10°W with measurements of hydrology, tracers and currents. To get the higher frequency variability of deep currents and water masses around the equator, four moorings will be moored at 10°W for one year.

4 Anthropogenic climate change

Scenarios of the climate affected by anthropogenic emissions, both past (20th century) and future (21st century) will be carried out using both french coupled models, in coordination with existing international exercices (CMIP, IPCC).
Specific research items will be associated with the realization of those scenarios:

Estimation of the uncertainty of the amplitude and regional aspects of climate changes

- estimation of cloud feedbacks, and development of specific validation methodologies using satellite data; same for surface parameterizations (vegetation, snow);
- comparison of different scenarios with a focus on regional features (for example, changes in NAO, or in Atlantic thermohaline circulation), and associated developpement of methodologies to regionalize the impact of climate changes(imbedded models, zoom models, statistical methods).
- use of paleoclimates to test the sensitivity of the climate models

Impact on polar climates:

- this involves embedded atmospheric models with increased resolutions over polar regions, and models of the polar ice-sheets. It is a first step toward assessing the impact of climate change on sea-level modifications.

Link with chemical and biochemical cycles:

- link with the carbon cycle (continental biosphere and ocean), sulfur cycle and tropospheric chemistry. Off-line studies of the carbon cycle response to climate change have been carried out. On-line studies are under way.
- relations between the ozone hole and the greenhouse gas increase are also studied with a coupled model with increased vertical resolution in the atmosphere.

5 Participation, data and computer facilities

Participation

The following list is not exhaustive and presents only the names of people in permanent position who have already expressed their willingness to take some responsibility in the national CLIVAR actions
CEREGE (Bard, Beaufort, Camoin, Gasse, Hamelin, Jolly, Vincens)
CERFACS (Terray)
CNRM (Planton, Ricard, Douville, Pettré, Céron, Guérémy)
CNSM (Raisbeck, Yiou)
CRC (Fontaine, Roucou)
DGO (Grousset, Pichon)
LBHP (De Beaulieu, Guiot)
LEGOS (Reverdin, Morrow, Du Penhoat, Eldin)
LGGE (Genthon, Barnola, Chappellaz, Raynaud)

LODYC/IPSL (Arnaut, Andrié, Boulanger, Delecluse, Fieux, Frankignoul, Herbaut, Houssais, Menkes, Molcard, Provost, Madec, Sénnéchael)
LMD/IPSL (Le Treut, Li, Dufresne, Hourdin, Bony, Laval, Polcher, Sèze, Grandpeix, Janicot, De Felice, Viltard, Picon, Desbois)
LPCM/IPSL (Metzl)
LPO (Blanke, Colin de Verdière, Speich, Mercier, Speer, Desaubies, Le Grand, Ferron, Gaillard)
LSCE/IPSL (Braconnot, Marti, Balkanski, De Noblet, Monfray, Orr, Ciais, Viovy, Dutay,Bassinot, Duplessy, Joussaume, Jouzel, Juillet-Leclerc, Labeyrie, Ramstein)
Muséum (Park)
SA/IPSL (Hauglustaine, Pham, Clerbaux, Granier)
ORSTOM (Cabioch, Corrège, Récy)
ORSTOM Noumea (Delcroix, Ioualalen)
ORSTOM Brest (Dessier, Servain, Gouriou, Bourles)
ORSTOM Montpellier (Laurent, Lebel)

Observations : Acquisition, Processing, and Valorization

CLIVAR data bases are special in the sense that to reach the objectives, long time series are necessary. It requires a new organization of the data bases and specific care to maintain the long term consistency. Moreover the global coverage is encouraged. More than ever, the free circulation and use of data is essential for the success of the programme. This is a strong requirement for the systems with the "operational" label. The archival of long and consistent time series will put a new pressure on the storage capacity.
For satellite data, dedicated centers (like the CTO) are supported. There is also a strong need to get global reanalyses by dedicated centres. The reanalysis of the CLIVAR period has to be included in the objectives of MERCATOR.

Numerical Simulations

To get ready to answer the CLIVAR questions will put an enormous stress on the computing ressources. The reasons are the following : CLIVAR models require increased resolution (especially ocean), they will use ensemble techniques to evaluate uncertainties, sensitivity and predictability, they will require long time series for reconstructing the climate of the last centuries and for experimenting abrupt climatic changes; addition of new components will increase the size of the system.

Estimation of standard experiment size in the three years to come:

- *Sensitivity of the atmosphere alone* (20 hours per year on C90). Set of ten experiments over fifty years: 10,000 hours.
- *Sensitivity of coupled ocean-atmosphere system*. Low-resolution 2° global model (three hours per year on C90)
- Ten sensitivity experiments over 200 years: 46,000 hours.
- *Predictability study.* 2° ocean model with 4D assimilation + standard atmosphere. 20 one-year experiments over 32 years: 40,000 hours.
- *Ocean/ice sensitivity with average 0.5° resolution* (160 hours per year on C90). Ten 50-year experiments: 32,000 hours.
- *Coupled low-resolution system*. Integration over 1000 years: 5000 hours.

The estimation of the pressure of CLIVAR related projects for 2000 is equivalent to 500,000 hours (on C90). It is expected to reach four million hours around 2003. To face this extremely large pressure, omputer facilities have to upgrade their facilities and laboratory hardware requires upgrade too. Adequate archiving facilities have to support this effort.

These figures also put in light that the issues of CLIVAR are far beyond the possibilities of a single nation and international collaboration is the key issue for the success of CLIVAR..

REPORT FROM GEORGIA

at the International Conference on Climate Variability and Predictability

N. Beradze, I. Khomeriki, G. Kordzakhia

Mr Chairman
Prof. G.O.P. Obasi, Secretary-General of WMO
Dr. Federico Mayor, Director-General of UNESCO
Ladies and Gentlemen,

We are grateful to have the honour to participate in such a significant and representative forum.

Our delegation is from Georgia - the small country, but rather important one for the World Community, that is determined by it geopolitical location. Georgia is situated in the Transcaucasus. Georgia is bordered by Russia in the North, by the Black Sea in the West, by Turkey and Armenia in the South, and by Azerbaijan in the East.

The most important projects for the world of the late XX century and early XXI century are being implemented on the region's and adjacent to it territories: Construction of the oil pipelines from Caspian States to Europe and so called "TRACECA" - the Transport Corridor Europe - Caucasus - Asia, which comprises highways, railways and marine main lines. "TRACECA" must connect in the shortest way the Asian countries with Europe.

Once more we want to underline the great importance of these partially exploited and mainly constructing main lines for the World Community, both in a view of political and economic aspects.

The meteorologists and hydrologists who present here, and not only the, know the necessity of the climate provision of these large-scale constructions, and when nowadays there occurred the increased rate of the climate variability on the background of current climate change, it obtains more and more importance.

On the other hand we want to pay your attention to the unique climate conditions of our region and particularly to those of Georgia. From 14 climate zones, which is distributed on the earth, 11 are met in Georgia, beginning from the Caucasus glaciers and ending with the subtropics of the Black Sea Coastal Zone. Flora and fauna of our country are also rich.

Keeping this perfectness and originality is our paramount problem. The solving of this problem is very difficult for Georgia as it's the country with economy in transition and it has financially shortages.

Mr Chairman
Ladies and Gentlemen

We want to note, that our Government and personally the President of our country, his excellency, Mr Edward Shevardnadze, clearly realise the scales of the possible changes of the climate system and their impact on the economy of our country. There is the President's special order "About approval of the National Climate Research Program, the Governmental Commission on Climate Change Problems, its Statement and Working Plan".

The Governmental Commission of Climate Research Program includes leaders from interested ministries and departments, also famous scientists and experts. Today Mr Nikoloz Beradze - the Deputy Chairman of Governmental Commission, the Deputy Minister of Environment of Georgia is leading our delegation.

In spite of current financial shortages of Georgia, assignations have been released (from 1996 - 2000) to implement the National Climate Research Program. The National regional Climate Research Centre, which was established especially for this case, is engaged in these problems.

With the efforts of Georgian hydrometeorologists the climate variability of our country has been studied based on the analyses of 150 years climatological data.

Variability of hydrometeorological parameters, which are determining the process of climate change are identified.

The informational bulletin of the National Climate Research Centre is issued for better information of the executive and legislative authority, population, which includes the results of conducted researches. Seven of them are already issued. Beginning from N4 these bulletins are being issued in English language too.

Mr Chairman
Ladies and Gentlemen,

Once more we want to note, that Georgia clearly realizes the worldwide importance of the "CLIVAR" program.

At the same time we want to make some remarks about this program, which in reality has the form of wishes:

1. To our mind it is very important for "CLIVAR" documents to be carried out on every main language of UN, because it is very labour-intensive for small countries to translate these documents on acceptable language for them, and on the other hand it is connected with great expense.

2. To our mind Georgia and other states of Transcaucasus (Armenia and Azerbaijan) can not develop the climate predictability due to lack of means of material-technical base, methodologies and financial resources.

That is why it would be desirable, that the developed countries would render the appropriate assistance.

In conclusion, we greet this International Conference once more and hope, that our country also will do his honourable bit in the implementation of the "CLIVAR" program.

Thank you for your attention.

THE GERMAN RESEARCH PROGRAMME FOR CLIVAR

1. Introduction

The research objectives of CLIVAR are of central interest for Germany. Climate variability is particularly strong over the North Atlantic and Europe, including pronounced circulation anomalies which can dominate the climate for longer periods of time. It will be a key objective of the German CLIVAR programme to better understand the mechanisms of decadal to centennial climate variability and predictability through the analysis of observations and the modelling of the coupled climate system. In studying the role of the ocean in determining time scales and variability patterns the German CLIVAR programme builds on the successful participation in WOCE and TOGA.

The modelling of anthropogenic climate change has been one of the main thrusts in the German climate programme. It is required to continue this work with an emphasis on the regional aspects including consideration of extreme events. Additional processes need to be considered including feedback, for instance with biogeochemical cycles such as the carbon cycle.

An important aspect of CLIVAR is the investigation of the longer time-scale processes within the climate system. This should be done with the help of palaeo data records at decadal to annual resolution to better understand the variability of present climate anomaly patterns. It is of special interest to obtain an understanding of the apparently abrupt events which have taken place in the past. Such events include drastic changes of the thermohaline circulation in the North Atlantic. Although abrupt events of this kind may be unlikely (but possible as a result of a higher concentration of greenhouse gases), the consequences for Europe would be severe, so it will be considered as an important part of the future German CLIVAR programme.

Below we summarize four possible themes of the German CLIVAR programme:

I. Decadal variability and predictability studies at middle and high latitudes with special emphasis on the North Atlantic Oscillation (NAO)
II. Tropical variability, prediction and consequences on the climate at middle and high latitudes
III. Anthropogenic climate change
IV. Abrupt climate change

2. German CLIVAR project areas

2.1 Decadal variability and predictability studies in mid- to high latitudes with special emphasis on the North Atlantic Oscillation, NAO

(1) Determination of the physics and dynamics of the decadal variability using observations and a hierarchy of models. In particular, a detailed analysis of historical observations is necessary, especially with respect to trends, cyclical variabilities, extremes and abrupt changes. The first objective is to understand the basic mechanisms which lead to the coherent evolution of the space-time structure of variations in the atmosphere in the range of several years to decades. The second aim is to relate these variabilities in mid-to high latitudes to changes in tropics like ENSO, Indian or African monsoon variations (G1, D1-D5).

(2) Determination of the interaction of atmospheric variability in the decadal range with oceanic processes. This research focus has two objectives: Firstly, to specify the oceanic response to interannual and decadal atmospheric variability in mid- to high latitudes, including the ocean's interaction with the atmosphere. And, secondly, to relate the decadal variability in mid to high latitudes to global oceanic key variability patterns like the tropical SST dipole or changes of the thermohaline circulation/meridional overturning cell (D1-D3, D5).

(3) Reconstruction of decadal to centennial variability patterns of about the last millennium and other

interesting and promising time windows from multiproxy and instrumental data.. The aim is to obtain decadal to centennial climate variability indices, like the NAO, and probably other large-scale features by a combination of various data sources at an annual time resolution (e.g. ice cores; marine: corals, sediments; terrestrial: tree rings, lake varves; historical data: fish catch, ice cover, ice edge locations, river floods, etc.). The reconstructed indices should include a measure of accuracy and should be regionally well distributed (D1, D3).

(4) Natural decadal variability, external forcings and anthropogenic influence on climatic changes - relevance for global and regional climate. An attempt will be made to determine the influence of increasing greenhouse gases and aerosol concentrations as well as land use impacts upon natural variability patterns in mid and high latitudes. Perturbations of the global and regional climates due to volcanic and solar activities will also be considered (D1, D3, A1, A2).

(5) Predictability studies on seasonal to interannual time scales. The aim is to estimate the degree of and the framework conditions for predictability of climate statistics on time scales of seasons, several years and even decades. Ensemble-type forecast studies are one tool for this approach while hindcast experiments utilizing the reconstructed and observed data provide a validation basis (D1, D5).

2.2 Tropical variability, prediction and consequences on the climate at middle and high latitudes

The general objective of this research area is to study the dynamics and the predictability of tropical climate anomalies on seasonal to interdecadal time scales and their role with respect to global climate variability. Specific research topics could be:

(1) Relation between climate anomalies, in particular precipitation over land, and surface boundary conditions. This includes the effects of ocean circulation variability and of changes in land surface parameters (G1, G2, G4, D2).

(2) Role of the tropical Indian and tropical Atlantic Oceans in global climate variability. This research objective requires the investigation of circulation anomalies in both tropical oceans, their interaction with extratropical marine circulation and their significance for the global circulation. The study includes the role of the Pacific to Indian Ocean throughflow variability for the Indian Ocean heat export (G1, D1, D2, D4).

(3) The importance of data assimilation for the quality of tropical predictions. Here the central objectives are the evaluation of the different data assimilation methods on prediction quality and studies on what types and distributions of assimilation data are most useful for prediction purposes (G1, D2).

(4) Interaction between intraseasonal and longer time scales. This research topic includes the effect of intraseasonal variability on ENSO, the cause of the interdecadal modulation of the occurrence and intensity of ENSO events, the role of the shallow tropical thermohaline cell in affecting longer-period tropical climate variability and the feedback mechanisms with climate-relevant processes on land (G1, D1, D2).

2.3 Anthropogenic Climate Change

Present studies of modelling climate response to anthropogenic influences have mainly been concentrated on global scales, while an in-depth understanding of the regional and local climate change requires a more comprehensive approach. A major objective is the development of more credible models able to realistically consider e.g. the natural climate oscillations and the way climate change may interact with and modify such oscillations. Other important areas are the integration of relevant atmospheric chemistry processes (sulphur and ozone-cycles) and feedback with the biosphere required for the incorporation of the carbon cycle. Model studies may have to be carried out as ensembles and as millennial simulations in order to separate the response to an external forcing from the internal climate variability. Principal research areas are identified below.

(1) Analysis of the processes which control the models' responses to different climate forcings.
Recent model intercomparisons show that major discrepancies exist in the way the models respond to climate forcing. In order to have a consistent picture of the climate variability as simulated by the models it is necessary to narrow down these inter-model differences (A1, A2).

(2) Consideration of additional forcing processes
Solar: The irradiance variation is strongly wavelength dependent, a circumstance, which has not yet been properly incorporated in models. Solar irradiance variations on decadal and centennial time scales are still an open issue and efforts to determine such variations through indirect and independent measurements are required.
Volcanic: Major volcanic eruptions associated with emission of sulphate aerosols in the stratosphere influence the climate for several years. A proper evaluation, including feedback with ozone requires better handling of dynamical, physical and chemical processes in the stratosphere.
*Land surfaces: l*and usage has led to changes in surface albedo as well as changes in the heat and water exchange between the atmosphere and the land surfaces. The possible long-term effect on climate needs to be better understood and quantified.
New greenhouse gases: new industrial gases are being added. Some of them have strong absorbing characteristics, they are increasing rapidly and they have a very long residence time in the atmosphere (A1, A2).

(3) Incorporation of biogeochemical processes (carbon cycle). Several model intercomparisons projects related to carbon including atmospheric transport models, ocean carbon models, terrestrial net primary productivity and terrestrial biogeochemical models, have implicitly/explicitly assumed an unchanged circulation, no feedback to a changing climate and no disturbances by changes in the biosphere (soils included). In view of potential feedback with land surface usage, changes in temperature and precipitation and changes in ocean stratification and circulation it is expected that the carbon cycle may change in a future climate and thus modify the atmospheric concentration of carbon dioxide (A1, D3).

(4) Detection and attribution. The main objectives are to improve the techniques and the models to detect the anthropogenic climate change in more detail, to separate it from the natural variability and to attribute the observed variability and change to natural/anthropogenic causes. The work should include

- the analysis of a variety of parameters including proxy-data
- looking into the possibility of combining quantities into a climate change index
- the development of more sensitive techniques for the signal-to-noise analysis, this includes the application of multiple (variety of forcing mechanisms) and multivariate (variety of climate elements) statistical analysis techniques to reproduce observed climate variability - this strategy enables a cross-validation of model results
- the realization of long numerical experiments with and without external/natural/anthropogenic forcings to be able to identify the long-term internal variability of the climate system and the signatures of the forcings in the climate, special emphasis will be put on persistent historic climate events like the Maunder-Minimum or the medieval climate optimum (A2).

2.4 Abrupt Climate Change

A better understanding of the nonlinear processes leading to abrupt climate change should be one of the goals of German CLIVAR research. It should encompass the following key research areas:

(1) Instability of oceanic convection and large-scale circulation. Instabilities of the thermohaline ocean circulation (THC) have been identified as a possible source of *climatic surprises* in the future. The main objective is a better and more quantitative understanding of the various feedback involved in the instability process, the evolution of the THC in global warming scenarios and the determination of a possible threshold for a shutdown of North Atlantic Deep Water formation (D3, A1).

(2) Biosphere-climate feedback. Modelling of biosphere-climate interaction is still in its infancy. Preliminary results suggest that land vegetation and soils may have a strong positive feedback on climate via

changes in the surface albedo, most of all in boreal and cool-temperate regions of the Earth, namely the northern high latitudes near the taiga/tundra boundary (snow-albedo feedback) and North Africa (albedo-monsoon feedback) leading to more than one equilibrium climate state in these regions. Greenhouse gas simulations suggest that future warming may be considerably amplified in certain regions through a similar mechanism if vegetation and soil feedback is taken into account. Other fast-acting yet badly understood processes are changes in the water budgets of large regions caused by man-made changes in vegetation and soils (A1).

3. Implementation

In line with Germany's federal structure, responsibility for research activities in the various structures lies with different funding agencies. While the Länder are responsible above all for research at universities, the Federal Government focuses on the funding of national research centres and other institutions and on support for science organizations (such as the Deutsche Forschungsgemeinschaft DFG and the Max Planck Society MPG).

Present funding by BMBF (Federal Ministry of Education and Research) is given within the national programmes *CLIVAR marine* and *Applied climate and atmospheric research* (which is focused among other things on the predictability of climate variations in Northern Europe). Furthermore, some Helmholtz-Institutes supported mainly by BMBF investigate *Natural climate variations during the last 10000 years*. BMVBW (Federal Ministry of Transport, Building and Housing) is responsible for the funding of various observation systems via the German Meteorological Service (DWD), the Federal Institute for Navigation and Hydrography (BSH) and the Federal Institute for Water Science (BfG). Because of the need for close cooperation between CLIVAR and GCOS and specifically GOOS, the national contributions to these observing systems will play an important role also in future.

DFG supports several CLIVAR-relevant projects, particularly through two special research projects (Sonderforschungsbereiche): one project is focused on the warm-to-cold water conversion in the subpolar North Atlantic, on its variability and related deep circulation and THC variation (Kiel); the other project deals with the NAO dynamics and atmosphere-ocean-ice interactions in the Nordic Seas as its central objectives (Hamburg). These are funding mechanisms which can continue for about a decade and thus provide the necessary long-term support for successfully pursuing CLIVAR objectives in Germany. Additionally, the project *Global change in the last 15000 years* (Schwerpunktprogramm) is being funded.

A new integrated national CLIVAR-programme is now in preparation with some components scheduled to begin in 1999, others in 2000. Further implementation details will be worked out in the next several months.

CONTRIBUTION OF GREECE TO THE CLIVAR PROJECT

Hellenic Republic - Ministry of Development
General Secretariat for Research and Technology
National Centre for Marine Research
Aghios Kosmas Gr-166 04 Hellenikon - Athens — Greece

The understanding of physical processes responsible for climate variability and the improvement of its predictability should be among the main priorities of research for the next century. Due to its complexity, the problem requires allocation of increased human/economic resources and calls for broad interdisciplinary and multinational cooperation. It is therefore necessary to build the international collaboration between scientists that CLIVAR is now trying to establish. Greece is going to contribute to this effort through national and EU supported / coordinated research projects.

From the preliminary contacts with relevant scientific groups, the following areas have been identified as possible contribution of Greece to the CLIVAR project:

- contribution to the Global Sustained Observations of CLIVAR
- contribution to Climatic Change Detection
- contribution to development of coupled ocean-atmosphere models

A more detailed description of the above tasks that could form the contribution of Greece to the CLIVAR project is given below.

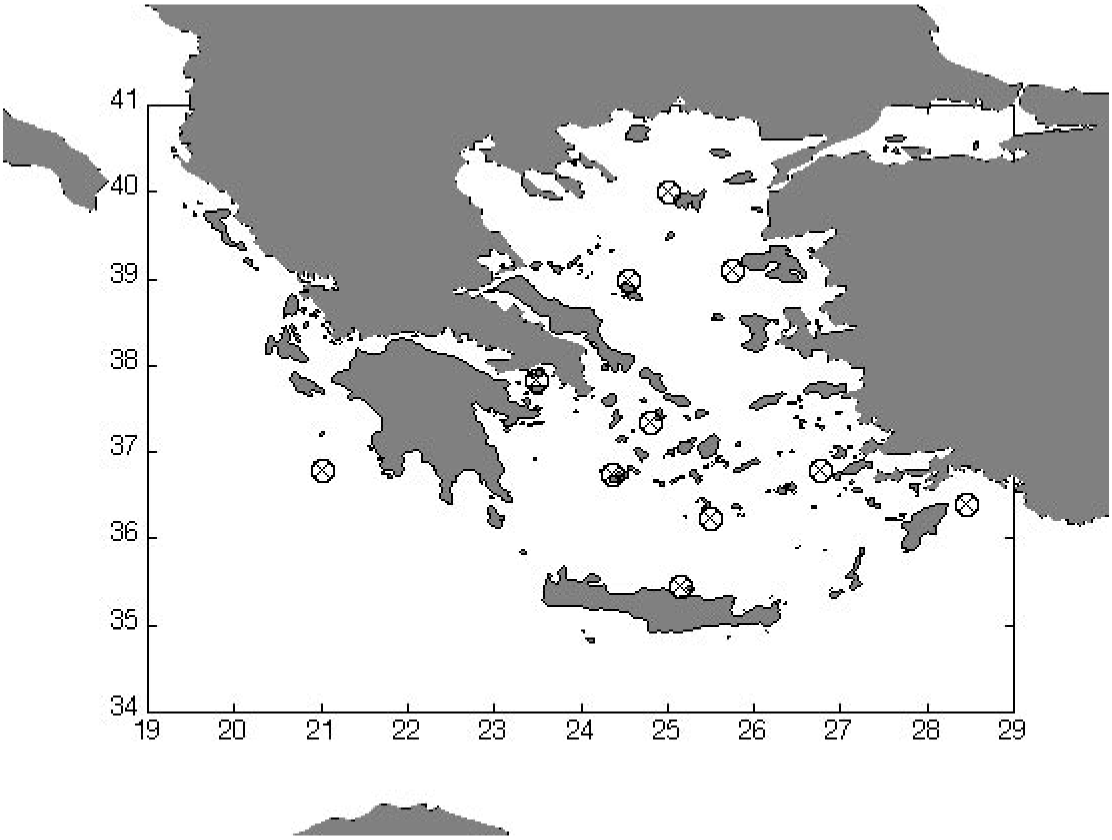
A. Contribution to Global Sustained Observations

During the last years, Greece has been actively participating in the GOOS effort through its European component (EuroGOOS). For Greece, GOOS is implemented mainly through the following two major research efforts: a) the national research project “POSEIDON” and b) the international research project Mediterranean Forecasting System “MFS”. Both programs aim to develop and implement real-time ocean forecasting systems on different spatial and time scales. The observational components of those projects produce upper-ocean and sea surface meteorological data that could contribute to the CLIVAR observational system.

The “POSEIDON” project is installing a network of 11 open sea buoys in the northeastern Mediterranean (Aegean Sea). The buoys monitor and transmit in real time near-surface (0-50m) physical (temperature, salinity, currents) and biochemical ocean parameters (oxygen, chlorophyll, nutrients) as well as surface meteorological parameters (wind, air-temperature, atmospheric pressure). At this phase the buoy network is designed for operational forecasting in short time scales. A planned upgrade of some buoys with sensors for deeper measurements (0-500m) will enhance the capability of the system for longer time scale forecasts.

The observational components of MFS (European Union funded project with multinational representation) include upper ocean temperature data (XBT) from VOS, continuous multi-parameter ocean & meteorological data from fixed stations (buoys) and remote sensing data (SST, SSH, ocean colour). In the present Pilot Phase of MFS a multi-parameter measuring system (called M3A) similar to TAO-TRITON system is being designed and implemented. The system will provide real time data for the upper 500m of the ocean (temperature, salinity currents and biochemical parameters) as well as for the air-sea interface (wind, air-temperature, humidity, solar-radiation, and atm. pressure). In the next phase of MFS, a network that will cover the whole Mediterranean Sea will be implemented. Both projects are expected to contribute to a permanent observation system of the Mediterranean Sea that will serve the purposes of GOOS and CLIVAR projects.

Figure 1 POSEIDON buoy network



B. Contribution to Climatic Change Detection

The deep waters of the ocean have a long memory of atmospheric changes and their study can be of significant interest to the climatic studies of CLIVAR. Regional seas, such as the Mediterranean, that are easily accessible and data-rich can be areas for useful case studies such as the response of the ocean to atmospheric variability at different time scales.

Recent compilation and reanalysis of available oceanographic data in the Mediterranean Sea have revealed the presence of important increasing trends of temperature and salinity in the deep waters of the basin. Those trends have been attributed to global warming (greenhouse effect) and to man-induced reduction of river runoff in the basin.

In the same time, significant changes have been observed in the thermohaline circulation of the Eastern Mediterranean during the last decade. Similar to the world-ocean, one main and two secondary thermohaline cells, driven by deep convection in selected areas compose the thermohaline circulation of the Mediterranean. Hydrological data since the existence of observations in the basin, indicate that the system was steady, at least during this century. Recent observations show that during the last decade a new area of deep convection has appeared, changing considerably the properties of deep waters in the eastern basin. The event was related to an extended dry period (reduced precipitation) for the whole eastern Mediterranean and to the exceptionally cold winters of 1992-93. The connection to larger scale anomalies such as the NAO index variability is currently under study. Greece intends to continue the research on this field with both observational programs and numerical studies that are expected to contribute to the CLIVAR objectives.

C. Coupled ocean-atmosphere numerical models

Coupling between oceanic and atmospheric models is a research field that is expected to be active in the next years. The relevant research in Greece is mainly focused upon coupling of ocean and atmosphere Limited Area Models such as models of the Mediterranean and the Aegean. In atmospheric models, this allows downscaling of global prediction to fine resolutions that are able to reproduce local meteorological phenomena.

The expected availability of atmospheric measurements over the sea through buoy networks will provide a basis for better understanding and more successful parameterization of air-sea interaction physics. The research in this field will improve the predictability in both domains and will allow the development of coupled models. The results are expected to contribute to the research on global atmosphere-ocean coupled models, which is one of the main priorities of CLIVAR.

The above research tasks are foreseen as possible contribution of Greece to the CLIVAR Project. Modifications and enrichment of those priorities should be expected during the long implementation phase of the project. Greece is willing to participate and promote new research efforts that will arise through the coming EU Framework-V and will foster the collaboration for CLIVAR on a European level.

NATIONAL REPORT ON CLIVAR FROM INDIA

1. Introduction:

A major component of World Climate Programme (WCP) is World Climate Research Programme (WCRP). In 1985 WCRP initiated the 10 year Tropical Ocean Global Atmosphere (TOGA) programme to study interannual variability driven by tropical ocean atmosphere system. Another WCRP programme World Ocean Circulation Experiment (WOCE) was launched to study the circulation of global ocean and its impact on global climate system. The observational phase of WOCE started in 1990. The Joint Scientific Committee of WCRP at its 14th session (March 1993) formally decided to undertake the Climate Variability and Predictability (CLIVAR) as a major new activity within WCRP, which would exploit the scientific results of TOGA and further develop ocean circulation variability research envisaged by WOCE.

CLIVAR programme is organised into 3 components :
A) CLIVAR-GOALS: A study of seasonal-to-interannual climate variability and predictability of the global ocean-atmosphere-land system;
B) CLIVAR-DecCen: A study of decadal-to-centennial climate variability and predictability;
C) CLIVAR-ACC: Modelling and detection of anthropogenic climate change.

India welcomes and supports the initiatives which have been taken in developing the CLIVAR research programme. CLIVAR will undoubtedly play an important role for climate research in years to come. In India so far CLIVAR research were taken up as a part of Indian Climate Research Programme (ICRP). The monsoons have naturally been a major focus of climate research in India.

2. Indian Climate Research Programme (ICRP)

The objectives of ICRP are:
I. Understanding the physical processes responsible for variability on subseasonal, seasonal, interannual and decadal time scales of the monsoon, the oceans (specifically the Indian Seas and the equatorial Indian
II. Ocean) and the coupled atmosphere-ocean-land system.
III. Study of the space-time variation of the monsoons from subseasonal, interannual to decadal scales for assessing the feasibility for climate prediction and development of methods for prediction.
IV. Study of change in climate and its variability (on centennial and longer time scales) generated by natural and anthropogenic factors.
V. Investigation of the links between climate variability and critical resources such as agricultural productivity to provide a basis for deriving agricultural strategies for maximising the sustainable yield in the phase of climate variability and for realistic assessment of impact of climate change. Thus the Indian Climate Research Programme could contribute to the CLIVAR programme and in turn derive benefit from it.

3. Participating Institutions:

The following are the major participating organisations/departments/institutes which are interested in the areas of research related to CLIVAR.
1) India Meteorological Department
2) Indian Institute of Tropical Meteorology, Pune;
3) National Centre for Medium Range Weather Forecasting (NCMRWF), New Delhi;
4) Indian Institute of Science (IISc), Bangalore;
5) Centre for Mathematical Modelling and Computer Simulation (CMMACS) of CSIR, Bangalore;
6) National Institute of Oceanography (NIO), Goa;
7) National Physical and Oceanographic Laboratory (NPOL), Cochin, Space Application Centre (SAC), Ahmedabad; Indian Institute of Technology (IIT), New Delhi.
8) Department of Science and Technology.
9) Department of Ocean Development.
10) Indian Council of Agricultural Research.

4. Existing facilities and ongoing activities:

4.1 Observational network

A large number of observatories (557 surface, 35 RS/RW, 65 PB, 199 Agromet, 45 radiation, 5000 rainfall stations, etc.) spread over the country have been collecting meteorological data during the last many years. Some of these data are even 120 years old. Special scientific expeditions sent to Antarctica have taken systematic meteorological observations including vertical ozone profiling from the Indian stations. Satellite based observation and derived data are also available from INSAT. BAPMoN observations are also recorded and archived. Marine meteorological data and data from special oceanographic cruise are also archived.

The climate data are being processed and quality controlled, efficiently archived and finally utilised in research and by other users interests.

National Institute of Oceanography (NIO), Goa is having long term observational programme in Indian seas. XBT observations are being carried out along 3 shipping routes viz., Madras-Port Blair-Calcutta, Bombay-Mauritius and Vishakhapatnam-Singapore.

The observational programmes like Bay of Bengal Monsoon Field Experiment (BOBMEX), Arabian Sea Monsoon Experiment (ARMEX). BOBMEX will be carried out in north Bay of Bengal during July-August 1999. Then during July-August 2000, offshore trough system and embedded mesoscale convection and their interaction with warm pool in the Arabian Sea will be studied.

The Indian contribution to International Experiment (INDOEX) involves multi-agency efforts with Department of Ocean Development for providing ships to NIO and other institutes participating in observational programme. DOD has an ongoing programme on ocean observation systems to continuously monitor meteorological and oceanographic parameters from drifting and moored buoys.

In addition to stationary ship polygon, XBT observations will be carried out in the region.

4.2 National Climate Centre

The National Climate Centre (NCC) of I.M.D. at Pune has been recently started. The objectives of the centre are :

I Climate Monitoring
II Climatological Services,
III Climate Diagnostic and Research.

The unit brings out monthly and seasonal 'Climate Diagnostics Bulletin of India', and other publications related to extreme climatic events and special climatological reports.

4.3 Institutes participating in studies on climate modelling

The Climate and Global Modelling Division (CGMD) was set up in Indian Institute of Tropical Meteorology (IITM) in January 1995 to study variability of climate using Atmospheric General Circulation Model (AGCM). Atmospheric models are being used by various institutes (IIT Delhi, IISc, IITM, SAC) in the country to simulate the observed seasonal monsoon better and to make seasonal monsoon prediction. Ocean models are also being developed to simulate the SST in Indian Ocean (IISc, CMMACS, IIT, Delhi).

4.4 On going Research Projects

Following are some of the important ongoing research projects :

- Climate change and climate trends on regional scale.
- Studies of interannual variability of the summer monsoon and its teleconnections, global atmospheric/ oceanic phenomena such as ENSO, QBO and other anomalies of the global general circulation.
- Intraseasonal oscillations of the tropical atmosphere, its interannual variation and its

- relation to monsoon.
- Refining the Long Range Forecast Models viz., Multiple Regression (MR), Power Regression (PR) and Dynamic Stochastic Transfer (DST) for improving their accuracy.
- Studies on variability of chemical composition of precipitation and atmospheric turbidity.
- Variability of atmospheric ozone and its impact on Indian climate.
- Impact of cloud radiation interaction on climate.
- Interannual variability of the simulated monsoon based on 15-year, 9 ensemble seasonal integrations.
- Development of a coupled ocean-atmosphere General Circulation Model for monsoonal climate studies.

5. Results relevant to CLIVAR :

Some of the results of research efforts having a direct bearing to CLIVAR are listed below:

- A small warming trend in temperatures of the order of 0.35°C during the last 100 years was observed throughout the country, some rising and falling trends of temperature were observed in various pockets over India. Warming over India was found to be mainly due to increase in the maximum temperatures. However, significant increasing trend in minimum temperature was found over urban stations.
- All India rainfall does not show any trend. A significant decreasing trend in the area affected by drought over India was noticed.
- The pH of rainwater from Allahabad, Pune and Visakhapatnam was found to be acidic. Increase in turbidity was found over almost all BAPMon stations.
- During years of low seasonal monsoon rainfall, the Southern Hemispheric Equatorial Trough (SHET) remains active for longer period during (JJAS) as compared to good monsoon years.
- The impact of El-Niño (La Niña) on the AISMR is more severe during the below normal (above normal) epochs of all India rainfall.
- The area average summer monsoon rainfall of India is significantly less in EW events in comparison to those in E events of El-Niño. The subdivisional rainfall of northwest and central India are also significantly lower in EW events than that in E events. E events relate to warming confined to an Equatorial eastern pacific and EW events related to warming over extended area of eastern equatorial Pacific. ENSO years were generally found to be associated with enhanced northeast monsoon precipitation.
- During the warm phase of the interdecadal oscillation, El-Niño events are expected to be strongly related to monsoon droughts. On the other hand, during the cold eastern Pacific phase of the interdecadal SST Oscillation, La-Niña events are more likely to be strongly related to monsoon floods.
- It was found that during good (poor) monsoon years temperature gradient in January over Eurasian land mass from subtropics to higher latitudes was directed equatorwards (polewards) indicating strong (weak) zonal flow.
- Simulation of Indian monsoon climatology using atmospheric general circulation model at various horizontal resolution show that the results are very sensitive to horizontal resolution. Performance of different models have been intercompared and sensitivities to SST, land surface conditions and internal variability etc., have also been studied at some centre.
- Maximum number of cyclonic storms occurred in the decade 1921-30 and minimum occurred during 1981-90 over Indian seas. Maximum number of cyclonic disturbances occurred during the 1941-50, the decade of least ENSO episode. A significant decreasing trend at 99% level of confidence in the frequency of the cyclonic storms was found over both the Bay of Bengal and the Arabian sea.
- Hybrid principal component neural network model for long range forecast of Indian Summer Monsoon Rainfall have shown good skill.
- Conical Correlation Analyses (CCA) for long range forecasts of subdivisional monsoon rainfall over India show good skill for some subdivisions.
- The studies carried on paleo climate using dendroclimatic reconstruction over the past 2 to 3 centuries has been done for the Western Himalaya, using an extensive collection of conifer tree ring samples. The climate during this period does not indicate any anomalous climate epochs in Himalayan climate. The

research is being carried out in IITM.

- Studies using remote sensed data were made by Meteorology and Oceanography group of Space Application Centre, Ahmedabad. Some of these are:
- It was found that the impact of increased soil moisture in the climate model improved the rainfall over India significantly.
- NCAR Community Climate Model - 1 has been used to assess the impact on Indian Monsoon due to surface albedo changes over the southeast Asian Region. In the one experiment carried out surface albedo was increased by 50% over India. This resulted in a decrease in rainfall by 0.98 mm/day on an average over India as a whole.

6. Future plan :

Climate and Global Modelling Division (CGMD), IITM, Pune, plans to carry out research in climate modelling, which will complement the work at NCC at IMD, Pune office.

Studies on variability of oceanic parameters and development of ocean model are planned by National Institute of Oceanography (NIO), Goa and National Physical Oceanography Laboratory (NPOL), Cochin.

To summarise the main thrust areas of research relating to CLIVAR are:

- The variability and predictability of seasonal climate in longer period scale using GCM.
- The non-linear dynamics of complex atmospheric systems and its application to predictability of different meteorological parameters.
- The association of monsoon variability with ENSO and Indian Ocean parameters.
- Monitoring of important Green House Gases (GHGs) like ozone, carbon dioxide, Methane, etc.
- Dendroclimatic studies using tropical tree rings for reconstructing the past monsoon behaviour.
- Study of ocean surface processes.
- Study of the variability of upper ocean thermal structure in the north Indian Ocean.
- Studies of air-sea interaction processes over the tropical Indian ocean in relation to summer monsoon.
- The study of ocean surface current in Bay of Bengal using GEOSAT altimeter data.
- Development of a conceptual model to assess effect of climatic variations on distribution of Himalayan Glacier.

India would like to cooperate in the CLIVAR research initiative through its efforts to continue and upgrade if possible its network observations in the ocean and atmosphere.

The initiative to pursue the major areas of research outlined above will be continued in the coming years.

NATIONAL STATEMENT OF REPUBLIC OF INDONESIA

Indroyono Soesilo and Tien Sribimawati

1 Background

The Republic of Indonesia is the world's largest archipelagic country with 17,508 islands stretching 5,100 kilometer from West to East, in the equator. It is also known as the only world's maritime continent right at the equator. With a population of 210 millions people, Indonesia is the world's fourth most populous nation on earth. Geologically, three plate tectonics collide in the Indonesian region. Those are the Eurasian Plate, the Indo-Australian Plate and the Pacific Plate. These are the reasons of many volcanoes, 129 are actives, and the country is also the place of earthquake occurrences.

Considering its unique feature, the Indonesian region is also known as the *"heat engine"* of global atmospheric circulations. Its complex physiography and its abundant of energy sources result in a complex ocean-atmospheric dynamics that are very active to form tall cumulus as a transporting mechanism of small constituents to other places of the globe.

Therefore, understanding internal ocean atmosphere dynamics is important in order to understand global climate system as it has been expressed by the international scientific community to deal research and observation within the region.

Furthermore, the influence of the El Nino, La Nina, the Australian Monsoon and the Asian Monsoon contribute to the unique climate conditions in this region. This area is becoming an important place for the global climatological change research activities.

Understanding internal ocean-atmosphere dynamics is not only the interest of international scientific community, but also the interest of national community in order to improve seasonal to interannual climate prediction. Asian-Australian monsoon region is a key to understand climate variability and prediction. The region is highly populated, where information climate fluctuations have important in implication for economiy and society. Being within Asian-Australian monsoon region, Indonesia is willing to cooperate and taking advantage from the outcome of the international scientific community effort to understand climate variability and predictability converging national-international effort is proposed. BPPT in cooperation with national research institutes and universities establish scientific networks to converge climate related research and observations activities and to prepare for the International scientific work. The purpose of this report is to provide Indonesian activities related to climate research and observations, and future direction of the activities.

2 CLIVAR Related Observations

As CLIVAR focused on the role of the coupled ocean and atmosphere, and ocean-atmosphere interaction is important to understand climate system within the Maritime-Continent Indonesia, Climate Variability program of BPPT is inventing ocean-atmosphere observations climate related and data within the surrounding Climate System. BPPT is thriving networking climate related activities both at national and international level.

On November 10, 1997, in Jakarta, on the opening address of the International Conference on Science and Technology for the Assessment of Global Environmental Change and its Impact on the Maritime Continent of Indonesia, the President of The Republic of Indonesia stated, among other, that: " Well aware of the importance of Indonesia's territory in understanding global climate, we are pleased to open ourselves and offer the uniqueness of our territory, weather at sea, on land and in the atmosphere for scientific studies on climate, weather and the environment".

The President's statement received very positive response from the Conference participants coming from the USA, Germany, France, Australia, Japan, Israel, Belgium, The Netherlands, Canada, Taiwan, Norway, The Philippines and scientists from the host country, Indonesia. The Conference participants also declared a FORUM STATEMENT which recommend Indonesia to promote the establishment of an International research center to serve the countries within the region. This center, named The Indonesian Research Institute for Climate, Environment and Society (INRICES), will conduct various researches related to climate prediction, crop estimation, disaster mitigation and their impacts to the environment and society. INRICES, and its scientists, will link up to the International bodies and individuals from all over the world.

It is very encouraging to witness the International positive responses on Indonesia's readiness to work together on the CLIVAR Program as it had been expressed in the *Report of the Asian-Australian Monsoon Panel Meeting,* in Kyongju City, S.Korea last April, 1998.

Atmosphere observations facilities have been established within the Indonesian region through the international cooperation. The four atmospheric radar facilities located in Koto Tabang-West Sumatera, Serpong, West Java; Pontianak, Kalimantan; and Biak, Irian Jaya is used by the scientific community to study the atmospheric dynamics above Indonesian region. Seawatch Indonesia will installed 11 (eleven) buoys across Indonesian ocean. Along with other research facilities, such as moored buoys, tidal gauge, and Baruna Jaya research vessels, ocean-atmosphere data within the maritime continent region will be developed. Ocean-atmosphere networks is on Figure 1.

3 CLIVAR Related Research

It is obvious that the *ENSO* phenomena, as it was experienced in the 97 *ENSO*, has an influence on Indonesian rainfall quantity. The impact has a serious economy and societal implications. The environmental cost of the impact is widespread across national boundary with the trans boundary haze. It also has a long life impact as it destroyed existing tropical forest within the region, and it produce small constituents in the atmosphere that might change the atmospheric energy balance. Since the impact is across national boundary, and it must contribute to the long-term climate condition, international effort is urgently required, and Indonesia is open for international cooperative work to observe the maritime-continent region to understand climate phenomena. To anticipate the overcoming *ENSO* event, Indonesia has developed Climate Variability Program, focusing on seasonal to interannual climate variability. The program has also been communicate with other climate related research activities through publication, workshop, and conference, involving universities at national and international levels.

3.1 The Indonesian Climate Variability Program (CLIVAR)

The initial CLIVAR program in Indonesia was started in 1992, and was conducted in cooperation between BPPT and The Japan Marine Science & Technology Center (JAMSTEC). Within the ARLINDO, TOGA-CORE and TOCS Programs, various measurements of ocean conductivity, currents and temperatures were being implemented in the Pacific oceans North of Irian Jaya, Indonesia. In relation to the expansion of CLIVAR program in Indonesia, negotiations between BPPT-Indonesia, JAMSTEC-Japan and LDEO-USA are currently underway for the deployment of Buoys in Banda Sea and in the Halmahera Sea.

The objective of Program on *Climate Variability in Indonesia* is to understand physical and dynamical processes relevant to seasonal to interannual climate prediction in Indonesia. The component of the study consists of observations, database development, analyses, and modelling. Strategy for implementing observations is through collaborative work with national meteorology service and international research infrastructure. Climate data sets are developed with geography reference modelling study starts with statistical modelling using in-situ data. Through collaborative work with Max Planck Institute for meteorology ECHAM climate model will be integrate with local data to establish systematic errors, and to be used in developing predictive model.

3.2 The ARLINDO Program:

The Indonesian throughflow study as a joint effort between BPPT-Indonesia and LDEO-Columbia University started in 1990 has been a major program to understand the connecting water between Pacific and Indian Oceans. Recent results of the program indicate that there are a close link between *ENSO* phenomena, and the water mass flows through Indonesian water. The warm water shifts during *ENSO-La Nina* phenomena is associated with atmospheric dynamics result in convective activities above it. Both modelling result (Schneider, 1998) and observations (Gordon, A.L. et.al., 1998) agreed to it.

Similar studies in cooperation with Scripps Institute of Oceanography, San Diego-USA, University of Washington, Université Pierre et Marie Curie, France and CSIRO-Hobart, Australia is on going and they are being aimed toward unraveling the scientific phenomena of the ocean-through flows on the Strait of Makassar, the Strait of Lombok and the Banda Sea. The ARLINDO Phase II and Phase III are currently underway. The ARLINDO US-Indonesian team will explore in more detail the influence of ENSO-monsoon phenomena on the water mass transport. For this purpose, long-term monitoring activities that are very useful to understand climate related phenomena is considered.

3.3 The Marine Geology & Geophysical Program:

Considering the tectonic conditions of land-ocean of Indonesia, International geological and geophysical research activities in the Indonesian seas are very active. The past and present marine geological research, include:

- Paleo-climatological studies of the Arafura Sea, Between Irian and Australia. This study was coordinated by BPPT and US Geological Survey.
- Geological and Geophysical Studies of Sunda Strait. This study was coordinated by BPPT and The French Research Institute.
- Geological and Geophysical Studies of the Sulawesi Sea. This study was coordinated by BPPT and BMG-Germany.
- Geology and Geophysical Studies of Banda Sea. This study was coordinated by BPPT and the French Research Institute.
- Geophysical Studies of Java Trench. This study will start on November 1998, and will be coordinated by BPPT and BMR-Germany. The SONNE research vessel from Germany will conduct the Expedition.

4 CLIVAR Related Facilities

Indonesia's readiness to participate in the Global Change Program are also exemplified by the provisions of various global change research facilities, such as:

1 The availability of six Baruna Jaya Class very modern research vessels dedicated for marine global change research activities,
2 The availability of six NOAA satellite groundstations and a SPOT, LANDSAT ERS-1, JERS-1 remote sensing satellite groundstation in Parepare, South Sulawesi for remote sensing satellite data facilities.
3 The establishment of three Boundary Layer Radar facilities in Biak-Irian Jaya, Serpong-West Java, and Koto Tabang-West Sumatera for climate research.
4 The establishment of Global Atmospheric Watch Station in Koto Tabang - West Sumatera.
5 The establishment of 112 meteorological stations, 16 climatological stations, 94 agricultural monitoring stations, 5038 rain gauge stations and 173 humidity measurement stations for weather and climate modeling.
6 The availability of land, coastal and marine data for further scientific researches.

5 CLIVAR Related Human Resources

Meanwhile, the Indonesian scientists involve in atmospheric dynamic researches, ocean research and in land-use land-cover change studies are very active working with their International counterparts.

During the Celebration of the United Nations International Year of The Ocean 1998, in Manado Bay, North Sulawesi, on September 26, 1998, the President of the Republic of Indonesia signed an OCEAN CHARTER 1998 and reiterate Indonesia's commitment, among other:

- The Goal To Protect the Ocean Environment Is To be Pursued both National and Internationally.
- Indonesia and other countries should work together to achieve common goals for the oceans.
- Indonesia and other Ocean States should make use of International and intergovernmental organizations to generate global programs and agreements.

The above mentioned programs, commitments and facilities offered by Indonesia should be responded by its International counterparts to work together in order to strengthened the common objectives on implementing the Global Change Program.

6 Proposed CLIVAR related activities in Indonesia:

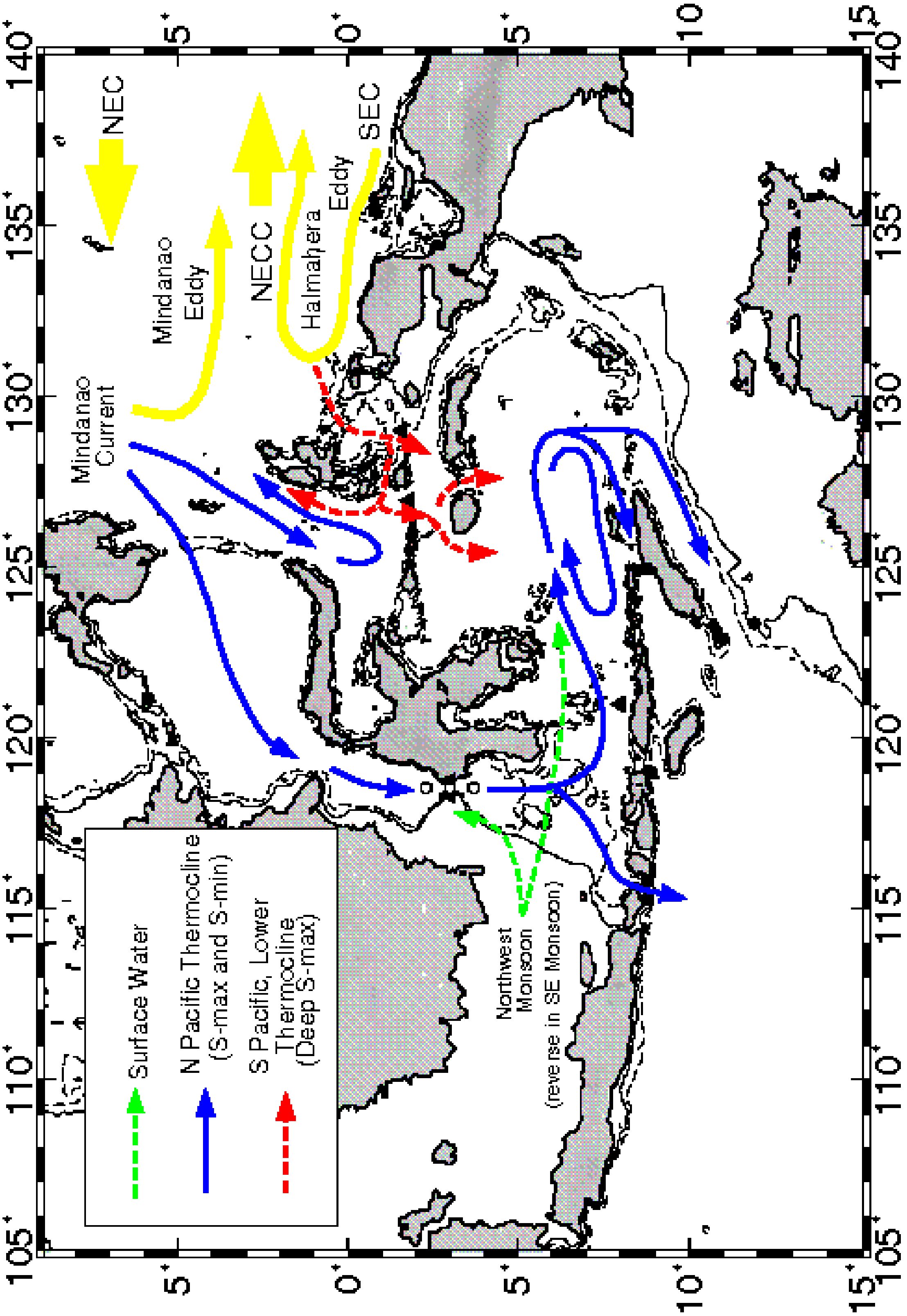
Results coming from the past and present climate related activities, Indonesia open new avenues for further research activities and Conferences in Indonesia under IGBP auspices in the coming years. Various proposed program activities for IGFA considerations are:
Climate Modeling of the Indonesian Regions:

6.1 Preliminary results and conclusions coming from the ARLINDO, CLIVAR and GRNS programs showed that the climatic conditions of the Indonesian region affect the regional climates. The climatic variabilities in this region are the results of ENSO, Asian Monsoon and Australian Monsoon. An Indonesian Monsoon concept is being proposed to be assessed. This activity will also geared toward supporting the establishment of Indonesian Research Institute for Climate, Environment and Society (INRICES) mentioned earlier.

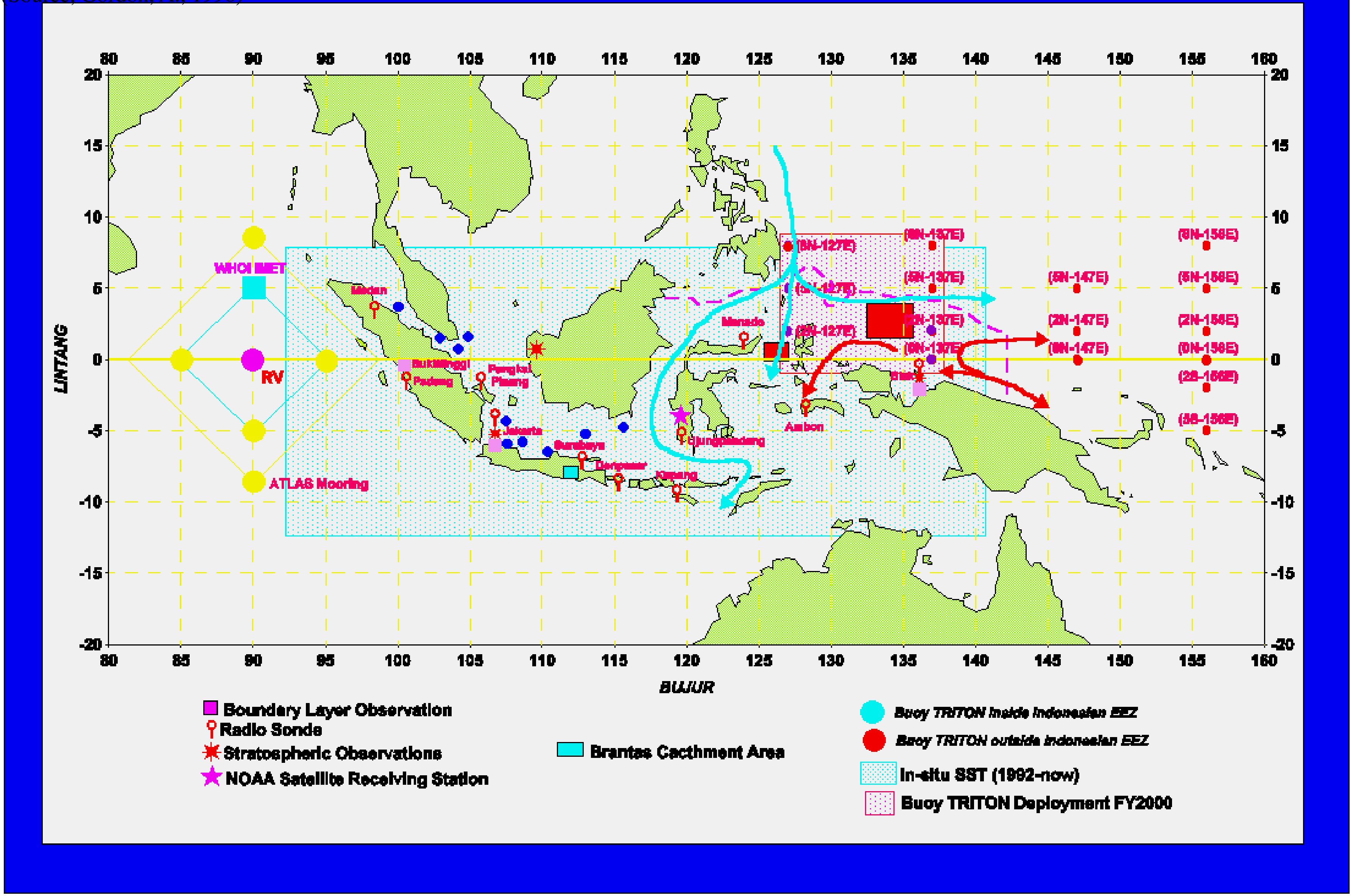
6.2 Land-Sea-Air Interaction of The Indonesian Region (ILUDWINA):
The Land-Sea-Air Interaction coming from an archipelagic nations, like Indonesia, produced scientific phenomena related to wind patterns, ocean current directions, coastal plain configurations, island topographic configurations and inter-island ocean characteristics. The ILUDWINA program will implement various earth observation satellite data, such as: ERS-1, ERS-2, JERS-1, JERS-2, MOS, Landsat, SPOT, RADARSAT, Topex-Poseidon, ADEOS, NOAA, for sea-air-land interaction studies. This ILUWINA Program will also geared toward the establishment of INRICES.

6.3 International Ocean Conference, in Jakarta, on October 1999:
Results of various ocean scientific research, living and non-living, will be presented in the International Ocean Conference in BPPT venue, Jakarta, on October 1999. In conjunction to the Seminar, there will be an International Exhibition which will exposed various science & technological products for ocean and maritime industries.

6.4 International Conference On Climate, in Bukit Tinggi - WestSumatera, Indonesia, on November 1999:
Various research result related to climate modeling, ENSO, La Nina, Asian Monsoon, Australian Monsoon, atmospheric research will be presented in an International On Climate in Bukit Tinggi, West Sumatera, November 1999. The Conference location is also the site of the Boundary Layer Radar Facility and the Global Atmospheric Watch in the equatorial Indonesia.


NEC
NECC
SEC
Mindanao Eddy
Halmahera Eddy
Mindanao Current
Northwest Monsoon
(reverse in SE Monsoon)
Surface Water
N Pacific Thermocline
(S-max and S-min)
S Pacific, Lower Thermocline
(Deep S-max)
105°
110°
115°
120°
125°
130°
135°
140°
5°
0°
5°
10°
15°

Indonesian Throughflow (ARLINDO), indicate the relationship between the relationship between ARLINDO and *El-Nino Southern Oscillation (ENSO)*
(Source, Gordon, A., 1998)



CLIVAR REPORT - ISRAEL

by Pinhas Alpert, (Tel-Aviv University)
Alex Manes and Ilan Seter (Israel Meteorological Service)

A. Climatic Changes in Israel in the second half of the 20th Century (T. Ben-Gai, A. Bitan, A. Manes, S. Rubin, P. Alpert)

1 Introduction

Significant changes in land usage have taken place since the National Water Carrier operation in the early 1960's. Such changes are reflected in the spatial distribution of the surface albedo pattern, obviously resulting in changes in the surface radiation balance and, subsequently, modifying the surface heat fluxes and the stability conditions of the Planetary Boundary Layer (PBL). This process of changes in momentum, moisture, and heat fluxes, known as the "Anti-desertification" process, should also affect climatic parameters of the boundary layer: rainfall patterns, temperature patterns, moisture, air pressure and wind, followed by changes in instability that could affect synoptic systems and rainfall amounts.

2 Albedo measurements

Estimations of the temporal changes in the albedo values for the last sixty years enable the estimation of possible temporal changes in heat and moisture fluxes, which may trigger rain. An Eppley PSP Pyranometer facing downward was mounted on a small Cessna aircraft and flown along the coastal plain from Tel Aviv to the northern Negev south of Beer-Sheva, at an altitude of approximately 500 feet, measuring surface reflection. The incoming solar radiation was measured simultaneously, at several surface radiation stations of the Israel Meteorological Service, along the flight path. The results show large differences in surface reflection distributions, between the cultivated areas in southern Israel (as low as 0.15), and the adjacent arid regions (with values of up to 0.35). Historical albedo maps were reconstructed according to land utilization maps of the 1930's and the 1960's. A comparison between recent albedo map and the reconstructed maps, indicates temporal changes in the surface albedo pattern during the last decades.

3 Rainfall trends

To reveal long term changes in distribution patterns of annual and monthly rainfall in Israel, the temporal and spatial distribution patterns since the 1930's, were analysed. A gamma distribution function was fitted to the annual and monthly rainfall at each station for two normal periods, and the shape and scale parameters of the distribution, as well as their percentage changes during the last normal period with respect to the first one, were analysed.

The analyses of the annual distribution function parameters reveal some appreciable changes, statistically significant, in the spatial rainfall distribution patterns, in the southern, northern and central parts of the country. The most striking feature is revealed in the South, with more than 60 percent increase in the shape parameter, and a similar rate of re-scaling, i.e. a decrease of about 40 percent in scale parameter. Analysing the monthly distribution revealed considerable changes in October and November, at the beginning of the rainfall season, and an appreciable change in March, at the end of the season.

4 Temperature Trends

Daily maximum and minimum temperatures in Israel were analysed, to detect long-term trends and changes in temporal and spatial distribution patterns during the second half of the 20th Century. The trend analysis, carried out for each station and each month of the year, reveals a rather complex changing pattern, with a significant decreasing trend of both the daily maximum and minimum temperature, during the cool season (November to March), and an increasing trend during the warm season (April to October). The seasonal temperature range exhibits an increasing trend: the summers have become warmer while the winters have become colder. The increase in the minimum summer temperature is more pronounced than the increase in the maximum temperature, while the decrease in maximum temperature in winter is greater than the decrease in the minimum, thus resulting in a significant decline in air temperature diurnal range in both seasons. It appears that the frequency of occurrence of extreme temperature events, with lower winter and higher summer temperatures, has increased, respectively. The above phenomena are revealed in the temporal behaviour of the lower and upper tails of the corresponding maximum and minimum temperature distributions during the warm and cold seasons, respectively. On an annual basis, there seems to be almost no temporal trends in minimum and maximum temperatures since the changes in winter and summer are of the opposite tendency.

5 NAO & temperature anomalies

Teleconnections with changing patterns of temperature and pressure anomalies observed in Israel during the second half of the 20th century is investigated. Relatively high, statistically significant, correlation of -0.8 and +0.9 were found between the North Atlantic Oscillation (NAO) Index anomalies and the cool season temperature and surface pressure anomalies in Israel, respectively. A relatively high positive correlation, as high as 0.8, was also found between the NAO Index anomalies and the smoothed (5 years running mean) geo-potential height of the 1000 mb pressure level, observed during the cool season at the Bet-Dagan (Israel Mediterranean coastal plain) radiosonde station of the Israel Meteorological Service. Correlation between NAO Index anomalies and the subsequent standard pressure levels, 850 and 700 mb, decrease gradually and become very poor for the 500-mb level. No statistically significant relationships were found between the maximum and minimum temperature and pressure patterns in Israel and the ENSO indices. This was also the case with a number of standardized northern hemisphere Teleconnections' indices, compiled recently by the Climate Prediction Center of NOAA (USA).

6 Upper-Air Trends

Radiosonde records from the Bet-Dagan aerological station of the Israel Meteorological Service were analysed to detect possible temporal trends in moisture content and potential instability of the atmospheric boundary layer. The analysis of the radiosonde data reveals a clearly defined, statistically significant increasing trend in the moisture content, mainly during summer. The stability of the surface layer, characterized by the Bulk Richardson Number, shows a decreasing trend since early 1960's. Potential relationship between these trends and land-use modifications are discussed.

Though it seems that the changes in climatic parameters, which were found in the second half of the 20^{th} century, point to a possible link to land use changes, connections with global trends should also be considered. The relatively high correlation between temperature anomalies and the North Atlantic Oscillation supports this connection. No link was found to the Southern Oscillation.

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Otterman ,J. A. Manes, S. Rubin, P. Alpert and D. O'c. Starr, "An increase of early rains in southern Israel following land-use change?" Bound. Lay. Meteor., 53, 333-351, 1990.

B Global and regional lightning activity: (C. Price and colleagues)

Dr. Price has established an observation site in the Negev Desert to continuously monitor extremely low frequency (ELF) electromagnetic waves from global lightning activity. In the ELF range (1-100 Hz) the electromagnetic waves from each lightning flash propagate a few times around the world, in the earth-ionosphere waveguide, before decaying. Hence, single station observations of these ELF waves from lightning, called the Schumann resonances (SR), are providing information on the time scales (hourly, daily, monthly, annual, El Niño, interannual). To observe these weak ELF signals from global lightning one has to be far variability of tropical lightning (and precipitation) on all away from local lightning activity and anthropogenic noise. Hence the Negev desert is an ideal location for studying these global signals. We are interested in monitoring the SR due to the evidence that global lightning activity may be stongly linked to global climate change. There are stong links between global surface temperatures and global lightning activity, while changes in global lightning activity will also imply changes in the concentration of upper tropospheric water vapour, and strong greenhouse gas. Hence, monitoring the variability of the SR may allow is to understand the variability of water vapour in the upper atmosphere, while also acting as a tropical thermometer.

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Price, C., 1993: Global surface temperatures and the atmospheric electric circuit, Geophys. Res. Lett., 20, 1363.

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C. El Niño effects on Israel weather (C. Price, P. Alpert and others)

After analysing many data sets related to the hydological cycle in northern Israel (rainfall, streamflow, lake level, snowfall) we have found that since the 1970s there is a highly significant positive correlation between El Niño years and above average precipitation, streamflow and lake levels. It was interesting to note, however, that these strong correlations do not exist prior to the 1970s. Furthermore, there is no linear relationship between the rainfall anomalies and the intensity of the El Niño event. It has been shown that significant changes have occurred in the intensity and frequency of El Niño events since the 1970s, which may have some influence on the teleconnections between the tropical Pacific and Israel. Similar connections only since the 1970s have also been found in southern Europe.

Reference:

Price, C., L. Stone, A. Huppert, B. Rajagopalan, P. Alpert, 1998: A possible link between El Niño and precipitation in Israel, Geophys. Res.Lett., in press.

D. Long term temperature trends in Cyprus (C. Price. S. Michalides and P. Alpert)

In a joint Israel-Cyprus study we have recently shown that the diurnal temperature range (max-min) has decreased dramatically over the last century in Cyprus. There are a few possible factors that can cause this long term change. Urbanization results in more warming at night relative to the day. Increased irrigation can reduce daytime temperatures while not influencing the nighttime temperatures. Aerosol changes have a similar effect to reduce daytime temperatures while not influencing nighttime temperatures. However, it is believed that changes in cloud cover are the most influencial in the case of Cyprus. Increases in cloud cover will result in daytime cooling while warming the nighttime temperatures. Although we need more data to verify our hypothesis, we feel that long term changes in the diurnal temperature range in Cyprus could well be related to long term changes in cloudiness.

Reference:

Price, C., S. Michaelides, S. Pashiardis and P. Alpert, 1998: Long term changes in diurnal temperate range in Cyprus, Atmos. Res., submitted.

E. Clouds, Dust, Sulphates - Microphysics and Climate Change (Z. Levin and colleagues)

Climate change or climate variability operates on a two way street with clouds and aerosols. A change in one affects the others. One of the elements that we study is the effect of sulphates on cloud and rain production. This effect occurs through the influence of large CCN on the cloud micro-physics and through it, on the distribution of hydro-meteors in the clouds. The change in the size and distribution of these particles determines the precipitation efficiency of the clouds as well as the electrical development in them.

We have measured dust particles that are coated with sulphate. Modelling results show that the coating is a result of SO_2 oxidation in the cloud drops. Evaporation of drops containing dust and sulphate produces the dust particles with the coating of sulphate on them. Subsequent penetration of these particles into other clouds modifies their development by making them more efficient rain producers.

A recent measurement of lightning activity in the US showed that introduction of large concentrations of CCN into thunderclouds modifies their lightning production. To this end we are measuring the lightning activity in the eastern Mediterranean and correlating them with radar measurements of cloud and rain development.

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Quantification of dust-forced heating of the lower troposphere (P. Alpert and colleagues)

In a paper accepted this month for publication in Nature we study the response of the climate - the air temperature - to the radiative effects of dust aerosol. Models can calculate the impact of dust on the atmosphere and climate but it is very difficult to measure it. The dust optical properties are also not very well known. In this study we "tricked" nature to reveal its secrets. We looked on the "corrections" or errors in model assimilation of the temperature field, off the west coast of Africa, an area with heavy dust loading. The model includes most atmospheric processes but not aerosol. Therefore the errors are affected by the presence of dust. By observing the correlation between the errors and satellite measurements of the dust presence, we were able to deduce the impact of the dust on the atmospheric temperature. The paper is the result of collaboration of Israeli, GSFC and French scientists all of them working or visiting GSFC. It shows a new pathway for studying climate and human impact on it using a combination of global circulation models and satellite data.

Reference:

P. Alpert, Y. Shay-El, Y.J. Kaufman, D. Tanre, A. DaSilva, S. Schubert, J.H. Joseph, "Quantification of dust-forced heating of the lower troposphere", Nature, Vol. 395, No. 6700 (24 September), 367-370, 1998.

Weizmann Institute of Science (E. Tziperman and colleagues)

A El-Niño-Southern Oscillation

We are investigating basic dynamical mechanisms that are responsible for the aperiodicity of observed ENSO events [1,2], as well as mechanisms leading to ENSO's tendency to peak towards the end of the calendar year [3]. In addition, we are developing a data assimilation and prediction scheme for the tropical Pacific based on a primitive equation ocean model (MOM 3 of the Geophysical Fluid Dynamics Laboratory (GFDL)) coupled to a statistical atmospheric model and based on the adjoint method of data assimilation. It is hoped that the combination of a state of the art model with a state of the art data assimilation scheme such as the adjoint method [4], would perhaps result in an optimized ENSO prediction skill.

B Thermohaline circulation, global climate dynamics

We have been investigating both the variability of the thermohaline circulation (THC) [5], and the stability of this circulation. We have found, using a realistic-geometry coupled ocean-atmosphere-ice general circulation model, that the present-day THC, which has been stable for the past 10,000 years, may be close to an instability threshold. That threshold may be reached if the THC is weakened by about 25% relative to present-day value [6]. Implications of this proximity to an instability threshold to climate variability and climate change have been studies. in addition to these studies of decadal climate variability mechanisms, we are involved now in the development of a new ocean model to be part of the next generation coupled ocean-atmosphere-ice climate model of GFDL.

C Glacial-interglacial dynamics

We are using simple models of the coupled ocean, atmosphere, sea-ice, land ice sheets and ocean biochemistry, to investigate glacial-interglacial climate variability. This is an extension of our previous work on the stability and variability of the THC, which incorporates the additional elements of the global climate system needed to represent the dynamics of long term glacial-interglacial climate variability.

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Tziperman, E. 1997: Inherently unstable climate behaviour due to weak thermohaline ocean circulation. Nature, 386, 592-595.

Hebrew University of Jerusalem (U. Dayan)

A Implications of Climate Change on the Coastal Region of Israel

I was appointed by the UNEP to prepare a report on:"Implications of Climate Change on the Coastal Region of Israel". The predicted variations in temperature and precipitation will be based on the analysis of the results obtained from the CRU-East Anglia research.UNEP/MAP(Mediterranean Action Plan) and the government of Israel signed an agreement on November 12, 1996 for the implementation of CAMP (Coastal Areas Management Program) in Israel. The programme consist of three phases:

1) Analysis of present and predicted climatic conditions.
2) Potential impacts of expected climatic changes on natural systems.
3) Suggested actions and recommendations.

I am responsible for the first phase and the predicted conditions will be based on results of scenarios produced by the Climatic Research Unit of the University of East Anglia. Enclosed are references of studies dealing with Israel's commitment within the UNFCCC (UN Framework Convention for Climate Change):

References:

Koch, J., U.Dayan and M. Graber, 1996: Complying with the U.N. Framework Convention for Climate Change - Israel as a case study. Proc. 6th. Int. Conf. of the Israel Society for Ecology and Environmental Quality Sciences, Jerusalem, June 30-July 4, 1996.

Koch, J., and U. Dayan, 1997: Inventory of Emissions and Removals of Greenhouse Gases In Israel. Part A: Carbon Dioxide and Methane, SNRC-2784, Soreq Nuclear Research Center, 1997.

The Volcani Center, Ministry of Agriculture (J. Stanhill and colleagues)

Long-Term Trends of Solar Irradiances

Long-term trends of global irradiances in Israel, Arctic, Antarctica, Ireland and other regions as well as the relationship(s) with air-pollution and urban activities are investigated.

References:

J. Stanhill and A. Ianetz, 1997: Long term trends in, and spatial variation of, global irradiance in Israel,Tellus, 49, 112-122.

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NATIONAL STATEMENT OF JAPAN

The Council for Aeronautics, Electronics and other Advanced Technologies presented a report entitled “Toward the Realization of Global Change Prediction” on 9 July 1996 and pointed out importance and urgency of the promotion of climate science, especially climate modelling, and the application of its results for the climate prediction including the possible future climate projection. The Science and Technology Agency (STA) has established “the Frontier Research System for Global Change (FRSGC)”, which is dedicated mostly to the process studies of the earth’s climate system, as a part of the realization of the above recommendation. STA has also started a project to develop a very fast parallel processor for the earth science (Earth Simulator Project), especially for climate modelling, recognizing that computing facility will play an essential role in developing climate science, especially a good climate model, and providing with reliable future projection of earth’s climate change.

The Meteorological Council for the Japan Meteorological Agency (JMA) presented a report on climate services of JMA on 27 October 1997. Among its recommendations, it says firstly to improve seasonal forecast through the introduction of dynamical methods and extend the forecast period further to the extent possible scientifically, and secondly to improve global warming detection and projection, especially projection in local scales around Japan and its vicinity. JMA has placed emphasis on the development of a climate model for climate services, and sustained atmospheric constituent observations and oceanographic observations, especially quasi-periodical comprehensive observations along the longitude 137°E since 1967 and 165°E since 1996.

What we have to do to improve our understanding of earth’s climate system and climate model, however, are so diverse that there are so many areas to be studied and so many fields to be observed. Therefore it would be ineffective for just one country to tackle them. What we have to do to solve the problems overlaps with the scientific goals of the Climate Variability and Predictability (CLIVAR) science program. The coordinated and cooperative international efforts within CLIVAR will be the most effective way to accomplish these objectives. The focus of Japanese research effort will be directed to phenomena in the Pacific, the Indian Ocean and Eurasia such as ENSO, Asian Monsoon and decadal to inter-decadal variabilities in the Pacific.

Major organizations which participated in research and observations related to the CLIVAR are summarized in Table 1. STA promotes science and technology through funding. The Japan Marine Science & Technology Center (JAMSTEC) and The National Space Development Agency (NASDA) are foundations supported by STA. FRSGC was established in October 1997 by STA as the joint program of both JAMSTEC and NASDA. FRSGC has its center in Tokyo (Institute for Global Change Research) and two branches outside Japan, one in Hawaii (International Pacific Research Center) and the other in Alaska (International Arctic Research Center). JMA is an operational agency for meteorological services, and the Meteorological Research Institute (MRI) is a research institute within the JMA. The Hydrographic Department of the Japan Maritime Safety Agency (HD/JMAS) and the Japan Fishery Agency (JFA) have research vessels and have been engaged in oceanographic observations and researches.

At universities, research activities related to the CLIVAR are also being carried out. The Center for the Climate System Research of the University of Tokyo (CCSR), the Oceanographic Research Institute of the University of Tokyo (ORI), Tohoku Univ., Hokkaido Univ., Tsukuba Univ., Kyoto Univ. and Kyushu Univ. are among them. Many scientists at the universities have participated in the projects sponsored by the Ministry of Education, such as the GEWEX Asian Monsoon Experiment (GAME), and in those by STA and FRSGC.

Major ongoing projects in Japan related to the CLIVAR and those planned are briefly summarized below (see Table 1 also). Besides them, there are also many individually oriented researches and small research projects which will greatly contribute to the scientific goal of the CLIVAR. In addition, as university researchers are yet to discuss their scientific plans, their plans are not included.

TRIANGLE Program by JAMSTEC

JAMSTEC has started "TRIANGLE program", which is a program to perform intensive oceanographic observations, analyses and numerical studies for the better understanding of the oceanic role in climate changes. There are three sites for intensive observation, i.e., the Western Equatorial Pacific, the Eastern Equatorial Indian Ocean, and the northern part of the North Pacific.

As the first step of the program, TRITON buoys are being deployed in the Western Equatorial Pacific succeeding TAO buoys. Buoys will be deployed further in the Eastern Equatorial Indian Ocean and in the Kuroshio extension in due course. A comprehensive oceanographic observation system will be deployed in the Kuroshio extension, starting from 2001, to clarify detailed structure of the gyre and its variabilities in the area, and the mechanisms. Several observation methods, such as acoustic tomography, current meters, CTD observations beside TRITON buoys will be employed.

Projects promoted by FRSGC

FRSGC has started three CLIVAR related projects and is to start another one in near future. The key words of them are "Climate variations", "Hydrological cycle", "Global warming" and "Integrated climate modelling". These projects will be continued for 20 years.

a) Climate variations research program
Main interest of this project is decadal to inter-decadal variabilities in the Pacific sector, especially climate regime shift in the North Pacific, decadal modulation of ENSO and oceanic meridional circulation changes in the North Pacific.

b) Hydrological cycle research program
One aspect of the earth's climate is that it is greatly influenced and characterized by hydrological processes. This program has three main objectives, i.e., the study on continental-scale hydrological cycle processes, the study on the land-surface hydrological processes and the study on clarification of cloud and precipitation process, and aims at developing comprehensive models on them.

c) Global warming research program
Besides the ordinary projection study of the global warming with the use of a comprehensive climate model, studies on the anthropogenic forcing, carbon cycle modelling and paleo-climate study are currently progressing. We expect contributions to the 4th IPCC report from this project.

d) Integrated modelling research program
This program is now in its preparatory stage. This project aims at developing a next generation climate model of very high spatial resolution to be executed on the earth simulator. How to parameterise physical processes for such very high resolution models will be one of central issues of this project.

Sub-Arctic Gyre Experiment (SAGE)

In recent years, the role of high latitude oceans on climate changes has been highlighted. However, total number of the observed data in such area is far from the satisfactory level. The Sub-Arctic Gyre Experiment in the North Pacific (SAGE), which is sponsored by STA, started in 1997 as a 5 year project to clarify mechanisms of the formation of the North Pacific Intermediate Water (NPIW), in close cooperation with scientists in the US and other countries.

Earth Simulator

The Earth Simulator is a project to develop a very fast parallel processor designed exclusively for the earth sciences based on the recognition that computing facility will play an essential role in the development of the earth sciences, especially in the high resolution climate modelling.

The project has started already. The simulator will have 640 nodes, and each node will be composed of 8 vector processors with 16 GB shared memory. The expected maximum speed of operation will be 40 TFLOPS. One of the unique aspects of this project is that this project is progressing in close collaboration of computer scientists and climate modellers. We expect this machine by the end of the fiscal year 2001. This will surely facilitate projection of global warming with a high resolution climate model and 4-dimensional data assimilation of the climate system, and will also allow the use of very high resolution climate models for research.

GEWEX Asian Monsoon Experiment (GAME)

GAME is one of international sub-projects of GEWEX. Japan has been deeply engaged in this project from its planning stage. Special observations performed under this projects will provide researchers with useful information about land surface processes in the East Asia. Such data will be utilized to see how seasonal predictions and simulation of Asian monsoon will be improved through the improvement of initial conditions of the land surface and the modelling of land surface processes.

Kuroshio Fluctuation Prediction Experiment

This is a project to challenge the prediction of fluctuations of the position and transport of the Kuroshio south of Japan. This study was started in 1997 as a five year project supported by the Core Research for Evolutional Science and Technology (CREST) which is sponsored by STA.

Sea Ice in the Sea of Okhotsk and its Role on the Climate System

The Sea of Okhotsk is one of the southernmost seasonal sea ice zone in the Northern Hemisphere and is the area where a relatively large amount of CO_2 is removed from the atmosphere by the ocean. In spite of the scientific importance of this area in the climate system, in-situ observations are extremely few, especially in winter.

The objectives of this study are to clarify water circulation and ventilation, source waters of NPIW, mechanisms of ice cover formation, the effect of sea ice on heat and moisture fluxes between atmosphere and ocean, and the exchange of CO_2 between atmosphere and ocean, etc.

To investigate the above problems, intensive field observations are planned as the cooperative study of Japan, Russia and United States. This study was started in 1997 as a five year project supported by CREST.

CLIVAR related studies at MRI/JMA

In JMA and MRI, many researches related to CLIVAR are currently progressing and will be continued further in future. Key words or phrases of ongoing or planned themes of research are; as for GOALS, the dynamical seasonal prediction, ENSO, Asian monsoon, Tropical Biennial Oscillation, land surface processes of the Eurasian continent and their impact on predictability; as for DecCen, decadal to inter-decadal variabilities in the Pacific; and as for ACC, improved detection and projection of the global warming and the local climate change projection, especially in Japan and its vicinity.

Digitization of Kobe Collection

The Kobe Marine Observatory of JMA has collected marine meteorological data measured by merchant ships mostly over the North Pacific from 1890 to 1960, and the data is called as “Kobe Collection”. The total number of data is about 6.8 million. All the data after 1933, which were digitized in 1961, have already been included in COADS Release 1. Recently about 1.6 million of the remaining ones were digitized by the project subsidized by the Nippon Foundation under the direction of JMA and will be opened for use as soon as quality checking process will be over. Remaining 1.5 million of them are to be digitized in due course. The digitized data could be used for the better detection of the global warming than present as well as for decadal to inter-decadal variability studies in the North Pacific.

Table 1. Major participating organizations and projects/research areas

Organizations	**Projects/Research areas**
The Science and Technology Agency (STA)	Earth simulator Subtropical arctic gyre experiment (SAGE) Triangle program
The National Space Development Agency (NASDA)	Climate variation res.
The Japan Marine Science and Technology Center (JAMSTEC)	Hydrological cycle res.
The Frontier Research System for Global Change (FRSGC)	Global warming res. Integrated modelling
The Japan Meteorological Agency (JMA)	Climate services
The Meteorological Research Institute (MRI)	Sustained observations Climate modelling Climate studies Digitization of Kobe collection
The Hydrographic Department of the Japan Maritime Safety Agency (HD/JMSA)	Oceanographic observation
The Japan Fishery Agency (JFA)	Oceanographic observation
Universities and research institutes	
The Center for Climate System Research/ the University of Tokyo (CCSR)	Climate studies
The Oceanographic Research Institute/ the University of Tokyo (ORI)	Climate modelling
Tohoku University	GEWEX Asian monsoon experiment (GAME)
Tsukuba University	
Hokkaido University	
Kyoto University	
Kyushu University, etc.	

SOME ELEMENTS OF CLIMATE VARIABILITY IN MALI
By Djibrilla A. Maiga

I. Introduction

Mali is a landlocked country, with an area of 1 241 000 km^2 and a population of 9 million inhabitants (80% in the rural areas), with an economy that is essentially based on agriculture, and therefore very dependent on climate conditions and more specifically on rainfall patterns (i.e. the quantity of rainfall during a given season, the spatial-temporal distribution, etc.)

Many studies have taken place in Mali and in the Sahel which have clearly shown a very important interannual and intra-annual rainfall variability generally seen in the following phenomena:

- a receding of the isohyets towards the South of the country ;
- a decrease in annual rainfall, August rainfall and water availability in general;
- variability of the agricultural season relating to onset, end and length of the rainfall season.

These elements represent a major climatic risk for the good unfolding of the agricultural season and therefore for the economy of the country and its population.

II. Impact of climate variability on agriculture and population

In Mali, agriculture is the field of activity most vulnerable to rainfall variability which can lead to major economic losses, starvation, rural depopulation, etc.

To this effect, several impact studies have shown the following:

- the northern limit of the millet farming has moved south;
- the reduction of surface used for farming and of the herbaceous cover growth;
- encroachment of sand on water sources
- the decrease in the regeneration of pasture land;
- the elimination of the species least resistant to drought;
- a modification in the flora, and as a consequence, the heavy pressure grazing on the pastureland resulting in the serious erosion of the soils
- the weakening of the ecological-sociological-economic systems.

All these phenomena lead to a decrease in the animal and vegetal population. This decrease also generates serious socio-economic problems, especially through the fact that villages are losing their work force to the cities, thus leading to the following problems:

- the increase of unemployment and insecurity in cities;
- the degradation of morals;
- the emergence of ghettos;
- the general unhealthiness and health problems increase;
- the shortage of drinking water.

III Some responses to the problems

As I mentioned earlier, agriculture, more than any other activity, suffers the most from climate conditions, even more so if we consider that, even with the strategies and research programmes that have been set up, dry years still result in crop shortages.

To reduce these negative effects and try to give some realistic answers to the concerns about a sustainable development in several socio-economic sectors of activity, it is necessary to collect and use meteorological data and to integrate them with other socio-economic information.

Using these meteorological and climatological data in the agricultural sector would allow us (among other things) to do the following:

- concerning early warning: to inform the authorities in charge of taking the decisions about food, health and soil situation, through the activities of a multi-disciplinary Working Group (GPT);
- concerning assistance to farmers: to supply them with useful information, based on climate forecasts, to allow them plan their farming activities (choice of the sites, varieties, and production systems, etc.), and to better plan the operational steps of farming, such as optional dates for sowing, spreading of fertiliser, insecticide, etc.

In other sectors, particularly energy, health and public works, useful climate information has allowed for better planning, evaluation and decision-making in the management of their activities, specifically taking into account climate predictions (monthly, seasonal and annual), which for economies heavily dependent of climate variations like that of Mali, give us a better chance to achieve productivity growth.

IV Users needs in meteorological information

Nowadays, more and more users actually follow the meteorological forecasts and are becoming more demanding about the accuracy of the forecasts, for instance:

- daily forecasts: more spatial accuracy,
- climate forecast: start and quality of the rainy season, when would be the dry periods during the rainy season, when could this spell of dry years be expected to end,
- forecasts of the maximum temperatures during the warm season, useful for the follow-up and management of the infectious and epidemic illnesses, etc.

V Conclusions and perspectives

The important results achieved in the field of climate variability studies and the applications of these studies have resulted in a reduction of the risks linked to climate variability and therefore need to be reinforced. In order to do this, we will have to:

- continue research on climate prediction, and adapt it to the different sectors of socio-economic development and distribute the results achieved;
- reinforce the national capabilities to that effect;
- reinforce the observation networks collecting and analysing meteorological data.

CLIVAR MEXICO

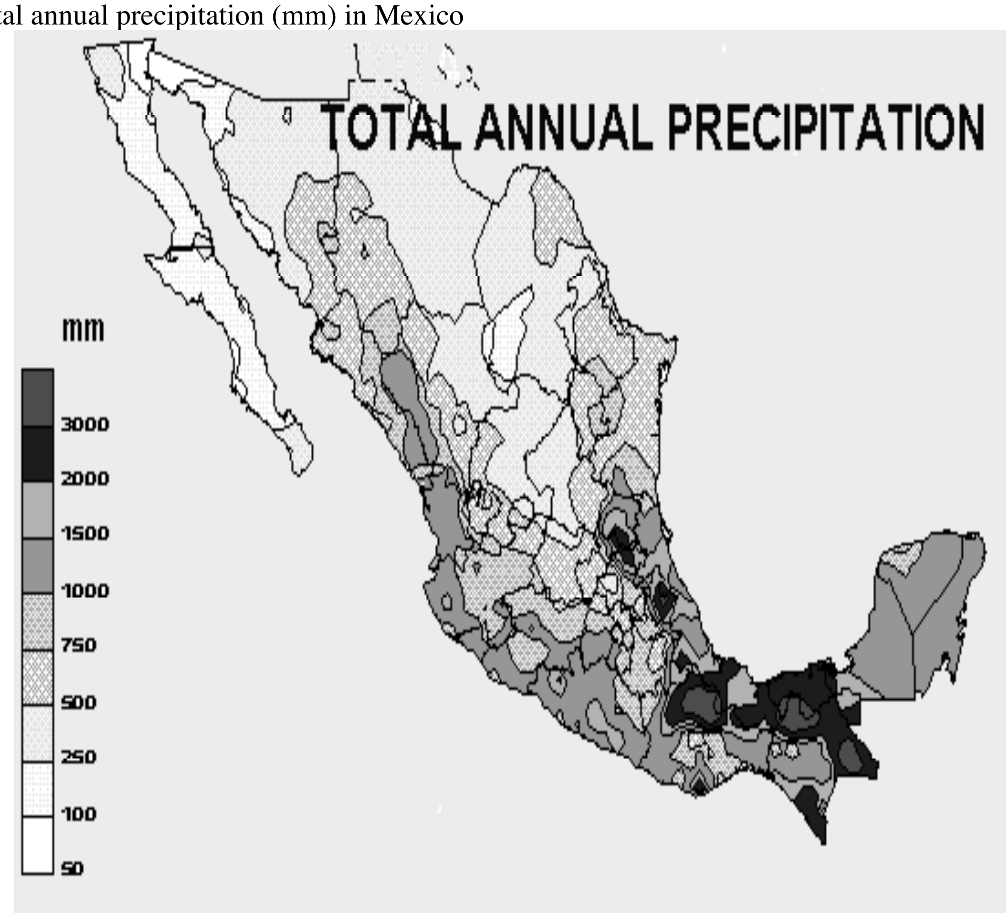
Introduction

It has been recognized for a long time that climate variability in Mexico affects many of its socio-economical activities. Agriculture, fisheries, communications, among others, are highly dependent on climatic conditions to function properly. Since almost two thirds of the Mexican territory are semi-arid, year to year fluctuations in precipitation usually have an impact in the Gross National Product. In addition, extreme weather events, whose frequency appears to be modulated by global climate variations are affecting a growing population.

The Mexican government has recognized the importance of climate variability and has begun to implement actions to diminish the negative effects of extreme climate conditions. The recent El Niño event in 1997 and 1998 made the population aware of the importance of climate and the benefits of implementing preventive actions based on climate predictions to diminish its vulnerability to natural hazards.

In most of Mexico, there is a well defined monsoon climate, with a well defined rainy season beginning in June and ending in late September. Winter precipitation though, is crucial in water management for the northern states, particularly in northwestern Mexico. Precipitation along border states may be as low as less than a 100 mm/year in some arid regions, while it may be more than 3000 mm/year in some regions near the southern parts of the Gulf of Mexico (Fig. 1).

Fig. 1 Total annual precipitation (mm) in Mexico

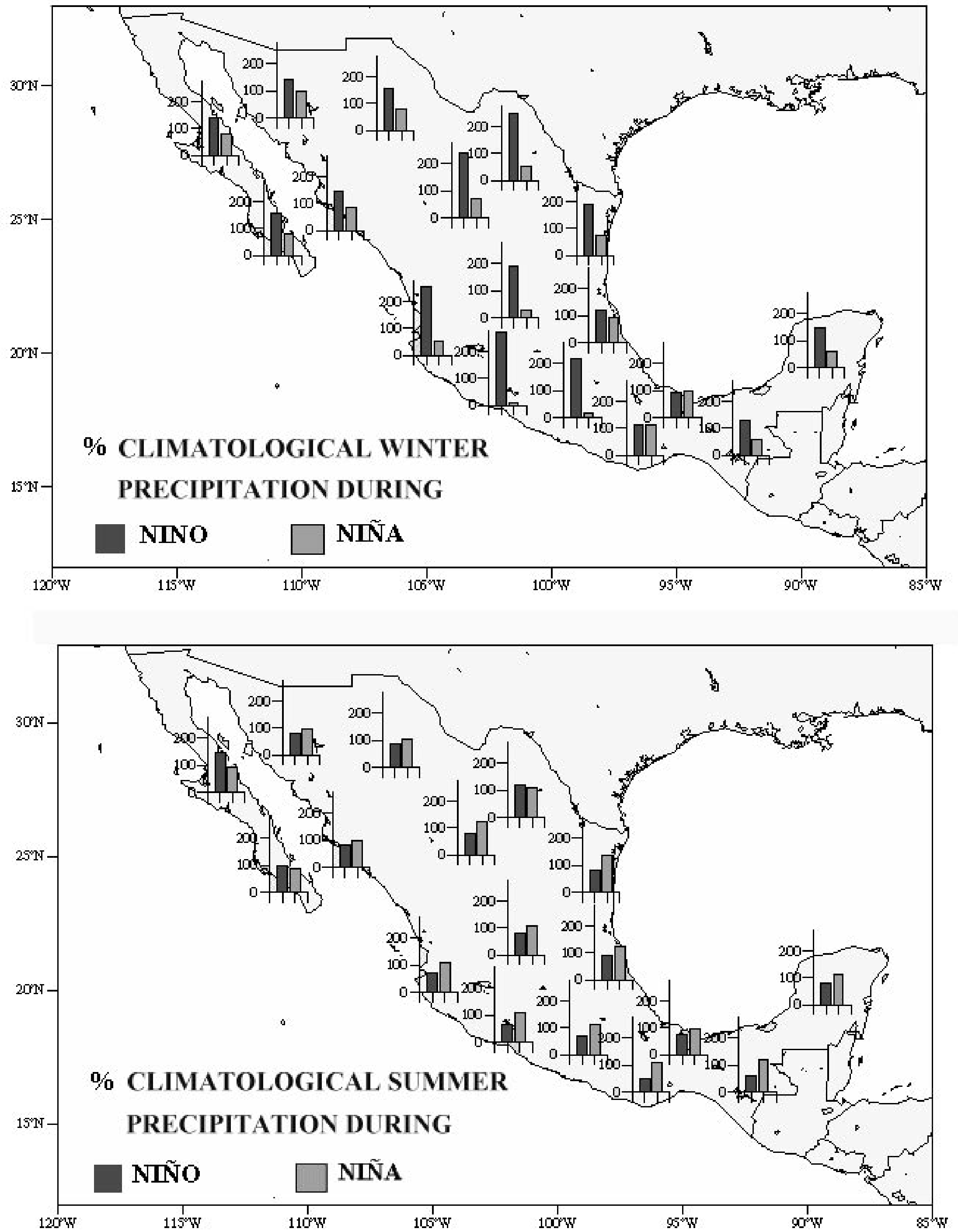


In order to have an adequate understanding of Mexican climate, studies should consider the presence of "warm pools" off the coasts of Mexico, plus the existence of complex terrain. Mexican precipitation is determined by a rich variety of meteorological phenomena. During winter, the midlatitude cyclones produce precipitation along the northern states. When such systems reach low-latitudes strong winds and heavy precipitation occurs along the Gulf of Mexico states in what is called a *Norte*. These phenomena involve tropical-extratropical interactions which vary on a year to year basis.

During summer, various systems control precipitation in Mexico, including the so-called North American monsoon, the Inter Tropical Convergence Zone (ITCZ), tropical cyclones, easterly waves, etc. The temporal variability in this systems includes the signal of a relative minimum in the middle of the summer rainy season known as the Mid-Summer Drought, detected in central southern Mexico, Central America and the Caribbean. In northwestern Mexico, the North American monsoon shows active and break periods frequently related to tropical cyclone activity and easterly waves.

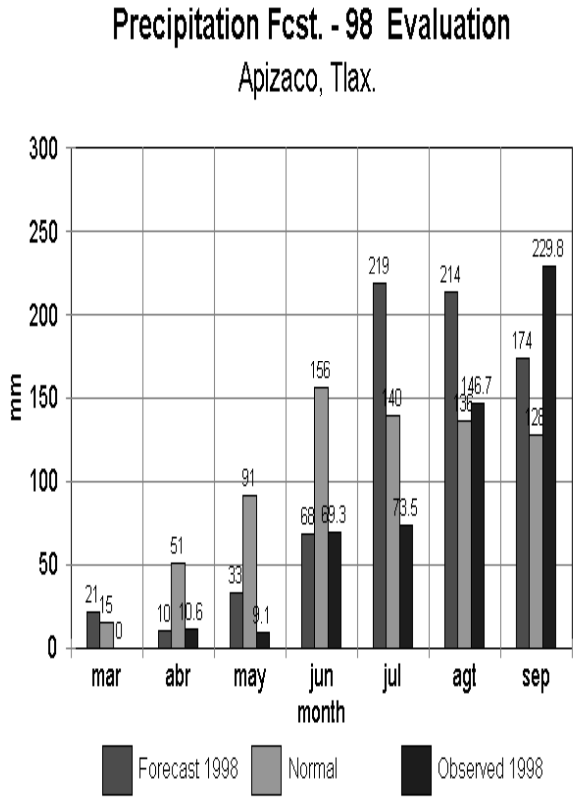
The El Niño - Southern Oscillation phenomenon is the major modulator of interannual climate variability. Its signal reflects in more intense winter precipitation in northern Mexico, and less summer precipitation over most of the country. Agriculture, fisheries and other socio-economical activities also exhibit the signal of El Niño. The recent 1997-1998 El Niño event resulted in economical losses of the order of 1.5 billion dollars and millions of people affected by drought, forest fires, and in some cases, flooding.

Fig. 2 Percentage of changes in precipitation during El Niño and La Niña years. a) during winter, b) during summer.



Nowadays, some programs involving the academic, government and private sectors maintain projects in which climate predictions (Fig. 3) are used to plan agricultural activities. The demand for climate predictions in the country has grown enormously since then. In some cases, climate information is provided by academic institutions involved in climate variability studies and sometimes by the National Weather Services or other agencies. Because of the diversity of the information distributed among decision makers and planners, an initiative to coordinate climate variability (diagnostic and prediction) activities is being prepared by several of these institutions in what is becoming the Mexican CLIVAR program.

Fig. 3 Experimental forecasts of precipitation in Apizaco, Tlaxcala, Mexico.



Previous Mexican programs on Climate variability and Climate Change

Various projects aimed at studying climate variability and climate change in Mexico have been developed in a coordinated manner at academic and government institutions, and even by private groups interested in climate information. These projects have brought together scientists, planners and private corporations.

One of the largest efforts to study Climate Change and its impacts at a regional level took form as the Country Study: Mexico project. This work resulted in a comprehensive analysis of Mexico´s vulnerability in various economical and social sectors and potential adaptation measures to diminish the negative impacts of climate change. This project was carried out with the financial support of the US Country Studies program.

Recently, the Mexican National Council for Science and Technology (CONACYT) financed (with almost 1 million dollars) a series of projects to document the impacts of El Niño phenomenon in Mexico. This initiative constituted an opportunity to establish fruitful interactions among scientists interested on El Niño on various fields: Meteorology, Oceanography, Hydrology, Fisheries, Agriculture, Economy, Sociology. The results of this effort have spurred the interest for more information on other climate phenomena.

With the support of the Inter American Institute (IAI) for Global Change Research, we have formed a Collaborative Research Network to study climate variability in the warm pools surrounding Mexico and Central America. Scientists from various countries (Mexico, USA, Costa Rica, Colombia, and Brazil) will participate in this Network whose main objective is to broaden our understanding of climate variability and improve our climate forecasts at a regional level.

The Mexican contribution to CLIVAR

The scientific interest of the Mexican climate community match the overall scientific objectives of CLIVAR. In particular, we are interested in pursuing research on:

- Physical processes responsible for climate variability at a regional level and predictability on various time scales
- Extend the range and accuracy of regional climate models
- Understand and project the response of the climate system to increases of greenhouse gases and aerosols

We understand that we cannot act isolated given the limited number of human and financial resources. Therefore, we commit to work so that the CLIVAR objectives be successfully achieved, following the CLIVAR guidelines accepted during the CLIVAR Conference held in Paris in December 1998. In particular, we will:
- maintain and promote continuous collaboration among Mexican and international scientists in the field, making use of institutional programs and financing mechanisms to this end
- participate in field campaigns in the region of Mexico and Central America to collect meteorological information to understand climate process. (Mexican academic institutions will participate in the EPIC experiment with ship and land meteorological and oceanographic observations during the Intensive Observing Periods)
- continue with out educational and training efforts in the field of Climate with students and scientists from countries in the region.

Recently, under a CONACYT initiative, a proposal to fully implement the Mexican CLIVAR program has been submitted ($4 million dollars). It is expected that under such financial support Mexico will maintain a Climate Variability and Climate Change program for the next five years, closely following the CLIVAR guidelines.

Participant Institutions :

Several Mexican institutions have expressed their interest in participating in the Mexican CLIVAR initiative including:

National Autonomous University of Mexico
National Institute of Ecology
Center for Scientific Research and Graduate Studies at Ensenada
National Weather Service
University of Veracruz
National Center for Disaster Prevention
National Water Commission
University of Guadalajara

For further information on the Mexican CLIVAR program, you may contact:

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CONTRIBUTION OF MOROCCO TO CLIVAR PROGRAM

A. Mokksit
Chef du Centre National du Climat et Recherches Meteorologiques

First of all the Direction de La Meteorologie Nationale would like to express his support to the CLIVAR Program and hope full success to all the work done under its framework.

This last decades, the needs in climatological information have increased for the Policy and Decision makers. The reason is due to the succession of a number of extreme events (drought, floods) during the last two decades in one hand and to the increasing attention paid to the issue of climate change.

The most important and frequent requests are related to:

1 Predictability at long range scale (monthly, seasonal) mainly for rainfall;
2 Management of extreme event and teleconnexion with known phenomenon like El Niño;
3 Climate change and its possible impact on socio-economic sectors.

To respond to these request the Direction de la Meteorologie Nationale have performed several substantial studies in areas as:

1 Global Modelling and predictability studies:

Since 1994 the Direction de la Meteorologie Nationale started two projects: AL MASIFA (in collaboration with Meteo-France, Medias-France, Tunisia, Algeria and funded by EEC) and AL MOUBARAK (with the CIMMSX of the University of Oklahoma). As result of the two project:

- DMN developed the capacity to run once a month a Global Circulation Model ARPEGE-CLIMAT to perform monthly forecast with 4 months lead. This after a verification/validation of this model on the Moroccan region and over a 15 years period.
- Some experiments with GCM ECHAM4 were also performed over Moroccan region.
- Some statistical studies related to:
  - i. Multidecadal variability of the North Atlantic Oscillation (NAO);
  - ii. Correlation between NAO and Moroccan rainfall;
  - iii. Correlation studies between Global SST, Tropical Pacific SST, Tropical Atlantic SST, Global SLP and Moroccan rainfall;
  - iv. Some statistical adjustment using ARPEGE-CLIMAT.

As concluding result there is:

a A potential predictability of ARPEGE-CLIMAT in some regions of Morocco
b Good simultaneous correlation between Rogers NAO Index and Moroccan rainfall
c Weak correlation between Tropical Pacific SST and Moroccan rainfall except for late rainy season (Feb-March);

2 Management of Extreme event and teleconnection with El Niño

In this area some studies were performed in order to evaluate the El Niño impact on the climatic situation in Morocco; No significant signal have been found.

3 Climate Change and its possible impact on socio-economic sectors

In this area multiple approaches to evaluate Climate Change were performed using simple indexes leading, sometimes, to opposites concluding results; So DMN filled the necessity to perform some climate Change detection/attribution studies based on appropriate indexes. Also, related to the Climate Change and its possible impact on the water resources management some studies were performed at regional level (Maghreb) in the framework of a UNDP funded project RAB/94/G31 using some down scaling approaches. The study had shown an important vulnerability of the region.

In Conclusion - it is clear that the DMN is already involved in some CLIVAR area of interest. We prospect to strengthen our effort in participating in CLIVAR work items as:

i Global Modelling and prediction:
- continuing EL MASIFA/AL MOUBARAK research using and "improving" some GCM like ARPEGE-CLIMAT, ECHAM4,
- developing Regional Model over our region
- studying the use of global atmosphere-ocean coupled model product at regional level.

ii Development of non conventional data (tree ring, paleoclimate,);

iii Global sustained observations
DMN have planned to pay attention while developing its observation network and database to meet CLIVAR needs.

iv Global Empirical Analytical and Diagnostic studies:
DMN is performing empirical predictability studies in connection with:
- large scale oscillations: NAO, ENSO,
- Atlantic depressional systems trajectories.

CLIVARNET
The Netherlands' contribution to CLIVAR

Summary

In the Netherlands a national CLIVAR committee was established in 1997. The Dutch contribution to CLIVAR will consist of ongoing work at a number of institutions and several projects funded under the Dutch National Research Programme on Global Air Pollution and Climate Change (NRP). In addition, the Netherlands Organization for Scientific Research (NWO) has made an initial allocation of M*f* 4.5 for CLIVAR-related projects. This allocation was based on a document entitled: "CLIVARNET, Contours of a Dutch CLIVAR contribution", in which priorities for the Dutch CLIVAR contribution were identified. One of the elements was an envisaged strengthening of the national coherence, by enhancing collaborations between sea-going oceanographers and modellers, and between palaeoclimatologists and climate modellers. CLIVAR was presented in the Netherlands at a special meeting at the Royal Netherlands Academy of Arts and Sciences (KNAW), in December 1997. At the same time a call for proposals was issued. In the summer of 1998 the first projects were approved after international peer review. A second call for proposals is expected in 1999.

A list of PI's and their projects is attached. The new NWO projects are marked with a plus sign. More information is available in a separate brochure, and in the original CLIVARNET document.

The Netherlands CLIVAR Committee, November 1998

Dr. Auke Bijlsma (Netherlands Organization for Scientific Research, NWO, secretary)
Dr. Bas van Geel (The Netherlands Centre for Geo-ecological Research, ICG)
Dr. Gerbrand Komen (Royal Netherlands Meteorological Institute, KNMI, chairman)
Prof. Jan de Leeuw (Netherlands Institute for Sea Research, NIOZ)
Prof. Cor Schuurmans (Institute for Marine and Atmospheric Research, IMAU)

Additional information: bijlsma@nwo.nl (secretary) or komen@knmi.nl (chairman)

CLIVARNET projects

Name [email] PI * Institute * Project

H.M. van Aken [aken@nioz.nl] * NIOZ * 1. Climatic variability of the sea surface height and circulation in the northern North Atlantic Ocean observed with satellite altimetry; 2. CAMP: Clivarnet Atlantic Monitoring Programme

G.J.H. Burgers [burgers@knmi] * KNMI * Advanced data-assimilation methods for ocean models and analysis of the tropical ocean with satellite observations

H.A. Dijkstra [dijkstra@phys.uu.nl] * IMAU * A dynamical system analysis of the global ocean circulation

H. Dolman, H.A.R. de Bruin and B. Holtslag [Henk.deBruin@user.metair.wau.nl] * WAU * Land surface feedbacks and decadal climate variations on the Iberian Peninsula

S.D. Drijfhout [drijfhout@knmi.nl] * KNMI * Tracing the origin and formation of North Atlantic Deep Water in numerical models

B. van Geel [vangeel@bio.uva.nl] * ICG * Palaeo evidence for solar forcing of climate change

E. Jansma [ejans@archis.nl] * NCD, RING * Reconstruction of the natural variability of precipitation in the Netherlands and North Germany for the last 8000 years using ultra-long tree-ring chronologies of oak

G. Können [konnen@knmi.nl] * KNMI * Reconstruction of past climate from historical and proxy records

G.J. Komen [komen@knmi.nl] * KNMI * Air/sea interaction and the wave and upper-ocean response

R. Leemans (rik.leemans@rivm.nl) * RIVM * Improvement of the climate component of the IMAGE assessment model (with KNMI)

H.J. Lindeboom [hanl@nioz.nl] * NIOZ * The tree of the Sea: climate reconstructions on the basis of the bivalve Arctica islandica

L.R.M. Maas [maas@nioz.nl] * NIOZ * SOMATICS: Symbolizing Ocean Mixing And Transport in Climate Studies

J. Oerlemans [j.oerlemans@phys.uu.nl] * IMAU * Climatic interpretation of glacier records by inverse modelling

J.D. Opsteegh [opsteegh@knmi.nl] * KNMI * Decadal climate variability related to the North-Atlantic Ocean

W.P.M. de Ruijter [w.p.m.deruijter@phys.uu.nl] * IMAU * Mixing of Agulhas Rings Experiment (MARE), jointly with NIOZ and KNMI

J.F. Vandenberghe/S.R. Troelstra [vanj@geo.vu.nl] * VU * Natural climate variability during the Late Glacial and late Holocene: comparison and integration of the marine and terrestrial record

C.J.E. Schuurmans [c.j.e.schuurmans@phys.uu.nl] * IMAU * Variability of Atlantic storm tracks

R. Tol [richard.tol@ivm.vu.nl] * IVM * Application of statistical methods to climate variability and climate change

van Ulden [ulden@knmi.nl] * KNMI * Natural variability of the radiative forcing

K. Wakker [k.wakker@lr.tudelft.] * DEOS * Satellite altimetry and applied physical oceanography

NATIONAL REPORT FROM NEW ZEALAND TO THE CLIVAR PLANNING MEETING,

John W. Kidson, New Zealand National Contact for CLIVAR
New Zealand Climate Committee, Royal Society of New Zealand

1. Executive Summary

New Zealand is susceptible to both short-term climatic fluctuations and long term climate change. We endorse a vigorous international programme of research to improve understanding and prediction of the climate system and its variability.

We strongly support the CLIVAR programme but recommend that greater emphasis be placed on mid-latitude and Southern Hemisphere predictability. This might be achieved through a PBECS programme that includes Southern Hemisphere mid-latitudes.

New Zealand will contribute an increased atmospheric and oceanic modelling effort, and observational programmes exploring southern ocean variability. We will continue to monitor the transport and exchange processes affecting greenhouse gas concentrations and will extend paleoclimate studies to the South Pacific.

2. Introduction

Many sectors of the New Zealand economy are sensitive to short term climate fluctuations. In recent years, for example, there have been concerns over droughts affecting the farming industry, and insufficient precipitation for hydroelectric power generation and urban water supplies. The losses associated with the 1997/98 El Niño have been estimated at around one billion New Zealand dollars. With primary production, including agriculture and forestry, an important part of the economy, there is also concern over possible adverse affects of climatic change.

Understandably, the New Zealand Government is keen to see effort spent on improving knowledge and prediction of both climate variations affecting New Zealand, and providing the best possible estimates of potential climate change and its impacts.

3. International collaboration and CLIVAR

It is recognised that a strong international effort is needed if progress is to be made in forecasting climate variations and in providing estimates of the likely effect of climate change. We have been encouraged by the establishment of the IRI and CLIPS programmes, and have long supported the initiatives of the WCRP. We participated in the TOGA experiment and in WOCE, and are now keen to see the success of CLIVAR.

So far, our enthusiasm has been tempered by the lack of sub-programmes dealing specifically with mid-latitude predictability, particularly for the Southern Hemisphere. New Zealand is sensitive to ENSO fluctuations and strongly endorses the continuing effort to understand and predict them. However, they contribute only a fraction of the potential predictability in New Zealand's seasonal temperatures and precipitation, and there is a real need to consider middle and high latitude processes.

The "ENSO: Extending and Improving Predictions (G1)" sub-programme formally includes the development of improved prediction of the extra-tropical circulation and we would like to see more weight given to this area of research. This might be accomplished through the proposed Pacific Basin Extended Climate Study (PBECS) which is not yet part of the CLIVAR programme. While the initial proposals are primarily for an oceanic programme we would prefer to see it integrated with atmospheric studies. Tropical forcing is an important source of variability in the New Zealand climate on intraseasonal through decadal time scales and we believe an integrated basin-wide study could provide the opportunities to develop further our predictive skill. In the proposals for PBECS that we have seen, it is apparent that South Pacific oceanic processes critical to the global climate problem are not being adequately addressed. As with the proposed Indo-Pacific Decadal Variability (D4) programme, PBECS appears to be largely focused on the North Pacific, and we believe there is strong scientific justification for extending the area of study in each to cover the poleward boundary of the South Pacific sub-tropical gyre. Previous research points to a more direct connection between waters subducted in the Southern Hemisphere and equatorial flow than is the case for the Northern Hemisphere. Expansion of the study area down to at least 40°S would allow New Zealand to contribute work on the East Auckland Current, a major component of the southern subtropical gyre, which shows strong low-frequency variability.

On longer time scales, the "Indo-Pacific Decadal Variability (D4)" and "Southern Ocean Thermohaline Circulation (D5)" sub-programmes cover areas of interest to us and we are keen to see these develop further with participation from New Zealand, where appropriate. This could include detailed XBT sampling on a number of transects and monitoring the production and circulation of Sub-Antarctic Mode Water over the Campbell Plateau as outlined below.

4. Present New Zealand contributions to international programmes

As a small country New Zealand's resources are limited. Our research strategy concentrates on climate processes affecting New Zealand and the Southern Hemisphere, to complement the more extensive international research effort. Some research is also directed towards increasing global knowledge of climate change, through regional monitoring of trace gases and radiation within the New Zealand region and in the Antarctic.

Research funding in the atmospheric and oceanic areas comes almost exclusively from government sources through the Public Good Science Fund (PGSF), administered by the Foundation for Research, Science and Technology (FRST). Currently the total funding from this source for Marine and Atmospheric research is $NZ24.4M. The PGSF provides additional funding to support climate process and climate impact research, and other climate-related research is funded by the Universities.

The largest individual contributor to atmospheric and oceanic research is the National Institute of Water and Atmospheric Research (NIWA) which has a staff of over 500 and a budget of $65M. NIWA owns two research vessels, and will purchase a supercomputer in mid-1999 to support atmospheric, oceanic and fisheries modelling. Significant contributions also come from other Crown Research Institutes and the Universities.

a. Contributions to CLIVAR-GOALS

Interannual climate variability and development of climate forecasting includes both diagnostic and modelling studies of variability in the southern hemisphere circulation with particular attention given to the Australian - SW Pacific sector. Empirical relationships revealed by these studies are incorporated in operational seasonal forecasting procedures, along with ENSO forecasts obtained from overseas. SH model validation studies are also carried out, and climate change scenarios developed through statistical and model-based downscaling of global predictions obtained from other modelling groups. In recent years, efforts have focused on the ENSO and its influence on the New Zealand region, low frequency variability in the extra-tropical Southern Hemisphere, and its influence on storm tracks.

Variations in the oceanic circulation: Recent research voyages have concentrated on variations in the East Auckland Current, forming part of the subtropical gyre, and associated large eddies off New Zealand's east coast which inject oceanic water onto the continental shelf. Emphasis is also given to variability in the South Pacific Deep Western boundary current, which passes along the New Zealand continental margin and is a major part of the global "heat engine". Work has also recently begun on monitoring the production and circulation of Subantarctic Mode Water over the Campbell Plateau to the southeast of New Zealand. Some of this work is associated with the World Ocean Circulation Experiment.

b. Contributions to CLIVAR - DecCen

Paleoclimate studies: Research includes the reconstruction of past climates from instrumental records, analysis of decadal-scale variations and processes using recovered and homogenised historical series for both New Zealand and South Pacific islands. Methods for the detection of long term trends in local and global data and model output have been developed and applied.

c. Contributions to CLIVAR - ACC

Greenhouse gases, aerosols and UV radiation: Research concentrates on the detection and interpretation of changes in the main atmospheric greenhouse gases, carbon dioxide, methane and nitrous oxide, in the New Zealand, SW Pacific, and Antarctic regions. Stratospheric ozone depletion is studied at Lauder (Central Otago), one of five primary sites in the International Network for the Detection of Stratospheric Change (NDSC). Physical and chemical properties of aerosols are measured to determine the contribution of oceans to cloud condensation nuclei. Also national regional emissions of greenhouse gases are the subject of inter-disciplinary studies with a major focus being on methane from ruminant animals.

Atmosphere-ocean fluxes: A recent research initiative is a study of the ocean - atmosphere exchange of sulphur and carbon in the New Zealand region. Atmospheric oxidation of DMS to sulphate aerosol is being studied to determine whether this affects new particle formation in the marine boundary layer. Rapid removal of DMS has been observed and attributed to halogen chemistry. Repeated surveys of surface concentrations of dissolved carbon dioxide are being used to characterise the systematic behaviour of carbon dioxide uptake by the oceans and improve understanding of the driving processes. Work on gas exchange across the air - sea interface is using radar scattering techniques to quantify sea state including the nature and extent of wave breaking.

Paleoclimate studies: New Zealand has abundant proxy evidence (e.g. tree-rings, speleothems, glaciers, pollen, bore holes, ocean sediments) from which to assess climate over the last 1000 years, to enable improved global integration and model validation studies for the data sparse Southern Hemisphere. This provides good opportunities to shed light on the underlying trends in climate, to help place the 20th century in perspective and evaluate the pre-industrial forcing factors.

d. Logistic support and local studies

Maintenance of an observing network and a database of climate observations: NIWA's Climate Data Services programme co-ordinates the National Co-operative Climate Network, to obtain and archive data from hundreds of climate and rainfall stations operated by many individuals and organisations, and from the Meteorological Service's upper air stations included in the Global Upper Air Network (GUAN). NIWA also measures and archives New Zealand river flow measurements and has established a coastal network of sea level recorders.

Assessment of regional impacts of climate change: The multi-agency CLIMPACTS programme aims to develop a flexible system of coupled models and data sets for making integrated assessments of climatic effects on New Zealand agricultural crops, pasture, fruit crops and soils. The outcome will be an improved basis for decision-making and sustainable management of the environment in relation to climate variations and change.

Brief abstracts and full FRST contract reports from the above research areas may be found at http://www.frst.govt.nz/apps/database/rrsearch/index.cfm

5. Future New Zealand Contributions to CLIVAR

New Zealand will continue with its contributions outlined in the previous section and also plans new initiatives in the following areas:

a. GOALS

Climate modelling: NIWA will purchase a supercomputer in mid-1999 and will expand its climate modelling effort to include an ocean modelling component and the use of coupled models to explore climate variability on interannual through decadal time scales.

Oceanographic measurements: The use of remote sensing techniques will be expanded and NIWA will contribute to a number of observational programmes including: monitoring of the East Auckland current, Tasman Sea WOCE sections and high resolution XBT sampling; high resolution transects between New Zealand and the Ross Sea; and the building and deployment of floats in the New Zealand region in support of the ARGO programme.

b. DecCen

Historical studies: New Zealand will maintain an active programme to document past ENSO variations from historical and proxy data. We will collaborate with overseas research partners to extend tree-ring studies to the South Pacific.

c. ACC

Trace gas monitoring and air-sea fluxes: Measurements of the concentration and isotopic ratios of key trace gases in the New Zealand region and across the Pacific are being extended and interpreted with the aid of atmospheric transport and chemistry models. Continuous measurements of atmospheric oxygen and isotopic measurements of CO_2 in the atmosphere and ocean will be used to determine the magnitude and variability of the southern ocean sink of atmospheric CO_2. New direct measurements of air-sea gas fluxes will be used with radar measurements of sea state to improve understanding of gas exchange processes. New Fourier transform spectroscopy systems will be used to test models of ozone chemistry and monitor the expected recovery of the ozone hole early next century.

Paleoclimate studies: We will continue with an active programme to synthesize past climate variations and contribute to global datasets for model validation, using both land and ocean-based paleoclimate indicators.

New Zealand contacts for the CLIVAR programme

Science Liaison

a. CLIVAR

The prime New Zealand science contact for CLIVAR is Dr John Kidson, a member of the New Zealand Climate Committee of the Royal Society of New Zealand.
Dr John W. Kidson, National Institute of Water and Atmospheric Research Ltd., P.O. Box 14901, Wellington.
Tel: +64 4 386-0311 Fax: +64 4 386-2153 Email: j.kidson@niwa.cri.nz

The Royal Society of New Zealand, through its affiliated societies and committees fosters collaboration between New Zealand researchers and is responsible for links to international organisations affiliated with ICSU. The Royal Society's New Zealand Climate Committee maintains links to WCRP programmes, including CLIVAR.

Climate Committee Convenor:
Dr David Wratt, National Institute of Water and Atmospheric Research Ltd., P.O. Box 14-901, Wellington.
Tel: +64 4 386-0588 Fax: +64 4 386-2153 Email: d.wratt@niwa.cri.nz

Royal Society of New Zealand contact:
Mrs Sue Usher, Executive Officer, The Royal Society of New Zealand, P.O. Box 598, Wellington
Email: usher.s@www.rsnz.govt.nz, Tel: +644472-7421 Fax: +644473-1841
WWW: http://www..rsnz.govt.nz

The National Science Strategy Committee for Climate Change determines a co-ordinated research strategy for New Zealand's response to climate change issues. One of its tasks is to identify the areas of priority for funding for all providers, funders and users.

Convener:
Ms Judy Lawrence, Chief Executive, Ministry of Women's Affairs, P.O. Box 10-049, Wellington Tel: +64 4 473-4112 Fax: +64 4 472-0961 Email: lawrence@mwa.govt.nz
WWW: http://www..rsnz.govt.nz/ctees/nssclimate/index.html

b. World Meteorological Organisation
Permanent Representative of New Zealand with WMO
Mr John Lumsden, Chief Executive, Meteorological Service of New Zealand Ltd., P.O. Box 722, Wellington. Tel: +64 4 470-0708 Fax: +64 4 499-1942 Email: lumsden@met.co.nz

c. PAGES
The New Zealand contact for the PAGES programme is
Dr James Shulmeister, Research School of Earth Sciences, Victoria University Wellington, P.O. Box 600, Wellington, New Zealand. Tel:: +64 4 495-5233 ext 8409 Fax: +64 4 495-5186 Email: james.shulmeister@vuw.ac.nz

d. Science Policy
Science policy advice to government is provided through the:
Ministry of Research, Science and Technology, P.O. Box 5336, Wellington Tel: +64 4 472-6400 Fax: +64 4 471-1284 WWW: http://www.morst.govt.nz

e. Science Funding
Administration of the Public Good Science Fund is handled by:
Foundation for Research Science and Technology, 15-17 Murphy St., Wellington. Tel: +64 4 499-2559 Fax: +64 4 499-2568

Details of its procedures, priorities, and present and past research contracts which it has funded, may be found at:
http://www.frst.govt.nz

CLIMATE VARIABILITY RESEARCH ACTIVITIES IN NIGERIA

C.O. DUBLIN-GREEN, L.F. AWOSIKA and R. FOLORUNSHO
Nigerian Institute for Oceanography and Marine Research, P.M.B. 12729, Victoria Island, Lagos, Nigeria

Abstract

The Nigerian Institute for Oceanography and Marine Research (NIOMR) is actively involved in climate variability related studies through cooperation with International Agencies such as Intergovernmental Oceanographic Commission (IOC) of UNESCO and the National Oceanic and Atmospheric Administration (NOAA).

NIOMR through the assistance of IOC of UNESCO installed a conventional float operated tide gauge at its jetty on Victoria Island, Lagos. Tidal data are collected regularly and periodically sent to the PSMSL Centre in Bidston, U.K.

NIOMR's interaction with NOAA resulted in the installation of the Next Generation Water Level Measuring System (NGWLMS). The water level measuring equipment is a high precision acoustic system with ancillary sensors for air and water temperature, wind speed and direction and barometric pressure. Another collaboration between NIOMR and NOAA is the SEAS III programme. This joint effort resulted in the take-off of the Lagos-Rio-Lagos VOS track route AX.14. Data regularly collected include depth, temperature as well as other meteorologic parameters.

The Nigerian Government through the Nigerian Institute for Oceanography will continue to participate fully in climate variability research and become full partner in the implementation of CLIVAR programme.

1. Introduction

Nigeria is a maritime state with a coastline of approximately 853 km. It is located between Latitude 4° and 14°N and Longitude 2°45 and 14°30E. It is bordered to the North by the Republics of Niger and Chad, to the West by the Republic of Benin, to the East by the Republic of Cameroon and to the South by the Atlantic Ocean.

Nigeria has a total landmass of approximately 924,000 km^2 and a population of 88.5 million (Anon. 1992). Current estimates put the country's population at about 109 million with 20% of the population inhabiting the coastal Zone.

Physiographically, the country consists of several extensive plateaux, low-land and coastal plains. The plateaux are underlain by basement complex and volcanic rocks, while the lowland and coastal areas are composed of sedimentary rocks.

2. Climate

The Nigerian climate varies from tropical in the coastal area to sub-tropical up north. There are two regimes of climate: a dry season and a wet season. These two regimes are very dependent on the two prevailing air masses blowing over the country at different times of the year. The South Westerlies which blew from the South-West across the Atlantic Ocean towards the country bringing rainfall, and the hot, dry, dust-laden Harmattan wind which blows from the North-East across the Sahara desert with its accompanying dry weather and dust-laden air.

2.1 Rainfall

Annual rainfall in Nigeria is highest in the coastal areas and decreases inland to the lowest in the northern boundary of the country. The commencement of the wet season is earlier in the south, where it occurs in

February or March. It then continues to the end of November. Northwards, the onset of the wet season becomes progressively more delayed occurring as late as July in the extreme north-east, while cessation of rainy season is early between September and late September.

The wettest areas are in the south-east with mean annual rainfall varying between 2540 and 4060 mm, mean annual rainfall in the north is between 500-1500 mm.

2.3 Temperature

Nigeria's atmospheric temperatures are continually high and relatively stable throughout the year. Generally, the mean temperature ranges between 25°C and 30°C towards the interior because of the moderating influence of the sea. In the dry season, temperatures reflect more extreme conditions ranging from 20°C and 30°C.

3. Oceanography

The entire Gulf of Guinea is highly stratified with a thin surface layer of warm fresh tropical water (Longhurst, 1964). The stratification of the upper water column along the Gulf of Guinea is generally very strong except in areas subject to upwelling events.

In the Nigerian coastal waters, the upper limit of the thermocline is generally shallow about 12-15 m. The depth of the thermocline tends to increase with increasing distance offshore over the continental shelf.

3.1 Sea surface temperature

The surface water of the Nigerian coast is basically warm with temperature generally greater than 24°C. Sea surface temperature show double peaked cycles which match quantitatively the cycle of solar heights. Between October and May, sea surface temperatures range from 27°-28°C, while during the rainy season of June to October, the range is between 24° and 25°C.

3.2 Sea surface salinity

The surface water is typically oceanic surface water of the Gulf of Guinea with salinity generally less than 35.00%. In the Niger Delta, salinity range between 27-30% in January to March and 28-30% in June to September. This low salinity values are due to the influx of fresh water from the numerous estuaries of the Niger Delta.

3.3 Tides

The tides off shore Nigeria generally approach from the south-west and are of the semi-diurnal type. Tidal amplitude along the coast increases from west to east. The semi diurnal tides affecting the coastline generate tidal currents which are in phase with tidal cycles. Tidal current are strongest at the inlets and could vary from about 2.0 m/sec to 5.0m/sec. Tidal currents are very important in sediment transportation and dynamics along the Nigerian coastline.

3.4 Longshore currents

Prevailing south-westerly winds produce large powerful swell waves which approach the Nigerian coastline from the south-west direction. The waves break obliquely on the western barrier coast and the Niger Delta coast, thereby generating longshore currents. The currents sweep sediments along the west coast and along each flank of the Niger Delta away from the axis. Velocities of longshore current as estimated by Allen (1965) ranged from 0.22 m/sec to 1.0 m.sec.

3.5 Ocean currents

The west-east Guinea current is the dominant ocean current affecting the Nigerian coastline. Eastwards, the Guinea current joins the equatorial counter current which transport warm saline waters formed along the southern edge of the North Atlantic eddy. From the south, the cold saline Benguela current flows northwards becoming the south equatorial current. The Guinea current is important for the dispersal of suspended fines beyond the influence of wave and tide generated currents.

3.6 Storm surges

Storm surges occur periodically along the Nigerian coastline. This happens when plunging waves overflow the beach berm spilling waters on to the beach. The months of April and August are associated with the development of low pressure systems far out in the South Atlantic Ocean. These low pressure system usually generate large swells at sea. These swells are associated with rough seas, high waves and high tides in the form of surges. On reaching the shoreline, the waves produced by the storms break with high ferocity.

Normal waves heights along the Victoria beach range from 0.9 m to 2.0 m. However, during these swells, wave heights could exceed 4.0 m.

4. Climate related research activities

Nigeria as a maritime state, is signatory to the Law of the Sea Convention. Her sovereignty extends beyond her internal waters to her Territorial Sea of 30 nm. Nigeria established an Exclusive Economic Zone adjacent to the Territorial Sea extending 200 miles from the baseline. The surface of the continental shelf is 46,300 km^2 while the EEZ covers an area of 210,900 km^2 (World Resources 1990).

The Nigerian Institute for Oceanography and Marine Research (NIOMR) was established in 1975 and has the mandate to conduct research into the physical, chemical and biological characteristics of the Nigerian Territorial waters, the continental shelf and the Exclusive Economic Zone. Under this broad mandate, NIOMR through the Divisions of Marine Biology, Geology/Geophysics, Physical and Chemical Oceanography undertake several climate related research projects including the following:

4.1 Tidal gauge data: Sea Level Monitoring Studies

NIOMR operates two tide gauges: an analogue tide gauge and an acoustic tide gauge under the GLOSS (Global Sea Level Observing System) network. The analogue tide gauge was donated by IOC of UNESCO. Sea level data and tidal data are collected regularly. Decoded tidal data are also sent to the Permanent Service for Sea Level in Bidston, U.K

The Next Generation Water Level Measuring System (NGWLMS) was donated to NIOMR by NOAA. It is an acoustic type tide gauge with ancillary sensors for monitoring climate related parameters such as; wind speed, wind direction, wind gust, barometric pressure, primary water level, air temperature and water temperature. Data collected from the NGWLMS are processed and analysed in NIOMR, while the raw data are sent to NOAA.

4.2 Ship Board Environmental Data Acquisition System (S E A S III)

NIOMR and NOAA are collaborating in a climate related research known as SEAS III. The project is designed to collect oceanographic and meteorologic data with prompted data entry and transmission.

This collaborative effort involves the use of a voluntary observing ship (VOS):- Clipper - Sao Louis which is equipped with NOAA's ship-board environmental data acquisition system.

The VOS regularly transects the WOCE/TOGA route AX.14-Lagos-Rio-Lagos (Appendix 1). Data regularly collected along this route include; depth, temperature, wind speed, wind direction, atmospheric pressure, cloud type, cloud height, surface visibility, swells, and ice.

Data collected during navigation are automatically sent to NOAA, while the downloaded data is processed and analysed in NIOMR.

4.3 Expanded ENSO Committee

In Nigeria, meteorological records have shown the occurrence of ENSO four times within the last 15 years. The drought of 1997 and the cold spell in the rainy months of 1998 have been linked to the ENSO of 1997/1998. The inability to adequately predict the ENSO phenomena has adversely affected agriculture, water resources and fisheries in Nigeria. As a result, a joint Nigerian ENSO Committee, consisting of scientists from NIOMR and the Department of Meteorological Services was established early in 1998.

The mandate of the committee is to collate and analyse all historical meteorological and oceanographic data available in Nigeria with the aim of understanding ENSO events and discerning climatic trends. Preliminary results of the work of this committee revealed large data gaps.

5. Conclusion

The Nigerian Institute for Oceanography and Marine Research has been actively involved in climate related research activities. NIOMR'S GLOSS Station located in Lagos is presently generating data which compliments global initiatives for monitoring and predicting global climate variability trends.

Recent study on historical oceanographic data has revealed very wide data gaps which are traceable to the non-availability of ocean based meteorologic and oceanographic monitoring stations. Consequently, there is need for assistance in the establishment of monitoring stations and training of scientists to man the stations, process and analyse data collected. Such assistance would enhance the acquisition of prediction capabilities and compliment CLIVAR programme at understanding the role of the coupled ocean and atmosphere in Tropical Africa.

References:

Allen, J.R. (1964): The Nigerian Continental Margin: bottom sediments, submarine morphology and geological evolution. Marine Geol. Vol. I, p.298 - 332.

Anon (1992): Census figure released. New Nigeria No. 8073.

Longhurst, A.R. (1964): The Coastal Oceanography of Western Africa. Bull. Inst. Afr. Noire. Ser. No. 2, p.337 - 402.

NORWEGIAN CONTRIBUTION TO CLIVAR

1. Norwegian interest in CLIVAR

Norway welcomes and supports the initiatives which have been taken in developing the CLIVAR research programme and CLIVAR will undoubtedly play an important role for climate research in the years to come. Norway is likely to be affected by a possible climate change, and coordinated efforts in order to understand both natural variability and possible anthropogenic effects are strongly encouraged. At present Norway is involved in several CLIVAR-related research areas. We envisage that these activities will increase and that CLIVAR will play an important role in this process. It is therefore with great pleasure we can announce that Norway will contribute to CLIVAR.

Norway is situated in an area exposed to considerable climate variability on annual, decadal and centennial time scales. So far, these variabilities are poorly understood. However, it is important for the society that scientists are able to describe, understand and predict them with some accuracy. This is particularly true when bearing in mind the probable anthropogenic global warming taking place. The present-day Norwegian climate is above all dependent on the unique conditions of the adjacent sea areas and the proximity to the Arctic. Norway may, because of its geography, long coastline and many activities related to the sea and the coastal area, be particularly vulnerable to changes in the frequency of weather patterns and extreme events such as storms, floods, and spring tides.

Within the broad range of research disciplines in the area of CLIVAR, special priority is given to areas where Norway is in good position to advance scientific knowledge and understanding as a result of its geographical situation, research traditions and know-how. Norway has long and strong traditions in geophysical disciplines which are basic for understanding climate variability and predictability, such as Meteorology and Oceanography. In particular, geophysical processes in the Nordic and Barents Seas and in the Arctic have attracted considerable Norwegian research. Norway also has a strong paleoclimatic community focusing on research relevant to CLIVAR. However, we are not in the position to run fully coupled climate models with high resolution over a long time. For this we will have to rely on activities and products from major climate centres. Instead we focus our activities to regionalisation, process studies, and data collection.

Our present research activities related to CLIVAR can be grouped as follows:
- Establishment and maintenance of long and coherent series of paleoclimatic data;
- Establishment and maintenance of long and coherent series of regular climate data, including oceanic data and data for Arctic sea ice;
- Statistical and dynamical regionalisation of global climate simulations;
- Process studies related to the North Atlantic and Arctic Oceans;
- Studies of atmospheric processes, including climate effects of radiatively active gases and aerosols, and clouds;
- Studies of variability and predictability of the coupled climate system through development and application of models of different level of sophistication.

2. Norwegian contact points

CLIVAR activities within Norway are coordinated by The Research Council of Norway Norwegian Research (attn. Assistant Director Kirsten Broch Mathisen) in close cooperation with the Norwegian Meteorological Institute (attn. Prof. Thor Erik Nordeng).

3. Norwegian agencies which will participation in CLIVAR

Norwegian funding agencies, research institutes and universities which at present have expressed their intention to contribute to CLIVAR are (contact points in brackets):
- The Research Council of Norway, NFR, (Assistant Director Kirsten Broch Mathisen)
- Institute of Marine Research, IMR, (Senior scientist Harald Loeng)

- Nansen Environmental and Remote Sensing Centre, NERSC, (Director Helge Drange)
- Norwegian Institute for Air Research, NILU, (Professor Frode Stordal)
- Norwegian Meteorological Institute, DNMI, (Prof. Thor Erik Nordeng)
- Norwegian Polar Institute, NP, (Senior Scientist Jan-Gunnar Winther)
- University of Oslo, Department of Geophysics, UiO-IfG, (Prof. Trond Iversen)
- University of Bergen, Geophysical Institute, UiB-GfI, (Prof. Sigbjørn Grønås)
- University of Bergen, Department of Geology, UiB-GI, (Prof. Eystein Jansen)
- University Courses on Svalbard, UNIS, (Assoc. Prof. Peter M. Haugan)

4. CLIVAR research areas and Norwegian participation

Norway will participate in all three main research areas identified by CLIVAR: GOALS, DecCen and ACC, with special focus on DecCen and ACC. Ongoing activities are listed and described below.

1 Operative activities supporting CLIVAR

Several ongoing tasks directly or indirectly supports CLIVAR. Institute for Marine Research (IMR), the Norwegian Meteorological Institute (DNMI) and Norwegian Polar Institute (NP) have all national responsibility for collecting and analysing climate data. This observational network and its data supports mainly activity ACC (Anthropogenic Climate Change) subtask on Climate Change Detection and Attribution.

Institute for Marine Research operates research vessels, which carry out approximately 4-5000 CTD-casts per year in the North-eastern Atlantic relevant to CLIVAR (Implementation Plan 7.3). Observations of SST and salinity are carried out twice a week along the Norwegian coast since 1936. In addition there are also some other SST-observations from ships of opportunity which have repeating tracks i.e. across the North Sea.

IMR has since 1936 carried out regular observations from 8 fixed station along the Norwegian coast. The observations cover the entire water column. In addition regular observations from more than 10 standard hydrographic sections have been carried out since early 1950. The observation frequency, however, has increased during the last 20 years, and the sections are taken from 2-12 times per year in the North Sea, the Norwegian Sea and the Barents Sea.

Of large significance to CLIVAR are those meteorological stations which the *Norwegian Meteorological Institute* operates in the Arctic. The Arctic is expected to be strongly affected by a global warming and it is anticipated that the first *greenhouse signal* will be detected in this area. An uncertainty is the natural variability, which in the Arctic is large and may dominate over a greenhouse signal. At Svalbard homogeneous data exists from 1912. This data set and other similar data sets are important for climate change detection and for model validation.

DNMI operates a weather ship at station M in the Norwegian Sea. It has a long record of atmospheric soundings, but maybe more important for CLIVAR is its long record of temperature and salinity at various depths in the ocean.

The net production of ice mass in the entire Arctic Ocean is transported by the Transpolar Current through Fram Strait; the major connecting passage with the world oceans. This transport represents the world's largest fresh water flux next to Amazons. The *Norwegian Polar Institute* has monitored these fluxes and their variability since 1990 by the use of upward looking sonars (ULS) mounted on top of moorings. The flux of ice and freshwater through Fram Strait is a key CLIVAR/ACSYS variable, and Norwegian Polar Institute plan to continue the monitoring programme. Additionally, NP has since 1966 undertaken yearly mass balance studies of selected glaciers on Svalbard. These measurements represent one of the world's longest records of glacier mass balance. Also, the Norwegian Polar Institute records meteorological data in Ny-Ålesund, Svalbard, and at the sub-Antarctic island Bouvetøya as well as at the Troll Station on the Antarctic continent.

DNMI and NP operates a common ice-edge data base where ice maps on CD-ROM are available for the period 1966-1993. Further, NP works on a historical data set of sea ice extent that reach back to the 17th century.

For several years the *Norwegian Institute for Air Research* has measured the concentrations of certain climate gases at the remote Arctic location Ny-Ålesund in Svalbard.

In addition, hydrographic observations from the Nordic Seas are collected on a regular basis by the Dep. of Geophysics, Univ. of Bergen and the Nansen Environmental and Remote Sensing Centre.

2 Research tasks and projects supporting CLIVAR

Norwegian universities and research institutions, including those with operative responsibilities as IMR, DNMI and NP, are all strongly involved in CLIVAR related research. Norwegian contribution to CLIVAR is mainly grouped under ACC (Anthropogenic Climate Change) and in DecCen (Decadal to Centennial Climate Variability) and to a lesser extent in GOALS (Global Ocean Atmosphere Land System). Research is funded internally (i.e. by internal funds at the various institutions (core activities), by The Research Council of Norway, by international funding agencies (e.g. the environment programs of the European Union) and others.

A significant part of the Norwegian activities related to CLIVAR Initial Implementation Plan (IIP) are connected to the project "Regional climate development under global warming" (RegClim).

This project is a coordinated effort with contributions from the following six Norwegian research institutions: The Norwegian Meteorological Institute, Institute of Marine Research, Department of Geophysics at the University of Oslo, Department of Geophysics at the University of Bergen, Nansen Environmental and Remote Sensing Centre and Norwegian Institute for Air Research. Around 30 scientists are part-time involved in the project. Funding agency is The Research Council of Norway, and the project runs for the years 1997-2001.

The project has two overall aims. The first is to estimate probable changes in the regional climate in Northern Europe, bordering sea areas and major parts of the Arctic given a global climate. The second aim is to quantify, as far as possible, uncertainties in these estimates, inter alia, by investigating the significance of regional scale climate forcing pertaining specifically to our region. This includes processes determining SST and sea-ice cover in the Nordic Seas, and processes related to radiatively active contaminants with a regional distribution (direct and indirect effects).

The project thus encompasses three areas:

- dynamical and statistical downscaling of climatic change estimates from coupled atmospheric-oceanic GCM's;
- variability of the Norwegian Atlantic Current (NAC) and the response of the Nordic and Arctic Seas to climate change,
- direct and indirect effects on climate of regional contaminants (ozone and aerosols).

Dynamical and statistical downscaling

The aim of this part is to estimate a probable regional climate change in our area, given the best estimates of climatic change from a coupled Atmospheric-Oceanic GCM. The dynamical approach is being made by the Nordic limited area model HIRLAM with physical parameterisation from the MPI-model, Hamburg. Stretched coordinates are used with a focus of the resolution over Scandinavia. The integration area includes Greenland. Different statistical downscaling methods are being evaluated. The downscaling activities take place at DNMI.

Variability of the Norwegian Atlantic Current

The aims of the ocean modelling are to establish and validate a model tool for the Nordic Seas and surrounding sea areas, and to study the variability of the circulation and the response to global warming. The aims of the coupled model, which focus on the air-sea interaction in the North Atlantic are to study the relative role of various mechanisms influencing the variability of the NAC. The main activities are centred at research institutions in Bergen and at DNMI.

The primary oceanic model is a polar version of the Miami Isopycnic Coordinate Ocean Model MICOM (University of Miami) developed at the Nansen Environmental and Remote Sensing Centre. The model, which covers the North Atlantic Ocean from 20 degrees south and northwards, including the Arctic Ocean, is used in a stretched mode with focus of the resolution in the northern areas. The horizontal resolution is sufficient to get a good representation of the flow between the Nordic Seas and the main Atlantic Ocean. In addition, the Princeton Ocean Model (POM) is actively used within the project. The proximity of extremely cold air masses over the Arctic ice has a significant influence of our climate. Realistic modelling of the variations of the sea-ice is of vital importance in the study of climate variations in our area. Because of this, sea-ice modelling and the coupling of the ocean model with a sea-ice model is given high priority.

Further, a global version of the above mentioned MICOM model will be coupled with the ARPEGE/IFS climate model. The global ARPEGE/IFS model has been tested on AMIP-data in a stretched mode with focus of the resolution on the North Atlantic Ocean. In addition, the atmospheric response to variations in the extension of the arctic sea ice is studied.

Regional distribution of direct and indirect radiative forcing from contaminants.

The aim of the studies of indirect effects is to refine the parameterisation of cloud processes of particular importance for our region and to link aerosols to the microphysics of the cloud scheme. In interaction with the radiation scheme the indirect radiative forcing of the aerosols is thus calculated, with little degree of parameterisation. The response on the climate will be estimated in a version of the NCAR atmospheric community climate model (CCM). The aim of the direct effect studies is to calculate the regional distribution of direct radiative forcing due to tropospheric ozone, sulphate and black carbon, and to estimate the response on the climate. The activity of the two tasks are centred to Department of Geophysics, University of Oslo and The Norwegian Institute for Air Research (NILU).

A similar coordinated project dealing with *paleoclimatic climate reconstruction* will be starting in 1999. The project, NORPAST, coordinates efforts from major Norwegian paleoclimate groups, mainly located at the Universities and at the Norwegian Geological Survey. The main focus of this project is a concerted effort in obtaining paleoclimatic time series from Norway and adjacent oceans from lake and marine sediments using paleoclimatic proxy methods to extract climatic variables covering the last 10.000 years with special focus on the last 2000 years. The aim is to extend the instrumental records in this manner and obtain a resolution which at a minimum shall resolve multidecadal scale variability. A coordination office will be established at the Norwegian Geological Survey in Trondheim.

An ongoing international project with large national involvement is VEINS (Variability of Exchanges in the Northern Seas). Norwegian participating institutions are Institute of Marine Research, The Norwegian Meteorological Institute, Geophysical Institute at University of Bergen, Norwegian Polar Institute and University Courses on Svalbard (UNIS). The overall objective of VEINS is to measure and to model the variability of fluxes between the Atlantic and the Arctic Ocean with a view on implementing a longer term system of critical measurements needed to understand the high-latitude oceans steering role in decadal climate variability. The project will quantify the magnitude of the variability of fluxes and improve the understanding of processes responsible for the variability. In addition a conceptual model of exchanges and water mass alterations between the Atlantic and the Arctic Ocean will be developed. It will be used to estimate the integrated effect of the exchanges from the measurement areas and to design an optimised measurement programme to be continued up to a decadal period. The project is limited in time, but it is a goal to define long term monitoring strategies, and it is anticipated that part of the measuring program will continue in order to monitor and assess to variability of Atlantic inflow to the Nordic and Barents Seas. Models will continue to be an important tool in understanding the forces behind the variability.

Research activities supporting CLIVAR within the different institutions (more information in Ap-

pendix)

Institute for Marine Research (IMR)

A large part of the climate research and monitoring at the Institute of Marine Research (IMR) is governmentally funded by the Ministry of Fisheries as a core activity, but important projects are also supported by The Research Council of Norway and EU. Most of the climate research on seasonal to decadal time scales is also linked to the effect of climate variabilities on the ocean ecosystems. Activities are concentrated around description of the marine environment (variability and state of climatic parameters) based on ship observations and numerical modelling.

Nansen Environmental and Remote Sensing Centre (NERSC)

The climate research at NERSC is focusing on problems related to the marine climate of the North Atlantic Ocean, the Nordic Seas, and the Arctic Ocean on seasonal to decadal time scales. Therefore, the DecCen sub-programs *The North Atlantic Oscillation* and *Atlantic Thermohaline Circulation* fall in the mainstream of existing activities at the centre. A substantial part of the activities are supported by the Norwegian Research Council and the MAST and Environment programs of the European Union, leading to tight contact with European climate centres. Ongoing activities focus on simulations of the general circulation and thermodynamics in the region by means of a high latitude version of the MICOM model developed at the centre; simulations of the natural cycling of carbon dioxide in the region; detection of seasonal to decadal variability of the North Atlantic and Arctic climate systems based on instrumental and high-resolution proxy records; and design of monitoring schemes and systems for the Nordic Seas and the Arctic Ocean.

Norwegian Institute for Air Research (NILU)

Norwegian Institute for Air Research (NILU) is involved in climate research in basically three different areas. For several years NILU has measured the concentrations of certain climate gases at the remote Arctic location Ny-Ålesund in Svalbard. Secondly, extensive studies have been made of stratospheric as well as tropospheric ozone, including observations of ozone and related chemical compounds, and theoretical studies of processes governing the ozone distribution in the atmosphere. The theoretical studies have over the last 5 years been directed much in the direction of understanding the role of ozone in the climate system. Finally, NILU has been working on calculations of the radiative forcing due to all man-made constituents that influence the climate system.

Norwegian Meteorological Institute (DNMI)

A substantial part of climate research at the Norwegian Meteorological Institute (DNMI) is funded internally as a core activity. In addition DNMI is running a number of research projects funded by The Research Council of Norway, the European Union or other international agencies. These research projects may mainly be categorised under CLIVAR DecCen and ACC. In addition to RegClim and VEINS, which are described above, these are studies of long time series of climate parameters, studies of local effects in terms of storms, storm surges and waves of a possible climate change and improving parameterisation methods used in climate models. DNMI is also running an assessment programme (data exist from 1985) to establish trends in air concentration and depositions over Europe on acidifying and eutrophying components.

Norwegian Polar Institute (NP)

The Norwegian Polar Institute is involved in a number of climate-related projects, mainly within oceanography and glaciology. With respect to the CLIVAR programme, the research falls thematically within DecCen and ACC. In total, 25 scientists are partly or fully involved in climate research at NP. Funding comes from the Ministry of Environment, the European Union, The Research Council of Norway, and other Norwegian companies. The Norwegian Polar Institute carries out projects in Arctic and Antarctica with main focus on sea ice, glaciers and snow and their role for the climate system.

University of Bergen, Geophysical Institute (UiB, GFI)

UiB-GFI covers both oceanography and meteorology. The climate studies are focused on physical processes related to climate variability, in particular those related to the marine climate of the North Atlantic, the Nordic Seas, and the Arctic Ocean on seasonal and decadal time scales. UiB-GFI is involved in collection and analysis of observations as well as development and application of numerical models of the atmospheric climate, the oceanic climate and numerical models of the coupled climate system. The CLIVAR DecCen sub-programs on The North Atlantic Oscillation and Atlantic Thermohaline Circulation are relevant for the research, but to a lesser degree also some issues of CLIVAR-GOALS and CLIVAR-ACC. The activity is supported by The Research Council of Norway and by different Environment programs of the European Union.

University of Bergen, Department of Geology (UiB, GI)

The paleoclimate group at the Univ. of Bergen is currently focusing more of its research into the time scales of CLIVAR DEC-CEN. The research activities focuses on assessments of the long term behaviour of decadal to century scale variations in oceanic heat flux off Norway for the past 2000 years, and in obtaining data for terrestrial temperatures and precipitation on the same time scales. The research is based on using paleoclimatic proxy methods from rapidly deposited sediments and carbonate fossils with annually resolved records to extract paleoclimatic data. The Department is together with the Dept. of Botany a major contributor to the NORPAST project mentioned above.

University of Oslo, Department of Geophysics (UiO, IfG)

A large fraction of the research activities at the Department of Geophysics, University of Oslo deals with anthropogenic climate change (ACC). The activities are related to CLIVAR's principal research areas ACC, (Climate Change Prediction) and ACC (Climate Change Detection and Attribution). Activities are mainly concentrated within studies of changes of the atmospheric composition due human activities, chemical and radiative feedback processes in the atmosphere and improving parameterisation schemes for condensation processes with emphasis on cloud microphysics.

University Courses on Svalbard (UNIS)

UNIS is an international university centre established by the four Norwegian universities with basic funding by the Norwegian government. UNIS gives courses in air-ice-sea interaction and related subjects and is a focal point for field oriented university research in the area. CLIVAR related research at UNIS includes studies of deep exchange through Fram Strait, the West Spitsbergen current, process studies of ice freezing and brine formation, open ocean deep convection, and seasonal variability of the Arctic air-ice-ocean system.

5) CLIVAR infrastructure

Institute for Marine Research is running the Norwegian Marine Data Centre (NMD) which is the Norwegian national oceanographic data centre. NMD has through EU project experience in storing and distributing data for projects with several participants. NMD may take responsibility for marine data from the Northeast Atlantic, which means the Nordic Seas (including the areas around Iceland and the Faeroes), the North Sea and the Barents Sea.

6) National comments on the Initial Implementation Plan

The CLIVAR Implementation gives a comprehensive and impressing review of issues that have to be addressed in climate research. It is the Norwegian position that attention should be given to further elaboration of CLIVAR research plans for climate variations in the Arctic, processes in the Nordic and Arctic Seas (including air-ice-sea interaction), to the exchange of water masses between the Arctic and Atlantic Oceans, and exchange processes between the troposphere and the stratosphere in polar regions. The close ties between CLIVAR and operational monitoring planned within GCOS through OOPC and AOPC are welcomed as it secures a maximum benefit from the observations carried out by those programmes.

Coupled GCM simulations under conditions with increased CO_2 concentrations indicate a maximum warming at high latitudes, particularly in late summer/early autumn due to a later sea ice formation. It has therefore been suggested that a *greenhouse signal* first will be detected in this area. This is not necessary true since the variability is large, reducing the signal to noise ratio. We therefore feel that CLIVAR should be strengthened on processes in the Arctic, e.g. by improving the modelling of difficult physical processes (strong surface fluxes, leads in the ice, shallow convection, convection in the sea, sea-ice modelling etc.).

The main exchange of water between the Arctic Ocean and the Atlantic takes place through the Nordic Seas. The inflow of Atlantic Water to the Arctic Ocean takes part with almost equal amounts through the Fram Strait and the Barents Sea, while the outflow mainly takes part through the Fram Strait. International research within CLIVAR could focus more on these water flows, since they beyond doubt play an important role for air-sea interactions relevant to climate variability. We would, however, encourage more focus on seasonal to decadal time scale in the studies of the North Atlantic. We believe that this short term variability also is important in order to understand driving forces, and especially interactions between atmosphere and ocean (including sea ice).

Appendix - CLIVAR activities within individual institutions

Institute for Marine Research (IMR)

A large part of the climate research and monitoring at the Institute of Marine Research (IMR) is governmentally funded by the Ministry of Fisheries as a core activity, but important projects are also supported by The Research Council of Norway and EU. Most of the climate research on seasonal to decadal time scales is also linked to the effect of climate variabilities on the ocean ecosystems. In addition to projects like RegClim and VEINS, which are described above, the main overall activities are:

- Description of the variability, state and next year forecast of the marine climate (environment) in the North Sea, Norwegian Sea, Barents Sea and along the Norwegian coast, reported annually based on 1000 ship-days of observations per year and extensive numerical model simulations.
- Identification and quantification of the variability of the most important climatic parameters (circulation, temperature, salinity, stability, turbulence, light) causing variability in the ocean ecosystems and their productivity (the North Sea, Norwegian Sea, Barents Sea, Norwegian coast and the Benguela upwelling system)
- Determination of the variability in and causes for the distribution and pathways of the main water masses (North Atlantic Water and Arctic Water (and Coastal Water) being critical for the Nordic climate.
- Development and evaluation of realistically forced 3-D numerical circulation models (coupled with primary production modules, contaminant and fish larval drift modules).
- A project on *Description and quantification of the Benguela coastal circulation and upwelling, and its impact on the biological productivity, recruitment and fish distribution (BENUM*) is partly relevant to GOALS *African Climate Variability*. The main objective is to understand and quantify the impact of upwelling and large scale ocean climate parameters on the plankton production, and the trophic transfer from plankton to fish in the Benguela ecosystem. This is done by setting up a coupled biological/physical numerical model for the region. Using real wind forcing, the model is run for several years, and the interannual variability is studied.

Nansen Environmental and Remote Sensing Centre (NERSC)

The climate research at NERSC is focusing on problems related to the marine climate of the North Atlantic Ocean, the Nordic Seas, and the Arctic Ocean on seasonal to decadal time scales. Therefore, the DecCen sub-programs *The North Atlantic Oscillation* and *Atlantic Thermohaline Circulation* fall in the mainstream of existing activities at the centre. A substantial part of the activities are supported by the Norwegian Research Council and the MAST and Environment programs of the European Union, leading to tight contact with European climate centres.

Over the last 5 years, a regional North Atlantic and Arctic version of the ocean model MICOM has been developed at the centre. The regional model is also extended and applied to global climate related problems. Ongoing modelling activities include examination of

- The effect coarse, medium, and high horizontal grid resolutions have on the sensitivity and the natural variability of the North Atlantic, Nordic Seas and Arctic Ocean climate system
- The effect prolonged anomalous wind conditions have on the circulation in the North Atlantic Ocean and

the Nordic Seas

- The patterns of natural variability of the atmosphere and the oceans on interannual to decadal time scales
- The stability and variability of the North Atlantic thermohaline circulation to input of fresh water into the Arctic Ocean
- The natural cycling of plant nutrients and total dissolved inorganic carbon in the North Atlantic Ocean and the Nordic Seas, including the natural cycling of carbon dioxide
- The oceanic thermohaline circulation on meso and large scales and its dependence on surface fluxes of heat, fresh water and momentum; and the fate of newly formed waters as they leave into the Norwegian Sea, the Iceland Sea and over the Denmark strait, thus contributing to the global ocean circulation

Additional CLIVAR related activities at NERSC include:

- Determination and interpretation of the characteristics of the seasonal to decadal variability of high-resolution instrumental and non-instrumental climate series from Norway and the adjacent seas
- Process studies related to the preconditioning, evolution, and fate of water masses taking part in winter time mixing in the Nordic Seas
- Systematic analysis of *in situ* and satellite data sets on climate parameters for the Arctic and Sub-Arctic; and design of a long term monitoring scheme to detect the patterns of high latitude Greenhouse Warming
- Development and design of an acoustic system for long-term monitoring of the ocean temperature and ice thickness in the Arctic Ocean, including the Fram Strait

Norwegian Institute for Air Research (NILU)

Norwegian Institute for Air Research (NILU) is involved in climate research in basically three different areas. For several years NILU has measured the concentrations of certain climate gases at the remote Arctic location Ny-Ålesund in Svalbard. Secondly, extensive studies have been made of stratospheric as well as tropospheric ozone, including observations of ozone and related chemical compounds, and theoretical studies of processes governing the ozone distribution in the atmosphere. The theoretical studies have over the last 5 years been directed much in the direction of understanding the role of ozone in the climate system. Finally, NILU has been working on calculations of the radiative forcing due to all man-made constituents that influence the climate system.

The research areas of relevance for CLIVAR at NILU are as follows:

- Observations of climate gases at the Zeppelin Mountain in Svalbard. These are background observations in a clearly remote region. Methane(CH_4), nitrous oxide (NO_2) and a wide range of CFC92s have been included in the measurement program. Up till recently, measurements were made as grab samples twice per week. Currently, methane is measured continuously, and there are plans to measure other gases continuously as well.
- Observations of stratospheric ozone and ozone depleting substances, by the use of ozone sondes at two locations in Norway, and remote sensing spectroscopic instrumentation in Ny-Ålesund.
- Modelling and other theoretical studies to study processes governing the distribution of stratospheric ozone, including understanding the observed ozone depletion at high and middle latitudes in the Northern Hemisphere.
- Observations of surface ozone at several locations in Norway, and ozone precursors in two locations. NILU has also participated in larger European projects where aircraft have been used to measure ozone and its precursors over Europe.
- Modelling and other theoretical studies of tropospheric ozone, aimed at understanding the processes governing the global and regional distribution of ozone, the trend in tropospheric ozone, and possible anthropogenic influence due to emissions of ozone precursors. During the last 5 years, special emphasis has been put on studies of the impact of emissions from aircraft.

Calculations of the radiative forcing due to man-made climate compounds, including CO_2, CH_4, N_2O, tropospheric ozone, stratospheric ozone, and aerosol particles. The estimations have aimed at making estimates of the effects of all of these species using a common methodology, to ensure proper comparison of the effects of the individual components. Originally the perspective was purely global, but it has now been extended to also emphasise also regional scales.

Norwegian Meteorological Institute (DNMI)

A substantial part of climate research at the Norwegian Meteorological Institute (DNMI) is funded internally as a core activity. In addition DNMI is running a number of research projects funded either by The Research Council of Norway or the European Union. These research projects may mainly be categorised under CLIVAR DecCen and ACC. In addition to RegClim and VEINS, which are described above, these are:

- Investigation of long-time variations and covariations between atmospheric circulation patterns and local climate in the Norwegian Arctic.
- Study how models simulate oceanic circulation on decadal time scales and to identify weaknesses in the model simulations (Semi-global Oceanic Teleconnections).
- To improve the description of clouds, condensation and precipitation processes in numerical atmospheric climate models.
- To study and compare how strong storms, storm surges and waves in a future climate, as given by scenarios from global circulation models, compare with present day climate.
- Running an assessment programme (data exist from 1985) to establish trends in air concentration and depositions over Europe on acidifying and eutrophying components.

Norwegian Polar Institute (NP)

The Norwegian Polar Institute is involved in a number of climate-related projects, mainly within oceanography and glaciology. With respect to the CLIVAR programme, the research falls thematically within DecCen and ACC. In total, 25 scientists are partly or fully involved in climate research at NP. Funding comes from the Ministry of Environment, the European Union, the Research Council of Norway, and other Norwegian companies. The Norwegian Polar Institute carries out projects in Arctic and Antarctica and the objectives of these activities are as follows:

- to study exchange of mass, heat, and salt through the Fram Strait, especially the transport of sea ice from the Arctic Ocean
- to monitor the variability of fluxes between the Atlantic and Arctic Oceans (VEINS)
- to examine the effects of the North Atlantic Oscillation (NAO) on the climate system such as on the sea ice extent
- to investigate changes in the thermohaline circulation and their impact on biodiversity and habitat for marine living resources in the Barents Sea
- to study large scale circulation patterns in the Kara Sea as well as shelf processes such as sea ice formation and sea ice drift
- to analyse melt-freeze processes beneath ice shelves in Antarctica and the formation of Antarctic bottom water
- to understand climatic variability on decadal to centennial time scale by analyses of ice cores in Antarctica and Svalbard together with marine sediment cores in the Atlantic Ocean
- to monitor glacier mass balance and dynamics and how glaciers respond to climate changes
- to undertake studies of the hydrological system through measurements of snow distribution, snow melt, surface energy balance, processes in active layer/permafrost, and runoff
- to analyse historical meteorological date series, in particular UV radiation and its effect on biota

University of Bergen, Geophysical Institute (UiB, GFI)

UiB-GFI covers both oceanography and meteorology. The climate studies are focused on physical processes related to climate variability, in particular those related to the marine climate of the North Atlantic, the Nordic Seas, and the Arctic Ocean on seasonal and decadal time scales. UiB-GFI is involved in collection and analysis of observations as well as development and application of numerical models of the atmospheric climate, the oceanic climate and numerical models of the coupled climate system. The CLIVAR DecCen sub-programs on The North Atlantic Oscillation and Atlantic Thermohaline Circulation are relevant for the research, but to a lesser degree also some issues of CLIVAR-GOALS and CLIVAR-ACC. The activity is supported by The Research Council of Norway and by different Environment programs of the European Union. Ongoing projects focus on:

- Physical processes and climate variability in The Nordic and the Arctic Seas
- Physical-dynamic processes in coastal and shelf waters (measurements and simulations)
- Physical processes in the Antarctic Ocean, in particular dense water formation at Filcher-Ronne Ice shelf and the Weddell Sea Continental Shelf
- Exchange of carbon in the Nordic and Arctic Seas
- Simulation of centennial variations in the global ocean
- Atmospheric variability, in particular classification of weather types in the North Atlantic (1880-1990), climate variations in Tibet (Landsat data) and precipitation variability in Equador
- Chemical and physical processes in snow and ice
- Simulations of polar lows, arctic inversions, arctic fronts and outbreaks of cold air from the sea-ice
- Global atmospheric simulations with use of stretched coordinates with focus in the North Atlantic. The model is used to study he influence of arctic sea-ice extension on climate variations and the effect of stratospheric ozone variations on the climate system
- Global coupled atmospheric/oceanic simulations. A model where the resolution is focused in the North Atlantic in both components is being developed (cooperation with NERSC).

University of Bergen, Department of Geology (UiB, IFG)

The paleoclimate group at the Univ. of Bergen is currently focusing more of its research into the time scales of CLIVAR DEC-CEN. The research activities focuses on assessments of the long term behaviour of decadal to century scale variations in oceanic heat flux off Norway for the past 2000 years, and in obtaining data for terrestrial temperatures and precipitation on the same time scales. The research is based on using paleoclimatic proxy methods from rapidly deposited sediments and carbonate fossils with annually resolved records to extract paleoclimatic data. The Department is together with the Dept. of Botany a major contributor to the NORPAST project mentioned above. Ongoing projects focus on:

- Assessing the decadal, century and millennial scale variability of the last 10.000 years in northern Europe and adjacent seas. Is the natural variability in principle the same during different forcing situations?
- Climatic variability and assessing the change in the northward oceanic heat flux during the last 2000 years. The aim is to assess the magnitudes of oceanic variability, its periodicities and the links between oceanic variations and terrestrial responses in temperature and precipitation before and under the influence of anthropogenic forcing. This work aims to obtain long time series of NAO related variability over the last 2 millennia.
- Rapid environmental change. Studies of the mechanisms for rapid climate change during forcing situations different from the modern to assess the sensitivity of the thermohaline circulation especially to freshwater forcing.

University of Oslo, Department of Geophysics (UiO, IFG)

A large fraction of the research activities at the Department of Geophysics, University of Oslo deals with anthropogenic climate change (ACC). The activities are mainly related to CLIVAR's principal research areas ACC (Climate Change Prediction) and ACC (Climate Change Detection and Attribution):

- Research on regional and global impacts of changes in the atmosphere's composition due to human activities carried out through global model simulations, where various chemical reactions are treated, as well as the dynamics and physics of the atmosphere with focus on tropospheric and stratospheric ozone and how human activities, including, e.g., aircraft emissions, affect the life cycles and concentrations of ozone.
- Studies of chemical feedback processes in the atmosphere and their impact on chemically active greenhouse gases like CH_4. Large attention is also given to investigations of the radiative forcing due to anthropogenic greenhouse gases.
- Direct and indirect effects of anthropogenic aerosols by modelling of the life cycles of sulphur and black carbon in the global atmosphere, and their radiative effects, and investigating their role in the cloud microphysics scheme of a climate model (indirect effects).
- Improving the parameterisation schemes used in global climate models, both to improve cloud parameterisations, with particular emphasis on cloud microphysics and the radiative properties of non-spherical ice crystals, and to develop parameterisation schemes for meridional eddy transport, e.g., for use in 2-D climate models. Work is also under way to develop chemical schemes to be included in climate mod-

els.

- Studies are being carried out of the response to forcing changes of non-linear systems, as a means of explaining observed climatological time series.
- Research related to the variability of the North Atlantic Oscillation (NAO), cf. CLIVAR's principal research area DecCen (North Atlantic Oscillation).

PARAGUAY

The vulnerability of a nation to the climate fluctuations and the effects of these in the economy were shown recently in Paraguay, country located in the center of the South American region.

This way, as consequence of the phenomenon ENSO (El Niño Southern Oscillation) 1997/98 in its warm phase, during the summery station, registered torrential rains whose volumes ended up triplicating the values seasonal means producing floods and enormous damages fundamentally in the social sector due to the evacuation of thousands citizens, as well as severe damages in the road infrastructure, the agricultural activity and the electric power distribution.

Although the ENSO has an important influence in the climate variability of the Paraguay, it is not the only factor that determines it. This way, annually they repeat intense rains, strong winds, waves of heat, floods and in occasions, periods of drought that have their origin in other factors, well-known some of them, and others that should be investigated.

So far, isolated efforts in empiric research on climate carried out by work groups composed for scientists of the National University of Asuncion and the National Weather Service (NWS) clerk of the National Direction of Civil Aeronautics (DINAC), national agency responsible for monitoring the atmosphere.

Considering that Paraguay bases its economic production fundamentally on the agriculture and the cattle raising, both highly dependent of the environmental conditions, any advance in the seasonal climatic forecast would allow to improve the planning to increase the production

In this sense, the Paraguay manifests its interest in the CLIVAR Programme, and to participate actively of it in its main research areas, with emphasis in:
G1: ENSO - Expansion and improvement of the predictions
G3: Variability of the American Monsoon System (VAMOS)
A1 and A2: Anthropogenic Climate Change.

The main contribution of Paraguay to CLIVAR Programme would consist on providing environmental data of the country (atmospheric, water resources, among other) available in the institutions interested in participating of CLIVAR. In a same way, the commitment of the scientists of the participant institutions to develop combined projects.

With regard to the available data, these are generated fundamentally by the observation network in real time of the National Weather Service of the DINAC. However, due to the existence of other nets of hydrometeorological and environmental observations, the National Weather Service is heading to integrate the data of the same ones and to compose a NATIONAL DATA BANK properly normalized and homogenized.

On the other hand, Paraguay has two projects at the present time in execution with main scope to improve the quantity and quality of the available data. With these projects at the end of 1999 NWS will incorporate to the system of atmospheric and hydrological observation of the country, a significant number of automatic weather station with satellite transmission and a meteorological radar (Doppler weather radar band C).

To medium range, with the execution of the Ibero-American Climate Project (WMO-IDB) the NWS hope sharp improvements in the system of observation of the atmosphere and water resources, the communication system and data process. Equally an important percentage of the budget will be dedicated in high level education in the meteorology, climatology and related sciences areas, scarce at the present time.

The national institutions interested in participate of CLIVAR Programme are:
The National Weather Service of the DINAC.

The National University of Asuncion through the following Areas:

Faculty of Exact and Natural Sciences - Laboratory of Atmospheric Research and Environmental Problems (LIAPA). This institution is focal point under the Interamerican Institute for Global Change Research (IAI).

Faculty of Polytechnic - Area of Meteorology.

Faculty of Engineering - Department of Development of Investigations (DDI).

Ministry of Agriculture and Cattle raising through the Vice Ministry of Natural Resources and Environment and the National Agronomic Institute through the Agrometeorology Programme.

Multipurpose Environmental Monitoring Center (will be implemented).

The NWS would act as the focal point for CLIVAR and can coordinate the activities with the other institutions with jointly developed projects. The proposed focal point is the Director of the National Weather Service of DINAC:

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Asuncion - Paraguay

Finally, through the Programa CLIVAR, the Paraguay waits:

- To increase the knowledge of the processes involved in the country and the region climate variability.
- To offer better quality in the services of climatic prediction (at the moment based on results of models of prediction of the specialized Centers like IRI, CPTEC, ECMWF and others).
- To promote new local researches and to upgrade the degree of the same ones.
- To participate actively, under its possibilities, of all the programs related with the CLIVAR pro-

THE POLISH CONTRIBUTION TO THE CLIVAR RESEARCH PROGRAMME

Prepared by Dr. Miroslaw Mietus and Dr. Jan Piechura

In Poland climatological researches have a long tradition. The analysis of instrumental observations and other paleo climate data have been performed by several Polish research groups for decades. The main activity is focused in the Institute of Meteorology and Water Management, Institute of Geophysics and Institute of Oceanology of the Polish Academy of Science, Institute of Environmental Protection and in geographical departments of several Polish Universities.

Institute of Meteorology and Water Management (IM&WM) serves as the Polish meteorological and hydrological service. Since 80 years Institute carries regular meteorological and hydrological observations and provides the government and the society with the vital information on the actual state of the atmosphere and the hydrosphere, prepares the weather forecasts as well as the warnings on specially dangerous phenomena. In cooperation with the other governmental agencies IM&WM also monitors the air and water quality including their radioactivity. Since the beginning of 20's Institute operates the marine weather service and is responsible for the sea level measurements. For the last 30 years IM&WM plays the key role in monitoring of environmental conditions of the Baltic Sea.

Institute provides the government and business with the high quality specialized expertise in area of meteorology, hydrology, climatology and oceanography.

IM&WM is routinely supporting the WWW, GCOS and GOOS with results of observations from the surface network, upper air sounding network including ozone information, sea level gauge system and VOS system. Real time transmitted data as well as the other ones from the national archive were used successfully within WCRP, IGBP and others. Since nearly 35 years IM&WM is actively participating in many international programs concerning interaction between atmosphere and ocean. More than 700.000 SHIP Reports were collected by Institute, controlled according to CMM rules and distributed according to area of responsibility. The scientists from IM&WM are actively participating in works of the IPCC.

For purposes of climate monitoring as well as to study its variability some long existing meteorological stations were designated as reference stations and were included to WMO specialized network. Several long-term time series of the main meteorological parameters were homogenized and used in many international projects. To ensure a proper realization of homogenization procedure the extended study concerning meta-data have been made. The old historical documents are actually study to reconstruct climatic conditions during XIV and XV century in region of old historical city Cracow.

The relationship between large scale and regional meteorological fields are studying for detection of existing teleconnections, eventual climatic changes and for preparing seasonal forecasts. The advanced method have been implemented to determine the empirical transfer functions between large scale parameters like atmospheric circulation and North Atlantic SST and the local climatic, hydrological and oceanographic condition in Poland. Defined connections and results from different GCMs are used to estimate possible climate realization under condition of doubling of CO_2 concentration.

For many years IM&WM carries on regular radiosounding of atmosphere including ozone profiles since the beginning of 90's.

Since 1987 the Institute of Oceanology, Polish Academy of Sciences in Sopot (IOPAS) carries on oceanographic research in the Norwegian, Greenland and the Barents Sea. The main goal of this project is to better understand short-term variability of oceanographic conditions and their influence on climate and marine life. Research is concentrated on 3 principal subjects:

- Monitoring type of research on variability of exchanges between Norwegian and Greenland Seas and the Barents Sea;
- Process oriental studies like: across frontal water, heat and salt exchange at the Arctic Front; structure and dynamics of the Westspitsbergen Current,

- Process oriented studies of fresh water production in the Svalbard fiords and water and properties exchange between coastal and open Sea on the Svalbard Shelf.

Production of dense water in the process of winter freezing and brine rejection in the Storfiord and its transport into the Greenland Sea is also investigated. Some interesting results show that in the process of eddies production at the Arctic Front and their transport from Atlantic Domain into the Arctic Domain can transfer very large amount of salt (up to 1.88×10^5kg/s) and heat into the Greenland Sea what can have significant influence on deep convection there. Shrinking of the Svalbard glaciers and increasing production of fresh water were observed in the West Spitsbergen fiords.

Mentioned above research is related to following CLIVAR's Principal Research Areas: North Atlantic Oscillation (D1) and Atlantic Thermohaline Circulation (D3) and partly to Climate Change Prediction (A1).

Besides, broad oceanographic research in the Baltic Sea are conducted by IOPAS and IM&WM, mostly devoted to the parameterisation of mass and energy exchange between atmosphere and the sea, understanding of water circulation, transport and properties exchange in the sea and modelling.

Institute of Geophysics of the Polish Academy of Science in Warsaw carries extended studies concerning sensitivity of the Polish hydrological system to the eventual changes of climate.

Poland is very active in polar researches. Since mid 70's the Institute of Geophysics of the Polish Academy of Science is running specialized programs in Arctic (at Hornsund on Svalbard) and Antarctica (at King George Islands). Meteorology is one of the research area, especially at the Geophysical Station at Hornsund. Results of standard observations are stored in archive of IM&WM and are used by scientific community to study permafrost and glaciological processes in Arctic. Some glaciological aspects concerning deglaciation in the region of this archipelago are investigated by the Silesian University.

We observe in last few decades an increasing number of climatic extremes or anomalies. They caused significant damages on national, regional and global scale.

Long persistent drought in beginning of 90's made several problems for agriculture and water supplying in several Poland's regions. Early winter in last few years was the reason for several losses of life. Poland experienced in 1997 very catastrophic flooding. 66 people lost their lives. Floods covered about 6720km^2 of arable land and meadows. A total of 164000 people were evacuated from their homes; 3080 km of roads, 490 bridges, 2000 km of railway track were destroyed or damaged. The total economic losses were estimated to US$ 3500 millions (1.68% GNP).

We understand that there are increasing threats for climatic system coming from the human activity but we also know that there is still too much uncertainty in our understanding of the all aspects of interactions between atmosphere, ocean and lands.

Therefore the understanding of the variability of climate system and improving its predictability on the seasonal, interannual and decadal time scale is of the great interest for Poland. We welcome CLIVAR with interest and we expect its successful realization.

Poland can support CLIVAR by continuation of its hitherto existing activity, by modernization and extending and improving observing systems, developing numerical models including its climatic versions.

In area of researches IM&WM together with other Polish partners is going to intensify activity which could extend our knowledge on climate variability and on relationships between different scale processes. To realize these goals IM&WM together with Institute of Environmental Protection prepared the proposal of the National Climatic Program. This proposal should give answers to the following questions:

- Is the climate of Poland really changing?
- What is the mechanism of climatic changes in Poland?
- What is the range and intensity of such changes?
- What kind of impact is expected on society, economy and nature?
- What kind of activity is necessary to limit negative influence of climatic changes?

Poland is expecting that due to participation in CLIVAR the systematic transfer of know-how will appear, cooperation between groups of common interest will start and the accessibility to results of global experiments and necessary computational facilities will be granted. It should help us to develop tools indispensable for realization of routine tasks in case of prediction of climatic conditions on seasonal and interannual time scale. It should be helpful in realization of the planned National Climatic Program.

Due to key role of IM&WM in area of climatic research in Poland Institute of Meteorology and Water Management can serve as national contact point for CLIVAR and Dr Miroslaw Mietus will be the contact person. His address is:

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THE PORTUGUESE CONTRIBUTION TO CLIVAR

1 Geographical profile

Portugal is located on the south eastern tip of Europe with a coastline of around 800 km. It has a series of topographical transitions from North to South and a total Mainland surface area of 9 189 892 ha. The territory is also comprised of the two archipelagoes of Madeira and the Azores, located in the Atlantic Ocean.

Mainland Portugal, between latitudes 37° and 42°N, is located in the transitional region between the sub-tropical anticyclone and the sub-polar depression zones. The most conditioning climate factors on Mainland Portugal are, in addition to latitude, its orography, the effect of the Atlantic Ocean and its continentality. Mainland Portugal effectively has a latitudinal extension of only 5°. As regards latitude, the highest values are between 1000 m and 1500 m, with the exception of the Serra da Estrela, with around 2000 m. As regards continentality, the regions furthest from the Atlantic Ocean are around 220 km away.

Portugal enjoys a temperate climate with average annual temperatures of between 7°C (in the inner highlands of central Portugal) and 18°C (in the southern coastal area). Average annual precipitation values vary from between 3100 mm in the mountainous northern inland regions and 450 mm along the southern coast.

2 Research and Systematic Observation

Portugal's endeavours in this domain are part of the definition of its general policy and it is an active participant in the international organisations to which it is a party. These include the World Meteorological Organization (WMO), European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the European Centre for Medium Range Weather Forecasting (ECMWF) in addition to the International Programmes: World Weather Watch (WWW), World Climate Programme (WCP), containing the research component (WCRP), Global Climate Observing System (GCOS) and others from the United Nations and from the European Union. Also included are the National Observing and Monitoring Programmes for the Atmosphere and studies on the composition of the atmosphere and climate.

Acquisition, Monitoring and Systematic Observation

Control of Climate System

The Institute of Meteorology (IM) is responsible for fulfilling commitments undertaken in the Meteorological and Climatology domains and has consequently been engaged on continuing and further developing these scientific and technical activities which began in Portugal in the middle of the 19th century with the installation of meteorological stations and the beginning of meteorological and climatological observations.

Therefore, climatological series with several parameters which are currently more than 140 years old, make it possible to undertake research into the domain of climate and climate changes, namely in terms of the analysis of trends and variability.

Systematic Observation implies the need for observation networks and the Institute of Meteorology has been responsible for the continued maintenance of 30 synoptical stations, 70 climatological stations, 700 udometric units (the majority of which come under the responsibility of Water Institute) and 3 aerological stations. It has also launched a process for the purchase and installation of automatic stations. Portugal is a member of two programmes in respect of the network for the Composition of the Atmosphere: BAPMon (Background Air Pollution Monitoring Network and GO3OS (Global Ozone Observing System).

Remote Sensing

In EUMETSAT, Portugal (through IM) is a party to the proposal for the creation of a Climate SAF (Satellite Application Facility) and is preparing to create an Land SAF.

In the domain of Remote Sensing we are equipped with reception facilities for METEOSAT and NOAA series meteorological satellites, a meteorological radar, and an aero-transportable multispectral sweep radiometer as well as the necessary, hardware and software for filing and processing applications in addition to SPOT and LANDSAT satellites.

In addition to the international effort being made in the domain of meteorological satellites, climatological studies on clouds have been carried out in addition to the cartography of major areas of vegetal covering in cooperation with the ISPRA Centre, the study of droughts, dryness indices of vegetal covering, biomass production calculations, etc. Several studies have been carried out on international environmental management projects under SGEOS.

The Institute of Meteorology is currently setting up a network of meteorological radar. Studies in this domain have been fundamentally covered by the COST intercommunication network and data Projects, in addition to projects directly related with the estimate of precipitation in hydrographic basins (flooding). The objective of the sweep spectroradometer was to equip the country with a facility for acquiring data on national territory in order to improve the management of existing resources as well as to facilitate prompt intervention in the event of natural catastrophes, forest fires, flooding and/or drought or industrial accidents.

The equipment is also expected to be used for the study of the heat island effect of residential communities populations and the study of urban microclimates.

3 Climate Vulnerability and the Potential Effects of Climate Changes

Portugal is a country of contrasts, not only on a topographical and climate level but also on a level of ecosystems. The geographical situation of Mainland Portuguese territory lends itself to the occurrence of episodes of drought, flooding and inundation as well as heat waves. In last few decades we observe an increasing number of climatic situations extremes.

Temperature distribution is the result of the difference in latitude (continentality) and altitude; the spatial distribution of precipitation contrasts markedly between regions north of the River Tagus and regions to the south of the river.

The geographical situation of the territory of Mainland Portugal favours the occurrence of droughts which are almost always associated with blocking situations in which the sub-tropical anticyclone in the North Atlantic is maintained in a position which prevents disturbances on the polar front from reaching the Iberian Peninsula. Droughts are common occurrences on Mainland Portugal, and special reference should be made to the most severe drought years of 1980/81, 1982/83, 1991/92, 1992/93 and 1994/95. Floods and inundation are also frequent and it should be pointed out that the major floods occurring over the last 20 years were in December 1981; November (catastrophic flooding in the Lisbon and Setúbal Regions) and December 1983; January and December 1996. Heavy, violent “downpours” in specific locations and of short duration can cause “flash flooding” which can occasionally have dramatic effects, particularly in the case of small hydrographic basins and in the west, south and urban regions owing to defective drainage.

Desertification is currently a reality which depends upon natural (droughts and climate variability) and human factors. This phenomenon is visible in Portugal and principally so in the inner eastern and southern regions which have been seriously affected by soil erosion caused by unsuitable agricultural practices and occurrences of intense precipitation over short periods of time.

Portugal is still affected by heat waves, i.e. major sequences of days with high air temperature levels and very low relative humidity levels.

An increase in the frequency of the occurrence of heat waves has a major effect on human health, e.g. heart disease. Atmospheric pollution, on the other hand has a markedly determining effect on certain types of illnesses such as asthma and emphysema. Accordingly, hotter and more extensive periods of time can aggravate atmospheric pollution conditions and, consequently, the incidence of these types of diseases. The potential effects of climate change will obviously depend on the dimension and degree thereof. The forecast climate changes will have a marked effect on agriculture, water resources, human health, sea levels and global ecosystems.

Eventual changes to climate conditions will most probably affect the hydrological cycle, the spatial-temporal distribution of hydro resources and water quality. Changes in precipitation patterns in Portugal, i.e. the significant reduction of the amount of precipitation in Spring over the last 30 years, with an even greater concentration of precipitation in Winter (practically over the Country as a whole, even if more expressive in the Beira Interior and the Alentejo, which are regions in risk of desertification), will have an effect on hydro resources, and will affect the availability of water for human consumption, energy production, the diluting of effluent and in agriculture.

Effects on agriculture will have an effect on local communities, the regional economy, particularly owing to changes in agricultural income and profitability, regional production costs, regional food production, regional disparities in income from agriculture and economic activity and regional employment.

4 Research Programmes

Three institutions are active in climate-related research and systematic observation besides the Institute of Meteorology: the University of Lisbon, the University of Aveiro and the University of Evora. Portugal participates actively in the EC climate research programmes and in other international programmes

Two areas of climate-related research were accorded priority in Portugal namely, studies on the impact of the oceans on the climate and establishment of the climate change scenarios by downscaling of the global circulation models, such as the United Kingdom model, to the local conditions. Based on these global models, efforts were aimed at developing a weather generator model for temperature and precipitation for Portugal.

The activities of Portugal under several EU programmes are worth mentioning here. The work by the University of Lisbon under the MEDALUS focused on assessment of desertification and formulation of relevant adaptation and mitigation measures. The impact of climate change on water resources was also studied by the University of Lisbon under the WRINKLE programme. Two projects have been launched under the PRAXIS XXI programme focusing on local climate change, namely: “The Effect of local Climate Change on the North Atlantic and Iberia”, coordinated by University of Aveiro and “ROCA” (Air Composition and Monitoring Network), coordinated by the Institute of Meteorology.

5 Future Developments

The thrust is expected to be in broadening and increasing surveillance of the composition of the atmosphere, climate variability and the possibility of climate change caused by human activity. With the above in mind, the regional limited area models included as part of numerical General Circulation models will play an important role in the evaluation of the effects foreseen by the climate scenarios in the different domains, as well as adaptation measures.

Portugal is expected to reinforce its involvement in international research programmes taking into account climate understanding and global change, in order answer to the following questions:

- How much is the climate of Portugal really changing?
- What are the mechanisms of climate change which affect Portugal?
- What kind of activities are necessary to reduce the negative influence of climate change?

NATIONAL REPORT FROM THE REPUBLIC OF KOREA
Korean Meteorological Administration

The recent frequent occurrence of extreme weather phenomena is jeopardising many countries and it is recognised that these might be caused from the anthropogenic factors. Climate variation appears in various forms such as flood, drought, heavy rainfall in all over the world and causes not only many casualties but also considerable damage of properties. Thus, many countries have collaborated against the unusual climatic events. In spite of three dimensional monitoring of global climate system with highly advanced tools such as satellite and weather radar, etc., it is still not an easy task to predict the future climate with reasonable confidence due to the complexity of the climate system itself, which might be a key factor to decide not only our human destiny but also survival of considerable part of the ecosystem on the Earth.

Now CLIVAR aims at the monitoring an prediction of the climate variation. Also, it focuses on the wide range of time scales from seasonal to centennial variation of the climate. Considering this effective goal, we believe that the international CLIVAR programme will provide a good opportunity to understand the climate system comprehensively and then the variability and predictability of climate. With great concern over the climate variation CLIVAR may play a key role in multinational collaboration on the current climate issues.

In Korea, the Korea Monsoon Experiment (KORMEX) has been planned and performed successfully to better understand the temporal and spacial characteristics of seasonal and interannual variation of Asian monsoon through collaboration with GEWEX/GAME. We have studied on the seasonal variation and prediction of regional climate near the Korean peninsula with both statistical and ensemble methods. Also, we focus our efforts on developing a model to predict the future climate including ENSO phenomena through coupling the global atmospheric and oceanic models.

Climate variation is a result of many physical interactions and feedbacks among atmosphere, hydrosphere, cryosphere, biosphere and lithosphere. Thus, an international effort is necessary to understand, monitor, and predict the climate systematically and comprehensively. Accordingly we would like to express a strong support to the activity of CLIVAR to understand the variability and predictability of the climate. We promise to do our role in international collaborations such as monitoring and prediction of climate and monsoon variation, ENSO, and developing a proper climate model, etc.

CLIVAR RELATED ACTIVITIES IN REPUBLIC OF MOLDOVA

Roman Corobov, Tatiana Constantinova*
Lydia Treschilo**

1. National interest in participating in CLIVAR

Republic of Moldova is one of the new independent states arisen at territory of the Former Soviet Union. Unfortunately, the present economic conditions of the country do not allow it to take an active part in the majority of the programs, which are carried out in the CLIVAR principal research areas, or to carry out independent fundamental investigations in this area. Therefore, the main task of Moldavian climatologists is mainly reduced, on the one hand, to a study of past and contemporary regional climate and, on the other hand, to a downscaling of global estimations of climate variability and changes to a country scale, with bringing of received results to the user-oriented outputs.

The Moldova researches' activity has significantly increased in connection with preparation of the First National Communication under the United Nation's Framework Convention on Climate Change. Assessment of impacts and adaptations of the different natural and socioeconomic systems to future climate requires knowledge of the parameters of likely climate changes in the region. Solving this task, the moldavian researchers have received some results, which may be useful for the other countries.

2. A matching of national research interests to elements of the Initial Implementation Plan

Moldova is interested in and is ready to participate in CLIVAR, especially in its Anthropogenic Climate Change (ACC) component, namely:

1 In Climate Change Prediction (A1 CLIVAR-ACC Principal Research Area), in the items concerning:
- the coupling between global climate models and regional and smaller scale models
- evaluation of models against observations
- comparison of the accuracy of statistical downscaling techniques with regional modelling.

2. In Climate Change Detection and Attribution (A2 CLIVAR-ACC Principal Research Area), in the next focused research areas:
- developing regional indicators and indices for climate extremes
- providing statistical methods for improved detection and attribution of climate change.

As an example of possible Moldova input to IIP we want to demonstrate (see tables below) some results of a case study: The effects of climate change on regional agroclimatic potential.

The idea of this research was to receive the projections of some climatic characteristics useful for the assessment of agriculture's adaptation to climate change. To fulfil this task, the regression analysis of relationships between agroclimatic indicators (dependent variables) and mean surface air temperature and precipitation (independent variables) was used. The latter were extracted from the results of Hadley Centre's climate change experiments. The comparison of temperature and precipitation simulated by different GCMs with the observed data has showed the best accuracy for Moldova of a CSIRO model.

Table 1.
Projected changes of surface air temperature and precipitation in Moldova with respect to 1961-1990 according CSIRO model for the case of Greenhouse Gas (GG) and Greenhouse Gas and Sulphate Aerosol (GS) 1%/year increase

Month	Timeslice 2010-2039		2040-2069		2070-2099	
	GG	GS	GG	GS	GG	GS
			Temperature, °C			
January	1.49	2.14	2.47	3.93	4.82	4.41
February	0.87	0.92	2.63	3.46	3.23	3.22
March	1.82	0.64	2.51	1.72	4.53	2.36
April	1.60	0.81	2.51	1.38	2.51	2.82
May	1.08	1.19	1.61	1.99	2.34	2.50
June	1.34	0.94	2.04	1.60	2.66	2.49
July	0.87	1.52	1.83	1.80	3.06	2.91
August	1.21	0.88	2.15	1.71	3.25	2.89
September	1.56	1.36	2.14	2.13	3.23	3.35
October	1.12	1.03	2.46	1.93	2.97	3.47
November	2.41	1.32	2.60	1.04	5.20	2.43
December	1.71	2.63	2.57	3.68	5.00	4.93
Annual	1.42	1.66	2.29	2.19	3.57	3.15
			Precipitation, mm/month			
January	4.96	10.85	6.51	17.36	10.23	13.33
February	4.56	2.56	10.26	2.56	9.69	11.68
March	3.41	4.65	3.72	3.41	13.95	8.37
April	9.30	2.40	12.60	0.30	12.00	9.30
May	-1.55	11.16	-1.24	7.75	4.96	4.65
June	9.00	-3.00	10.50	-0.30	2.70	7.50
July	2.48	10.54	-3.41	-0.31	2.79	2.79
August	0.93	-4.03	4.96	-4.34	-4.34	-8.37
September	3.90	10.20	4.50	1.20	-0.60	-4.20
October	2.79	0.93	11.16	4.65	4.65	2.79
November	1.50	5.70	-6.00	4.80	-10.50	6.30
December	6.51	-1.55	11.16	1.55	14.57	11.16
Annual	47.76	50.40	64.68	38.64	60.12	65.30

Table 2.
Relationships between different agricultural seasons' duration Di (i -mean daily temperature), ° C;

Ds,a - day of the beginning of year) and mean monthly surface air temperature Tii (ii - month)

Transition of daily temperature over:	R2	R	p	Equation of regression
0 ° C				
In spring	0.719	0.848	0.000	Ds=67.2-2.01 T02-4.49 T03
In autumn	0.623	0.789	0.000	Da = 32.7+4.01 T11+3.65 T12
Duration	0.787	0.887	0.000	D0=262.1+2.0 T02+3.6T03+4.0 T11+4.7 T12
5 ° C				
In spring	0.755	0.869	0.000	Ds=108.7-2.96 T03-1.91 T04
In autumn	0.560	0.748	0.000	Da=285.7+1.41 T10+3.62 T11
Duration	0.610	0.781	0.000	D5=171.4+3.36 T03+2.40 T04+1.82 T10+3.18 T11
10°C				
In spring	0.663	0.814	0.000	Ds=153.0-4.77 T04
In autumn	0.581	0.762	0.000	Da=246.4+4.49 T10
Duration	0.601	0.775	0.000	D10=90.84+5.22T04+3.83 T10
15° C				
In spring	0.654	0.809	0.000	Ds=223.4-5.68 T05
In autumn	0.619	0.784	0.000	Da=186.6+4.02 T09+1.66 T10
Duration	0.656	0.810	0.000	D15=-17.57+4.32 T05+3.96 T09+2.46 T10

Table 3.
Projections of the agricultural seasons' changes in Moldova (days) as function of the mean month temperature changes

Transition of mean daily temperature over:	Timeslice 2010-2039		2040-2069		2070-2099	
	GG	GS	GG	GS	GG	GS
0°C						
In spring	-9.9	-4.7	-16.6	-14.7	-26.8	-17.1
In autumn	15.9	14.9	19.8	17.6	39.1	22.2
Duration	26.0	21.8	36.8	34.6	67.1	47.8
5°C						
In spring	-8.5	-8.8	-12.2	-7.7	-18.2	-12.4
In autumn	10.3	6.8	12.9	6.5	23.0	13.7
Duration	19.6	10.2	27.2	15.9	43.2	28.7
10°C						
In spring	-7.6	-3.9	-12.0	-6.6	-12.0	-13.5
In autumn	5.0	4.6	11.0	8.7	13.3	15.6
Duration	16.6	8.2	22.5	13.7	24.5	28.0
15°C						
In spring	-6.1	-6.8	-9.1	-11.3	-13.3	-14.2
In autumn	8.2	7.2	12.7	11.8	17.9	19.3
Duration	13.6	13.1	21.5	21.8	30.2	32.6

Table 4.
Relationships between evaporation (E, mm) and mean monthly air temperature (T,° C), and precipitation (P, mm)

Month	R2	R	p	Equation of regression
January	0.802	0.896	0.000	E=20.77+1.10 T01-0.06 P01
February	0.668	0.817	0.000	E=24.14+1.56 T02-0.09 P02
March	0.729	0.854	0.000	E=28.25+4.34 T03-0.18 P03
April	0.780	0.883	0.000	E=25.69+6.49 T04-0.35 P04
May	0.849	0.921	0.000	E=11.71+7.80 T05-0.50 P05
June	0.736	0.858	0.000	E=-107.75+12.62 T06-0.20 P06
July	0.694	0.833	0.000	E=-71.35+10.21 T07-0.25 P07
August	0.797	0.893	0.000	E=-68.33+10.47 T08-0.38 P08
September	0.806	0.898	0.000	E=-56.48+10.38 T09-0.29 P09
October	0.536	0.732	0.000	E=42.06+2.33 T10-0.39 P10
November	0.334	0.578	0.005	E=23.28+2.49 T11-0.16 P11
December	0.342	0.585	0.003	E=19.0+0.67 T12-0.08 P12

Table 5. Projection of evaporation change (mm) in Moldova as function of mean monthly temperature and precipitation changes

	Observed data	T i m e s l i c e					
Month	1961-1990	2010-2039		2040-2069		2070-2099	
		GG	GS	GG	GS	GG	GS
January	14.5	1.6	2.3	2.3	4.3	5.3	4.8
February	17.7	1.4	1.4	4.1	5.4	5.0	5.0
March	33.5	7.9	2.8	10.9	7.4	19.6	10.2
April	74.8	10.3	5.2	16.2	8.6	16.2	18.2
May	106.3	8.4	9.1	12.6	15.4	18.2	19.4
June	113.6	16.9	11.9	25.6	20.2	33.6	31.4
July	116.5	8.9	15.4	18.7	18.4	31.2	29.7
August	120.1	12.7	9.3	22.4	18.0	34.1	30.4
September	92.1	16.2	14.0	22.2	22.1	33.5	4.8
October	54.5	2.6	2.4	5.6	4.4	6.9	8.1
November	26.7	6.0	3.3	6.5	2.5	13.0	6.0
December	15.9	1.1	1.8	1.7	2.5	3.4	3.3

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5. Suggested amendments to the Initial Implementation Plan

Deepening of IIP regional aspect both in its research and practical chapters that will give a chance to small country to make greater contribution to CLIVAR.

CLIMATIC RESEARCH IN ROMANIA AND FUTURE INVOLVEMENT IN THE CLIVAR

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Introduction

The results of climate research are relevant to social and economical activities. They could contribute to a sustainable development and a faster integration of countries in transition, like Romania, in the European and global structures. The global dimension of the climate related problems makes necessary an international collaboration of all national research communities. During last years Romanian climatologists have been involved in CLIVAR related activities together with research groups from Max-Planck Institute for Meteorology, Hamburg, Laboratoire de Meteorologie Dynamique, Paris, LEGOS/GRGS-Observatoire Midi-Pyrenees, Toulouse, Meteo-France, CNRM, Toulouse, Institute of Hydrophysics of the GKSS Research Centre, Geesthacht, the Hadley Centre, Bracknell. Romania is ready to use its scientific resources in order to contribute to further international efforts regarding climate research activities.

National interest in CLIVAR

The climate research in Romania has been developed in the framework of a National Research Programme and is directed towards scientific goals related to the CLIVAR objectives. The main objectives of the National Climatic Research Programme are:

- to study the physical processes responsible for climatic variability and predictability at a regional level, on seasonal, interannual and decadal time scales using the analysis of observational data and available General Circulation Model (GCM) outputs;
- to improve prediction methodology of monthly, seasonal and interannual climatic fluctuations;
- to identify the impact of anthropogenic activities on the climate in Romania;
- to assess the climate impact on the natural ecosystems, resources and the human society
- to increase the interest of the Romanian end-users in the climatic information provided by the climatologists.

Climate research activities are mainly developed in the National Institute of Meteorology, Hydrology and Water Management, Bucharest, Faculty of Physics, Department of Atmospheric Physics and Faculty of Geography, University of Bucharest, the Institute of Geography of the Romanian Academy, the Academy of Agricultural and Forestry Sciences.
Romanian organisations potentially interested in supporting CLIVAR-related research are the Ministry of Waters, Forests and Environmental Protection, National Agency for Science, Technology and Innovation, Romanian Academy. Participation in CLIVAR research activities is of central interest for Romania due to the social and economical benefits.

The main fields of interest for contributions in CLIVAR

Themes and approaches

Global modelling and prediction

- participation in the validation and intercomparison of the climate model results
- The ability of various global models to simulate the climate in Romania has been assessed by Romanian scientists using the model results obtained from Max-Planck Institute for Meteorology, Hamburg, Institute of Hydrophysics, Geesthacht, Laboratoire de Meteorologie Dynamique, Paris and Meteo-France/CNRM, Toulouse, France. As new model results will be made available by the modelling community they will be further compared with the observational and other simulated data.
- the use of modelling results to identify the potential signals of climate change for the Romanian territory

- Statistical models for downscaling have been built to make the connection between the regional climate (temperature and precipitation) and large scale sea level pressure. Various scenarios of regional climate change have been developed using various climate models. The results obtained from the new versions of climate models will be used when they will be made available by the CLIVAR modelling community. Dynamical downscaling procedures are intended to be developed in the future using the climatic version of a limited area model.
- the use of various coupled model outputs in order to study predictive potential for the key regions on time scale ranging from seasonal to interdecadal
- the development of a extended range prediction methodology for the Romanian territory

Global and regional scale empirical, analytical and diagnostic studies

- participation in the process of quality control and homogenisation of the climatological time series
- participation in the investigations on various time scales of climatic anomalies related to NAO, ENSO and other large scale phenomena

Global sustained observations

- participation in the Atmosphere and Land Surface Observing Systems with land stations with quality controlled data

Data set development, policy and management

- support to ongoing activities for the developing historical data sets in the framework of CLICOM and DARE projects.
- the development of a Romanian proxy data set.

Principal research areas

Considering the experience acquired in the framework of the National Climatic Research Programme and the existing technical capacity, our priorities for the involvement in the CLIVAR Implementation Plan at national level are the following:

The North Atlantic Oscillation (D1)

- The analysis of the NAO signals using different climate models results made available by the modelling CLIVAR community is necessary in order to identify the physical mechanisms involved in the NAO development and persistence.
- The comparison of the simulated and observed NAO patterns will be done on different time scales from the predictive perspective.
- The effects of NAO variability on climate fluctuations in Atlantic-European region and especially for Romania have to be analysed in relation with the seasonal cycle. A predictive methodology for seasonal and interannual temperature and precipitation anomalies will be developed using the results of the NAO studies.

Tropical Atlantic Variability (D2)

- The linkage between tropical Atlantic variability and NAO using both simulated and observational data will be investigated to reveal the mechanisms involved in the coupling between extratropics and tropics relevant from the standpoint of climate prediction in the Atlantic-European region.

Variability of the Asian-Australian monsoon system (G2)

- The fluctuations in the intensity of the Asian-Australian monsoon system is interesting to be studied from the standpoint of its possible connection with European climate variability.

Climate Change Prediction (A1)

- Statistical and dynamical downscaling of global climate change signals for the Romanian territory is necessary to be further developed. Statistical models for downscaling have been already built to link the regional climate (temperature and precipitation) with large scale sea level pressure patterns. Various scenarios of climate change will be analysed using the available climate model results obtained from CLIVAR modelling community.

- Studies of signal to noise ratio for the outputs of experiments corresponding to various scenarios of increasing of CO_2 concentration will be carried out.

Climate Change Detection and Attribution (A2)

- Studies of climate variability and the analysis of extreme events (droughts, floods) will be carried out from the climate change detection perspective. Change point detection in time series of various meteorological and hydrological parameters have to be identified at stations in Romania and related to large scale climate variability.
- Stochastic and deterministic aspects of climate transitions are topics to be taken into account for the study of variability and tendencies of the total ozone amount and the contribution of the natural and anthropic factors to this variability.
- The links between climate change and water resources will be analysed in order to use the climate data in integrated management projects of the hydrographical basins.

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STATEMENT OF THE RUSSIAN FEDERATION

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Participation of the Russian Federation in the WCRP Climate Variability and Predictability Study (CLIVAR programme)

In connection with the forthcoming International CLIVAR conference (Paris, 1-4 December 1998) I am pleased to inform you that the Russian Federation is planning to take active part in the implementation of the CLIVAR Programme.

National position and plans regarding the CLIVAR Initial Implementation Plan will be represented by the delegation of the Russian Federation at the International CLIVAR Conference.

The Initial CLIVAR Implementation Plan contains a number of important research issues which are closely connected with the objectives of the national climate research activities. There are, however, some crucial issues which have specific regional impact and will be included in the National CLIVAR Implementation Plan.

National CLIVAR Working Group has been established to prepare the National CLIVAR Implementation Plan. The draft national plan will be presented at the Conference. Participation of Russia in the CLIVAR programme as well as actions leading to the preparation of the National CLIVAR plan were discussed and endorsed by the National Oceanographic Committee of the Russian Federation at its meeting on the 8th of October 1998. The formation of the National CLIVAR Committee is under way and expected to be completed by the end of 1998.

In Russia, several research institutions of the Russian Academy of Sciences and the Federal Service of Russia for Hydrometeorology and Environmental Monitoring will take part in CLIVAR under the auspices of the Ministry of Science and Technologies of the Russian Federation.

Russian climate community is planning to participate in all three CLIVAR principal research areas (GOALS, DecCen and ACC). Among the objectives declared in the CLIVAR Initial Implementation Plan those which are focused on the mid-latitudinal and polar climate processes and which affect changes in the global climate system (G1, D1, D3, A1, A2) are considered of high priority for Russia. However it does not mean that the other issues will be ignored. They will be incorporated into the National CLIVAR Plan. Moreover, there are several research areas of particular importance for Russia such as variations of the Caspian Sea level, changes of Eurasian permafrost, climate variability in the Arctic. They will be included into the National CLIVAR Plan. In other words, endorsing in general the CLIVAR Initial Implementation Plan, the climate community of Russia will prepare the national plan taking into account some additional issues of special importance for our country.

We wish to confirm our intention to contribute to the implementation of the CLIVAR programme and will keep you informed about all steps in this direction.

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NATIONAL CONTRIBUTION ON THE CLIVAR IMPLEMENTATION PLAN BY SOUTH AFRICA

1 Introduction

The African climate system and its surrounding monsoons are key elements of the global circulation. For many years South African scientists formed an integral part of international researchers who were wrestling with intricate questions on the climate of South Africa, its predictability and its socio-economical influence on the Southern African subcontinent. The variability of rainfall in the region and the impact of frequent disastrous droughts and floods, especially in recent decades, raises serious concerns relating to sustainable development within the region. It is thus very important that the variability of the climate of Southern Africa is understood within the context of the African and global climate system.

Seasonal rainfall predictions, which could improve decision making and benefit the local population, require enhanced observing networks and greater scientific understanding of the physical mechanisms at play. These goals can best be achieved through co-ordinated international research efforts. The CLIVAR-African Study Group under the auspices of the CLIVAR Scientific Steering Group will guide the research and facilitate this international co-operation. A primary goal will be to gain an understanding of relationships between seasonal rainfall and ENSO through knowledge of ocean-atmosphere coupling over the tropical Atlantic and Indian Oceans.

South Africa therefore wishes to acknowledge the importance of CLIVAR in its quest of unravelling the uncertainties in predictability of the climate system. South Africa also supports the CLIVAR Implementation Plan, and intend to participate in CLIVAR program in its Principal Research Areas (PRA), with emphasis in:

G1: ENSO -Extending and Improving Predictions and especially
G4: African Climate Variability.

2 Current research

In addition, CLIVAR related research is being carried out at the South African Weather Bureau,University of Cape Town, University of Witwatersrand, University of Natal, University of Pretoria and University of Zululand, where several tools are used to study climate variability. Although these institutions are widely distributed throughout the country, there exist good communications via regular meetings, workshops and e-mail on a wide range of activities falling under the CLIVAR umbrella. Through the pioneering Southern African Regional Climate Outlook Forum (SARCOF), scientists, decision makers and users can join hands in using existing knowledge of seasonal prediction to the benefit of sustainable development in the region. However, SARCOF is just the start of a process.

Climate research and development in Southern Africa focussed in recent years mainly on seasonal and centennial predictability. This involved not only local scientists, but also esteemed international researchers and research institutes. In view of the strong teleconnections between sea surface temperature changes in the tropical Indian, Pacific and Atlantic Oceans with rainfall and temperature over the subcontinent, a fair amount of success was achieved during the 1997/1998 rainfall season. Inter-annual climate variability and development of climate forecasting include both diagnostic and modelling studies, variability in the southern hemisphere circulation with particular attention given to southern Africa and surrounding oceans. Empirical relationship revealed by these studies are incorporated in operational seasonal forecasting procedures, along with ENSO forecasts obtained from overseas.

2.1 Past Studies

Africa's climate is governed indirectly by monsoon circulations that extend across large parts of the Atlantic and Indian Oceans. Recent research provides an indication of current foundations and promising directions for future work. Year-to-year fluctuations in rainfall over Africa are determined by circulation regimes that alter the preferred location of tropical convection (Harrison 1986) and the intertropical convergence zone (ITCZ). Skilful seasonal predictions of rainfall depend largerly upon our ability to monitor real-time ocean-atmosphere states and to model, using statistical or dynamical methods, the large-scale atmospheric response over Africa to ocean-atmosphere coupling locally and globally (e.g. Ward et al., 1993; Hastenrath at al., 1995; Mason et al., 1996).

El Niño-Southern Oscillation (ENSO) warm events in the equatorial Pacific and Indian Oceans are associated with warm dry over much of Africa (Ropelewski and Halpert, 1997; Shinoda and Kawamura, 1996). A warmer tropical Indian Ocean is frequently associated with dry (wet) conditions over southern (eastern) Africa. Establishing a causal relationship from Indian Ocean SSTs to the African atmosphere is difficult because warmer Indian Ocean is itself part of the global ENSO teleconnection (Cadet, 1985; Jury and Pathack, 1993; Mason, 1995). During El Niño conditions, the central Indian Ocean experiences changesin zonal wind stress (Hastenrath et al., 1993; Latif et al., 1994) and a deepening of the thermocline (McCreary at al., 1993; Toure and White, 1997).

GCM and empirical modelling are one of the primary tools being used to study and understand the mechanisms responsible for seasonal variability and predictability of the South African climate.

3 Future research

A number of diagnostic studies are required, including observational campaigns, to improve our understanding of physical processes in the African region in conjunction with modelling experiments. CLIVAR-Africa proposes a number of thrusts, initially mainly of an empirical and diagnostic nature. As the seasonal distribution of rainfall (seasonal onset, peak, decay) is particularly at regional scale (Taljaard, 1986), it is proposed that investigations be conducted to establish the spatial and tempoarl nature of this variability and its regional teleconnections. The principal research area, the African Climate Variability (G4), with other principal research areas, can play an important role in enhancing the knowledge needed to increase operational predictability.

In this regard South Africa is committed to use its resources in this field within its financial and other constraints. Although funds are limited, South Africa can offer valuable participation in kind. It aims to maintain its drifting buoy programme in the surrounding oceans, and to do its utmost to maintain and improve the current observational network. Research on the improvement of seasonal prediction will continue to receive a very high priority. This will be done through statistical and dynamical modelling, diagnostic studies and physical explanations. Modelling the impact of climate change will also remains a high priority. Important work is underway to study the links between aerosols from biogenic and industrial sources, their re-circulation over southern Africa and rainfall production efficiency. South Africa is also committed to its regional role and will enhance training and scientific cooperation in the Southern African Development Community. CLIVAR-Africa will collaborate with and support expanded training efforts to establish research expertise and infrastructure in Africa. User-based operations and research will be fostered whenever possible.

To meet the stated goals of CLIVAR-Africa, a numerical modelling effort will be promoted initially applying simple, low-resolution atmospheric GCMs, and later advancing to fully-coupled GCMs. The work can progress from model development, to validation, to application. In initial phase, sensitivity tests will be guided by statistical studies of observed climate variability and its sensitive to changing lower boundary conditions, namely SST. A number of global experiments have been conducted, for which little emphasis has been given to African climate. CLIVAR-Africa can remedy this through joint interpretive efforts. Monsoon circulations over Africa are part of the coupled ocean-land atmosphere system. So it is natural to expect that coupled GCMs will be used to address regional predictability.

In view of the current limitations of coupled models for African climate studies, the main requirement of the CLIVAR-Africa modelling component in the initial stage, is the assesment of atmospheric GCMs driven by historic SSTs to reproduce the mean climate of Africa, its seasonal cycle and interannual variability. The relationship between a model's ability to generate realistic intraseasonal variability and a model's skill at the seasonal time scale will be addressed. The potential benefits from nesting mesoscale limited area models inside GCMs will also be considered.

3.1 Role of CLIVAR-Africa

Observations of the African climate system and its oceanic teleconnections, both real-time and historical are essential to the aims of a CLIVAR-Africa programme. The observing network must be supplemented by stations with telemetering capability, application of satellite technology, and measurements from aircraft and ship platforms. Through additional observations which improve our knowledge of the initial state of Africa's weather, the detection of linkages with the global climate can be revealed. Accurate specification of atmospheric conditions will ensure that 'control runs' for numerical experiments can function as a true baseline for 'perturbation runs', and that GCM predictions evolve from known states.

Expanded observational coverage of sub-surface ocean conditions and air-sea interactions in the tropical Atlantic and Indian Oceans adjacent to Africa is seen as pre-requisite to improved seasonal rainfall forecasts. A number of approaches to long-range forecasting of African climate are being explored, and over the last decade, some of these have been employed in real-time with promising success. CLIVAR-Africa can build on these foundations, through underpinning scientific observations, diagnostic analysis and modelling efforts. Considering the modes of inter-annual climatic variability (Janowiak, 1988) and Africa's heterogeneous terrain and vegetative cover, it is desirable to partition Africa into three regions:

north and west Africa;
east and central Africa; and
southern Africa.

Each region has distinctive interannual climate anomalies and teleconnections (Semazzi et al., 1988). The eastern and southern regions are dominated by the ENSO signal with opposite polarity, while the northern and western regions experience climate anomalies that are generated through a mix of regional processes combined with global ENSO influences. However, ENSO-based predictability appears to be highest for southern Africa. To capitalise on this, one focus of the CLIVAR-Africa research programme will be statistical and numerical modelling efforts directed at securing the knowledge of the climate system in this region that will improve the reliability and confidence in seasonal forecasts for southern Africa. Another focus of research will be empirical and modelling studies that explore the limits of predictability of the African climate system. It will be necessary to quantify the relative contribution from ENSO and regional influences, and relationships between remote boundary conditions and internal dynamics over the continent. To achieve these goals, the CLIVAR-Africa Implementation Plan proposes a number of themes relating to the interaction of African climate with tropical monsoon convection, coupled ocean-atmosphere-land processes and extra-tropical circulation regimes (Tyson, 1986). To achieve success, it will be necessary to characterise climate anomalies over Africa and to perform modelling and diagnostic studies leading to predictability at interannual scales.

4 Programme objectives

The CLIVAR-Africa Implementation Plan will promote multi-lateral projects along the following lines:

- analyse and describe the spatial structure and temporal variability of the African climate system from intraseasonal to interdecadal time scales;
- construct quality data bases of precipitation, temperature, etc. to characterise intraseasonal weather events and lower frequency climatic oscillations and their spatial character;
- evaluate reanalysis products over Africa and the surrounding oceans for adequacy and reliability, and assess which additional observations will lead to the necessary improvements for useful climate studies at synoptic and intraseasonal scales;
- in a similar way, assess the additional real-time observations that are needed for climate prediction;
- develop innovative, low-cost solutions for enhancing land-based observing networks and telecommunication needs;
- identify the nature of and the mechanisms for intraseasonal convective activity and their links with:
- rainy season onset,

- African weather systems,
- large-scale circulation features like jet streams and monsoon circulations
- regional coupled ocean-atmosphere processes
- the global ENSO and its interannual variability
- identify regions where oceanic anomalies influence monsoon circulations over the Atlantic and Indian oceans and quantify the underlying physical processes;
- determine the relative contribution of internal dynamics (eg. soil moisture, vegetation cover, etc.) and external forcing, and study synergistic relationships between tropical circulation cells over Africa and the Pacific hemisphere, and linkages with the extra-tropics and southern ocean;
- explore the limits of predictability of African climate taking a regional approach, with special attention to ENSO response areas, monsoon circulation systems, and the tropospheric biennial oscillation and its regional interaction (Yasunari, 1991; Meehl, 1993; Tourre et al, 1997);
- apply GCMs (both atmospheric and coupled ocean-atmosphere models) to African climate prediction and *inter alia* oceanic controls of climate variability, consider also the influence of African climate anomalies on the nearby oceans;
- analyse tropical/mid-latitude interactions and predictability, particularly for northern and southern Africa and the adjacent high latitudes, with an emphasis on NAO for northwest Africa;
- monitor and understand land-sea-air interactions by remote and *in situ* observations and numerical modelling, to establish feedback pathways and processes (e.g. evapotranspiration, surface heat fluxes);
- develop the potential to accurately predict SST and ocean-atmosphere coupling processes in the tropical Atlantic and Indian Oceans at interannual to interdecadal time scales; and
- assess the interaction of interannual to interdecadal processes in the coupled ocean-land-atmosphere system, including the role of changes in land surface characteristics and the process of desertification.
- identify centres of existing expertise in African climate dynamics and develop assistance programmes and multi-lateral projects to ensure the potential for on-going CLIVAR research in Africa;

To monitor the evolution of global ENSO events, tropical meridional SST differences and regional coupled ocean-atmosphere events in the tropical Atlantic and western Indian Oceans, an African TAO array is proposed. Given limitations of internal funding, such a project will be international in character, yet of benefit to neighbouring continents. It is expected that much of the work described in this Implementation Plan will be planned and co-ordinated in 1998-2000 and conducted up to 2010. The timetable for the CLIVAR-Africa programme is thus more gradual than its international counterparts and linkages to CLIVAR thrusts: G1, G2, D1, D2, and D3 are essential to its success.

5 Observational requirements

5.1. Atmospheric needs

Routine weather observations provide the foundation for CLIVAR-Africa's scientific research plan. Data from radiosonde and surface observations in many key areas are lacking . Evaluation of reanalysis products will determine reliability, and discrepancies could point to where new observational efforts are need. For monitoring purposes, satellite data will play a critical role in filling out the observing system. Satellite-derived winds have been unavailable over the Indian Ocean from 55 to 85°E, and profiles of thermal stability and moisture flux are required to supplement the observing system. Real-time satellite data from METEOSAT, INSAT and TRMM need to be made available to CLIVAR-Africa researchers. The deployment of instruments to measure the hydrological and radiation budgets both over land and in key ocean areas will also underpin the science. Finally, wind profilers would provide valuable information in key regions where intraseasonal oscillations occur, e.g. in the region of the Seychelles. This would allow for continuous monitoring of boundary layer and upper wind conditions. The ways to achieve these observations and to utilise them for predictive purposes need careful consideration.

5.2. Oceanographic measurements

Our understanding of the mechanisms that produce SST anomalies in the Atlantic and Indian Oceans is quite limited. The air-sea interactions are complex and estimates of fluxes derived from NWP models will contain errors. Regular subsurface data in monsoon regions adjacent to Africa are insufficient. Blended SST products based on satellite and irregular ship reports are likely to be in error in cloudy regions outside shipping lanes. The XBT network needs to be expanded in the Atlantic and Indian Ocean as part of GOOS support to CLIVAR-GOALS, in conjunction with TRITON and PIRATA ocean moorings. Extension of these ocean observing systems towards Africa would benefit climate prediction efforts across the region.

5.3. Land-based observations

In order to understand the mechanisms of boundary forcing and internal dynamics of the African climate system, monitoring of land surface processes is necessary. Key land variables include soil moisture, vegetation, streamflow, run-off, and surface heat and radiation budgets. Currently, these observations are lacking, except in few areas. Together with GEWEX, multi-lateral monitoring studies to compare land- and marine-based heat fluxes are needed. Satellite estimates of land surface characteristics such as the vegetation index NDVI and microwave satellite SSMI-derived soil moisture will be exploited.

6 Training

South Africa recognises its role in CLIVAR and is willing to take up the challenges. Simultaneously we urge the international community to maintain its high level of involvement in the developing world, both regarding research and training efforts of meteorologists on advanced techniques of Regional Climate Models, and NWP as well as GCM. These training efforts could be carried out in conjuntion with the existing programmes. For example, training programmes at the African Centre for meterological Applications and Development (ACMAD), Drought Monitoring Centres (DMC), planned SADC training at South African Weather Bureau (SAWB) and conferences with the African meteorological Society.

Other opportunities could include regional conferences and workshops, African Universities and national weather service ‘summer schools’, and projects under internationally sponsored programmes of WMO/UNDP, IGBP/IHDT-START, MEDIAS, the IRI, FIRMA, and the European Community. Funds will be requested to support meetings, for scholarships to promising researchers, for infrastructure to enable CLIVAR-Africa research, and for networking and information exchange. This will increase capacity building of researchers who will be responsible for CLIVAR related research. A high level of involvement is also needed in improving observational networks in the CLIVAR-Africa region. Africa is rising to its potential and task, and will be a crucial partner in CLIVAR-Africa and the other principal research areas.

In conclusion, further understanding of other parameters affecting the climate variability over South Africa is needed. The South African contributions to CLIVAR will consist of ongoing work at a number of institutions and several projects carried out at the SAWB. CLIVAR was presented in South Africa during a special meeting to some government departments and stakeholders who responded positively to the initiative.

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SPANISH NATIONAL STATEMENT
FOR THE INTERNATIONAL CLIVAR CONFERENCE.

Spain shares the great interest of the international community in the matters and issues related to the climate, its variability and their effects on the economic and social activities. Spain welcomes the establishment of CLIVAR and expects to join her effort to its progress and development.

The participation of Spain in the planning phase of CLIVAR has been limited. However, we expect from now on that actions will be initiated and promoted to attract the interest of our scientists to this project. As well as to include some of their objectives and goals in the next national research programme which preparation is due to start soon. At the same time, advantage will be taken of the ongoing Spanish activities from which CLIVAR could benefit. In particular, the studies of processes related with the CLIVAR objectives, ongoing modelling efforts and the systematic collection of data, and their availability, in the different components of the climate system.

The interest of Spain is concentrated particularly on the principal areas D1, D2 and D3, variability in the Atlantic Ocean and Thermohaline Circulation, and in the areas which deal with the human influence on the climate, A1 and A2. The climate of the Iberian Peninsula and many of the Spanish economic and social activities are closely related to the variability in the Atlantic.

At present, Spain, through her membership in several European or international bodies, participates in different missions of which data and results CLIVAR can benefit. Her relationship with the European Space Agency (ESA), the European Meteorological Satellite Organization (EUMETSAT), the World Weather Watch (WWW) and Global Atmosphere Watch (GAW), Global Ocean Observing System (GOOS), World Ocean Circulation Experiment (WOCE), International Geosphere Biosphere Programme (IGBP), European Centre for the Medium Range Weather Forecast (ECMWF), etc. provides a very adequate platform to exercise our future involvement in CLIVAR.

Spain also maintains several observation systems in the atmospheric, oceanic and land components that can serve to CLIVAR purposes. The national meteorological observation network contributes to the WWW and GAW programmes and to the activities of the ECMWF. A net of meteorological-oceanographic buoys moored along the Spanish shelf break in the Atlantic and Mediterranean, several tide gauge networks in the process of being integrated, periodical oceanographic surveys in chosen sections and the European Station for Time Series in the Ocean in the Canary Islands (ESTOC), a co-operation between Spain and Germany, constitute a promising base to found a operative oceanographic system.

The Spanish community has carried out several numerical experiments and simulations of the climate at a regional scale. They have used models like ARPEGE, PROMES and HIRLAM. Several research groups have emerged with capacity to co-operate in the intercomparison, verification and validation of global models and in the development of statistical techniques to obtain regional climatic scenarios. Through the ECMWF, Spain will contribute to the 40-year reanalysis that will be an essential tool in the establishment of the reliability of seasonal prediction.

Other groups are running the wave spectral model WAM and 3-D hydrodynamical model HAMSOM in order to provide a forecast of wave fields and sea surface elevation. WAM runs on the North Atlantic basin and on a nested regional scale (Gibraltar Strait and West Mediterranean Sea). HAMSOM runs on a regional scale covering both the coastal waters of the Iberian Peninsula and the Spanish archipelagos. Real time buoy measurements are taken into account to validate wave forecast. Real time coastal tide gauges records are taken into account for assimilation into HAMSOM forecasted sea-level fields in order to improve its quality

Long term reanalysis of wave climate using wave generation models improves the knowledge of the mean wave conditions in the ocean and in turn, parameterisations of magnitudes depending on the sea surface can be improved. Some groups are contributing to improve the atmospheric modelling and the modelling of the marine boundary layer winds within EU funded projects. Downscaled modelling of waves is necessary to assess the impact of these variations in the coast. The procedures to forecast waves in the coast are run operationally - based on a system of two-way and one-way nested applications of generation and propagation models - will be applied and improved for this purpose in the frame of CLIVAR.

During the meeting, January 19th 1999, held in Madrid by the Consejo Nacional del Clima a proposal was approved to create a Spanish Committee of CLIVAR which will be composed of representatives of several national agencies in charge of meteorology, ocean and general research affairs.

SWEDISH CONTRIBUTIONS
TO THE CLIVAR RESEARCH PROGRAMME

Introduction

CLIVAR relevant research activities in Sweden fall into two distinct areas: One is regional climate modelling and application oriented interpretations of climate change. The other is North Atlantic ocean observations with a focus on the thermohaline circulation. The CLIVAR research areas involved are A1 (Climate Change Prediction), D1 (The North Atlantic Oscillation) and D3 (Atlantic Thermohaline Circulation). We first describe the two main research areas and then follows an organizational description. Finally contact points and names of the principal scientists involved are given.

Regional Climate Modelling

Within the Swedish national research programme SWECLIM, regional interpretations of global climate change scenarios are undertaken. A major part of the programme is devoted to physical modelling of the climate system, both from a meteorological, oceanographical and hydrological point of view. Using global scenarios from elsewhere (Hadley Centre, UK and Max-Planck-Institute, Germany) we run a regional, high resolution climate model for the present climate and future climate scenarios. A main emphasis is put on user oriented interpretations of the climate scenario runs. One example is hydrological interpretations of river flow intended for the hydro power production industry. The regional climate model is based on the regional weather forecast model HIRLAM which is used for operational weather forecasting in the Nordic countries. We have also found it important to include regional models for the Baltic Sea and large lakes. Global climate models do not include large lakes and large estuaries, such as the Baltic Sea, are poorly described. The SWECLIM regional climate model thus involves not only an atmospheric part but also an oceanographic component. Of particular importance for the Swedish region is the handling of ice, both in lakes and in the Baltic Sea.

As an interpretation tool we use a hydrological model originally developed for diagnosing and predicting river flow. Using temperature and precipitation as input the hydrological model calculates time dependent river flow from a catchment area. The model has been extensively tested in operations using both observed and predicted atmospheric conditions. The climate change found over the Nordic region towards the end of the next century in climate change simulations has a profound influence on river flows. Not only precipitation changes but also temperature changes will dramatically alter the seasonal variations in river flow. In some regions the characteristic spring time flooding due to snow melt in today's climate will almost disappear in a greenhouse warming scenario.

A crucial component in a regional climate model is the land surface parameterisation. Within SWECLIM we are giving this area special attention and we intend to integrate the hydrologic model described above in the regional climate model. Hydrological processes influence the local energy balance as well as the outflow of fresh water into the Baltic Sea estuary. The fresh water flow is a driving force for the water circulation in the Baltic as well as a regulator of sea ice. Over land the surface energy balance is determined from local soil properties and with a relaxation towards the global model deep soil temperatures. The water balance will be governed by a scheme which closely follows the hydrological model used for the interpretation studies. This feature will enable us to integrate the hydrologic interpretations into the regional climate model and to benefit from a well tested and robust water balance scheme.

A final aspect of regional climate modelling is the variability of large scale flow patterns such as the NAO and possible systematic shifts of these in a changed climate. The mechanisms behind large scale, persistent flow regimes will be investigated using both observations and models of varying degrees of complexity. A central question is which mechanisms that are involved in the formation and maintenance of flow regimes. In SWECLIM we will focus on atmospheric mechanisms, in particular the relation between large scale persistent flow features, high frequency transients and orographic forcing.

Oceanographic field programmes in the North Atlantic

Within the field of physical oceanography Swedish contributions will form parts of two large Nordic field programmes which are relevant for CLIVAR PRA D3 (Atlantic Thermohaline Circulation).

The first of these represents a continuation of the activities originally launched under Nordic-WOCE and presently carried out under the auspices of the European Union VEINS programme. This programme is aimed at monitoring the exchanges between the North Atlantic and the Nordic Seas over the Greenland-Scotland Ridge. These exchanges comprise a northward flow of warm and high-saline surface water as well as the southbound overflows of deep-water. The Nordic task, which primarily focuses on the Faroe region, is hence comparatively demanding. It not only involves hydrographic work carried out four times yearly over standard sections, but also the maintenance and upkeep of Acoustic Doppler Current Meter arrays. Presently the fourth year of records is being gathered, and intensive efforts are under way to assure that the programme is prolonged well into next century.

The second of these large Nordic programmes is presently being launched. It represents a collaboration between the Nordic group referred to above and the University of Rhode Island/USA and is based on the installation of an ADCP on a Danish merchant vessel which plies the route between Aalborg in Jutland and Nuuk in Greenland on a regular basis, this scheme being feasible thanks to the extremely cooperative spirit demonstrated by the ship-owners. Together with data from regularly launched XTDs (by courtesy of the ship's officers) this ADCP data set should form the basis of estimates of the northward oceanic heat flux across a section between Cape Wrath and Cape Farewell and its variability over time, hence nicely complementing the work described above. Since URI has previous experience of activities of this type from the Bermudas-Baltimore run it appears quite likely that the planned programme is realistic and can be carried through. The present status of this project is that the vessel (M/S NUKA ARCTICA) has been modified with a specially built cofferdam for the ADCP sensors and that the necessary installations for connecting cables etc. have been carried through. The ADCP is presently being overhauled by the manufacturer and will be mounted in the spring of 1999. Financial support for the data acquisition system, including a multi-antenna GPS system for accurate heading information, is forthcoming from Swedish sources and it hence appears likely that the planned system will become operational and subjected to the first trials during 1999. Finally it may be worthwhile to underline that there is reason to hope that this NUKA ARCTICA programme may come to represent a long-term contribution to CLIVAR in that the vessel which will be utilized is specially built for the Greenland trade with ice-reinforcements etc., thus making it highly unlikely that the ship-owners will employ the vessel for other purposes or subject it to long-time charter on other runs, a common problem with VOSs, as many national meteorological services are well aware of.

Organisational structure of Swedish CLIVAR activities

Meteorology and hydrology

The Swedish Meteorological and Hydrological Institute (SMHI) in Norrköping is the focal point of the regional climate modelling activities described above. A special research unit, the Rossby Centre headed by Dr Lars Moen, has been formed in 1997. At the Rossby Centre a regional climate modelling system is developed and maintained. The Rossby Centre is contained within SWECLIM (SWEdish regional CLIMate modelling programme) which is a national programme involving also university departments and research units in meteorology, oceanography and hydrology. The programme director for SWECLIM is Erland Källén, professor of dynamical meteorology at Stockholm University. The department of meteorology at Stockholm University (MISU) is thus very much involved in climate modelling activities and in addition the research section at SMHI takes part in both meteorological and hydrological research activities which are closely connected with SWECLIM. For a description of the oceanographic research group structure, see below. Please note that the Rossby Centre and the research section at SMHI are separate units.

Oceanography

At the present stage the oceanographic efforts described above have their basis within the Swedish university system. In addition to the Department of Meteorology at Stockholm University (described in connection with climate modelling above), the Oceanographic section of the Earth Sciences Centre at Göteborg University is involved in the studies of dynamical processes in the ocean, particularly the hydraulics of the deep-water transports to the North Atlantic and their subsequent mixing into the main body of NADW. Tracer work, especially on the basis of CFC measurements and with focus on Arctic conditions as well as the exchanges across the Greenland-Scotland Ridge, is being pursued by the Department of Analytical and Marine Chemistry at Chalmers Technical University. Since this latter work aims at the identification of water masses and elucidation of their mixing properties, it nicely complements the purely physical inquiries being undertaken within the two first-mentioned university departments. Projections for future organizational developments are primarily concerned with the NUKA ARCTICA project outlined above. If or when this proves to be a viable undertaking, it is not likely that it can be managed from university departments, and hence it will be necessary to involve the competent national authorities in the maintenance of the observational programme. In the case of Sweden this will be SMHI, described above in connection with the climate modelling.

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THE SWISS CONTRIBUTION TO CLIVAR

compiled by T.F. Stocker and U. Neu

1 Introduction

Switzerland has a long tradition in climate research. Instrumental observations and paleo climate analyses have been performed by many Swiss research groups for decades. There is also a long tradition in modelling climate and climate related changes, in particular in relation to the global carbon cycle and, during the last decade, dynamical climate modelling and high-resolution regional modelling. Based on this research experience, Swiss scientists anticipate contributing significantly to several activities within CLIVAR.

2 National interest in CLIVAR

The national funding agencies support CLIVAR-related research primarily on an individual project basis. There is no earmarked budget set aside for such activities. In a few cases national coordination centers for program elements have been funded. Swiss scientists intend to investigate such a possibility for CLIVAR. Furthermore, the establishment of a small number of National Research Centers is planned over the next years in Switzerland with longer term commitments. One of these centers may be of relevance to CLIVAR.

3 Support for infrastructure and Swiss contact point

The Swiss contact point for CLIVAR will be ProClim, the Forum for Climate and Global Change1. ProClim is an information platform for Swiss climate and global change science (http://www.proclim.unibe.ch). ProClim will provide its web-based information system for CLIVAR purposes. The office of an IGBP core project, PAGES (Past Global Changes, (http://www.pages.unibe.ch), is located at the same place in Bern. It will operate as a coordinating office for the important PAGES/CLIVAR intersection.

4 Parts of CLIVAR with particular national interest

Swiss research will make substantial contributions to CLIVAR in the fields of observation of climate variability based on instrumental records and high-resolution paleorecords. Therefore, Switzerland will be strongly engaged in the PAGES/CLIVAR intersection and thus provide information on the long-term, centennial-scale variability in the Earth system. Switzerland will also contribute to modelling on the global and regional, mainly W Europe and Alpine, scales. Of particular interest will be the mechanisms and effects of modes of natural climate variability in the Northern Hemisphere (e.g. North Atlantic Oscillation, see Fig. 1) as they can be deduced from observations, high-resolution paleoclimatic records and models.

4.1. Instrumental observation and paleo climate analyses

a) Polar and Alpine Ice Cores

Greenhouse gas concentrations enclosed in bubbles trapped in ice cores carry invaluable information of changes of the Earth system and provide an important boundary condition for models. A special focus is on the high-resolution analysis of rapid events of the glacial and natural variability during the Holocene based on polar ice cores. The goal is to construct long-term records of indices of natural climate variability (e.g. the North Atlantic Oscillation index), which will serve as benchmarks for long-term model integrations.

b) Lake Sediments

Studies of biological and physical proxy data in lake sediments extend our knowledge of climatic and environmental change in the past. Decadal changes can be identified in annually laminated archives. These signals will provide additional knowledge on changes in climatic conditions during the Holocene.

c) Tree Rings

The densitometric analysis of tree rings of conifers in a circumpolar network provides annually resolved reconstruction of the last 400 years and, in some places, of the entire Holocene. Work towards a hemispheric tree ring archive will allow us to obtain a clearer picture of variability and its regional expression in high latitudes.

d) Long Observational Time Series
The study of long-term instrumental time series is the basis to assess natural climatic variability and identify anthropogenic changes. A data base with homogenized climatic time series of surface air temperature and precipitation has been established. The combination of instrumental data sets, historical documents, and synoptic analyses permit the extension of these records further back in time. The specific spatio-temporal analysis of long time series allows one to diagnose the synoptic variability (including low frequency cycles) of pressure systems and their relation to different forcing factors. Also the impact of atmospheric circulation on regional climate can be addressed.

e) Monitoring and Observation
Within the framework of the WMO monitoring activities, Switzerland has established a network of isotopes in precipitation. There are also important activities related to the Global Atmosphere Watch program (GAW) concerning ozone, aerosol, and radiation. Switzerland also supports corresponding activities in Africa. The World Radiation Center in Davos is responsible for world-wide instrument calibration and is one of two observatories of the solar constant worldwide.

4.2. Modelling
a) DecCen Variability and Abrupt Change
A hierarchy of ocean and coupled climate models is currently being developed with the goal to simulate the decadal-to-century time scale variability. These physical models are coupled to biogeochemical models which permit direct analysis of the variables recorded in various paleoclimatic archives. The physical aspects of abrupt climate change have been successfully simulated using such models and they will be further used to quantify changes in biogeochemical variables.
b) Anthropogenic Changes
Time-slice simulations of the climates at the present and for the middle of the next century are carried out with high resolution GCMs. Research focuses on the radiation budget and its perturbation by additional greenhouse gases, and on the related consequences for surface climate, hydrology, and changes in the mass balance of polar ice sheets.
c) Regional Impacts and Downscaling
Regional climate models are used to investigate the dynamics, and future evolution of the climate on the European and Alpine scale. They address particular aspects related to the water cycle such as the frequency and distribution of heavy precipitation events and the role of continental-scale processes for interannual variability and the occurrence of extreme events. In order to enhance our understanding of the regional response of environmental systems to large-scale climatic forcings, nested modelling approaches are carried out.
In summary, Switzerland will continue to contribute substantially to the science of climate and its changes and, in particular, to the CLIVAR DecCen and CLIVAR ACC programmes as well as to the PAGES/CLIVAR intersection.
Information about CLIVAR-related projects in Switzerland can be found on the ProClim-homepage under http://www.proclim.unibe.ch/PCInfoSyst.acgi$Detail_Program?CLIVAR

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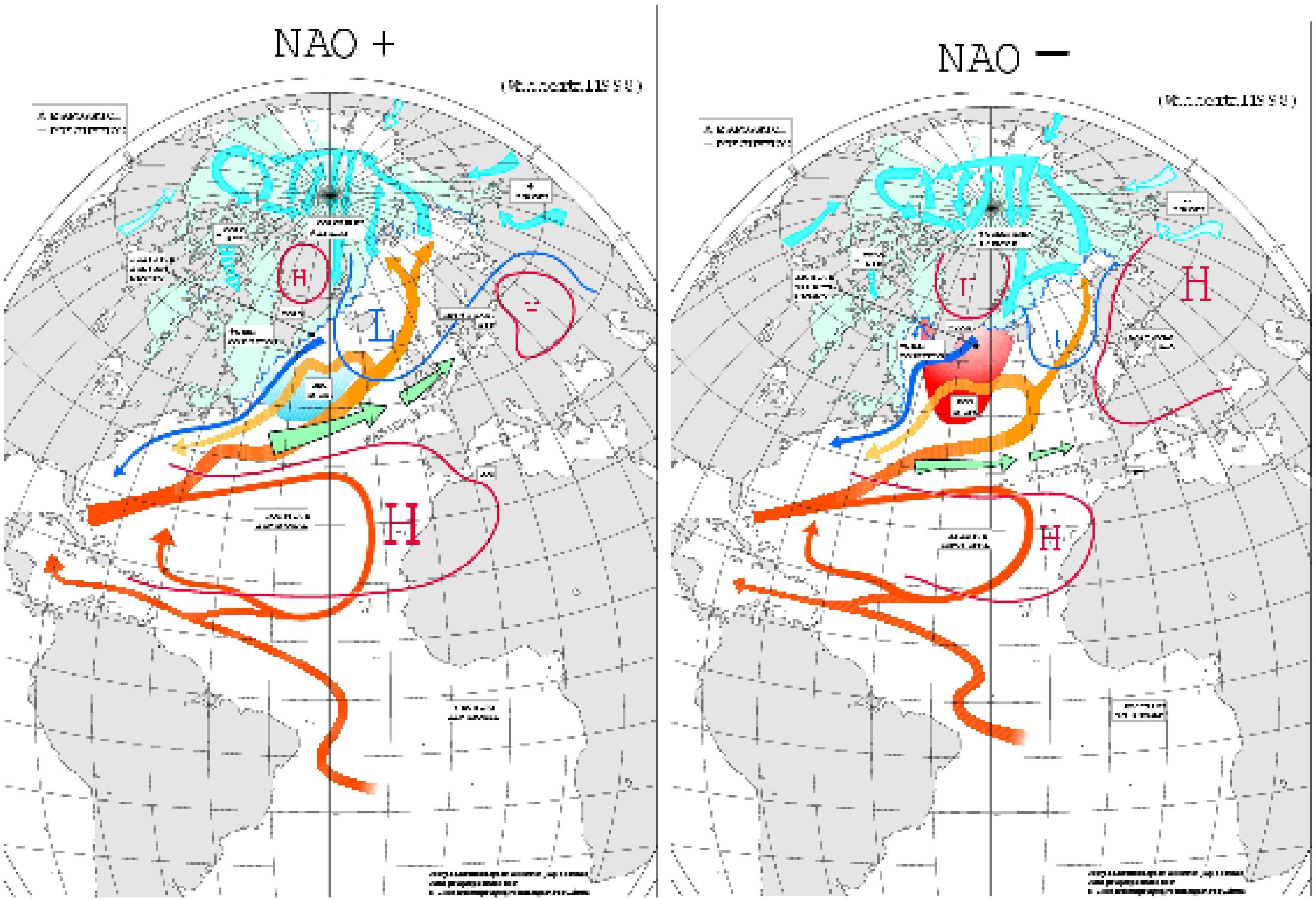
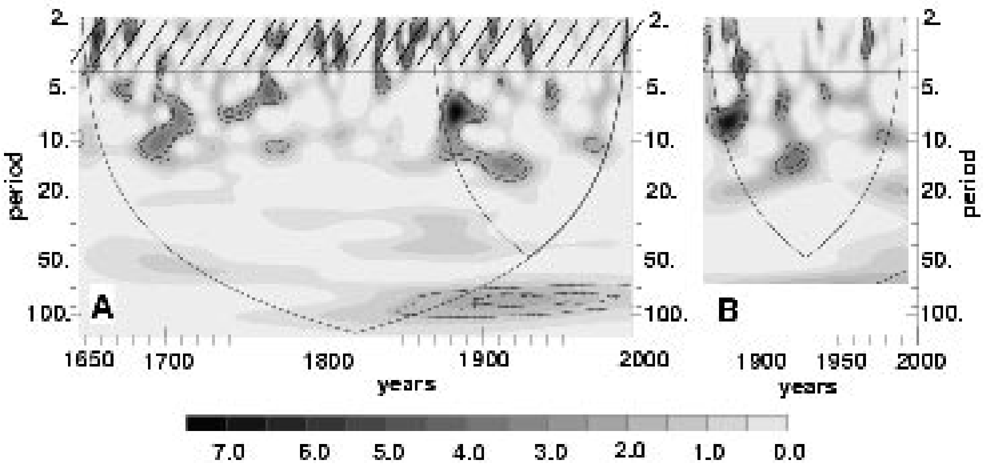


Figure 1: Positive (a) and negative (b) phases of the North Atlantic Oscillation and its effects on different parts of the climate system in the North Atlantic Regions (from Wanner et al 1999)

Fig 2: Local wavelet spectrum for the proxy North Atlantic Oscillation index derived from the accumulation rate determined on an ice core from northwest Greenland (a) and for the index based on direct observations (b). Amplitudes are scaled with the variance such that the expected power of white noise is 1 (from Appenzeller et al. 1998).



CLIVAR RELATED STUDIES IN THE UKRAINE

In the Ukraine studies connected with long period weather or short period climate variability were conducted during last years in the next directions: - data analysis of the field experiments of meridional heat and mass transport in the Atlantic carried out in the framework of “Sections” program; - cluster analysis of interannual ENSO-related variability and teleconnections (Pacific - Atlantic, ENSO - Europe, ENSO - NAO, ENSO - West Africa) using COADS data with the purpose of classification of global temporal and spatial ENSO-type patterns and their connections; - seasonal instability of long-scale SST anomalies in the World Ocean in relation to the barrier of spring predictability of ENSO and revealing seasonal instability of anomalies (closed to annual cycle) in different oceans (including the Pacific, Atlantic oceans and Mediterranean); - large scale interannual SST anomalies in the Atlantic in relation with the conveyor-belt and the North Atlantic Oscillation and physics of cross equatorial SST dipole forcing; - heat balance estimations of the Black Sea region on the basis of many years in situ and satellite data for checking the bulk formulas and forming climatic heat atlas of the Black Sea; - study of transient eddy statistics and long period variations on the basis of NCEP, TOGA reanalysis data.

Continuation and development of above mentioned studies are supposed to perform with special emphasis on the regional problems for the Ukraine, the Mediterranean and Black Seas. In general, they are related to G1, D1, and A1 of CLIVAR Principal Research Areas. In particular, we are planning:

- to continue the activity on converting the archive data of local hydrometeorological stations in electronic format for statistical estimations of climatic trends (downscaling);
- to study on the basis of all accessible reanalysis data (NCEP and ECMWF) the regional response of atmospheric circulation to main global patterns using known and advanced methods;
- to study the physical mechanisms of connections between synoptical and interseasonal variations;
- to apply the regional ACM for study of local climate changes forced by large scale anomalies of NAO-type;
- to study the heat climate of the Black Sea, as near closed basin, for testing available data of heat fluxes and estimation of possible changes.

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A SUMMARY OF THE UK CONTRIBUTIONS TO CLIVAR
with particular focus on
ATLANTIC CLIMATE VARIABILITY AND CHANGE AND ITS EFFECT ON EUROPE

Prepared by T H Guymer, A L New & H Cattle
on behalf of the Royal Society Global Environmental Research Committee

1 Introduction and Rationale

CLIVAR is a major WCRP initiative which will explore the predictability of the climate system, enable improvements in our ability to make predictions of seasonal climate and climate change, and enhance our ability to distinguish anthropogenic climate change from natural variability. The UK has an existing programme of research that maps strongly onto the themes of CLIVAR. In particular, the study of climate variability and detection and prediction of anthropogenic climate change across the whole globe will form a key element of the UK effort which will provide an important contribution to all three components of the CLIVAR programme.

The Atlantic sector is a key region for understanding the climate of Europe and for predicting likely changes in the future, both through natural and anthropogenic causes, which will affect the quality of life and commercial activities of the region. Of fundamental concern is whether the changes we are now observing are the result of natural fluctuations in the climate, or whether they are attributable to anthropogenic causes. On the seasonal to decadal timescale, the tracks and intensities of storms and the North Atlantic Oscillation (NAO) are of particular importance. On the decadal and longer-term timescales, understanding and prediction, including prediction of the impacts of anthropogenic climate change, requires improved knowledge of the thermohaline overturning circulation of the Atlantic and its relationship to rapid climate change, and also of the way that the Atlantic sector responds to events in other parts of the world.

This document outlines the current and future UK contribution to research in this area as one particular unifying focus for UK participation in CLIVAR. It provides a rationale to structure the programme and builds on strengths of the UK community (detailed below) by exploiting its expertise in modelling, observations and analysis and interpretation of data, and the synergy that results from combining these approaches. The observational strategy will utilise a wide variety of existing and emerging technologies, and a programme of continuing model development and experimentation is also underway which will enable the UK to maintain its current strong position at the forefront of this area.

The research proposed will be a significant contribution to international CLIVAR. It is ambitious in scope and beyond the abilities of any one UK institution to achieve. Coordination and cost-effective sharing of resources will be required, and funding will be sought from a number of sources. The present document is intended to act as a framework which will be used to shape collaboration with enterprises such as EuroCLIVAR, the various global observing system programmes whose data will be vital for many of our projects such as GOOS and its European component EuroGOOS, and other EC programmes and international initiatives.

The key issues for this UK focus are outlined in section 2, followed by a more detailed description of the themes envisaged in section 3. Sections 4 and 5 then describe the UK resources and future intentions.

2. Key Issues Relating to North Atlantic Variability

On the timescale of years to decades, the principal mode of variability in the Atlantic sector (and indeed in the whole extratropical Northern Hemisphere) is the North Atlantic Oscillation (NAO). The NAO is correlated with the distribution and intensity of storms impacting upon Europe, with high NAO periods corresponding to stronger winds, more frequent storms, higher waves, larger currents in the North Atlantic, and increased precipitation in Northern Europe. Over the last 3-4 decades, the NAO has amplified beyond past experience in a century-long record. If, as suggested by coupled models, the NAO continues to amplify in response to global warming, extreme events such as storms, flooding and increased rainfall, are likely to become much more frequent.

On the timescale of decades to centuries, the thermohaline circulation (THC) of the Atlantic becomes important. The northward flow of warm, near-surface waters is balanced by a return flow of deep cold waters, the whole process acting as a “conveyor belt. This drives a large component of the thermohaline circulation of the world’s oceans, emphasising the importance of the Atlantic in the global climate system, and the resultant northward heat transport is an important factor in maintaining the present equable climate of NW Europe. Palaeoclimate records indicate that rapid changes of several degrees C have occurred since the last ice age which have been ascribed to variations in the strength of this overturning. There is also evidence from models that a shutdown of this circulation is a possible consequence of global warming, leading to sea-surface temperatures in the North Atlantic cooling by 5-6°C, and a much colder climate over the European land-mass. In addition, alterations to the THC could result in large changes in sea level around the UK and European coasts.

However, the Atlantic clearly cannot be considered in isolation. It is influenced by the Arctic Ocean and its ice cover. This acts as a source of cold fresh water input to the northern North Atlantic which regulates the strength of the thermohaline circulation. There are also exchanges with the Southern Ocean through the South Atlantic, but the route by which this occurs, and the role of the Antarctic Circumpolar Current (ACC) in this process, are still open to question. In addition, the ENSO phenomenon in the tropical Pacific is important. Not only is it connected with the variability of the ACC, but may also influence the North Atlantic via atmospheric teleconnections.

3. Atlantic Climate Variability - Research Themes

The processes and phenomena outlined above have a huge potential impact upon European climate, but our present understanding of them, and our ability to predict their natural variability and response to anthropogenic forcing, is still only rudimentary. The UK contribution to CLIVAR relating to Atlantic variability will help to redress this situation, and can be categorised under three themes as now described. For each theme, present and continuing UK activities of relevance are summarised. It is envisaged that work under these themes will be continued and expanded in the future under CLIVAR. It is important to emphasise again that the broader UK research, on climate variability and the role of anthropogenic forcing across the whole globe, provides an important programme which runs through and supports each of these themes.

(a) Storms, Gyres and the NAO - Mechanisms of North Atlantic Variability

_____This theme is directed at understanding how the European climate depends upon processes in the North Atlantic sector, and at assessing the predictability of those processes and the likely impact of anthropogenic effects.

Coupled atmosphere-ocean modelling is one of the primary tools being used to study the Atlantic sector of the climate system and its effect upon Europe. The models are being integrated both with and without increasing levels of greenhouse gases, and are being compared with and validated against directly-observed and palaeo-proxy data. Work is also underway to improve various aspects of the coupled models, such as enhanced cloud physics and river runoff schemes. Specific research with these models includes studies of the influence of Atlantic sea-surface temperature (SST) on the atmosphere over Europe, factors affecting the North Atlantic storm track, its impact upon the European system, and its relationship with the NAO. Changes in the storm track will cause changes in the precipitation, river flow, and possible flooding in Europe, and the economic consequences of improved prediction are enormous. The coupled models are also being used to determine whether or not the NAO is effectively a coupled phenomenon.

The UK is also seeking to quantify and understand the seasonal to decadal variability of the North Atlantic ocean using observed hydrographic datasets, satellite remote sensing, a new surface flux climatology, and high-resolution ocean (-only) circulation models, with a particular focus on the decadal variability of the subpolar gyre and how this relates to the NAO. A recently-commenced oceanographic section from

Scotland to Iceland is being maintained in this context, and a network of bottom-pressure recorders (BPRs) and inverted echo-sounders (IESs) is being used to monitor volume flux variability at certain key sections. We are also studying the impacts of North Atlantic variability upon shelf and coastal regions of the oceans around the UK, including sea-level changes and the risk of flooding from tides and surges.

Current research is showing that the NAO is involved in the coordinated production (through air-sea interaction and oceanic convection) of Atlantic mode waters, and significantly affects the strength of the gyre circulation (by up to 30%), the heat content, and heat transport of the North Atlantic. We are also finding that the NAO may be connected with sea-surface temperature anomalies (the surface expressions of mode waters) which propagate around the subpolar gyre, with decadal variations in outflow from the Nordic Seas, with interannual variability in surface wave-heights, and with fluctuations in the position in the Gulf Stream.

Palaeo-climate datasets play an important part in assessing the likely extent to which present-day changes can be explained by natural variability, so aiding the detection of anthropogenic effects. Current research has enabled the NAO index to be extended back to 1822 using early pressure data from Gibraltar and Reykjavik, and tree-ring data are being used to explore the NAO back to the 15th century. It is now also likely that climatic signatures can be extracted from rapidly accumulating lake sediments that will enable the NAO to be extended back to the Holocene. In addition, a considerable amount of effort is being directed at the extraction and study of proxy records of floods and droughts extending back for many centuries.

(b) Rapid Climate Change - Thermohaline Circulation

This theme is aimed at determining the characteristics of the interannual to centennial variability in the Atlantic thermohaline circulation (THC), at understanding the mechanisms involved, and at assessing how the system will respond to anthropogenic forcing and the consequences for European climate.

A primary activity is the use of long-term hydrographic datasets, such as those recently collected by the UK within WOCE (the World Ocean Circulation Experiment) to characterise the decadal timescale variability in the Atlantic THC. Efforts have been so far focused on the 24°N section, sections through the subpolar gyre, the IGY section to Greenland, the “Ellett section” from Scotland to Rockall, and the deep outflows from the Nordic Seas via the East Greenland Current. In addition, twice-yearly AMT (Atlantic Meridional Transect) cruises from the UK to the Falkland Islands are providing valuable data for monitoring the upper ocean and the validation of satellites. These activities will be maintained and broadened, including the development of improved surface, aerological and satellite datasets for the assessment of natural variability. Further monitoring of the North Atlantic is being provided by a network of Bottom Pressure Recorders, and AUTOSUB (an autonomous underwater vehicle) will soon be capable of providing useful routine hydrographic measurements.

A parallel activity is to understand the processes in the Atlantic which maintain the THC and drive its variability. This requires circulation models, data and process experiments (including process models). Several relevant large-scale circulation (ocean-only, and coupled atmosphere-ocean) models have already been developed in the UK, and these must now be evaluated against observations, such as the trans-oceanic WOCE sections. A key initial test is whether they can simulate the mean oceanic transports correctly. The ability of the models to reproduce the variability of the THC on various timescales will then be assessed. In addition, process-oriented programmes, initially in the subpolar gyre of the North Atlantic, will enhance our understanding of the mechanisms involved in the THC, will enable assessments of the strengths and weaknesses of the circulation models, and will lead to improved parameterisations of the various processes within the circulation models. Work is also underway to develop enhanced models of the cycling of carbon and nitrogen, and to quantify the ocean’s uptake of halogenated compounds involved in greenhouse warming, in order to improve the predictive capability of the coupled climate models.

The utilisation of palaeo-climatological data and models will also be important to extend the timespan of the above studies, to gather evidence of the past (natural) variability, and to provide a framework for the detection of anthropogenic change. Activities include the extraction of climatic signatures from rapidly accumulating sediments covering the Holocene and beyond, and the possible extension of oxygen isotope techniques for describing past modes of circulation. In addition, studies are being carried out using both fully-coupled general circulation models and relatively simple models that can be integrated for centuries to millennia. These studies aim to explore the potentially wide range of triggering mechanisms for rapid climate change and the collapse of the thermohaline circulation.

(c) Interactions of the North Atlantic with the Global Climate System

This theme addresses the decadal timescale variability of the Southern Ocean and its interactions with the South Atlantic, the impacts of the Arctic and Nordic Seas and cryosphere upon the North Atlantic, the relationship of remote phenomena such as ENSO to Atlantic variability, and how each of these may change under anthropogenic forcing.

In the Southern Ocean, a key issue is the determination of the pathways, and their variability, by which upper ocean water masses transit into the South Atlantic. These flows may derive from either cold water from the Drake Passage or warmer water from the Indian Ocean. An oceanographic survey is now being planned to study the role of the Scotia Sea in this respect, which will include repeating earlier occupations of the Drake Passage and other key sections. The Drake Passage is an important choke point influencing the cold water path and the Antarctic Circumpolar Current (ACC, which itself directly connects the South Atlantic with the rest of the global ocean). The survey will also complement deployments of Bottom Pressure Recorders (measuring the volume flux through the Passage) which are now in place. In addition, ocean circulation model studies are underway and are indicating that the balance of the cold/warm water pathways into the South Atlantic is linked to deep water production in the North Atlantic and the Southern Ocean (which itself may be linked with variability in the ACC).

The Arctic and Nordic Seas, and their ice cover, significantly affect the Atlantic THC. Overall, Atlantic-derived inflows merge with Arctic outflows in the Nordic basins to form dense outflows back to the deep Atlantic. This process is intimately linked with deep convection in the Nordic Seas, which is likely to be regulated by the production of large volumes of freshwater there. Moreover, variability in the export of fresh water from the Arctic and Nordic Seas can result in large-scale anomalies which propagate around the subpolar gyre and interact with the atmosphere. The mechanisms and processes involved here, the circulation pathways and timescales, and their variability and relationships to phenomena such as the NAO, are all relatively unknown at present, but further study is anticipated through observations and modelling. We also need to enhance our understanding of, and capacity to predict, variations in the Arctic cryosphere, and work is currently underway to improve techniques to derive sea-ice thickness from satellite remote sensing. The relationship between the cryosphere and the abruptness of climate change revealed in North Atlantic marine geological and ice-core records also needs to be better understood.

The North Atlantic is also known to be affected through (atmospheric) teleconnections by the Asian Summer Monsoon, the African climate system, and the ENSO phenomenon in the tropical Pacific. For instance, waveheights (derived from satellite observations) in the North Atlantic are low during ENSO years, and high during La Niña years. Consequently, the ability to predict ENSO is commensurate with an ability to predict the wave climatology (and by inference the near-surface wind speeds) in the North Atlantic, with obvious benefits for Europe. The development of multi-seasonal forecast models of the ENSO phenomenon are therefore underway, as are studies of the response of ENSO to climate change. In addition, palaeo-data from lake sediments is being utilised to study the relationship between ENSO and the North Atlantic back to the Holocene.

4 UK Resources

The UK currently has a strong and ongoing programme of world-leading research relevant to CLIVAR, comprising not only the aspects of Atlantic climate variability outlined here, but also encompassing the prediction, assessment and detection of anthropogenic climate change. This is being undertaken at centres of expertise funded by a wide variety of mechanisms and comprising Government Agencies/Laboratories, NERC Centres and Surveys and leading University groups (a list is appended below). Modelling is well served with highly regarded efforts in coupled climate modelling, atmospheric models, models of the deep ocean and shelf seas, and palaeo-climate models at the various centres, supported by high-powered super-computing facilities at Edinburgh, Manchester and the Meteorological Office. Observationally, the UK benefits from ready access to a wide variety of platforms including research ships and aircraft, together with expertise in satellite remote sensing, tide-gauges, bottom pressure recorders, purposeful tracers, glaciology, and in the development of new technology such as the AUTOSUB. In addition, the UK has established data centres for the archival and retrieval of atmosphere and ocean data, and for mean sea-level, which support the community by providing access to assembled and quality-checked datasets.

5 UK Intentions and Plans

While we cannot adequately describe the full spectrum of UK plans in the present document, we here summarise the more important aspects. These will be supported by building on the existing UK programmes and by seeking further funding through established mechanisms, in order to contribute to CLIVAR in the longer term. Throughout, close liaison will be maintained with the EuroCLIVAR and EuroGOOS projects.

Firstly, the UK is pleased to host the International CLIVAR Project Office, and, through NERC and the Meteorological Office, is already contributing to its funding. A bid to continue financial support until at least 2005 has been made to NERC and formal confirmation of the bid is expected soon. Observationally, the UK plans to seek further funding to contribute to the DecCen “NAO array” of moored profiling CTDs, to the global network of ARGO floats, for the implementation of a time-series station in the northeast Atlantic, to continue regular (or make new) occupations of, or deploy long-term moorings at, critical ocean sections in the North Atlantic and Southern Ocean, to extend the directly observed NAO index back to about 1760, and to acquire and analyse additional atmospheric datasets, particularly through participation in the GCOS Station Network and the GCOS Upper Air Network. There will also be a continued development of state-of-the-art and simplified coupled-climate and component models, and of relevant data assimilation schemes, and assessments will be made of the ability of these models to capture the mean state and variability of aspects of the climate system. In addition, satellite data will be used to derive enhanced surface climatologies and to make improved estimates of Atlantic circulation and heat transports. We also envisage the maintenance and extension of networks of Bottom Pressure Recorders, tide gauges, and inverted echo-sounders in key regions, together with the development and exploitation of new technologies for autonomous monitoring of the ocean and atmosphere, including the AUTOSUB and acoustic thermometry. The UK’s research ship facilities will be used to assist in the deployment of these and other instrumentation, as well as to contribute more generally to CLIVAR-related oceanographic science.

6 Summary of UK CLIVAR-Related Agencies, Centres and Institutes

British Atmospheric Data Centre
British Oceanographic Data Centre
Centre for Environment, Fisheries and Aquaculture Science
Centre for Global Atmospheric Modelling at UR
Climatic Research Unit at UEA
Natural Environment Research Council (NERC)
Research Vessel Services
Scott Polar Research Institute
University of East Anglia (UEA)
University of Liverpool
and
University of Oxford

British Antarctic Survey
Centre for Coastal and Marine Science
Centre for Ecology and Hydrology
Centre for Polar Climate at University College London
Hadley Centre for Climate Prediction and Research, Meteorological Office
Permanent Service for Mean Sea Level
Southampton Oceanography Centre
Space Science Department at the Rutherford Appleton Laboratory
University of Edinburgh
University of Manchester Institute of Science Technology
University of Reading (UR)

NATIONAL STATEMENT FROM TANZANIA TO THE CLIMATE VARIABILITY AND PREDICTABILITY (CLIVAR) CONFERENCE

1 Introduction

Recent extreme weather events in Tanzania have caused severe damages to the economy. The La-Niña event of 1996/97 was possibly responsible for the severe drought that occurred in most parts of the country leading to insufficient rainfall for hydroelectric power generation and urban water supplies. Rangelands could not support livestock resulting in serious animal losses. Another La-Niña event has again affected the 1998/1999 rainfall season and is expected to affect crop production and livestock. The El-Niño of 1997/98 brought with it widespread flooding which destroyed large crop acreage and infrastructure.

Rainfall in Tanzania is a very crucial factor in the ability of farmers and pastoralists to produce the food stuffs needed for consumption by the people. Rainfed agriculture is the mainstay of the economy, consequently severe drought or floods have disastrous impacts on the socio-economic development of the country. Causes of droughts/floods in Tanzania are to a large extent complicated. The weather systems that cause variations in the country's weather and climate are varied and include Monsoons, the Intertropical Convergence Zone(ITCZ), Tropical Storms, the Subtropical Anticyclones, African Jet Streams and Easterly/Westerly wave perturbations. Although several studies have been conducted in this country in an effort to understand and predict the climate, we are still keen to see more efforts spent on improving our knowledge.

2 International and Regional collaboration

Progress in forecasting climate variations and providing reasonable estimates of the likely effect on climate change can be made if there exists a strong regional/international co-operation. The activities of the World Climate Research Programme (WCRP) of the World Meteorological Organization (WMO) has been strongly supported by many nations. This programme has led to other sub-programmes such as the WMO Climate Information and Prediction Services (CLIPS) and Tropical Ocean-Global Atmosphere (TOGA) which have been very useful in climate prediction services in our country. The El-Niño/Southern Oscillation (ENSO) fluctuations have been found to be associated with climate anomalies in Tanzania.

At the regional level, Tanzania is collaborating with the regional drought monitoring centres of Nairobi, Kenya and Harare, Zimbabwe. The are other regional projects like the Nile River Basin water project, Lake Victoria Environmental Project and Lake Tanganyika Project. The African Climate Variability priority area for CLIVAR research will play an important role in enhancing the knowledge needed to increase operational weather predictability. The establishment of the Southern African Regional Climate Outlook Forum (SARCOF) which brings together scientists, decision-makers and users is useful in utilizing existing knowledge of seasonal weather prediction for the benefit of sustainable development in the region.

However, we do not have a strong paleoclimatic community or the capability of running coupled climate models with high resolution. We entirely rely on activities and products from major climate centres. Thus, Tanzania scientists focus mainly on process studies and data collection activities.

3 Present contributions to CLIVAR

Tanzania is a poor country with only limited resources. Our research activities are mainly centred on observational studies and instrumental data collection. The following diagnostic studies have been done recently:

- drought analysis in the country
- an initiative towards developing a long-range rainfall forecast in Tanzania

Other studies have also been done using climate information in collaboration with the Tanzania

Centre for Energy, Environment, Science and Technology(CEEST) the following studies on "Assessment of Vulnerability and Adaptation to Climate Change Impacts " have been completed:

- water resources sector
- coastal resources(sea-level rise) sector
- grassland and livestock
- agriculture(crops) sector
- - coffee production
- - cotton production
- - maize production
- forestry sector
- health sector

4 Future contributions to CLIVAR

Tanzania will continue with its contributions as outlined in section 3 above and also plan new initiatives in the area of Numerical Weather Prediction. We need to acquire knowledge and facilities to scale down the Global Ocean-Atmosphere Coupled Circulation Models to Limited Area Models for our country to obtain a better resolution. The development of statistical models that correlate our weather with West Indian Ocean and Eastern Atlantic sea surface anomalies will be a high priority area. A detailed study of the Hadley Cell Circulation over the country and adjacent ocean areas is also envisaged as more accurate winds from remote sensing facilities are made available.

5 Conclusion

We support the initiatives which have been taken in developing the CLIVAR research programme that we hope will play an important role for future climate research activities.

Within our existing funding we intend to align our research more closely to the common goals of CLIVAR and with some external financial support, we shall contribute to special observational programmes of WMO and those of our region.

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UNITED STATES OF AMERICA
CLIVAR NATIONAL STATEMENT

Summary

The Climate Variability and Predictability (CLIVAR) science program offers the United States an opportunity to cooperate in a comprehensive study of climate variability and change. This World Climate Research Programme (WCRP) project aims to understand the causes of climate variability, to improve predictability of this variability, to extend pre-instrumental climate records into the past, and to understand and predict the climate changes caused by growth of radiatively active gases and aerosols in the atmosphere. These goals are accepted by U.S. climate scientists and funding agencies as scientifically timely and of great importance to the U.S. and the world.

There is U.S. interest and scientific activity in all the CLIVAR Principal Research Areas (PRAs) described in the Initial Implementation Plan (IIP)[1] as well as in connecting and expanding some PRAs. A coordinated international effort, however, is required to meet the scientific objectives of CLIVAR. A focus of the U.S. effort will be understanding seasonal-to-interannual climate variability and enhancing its prediction, but appropriate efforts in decadal variability and anthropogenic change will have a similarly high priority.

While the time scale distinctions between seasonal-to-interannual and decadal-to-centennial have helped frame the initial science questions to be addressed, the importance of the interaction of variability across time scales is sufficiently compelling to consider the acceleration of an ultimate intent of CLIVAR: to enhance predictive capability on multiple time scales and to apply forecasts on regional scales. Each of the Global Ocean-Atmosphere-Land System (GOALS) and Decadal-to-Centennial (DecCen) PRAs has specific regional domains and address phenomena that exhibit variability from subseasonal to centennial. As CLIVAR is being implemented, the U.S. recommends that the CLIVAR Scientific Steering Group consider reformulating the PRAs, to the extent appropriate, so that they focus on the variability and predictability of regional climate phenomena across the range of time scales.

This U.S. Position Paper has been developed with extensive input from the U.S. Science community. The U.S. initiated in 1993 the planning of programs intended to contribute directly to CLIVAR. The U.S. National Research Council (NRC) established two Panels, for GOALS and DecCen, to develop consensus U.S. science plans[2,3]. U.S. funding agencies also sponsored a number of meetings and workshops to draft more detailed U.S. science and implementation plans for specific research areas within CLIVAR, including Pan American Climate Studies (PACS)[4], Pacific Basin-scale Extended Climate Studies (BECS)[5], the Atlantic Climate Variability Experiment (ACVE)[6], and the Asian-Australian (AA) Monsoon[7]. An interagency group of program managers from the National Aeronautic and Space Administration (NASA), the National Science Foundation (NSF), the National Oceanographic and Atmospheric Administration (NOAA), and the Department of Energy (DOE) started meeting regularly earlier this year to begin more formal coordination of CLIVAR-relevant projects among the agencies and to discuss the mechanisms for implementing CLIVAR research in the U.S. One of the first activities of the interagency group was to establish a U.S. CLIVAR Science Steering Committee (SSC) to provide overall scientific guidance, to recommend priorities and effective sequencing of U.S. CLIVAR activities, and to ensure balance within the various elements of the program. At its first meeting in September 1998, the SSC reviewed program plans and forwarded recommendations to the interagency group on specific actions that should be undertaken. The position paper reflects those recommendations and the plans of agencies.

Within the U.S., the best-developed plans are in the G1 and G3 PRAs, in decadal modulation of El Niño Southern Oscillation (ENSO) (bridging G1 and D4), and in seasonal-to-decadal variability in the Atlantic sector (PRAs D1, D2 and D3). Efforts in G1 include global modelling and empirical studies coupled with enhanced observations in the Pacific Ocean. Efforts in G3 are integrated with the Variability of the American Monsoon System (VAMOS) program and new tropical ocean and atmosphere observations. Modest expansions of the modelling, empirical and observational studies needed for these efforts will support studies of decadal variability (under D1, D2, D3 and D4). A majority of the U.S. work in PRAs A1 and A2 will be

based on a coordinated modelling effort. Planning and pilot studies for G2 will be initiated. Other areas, such as G4, extending D3 to study Arctic changes, and D5, are of great interest and current activity, but the U.S. hopes other nations will take the lead in developing and implementing a strategy to satisfy CLIVAR objectives.

Many ingredients of research in the individual PRAs are common to them all. The U.S. will support integrating efforts such as development of models and data assimilation techniques, design and implementation of improved observing systems, and continuation of present satellite and in-situ observations. The U.S. also recognizes the interdisciplinary nature of the climate research. Close cooperation with operational activity in the World Weather Watch (WWW), the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS), and the Global Ocean Data Assimilation Experiment (GODAE), and with complementary research programs such as the Global Energy and Water Cycle Experiment (GEWEX) and Past Global Changes (PAGES) is required. In particular, the U.S. CLIVAR program is predicated on continuation and evolutionary improvement of (a) satellite and in situ measurements that support operational analyses of the atmosphere, (b) satellite measurements of sea surface topography and surface winds over the ocean, and (c) the Tropical Atmosphere Ocean (TAO) array.

For the past several years, U.S. agencies have been providing support both for pilot projects exploring the actual use of climate forecasts and social science research on the incorporation of climate information into decisions that improve adaptation to climate variability. In recent years, effort has increased to draw actual decision-makers into a process to better articulate and define their information needs regarding their coping strategies for variability in climate conditions. To the extent that CLIVAR's mission is to provide information useful to society, these ongoing research efforts should offer guidance for the relative benefits of different forms of climate analysis and predictive information. An enhanced and sustained dialogue between CLIVAR's science planning efforts and applications/adaptation research programs should result in clear examples of adjustment strategies around the world.

The following summarizes U.S. plans more completely described in the full document:

1. Global Seasonal-to-Interannual Predictability: ENSO and Monsoons

The present efforts in diagnosis and experimental forecasting of ENSO will continue. Maintenance and evolution of the TAO array and satellite measurements of the surface wind field and sea surface topography are crucial to this effort. Changes to these systems should have sufficient overlap for careful assessment. Deliberate expansion of studies of the American Monsoon will proceed, extending first to the Pacific cold-tongue and stratus region because of relevance for ENSO prediction, and then to the American Monsoon region and into the tropical Atlantic. Studies of the Austral-Asian Monsoon system will proceed through a phased approach, beginning with pilot studies and development of international collaborations.

2. Decadal Modulation of ENSO

The U.S. will contribute significantly to the study of decadal modulation of ENSO in the Pacific sector throughout the life of CLIVAR. This study will involve a coordinated observational and data assimilation study, empirical and paleoclimate studies, and research with a spectrum of climate models. Continuation and evolution of TAO array time series are vital elements of this program.

3. Atlantic Climate Variability

The U.S. will contribute significantly to the study of climate variability in the Atlantic sector, focusing specifically on the North Atlantic Oscillation (NAO) and, especially, Tropical Atlantic Variability (TAV). A coordinated upper ocean observing system will be required in the tropical Atlantic extending throughout the North Atlantic Ocean coupled with a basin-wide ocean data assimilation effort. Modelling and limited observations to define and understand climate-scale variability in the deep ocean will be included. Progress on the variability in the North Atlantic will require close collaboration with existing national and international programs of research in the Arctic.

4. Anthropogenic Climate Change

U.S. CLIVAR, in conjunction with other related programs, will develop a coordinated national effort toward the modelling of natural climate variability and its connections to the climate change associated with forcing of the climate system by both natural (e.g., volcanic and solar variations) and anthropogenic (e.g., land use and aerosol loading) sources. This research will require ongoing evaluations of the observational data on the variability of the climate system and its forcing functions. It will also require a rigorous program for the continual evaluation and development of the climate models that are used to evaluate and predict the decadal to centennial change in the climate system due to natural and anthropogenic forcing

5. African Climate Variability and Southern Ocean Thermohaline Circulation

Understanding the variability of the African climate system involves studying at least three distinct regions of the African continent, east and central Africa, north and west Africa, and southern Africa. A limited number of U.S. scientists are engaged in observational and numerical modelling studies to gain insights into these scientific questions. It is expected that these investigations will continue with increasing collaboration with researchers in Africa.

The Southern Ocean may be a significant role in climate variability through dense water formation, exchanges between ocean basins and abrupt changes through ice sheet dynamics. Since the observational base and modelling capabilities are not as well developed as in other regions, the U.S. endorses the recommendation in the IIP that initial emphasis be put on exploratory investigations of this region.

6. Climate Modelling

In addition to a continuing aggressive program of numerical experimentation, effort will be put into improving coordination of modelling efforts. Efforts will be made to facilitate open and ready access to well-documented models, data assimilation systems, simulations, and observations. A common programming paradigm should be adopted to facilitate exchange of model modules such as physical parameterizations. Modelling, assimilation and observation programs need close coordination and interaction.

7. Sustained Observations

Success of CLIVAR depends, in part, on the continuation and enhancement of the atmospheric observing network (including the WWW network), and this will be a high priority for U.S. CLIVAR. Improvements are needed to this and other observing systems in order to accomplish the CLIVAR research objectives. The legacy of CLIVAR must be a global climate observing system that is evolutionary, providing adequate observations for operational and research purposes and a capability for assessing the impact of its elements. Priorities for observations that are not yet available in an operational context are:

(i) Enhancement of the atmospheric weather observation network to make it adequate for long term monitoring of climate variability.
(ii) Measurements of temperature and salinity in the upper 1500 meters focused in the subtropical Pacific (35°S to 40°N) and Atlantic (35°S to 65°N)
(iii) Sea level of sufficient accuracy (1-2 cm) and duration (at least the next 20 years) to detect decadal changes in ocean circulation, changes in the mass balance of the polar ice sheets, and changes in mean sea level.
(iv) Sustained, accurate measurements of surface vector winds over the ocean.
(v) Estimates of surface fluxes of heat, freshwater, energy and momentum at selected ocean and land sites, including improved measurements of cloud properties and soil moisture.
(vi) Collection of long time series from the ocean at select Eulerian stations and from repeat ocean sections.

Two implementation activities are planned. First, there will be phased deployments of instruments aimed at meeting the needs of particular CLIVAR PRAs. Second, in coordination with international and non-CLIVAR programs, U.S. CLIVAR should build toward a sustained, global climate observing system. In both these activities, U.S. CLIVAR will promote strong ties between observational, modelling and data assimilation activities. In particular, the upper ocean observing system will be assessed, and will evolve, in the context of the value added by data assimilation. There must be free, open and timely exchange of data from all sustained observing systems.

8. Data Set Development

A fundamental objective of the U.S. CLIVAR policy on data management will be the free, open and timely exchange of CLIVAR related data and products. The U.S. will have a strong policy of keeping as much data as possible in the public domain and limiting the time that data can be restricted. U.S. CLIVAR will support development of comprehensive, long-term data sets by improving the quality and volume of the historical database through data archeology, supporting the development and evaluation of data sets, development of integrated proxy records and continuing to reanalyze historical data for the atmosphere and ocean, as well as satellite-based products.

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In addition, several U.S. scientist-generated planning documents and reports on the American monsoon have been generated under the Pan American Climate Studies (PACS) Program. They are available on-line at the PACS homepage: http://tao.atmos.washington.edu/pacs/plans.html.

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CLIMATIC VARIABILITY AND CLIMATE CHANGES IN VENEZUELA

Over the past few years the world has witnessed significant climatic anomalies which have had a major impact on societies and the economy at global and regional levels. No longer can 'climate' be considered to be the average state, over relatively long periods of time, of the major atmospheric fluctuations that occur from hour to hour or day to day. Accordingly, the term 'climatic variability' has acquired important significance, and for this reason an understanding of the processes that affect the climate and possible ways of predicting it are now one of the fundamental objectives of research throughout the world.

In Venezuela, climatic variability in all parts of the country has a profound effect on the primary sector of the economy. For this reason, research workers in Venezuela have focused their studies on the impact that interaction between the ocean, land and atmosphere in the tropical Americas, and that the El Niño/Southern Oscillation (ENSO) have on the climatology of our country, taking into account the proven forecasting possibilities for these factors. In this context, the following research projects have been developed:

1 The influence of the Pacific and Atlantic Oceans on rainfall variations in Venezuela.

It has been determined that the tropical North Atlantic plays a key role in rainfall anomalies that occur from April to July. On the other hand, observations have revealed that the thermodynamic situation in the Pacific Ocean primarily influences rainfall in February. This latter situation affects 32% of the stations located in areas where there is a biannual pattern; that is, where there are two oscillations between rainy and dry periods during the course of the year. It was also found to affect the southern region of the country. Since the statistical model used in this study revealed a forecasting skill of 70% to 80%, it is considered that, based on SST of both the Atlantic and the Pacific Oceans, a good precipitation predictability can be obtained for the various regions in the country.

2 A comprehensive assessment of the impact of ENSO and climatic changes on agriculture in the Andes.

This investigation is being carried out jointly with Peru, Colombia and Ecuador. Its purpose is to develop a scientific base which will be used to conduct a comprehensive investigation into how ENSO and climatic changes in the Andean eco-region stretching from Bolivia to Venezuela affect humans. The project will be based on the integration of climatic variability associated with ENSO and climatic changes with biophysical and economic models, and will cover the principal agricultural regions of the Andes. At the same time, an evaluation is to be carried out of the adaptability, vulnerability and sustainability of Andean agriculture in relation to expected ENSO events and climatic changes, so that political and technological options may then be proposed with a view to mitigating the adverse effects of these phenomena.

3 The effects of ENSO and climatic variability on the water balance, ecosystems and agriculture in the Venezuelan plains.

This investigation is being conducted jointly with the United States. Its purpose is to determine whether indications of forthcoming ENSO events can be found in the climate of the Venezuelan flatlands, and whether there is a relation between the climatology in the region and the SST of the Atlantic and Caribbean. Using simulation models previously calibrated for various locations, studies are being undertaken on the impact of year-to-year variability on the principal eco- and agrosystems of the flatlands.

4 Study of the variability of daily precipitation in a tropical mountain region.

The goal of this project is to provide a temporal characterization of daily precipitation in a tropical mountain region, and to formulate atmospheric mechanisms with a view to explaining the variation patterns and ecological effects in some tropical mountain ecosystems, such as cloud forest.

5 Forecasting anomalies in the discharge of the River Caroní.

In this study, methods were developed for forecasting minimum discharge in the River Caroní during the months of February and March, using anomalies recorded in the SST of the Pacific Ocean as the predictor field. Real time validation is currently in process.

6 Analysis of the influence of ENSO on the growing season in Venezuela.

The purpose of this study was to determine whether the ENSO phenomenon produces changes in the distribution of rainfall in Venezuela that would affect any of the following agricultural elements: date of the start of the growing season, duration of the growing season, amount of precipitation. The study established that ENSO did not have such a marked effect on Venezuela as it did on countries of the Pacific rim. An analysis of the tercile of intensity of SST anomalies in both the Pacific and the Atlantic showed that an upper tercile in the Atlantic and a middle tercile in the Pacific translates to an early start to the growing season.

Projects developed within the framework of CLIVAR and of interest to Venezuela

Based on the results of the various research projects conducted in the country, Venezuela attaches much importance to joint support for the implementation of projects developed by the World Climate Research Programme (WCRP) as part of the Study on Climate Variability and Predictability (CLIVAR), in particular:

1 CLIVAR-GOALS
- ENSO: extension and improvement of predictions (G1)
- Variability of American monsoonal systems (VAMOS)

2 CLIVAR DecCen
- North Atlantic Oscillation (D1)
- Variability of the Tropical Atlantic (D2)
- Circulation of the Atlantic Thermoclimate (D3)
- Decadal variability of the Indian and Pacific Oceans (D4)

3 CLIVAR ACC
- Prediction of climatic changes (A1)
- Detection and factors of climatic changes (A2)

Venezuelan support for CLIVAR

Because the studies planned under CLIVAR are of great importance to Venezuela, the National Council for Scientific and Technological Research (CONICIT), through the Administration for International Cooperation, now looks set to approve Venezuela's participation in a supporting capacity, and to fulfil the commitments that such participation would entail.

Furthermore, through its project for Improvements to the Hydrometeorological System of Venezuela, the country will also be in a position to contribute to 'CLIVAR data'. As of 1999, information from 12 new synoptic stations and three upper-air observing stations to be installed in the southern part of the country will be transmitted over the GTS.

Lastly, the Venezuelan Navy has agreed to participate in the PIRATA project, with the result that studies may now be undertaken on the possibility of extending the meteorological buoys network to the Caribbean Sea.

NATIONAL STATEMENT OF THE SOCIALIST REPUBLIC OF VIETNAM

Vietnam is located in the area affected by the transverse and lateral components of monsoon system and the Walker circulation and the country is often threatened by storms, flood, inundation and salinity intrusion. So we strongly support the CLIVAR programme and endorse a vigorous international programme of research to improve understanding and prediction of the climate system and its variability.

Due to the importance of climate variability and climate change to Vietnam, the country pays more attention to serving and monitoring the climate and atmosphere to provide the data for climate research, monitoring and prediction, supports applications of climate information such as seasonal and interannual prediction and has actively responded to the issues of climate change raised by scientific researchers throughout the world.

Upon on the grade of historical climate data, and by using the dynamical and statistical methodologies, there are series of studies had been published and applied to predict climate variations and tendency in Vietnam such as

- Medium-range forecasting (10 days) processes on medium and heavy rainfall in the North of Vietnam;
- Establishing medium- and long-range forecast of winter and summer season temperatures in North regions of Vietnam;
- Predicting onset of the first severe cold of winter season;
- Forecasting trends of climatic change in Vietnam;

But almost studies based on the computation of averages and particularly trends for each data time series and the analysis of correlation coefficients, linear regression, or multi-regression,..., and there is no climate specific prediction model (global or regional) applied in Vietnam.

Due to the insufficiency of the computerizing capacity including computer hardware and software for model operations and shortages of skilled personnel and expertise in development of numerical modelling experimentation, until now there has not yet Numerical Prediction Section in Hydrometeorological Service of S. R. of Vietnam. The Climate Research Centre has just been established since 1995 and our ability to predict climate on the short and long time scales as well as further changes is still limited. The present research programme (for 1999-2002) on establishing technology base for empirical study on climate prediction and issue of climate bulletin in Vietnam prepared by the Climate Research Centre is based on a call for proposals.

However, we are waiting for benefits that will come from successful completion of the World Climate Research Programme (WCRP), especially CLIVAR, CLIPS and others to develop the ability to predict the climate system on “seasonal, interannual, decadal, and centennial time scales”, and to “predict the response of the climate system to human influences.

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DROUGHT RESEARCH AND DROUGHT-RELATED ACTIVITIES IN ZAMBIA

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Abstract

Research into questions directly related to drought in Zambia is limited largely to the work at the Zambia Meteorological Department (ZMD) and the university of Zambia. However, there is a much larger body of research in the country, but is rather less directly related to problems of drought.

This inventory of researches on drought-related activities does not only include current and outgoing projects but also work conducted since the 1970's when drought impacts became more apparent than before. This research inventory is divided into two:
(a) Drought Research, further subdivided into Basic research and Drought impacts research; and
(b) Drought-related Activities

For most of the research carried out in Zambia, one of the weather and climatic parameters made at Zambia Meteorological Stations, rainfall is the most sought parameter by many users. This is due to the fact that rainfall in Zambia has influence on socio-economic development such as on agriculture food production and energy generation power (hydropower).

1. Introduction

Zambia lies between 22° and 34° east of Greenwich and 8° and 18° south of the Equator. The country consists mostly of plateaux with an elevation between 950m and 1350m, although there are some hill ranges with peaks of up to 2000m. The nearest sea mass is that of the Indian Ocean approximately 800kms to the east. The average highest temperatures over Zambia occur in October, most stations mean daily daytime within the range of 28-31°C. The temperatures then drop during the rainy season November to March to 20-26°C and night temperatures vary between 17°C and 21°C and fall to a minimum between 8°C and 9°C at dawn in June to July.

The maximum cloud coverage occurs during the rainy season as might be expected and on average the northern half of the country has the greatest annual amount of cloud, concurrently with the highest rainfall. Convective clouds are the predominant types during the rainy season also layer clouds formed by the spreading out of cumulus and cumulo-nimbus are common. In the hot season clouds are mainly by convection currents, due to high day time temperatures.

In general, the year in Zambia can be divided into two distinct halves, a dry half from May to October and a wet half from November to April.

2. Drought In Zambia

Although drought is a normal part of climate, what has remained constant about climate is its variability. Zambia like any other country has experienced droughts from time in memorial. Drought periods of 1921-1930 were severe. The 1930-50 dry alternated by rapidly wet years but on the whole the rainfall season was relatively good. In parts of southern Africa moderate to severe drought was reported between 1930/31 and 1932/33 and 1946/47 is much talked about famine, but was followed by good rains for a while. The 1967/68 heralded the beginning of a period of successive dry years across Africa. From 1981-1992 wet years were rare and drought was norm for most of the years. In 1981/82 drought intensified.

In 1991/92 Zambia experienced devastating effects of drought resulting in serious food shortages. The president of the Republic of Zambia declared the whole of the country a disaster. The drought of 1991/92 is described as one of the worst during the century. It should be noted that not all El-Niños are associated with droughts in Zambia. The 1997/98 El-Niño had two effects of the weather over Zambia i.e. excessive rains (floods) in the northern half of the country and less rain (below normal) in the southern half.

3. Climate-Related Research Activities

Climate research and development in southern Africa focused in recent years mainly on seasonal and centennial predictability. This involved both local and esteemed international researchers and research institutes. Since the sea surface temperature changes in the tropical Indian, Pacific and Atlantic oceans has a significant teleconnections with the rainfall and temperature over the subcontinent, Some success was achieved in the issuance of the 1997/98 rainfall season. This achievement is done through the Southern African Regional Climate Outlook Forum (SARCOF). Scientists, decision makers and users work together to produce with their expertise the seasonal forecast for the subcontinent. The forecast based on this are down-scaled by the Meteorological services to put other local factors in order to come up with the final forecast for their respective countries.

4. Conclusion

Weather and Climate play an important role in the socio-economic development of Zambia. In this regard Zambia wishes to acknowledge the importance of CLIVAR. The implementation of CLIVAR is relevant to all nations in that if successful, it will leave in its place a basis for climate prediction activity that the nations of the world will implement. It will help to improve scientists ability to predict the global climate system on "seasonal, interannual, decadal and centennial time scales", and predict the responses of the climate system to human "influences". In this regard, there is need for assistance from the international community to strengthen the Meteorological Department to enable it acquire data and information. Its capacity be enhanced in terms of human resources and develop research and training, and improve observational networks in the CLIVAR-Africa region.

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EUROCLIVAR

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Abstract

Euroclivar was established to help implement CLIVAR in Europe. Euroclivar organised eight specialised workshops and formulated recommendations for future climate variability research in Europe, as a contribution to CLIVAR. The establishment of an observational network and a European Climate Computing Facility are strongly recommended.

Introduction

Euroclivar was set up with the following objectives:

- To review ongoing CLIVAR-related activities in Europe,
- To stimulate CLIVAR-related research in Europe,
- To encourage the exchange of information between CLIVAR-related programme components,
- To increase the awareness of CLIVAR and the CLIVAR objectives among European scientists,
- To define scientific priorities for future programmes.

EUROCLIVAR - Activities

The idea for Euroclivar emerged from a meeting in Brussels to which participants of different countries and different disciplines had been invited. It was decided that a limited group would submit a formal proposal, but that a larger and fairly open committee would be set up. This committee consisted of a number of scientists and a representative of the EU Environment and Climate Programme. All European members of the CLIVAR scientific steering group were also members of Euroclivar. When the CLIVAR SSG membership changed the new European members were invited - and accepted - to join the Euroclivar committee. The committee held six general meetings, where activities were planned, and two additional meetings which discussed modelling collaboration.

Euroclivar workshops

Euroclivar organised eight specialised workshops. The subjects, selected on the basis of discussion in the Euroclivar committee, were the following:

- Atlantic Ocean DecCen Variability
- Cloud Feedbacks and Climate Change
- Past Climate Data
- Climate Change Detection and Attribution
- The Role of the Atlantic in Climate Variability
- African Climate Variability,
- Climatic Impact of Scale Interaction for the Tropical Ocean/Atmosphere System
- Data Assimilation in Ocean Models

For each workshop objectives were carefully discussed beforehand and the experts to be invited were selected with care so as to have an optimal spread in scientific input while still limiting the number of participants to allow for easy discussion. When necessary experts from outside Europe were invited. In some cases workshops were jointly organised with other bodies. More details are given in separate workshop reports (see list of references).

Other activities

Euroclivar undertook several activities in order to keep contact with European climate scientists. First of all a web site (http://www.knmi.nl/euroclivar) was set up and maintained. This site contained information about Euroclivar, but it also had an overview of national European activities, and links to relevant international sites. Euroclivar actively stimulated the establishment of national CLIVAR committees. On the other end, Euroclivar maintained contact with international CLIVAR. In particular, Euroclivar reported on its activities at the meetings of the CLIVAR scientific steering group and it prepared regular progress reports for “Exchanges”, the CLIVAR newsletter. In 1997 Euroclivar organised a special session at the European Geophysical Society meeting in Nice, which was widely appreciated.

Recommendations for future research

In order to focus the discussion, Euroclivar spent considerable energy on the formulation of recommendations for future research. These recommendations will be presented in a separate report (Anderson et al, 1998b). This report contains recommendations for European research on global climate variability and predictability, as a European contribution to the global CLIVAR programme. A better understanding of climate is of great importance for Europe for a number of reasons:

1. Natural fluctuations of the climate of Europe have many very significant consequences for safety, health, infrastructure, agriculture, energy, economy.
2. Natural climate fluctuations elsewhere in the world have European implications through geophysical, socio-economic and political mechanisms. 3. Improved prediction and detection of anthropogenic climate change will provide a firmer scientific basis for active emission, mitigation and adaptation policies.

Scientific issues

Natural climate fluctuations and human-induced climate change are intricately related and need to be studied together. Euroclivar recommends that high priority be given to the following topics: 1. European and Atlantic variability; 2. Global teleconnections; and 3. Anthropogenic climate change.

The climate in the North Atlantic/European domain exhibits significant variability on interannual and decadal time scales, involving interactions between the atmosphere and ocean circulation. At the same time this region is affected by major teleconnections linked to phenomena in the tropical atmosphere/ocean/land system, such as El Niño, African climate variability and the Asian monsoon. There are discrepancies between predictions of climate change made by different models which need to be understood and reduced. The scientific basis for detection and attribution of climate change must be improved.

The predictability of the climate system on time scales from seasonal to centennial needs to be quantified and models suitable for climate prediction must be developed.

Climate observations

To achieve the Euroclivar objectives, the establishment of an integrated observational network is imperative. This network, to be implemented in cooperation with nations adjacent to the Atlantic, should include:

1. an extensive network of profiling floats in the Atlantic;
2. an operational tropical Atlantic array of moored atmosphere/ocean observing stations (PIRATA);
3. basin-wide measurements of the Atlantic water mass and circulation variability at critical latitudes;
4. continuation, at the present level, of the ocean/atmosphere observations with voluntary observing ships; and
5. continuous contribution of satellites to the global coverage of the ocean and atmosphere. In addition, past climate variability needs to be reconstructed, using both the instrumental and the palaeoclimatic records.

A European Climate Computing Facility

Reliable regional climate change predictions cannot be achieved without enhanced European collaboration and substantial increases in computing resources. These are needed so that multi-century simulations can be made with sufficient complexity that important climatic features, physical processes and regional details are resolved. In addition, ensembles of integrations must be made to estimate the impact on climate

predictions of uncertainties in initial conditions and model formulation. The computational requirements for such simulations cannot be met from purely national resources. It is therefore strongly recommended that a European Climate Computing Facility be established.
The detailed recommendations can be found in Anderson et al (1998b).

Conclusion

European scientists have formulated a comprehensive set of recommendations for climate variability and predictability research in Europe. These recommendations are based on intense discussions and on the results of eight specialised workshops. It is hoped that these recommendations will be implemented under the Fifth Framework Programme.

Acknowledgements

I would like to thank the Euroclivar committee members, workshops organisers and participants and the international CLIVAR staff for their help and contributions. Euroclivar was supported by the European Commission under the Environment and Climate programme (1994 - 1998), contract ENV 4-CT95-0073.

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POTENTIAL SCAR INTERACTIONS WITH CLIVAR

Introduction

This document sets out a very brief statement of the possible interactions between the developing CLIVAR programme of WCRP, and the science activities in Antarctica and the Southern Ocean under the aegis of the Scientific Committee on Antarctic Research (SCAR). Various practical linkages between SCAR science and the planned activities of CLIVAR can be identified. These are:

- Existing science within SCAR contributing directly to CLIVAR objectives
- The potential to implement CLIVAR objectives within projects undertaken within SCAR by expanding these projects
- Using SCAR and the committee of Antarctic programme managers (COMNAP) as conduits between CLIVAR and national operators to implement key observations (such as autnomous instrumentation deployment and 'ship-of-opportunity' programmes)

Background

SCAR is the ICSU body responsible for coordinating scientific research in the Antarctic. It plans scientific programmes and undertakes other related activities mainly through discipline-based Working Groups and shorter-lived, more tightly focused Groups of Specialists.

SCAR activities relevant to CLIVAR and to broader global change science research are undertaken through coordination by the Working Groups on *Glaciology* and on *Physics and Chemistry of the Atmosphere* (PACA), and by the Group of Specialists on *Global Change and Antarctica* (GLOCHANT). SCAR does not currently have a Working Group responsible for oceanographic studies, but GLOCHANT provides a framework within which many ocean-focused global change projects interact.

GLOCHANT includes nine programmes. These are grouped under four foci, shown in Fig. 1. Most of the programmes are co-sponsored with bodies outside SCAR. Three programmes have actual or potential links to WCRP, through CLIVAR and CLIC.

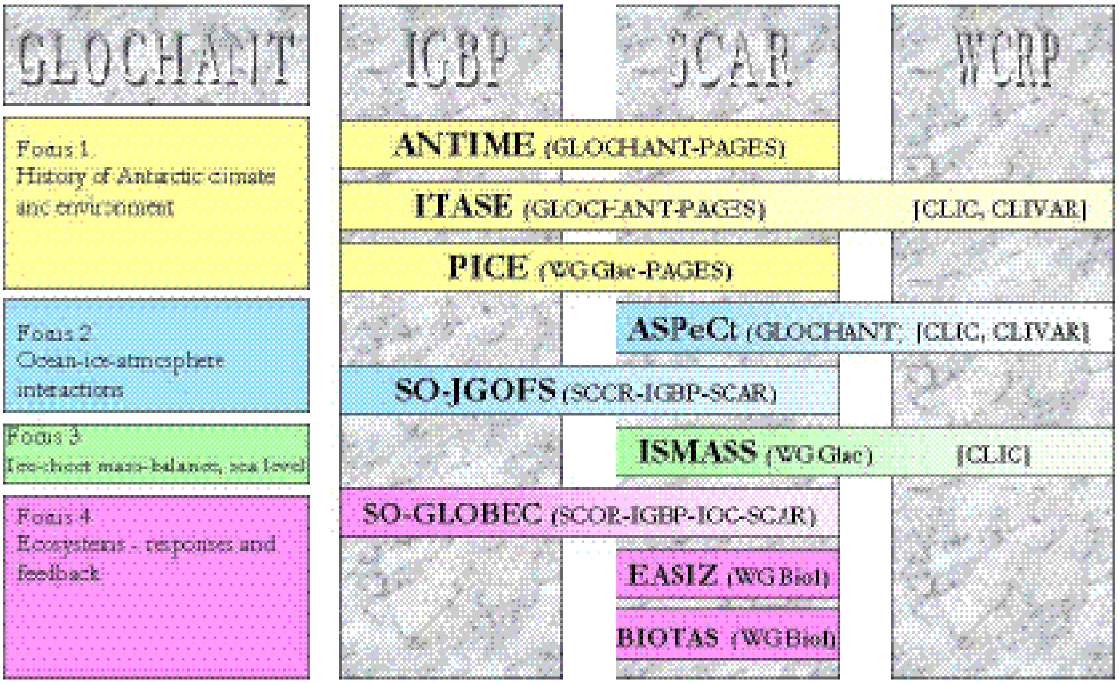

Figure 1. Diagram showing the four scientific foci of the SCAR-GLOCHANT. The affiliation of the nine programmes which are interlinked through GLOCHANT are shown. Links of the ASPeCt and ISMASS programmes to WCRP are tentative at present and anticipate the development of the Climate and Cryosphere (CLIC) initiative.

There are three areas where science activities within SCAR as a whole relate to the aims and objectives of CLIVAR. These are:

- Regional climate change and variability
- Sea-ice climatology and variability
- Palaeoenvironmental studies

These science areas are examined in more detail below.

Regional climate change and variability (WG-PACA)

Areas covered by current observational and modelling programmes focus on the current observed warming in the Antarctic Peninsula region, the so-called ‘Pole of Variability’ in the Amundsen Sea region, and teleconnections between meteorological variability over Antarctica and the Southern Ocean, and lower latitudes (Fig. 2).

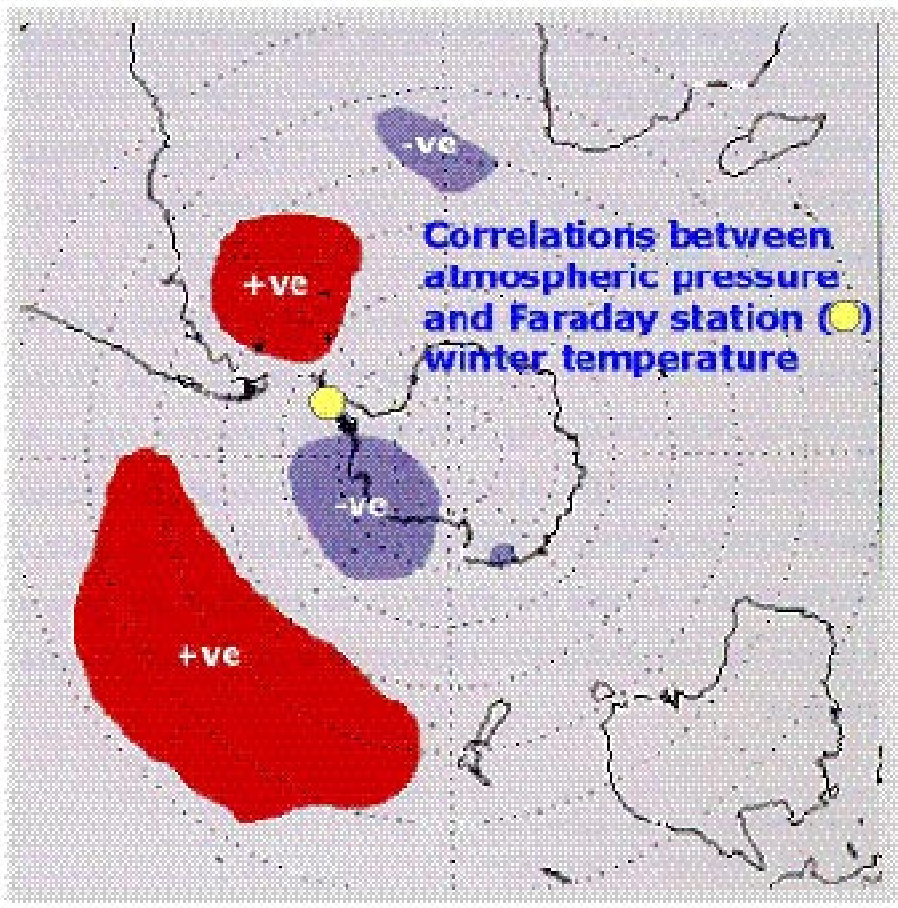

Figure 2. Teleconnection between climate variability in Antarctica and at lower latitudes in the Southern Hemisphere. The shaded areas are those where atmospheric pressure correlates strongly with winter temperature at Faraday-Vernadsky station (dot on Antarctic Peninsula). The area of strong negative correlation to the west of Faraday is located over the so-called 'Pole of Variability', the location of maximum atmospheric pressure variability in the region. (Figure courtesy of Dr John King)

Sea-ice climatology and variability (GLOCHANT ASPeCt programme)

Sea ice is both a key determinant of regional and global ocean-atmosphere interactions, and an important indicator of regional interannual and decadal variability, and potentially of secular change. Main activities concern ice-ocean-atmosphere processes which are crucial to global modelling, and construction of a circum-Antarctic sea-ice climatology. The latter activity is being addressed by a programme of transect studies (1998-2007), together with the assimilation of existing observations to produce a separate retrospective climatology for 1980-97.

The ASPeCt programme has close relations with the iAnZone physical oceanography programme (SCOR Affiliated Programme). ASPeCt is likely to be included within WCRP CLIC (*Climate and Cryosphere*).

Palaeoenvironmental studies (GLOCHANT ITASE, co-sponsored with IGBP-PAGES)

The ITASE study uses high-resolution ice- and snow-cores to study the changes in climate over the last 200 years. The programme has two major elements - the collection of cores along a series of priority transects over the Antarctic ice cap, and the assembly and consolidation of a dataset based on existing cores. These objectives are set out in the Science and Implementation Plan (published as PAGES Workshop report 97-1).

Two other SCAR programmes examine palaeoenvironmental records on longer time-scales than are appropriate to CLIVAR. ANTIME is concerned with the evolution of the continental margin of Antarctica, and combines interpretation of several different types of records. PICE is concerned with the climate records from deep ice cores such as those from Vostock (Antarctica) and Greenland. Both programmes are joint activities with PAGES.

Workshops

In addition to the field programmes outlined above, SCAR and its programmes are organizing a series of workshops to evaluate data series and to consolidate their interpretation. Many of the planned workshops are cross-disciplinary.

Two workshops of particular relevance to CLIVAR are:

Recent Antarctic climate history (joint activity of ITASE and WG-PACA). University of New Hampshire, Durham, New Hampshire, US. 19-23 April 1999. Contact Ian Goodwin (address below).

Interannual variability in the Southern Ocean (coordinated by GLOCHANT). British Antarctic Survey, Cambridge, UK. 2-7 August 1999. Contact Julian Priddle (address below).

Appendix 1. List of programmes participating in GLOCHANT

Polar climate system
ASPeCt (SCAR GLOCHANT - potential WCRP CLIC component) - sea ice physics and climate
ISMASS (SCAR WG-Glaciology - potential WCRP CLIC component) - ice-sheet mass-balance

Palaeoenvironmental studies
PICE (SCAR GLOCHANT-PAGES) - long-term climate change records in ice cores
ITASE (SCAR GLOCHANT-PAGES) - recent history of climate change
ANTIME (SCAR GLOCHANT-PAGES) - history of the Antarctic continental margin

Ecological and biogeochemical studies in the Antarctic and Southern Ocean
EASIZ (SCAR WG-Biology) - marine coastal ecology
SO-JGOFS (IGBP, SCOR) - ocean biogeochemistry
SO-GLOBEC (IGBP, SCOR, IOC) - marine plankton dynamics
BIOTAS (SCAR WG-Biology) - terrestrial ecology

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A STATEMENT BY THE COMISIÓN PERMANENTE DEL PACÍFICO SUR (CPPS)
(South Pacific Permanent Commission)

A Buoys Monitoring System for the South East Pacific

During the 13th meeting of the CPPS Scientific Committee on El Niño -ERFEN XIII- (Guayaquil, Ecuador, 2-4 November 1998) the four South Pacific countries of the CPPS (Colombia, Chile, Ecuador and Peru) undertook an in-depth study of the origins and evolution of the 1997-98 «El Niño» and of its impacts on their respective coastal areas.

Immediately after ERFEN XIII, the IOC-WMO-CPPS Joint Group on El Niño held its 9th Meeting, also in Guayaquil, to review the scientific activities carried out its prior meeting. It drew up a coordinated plan to be implemented in the future by the three institutions of the Joint Group.

One the lessons learnt from the 1997-98 El Niño, was that the information now available for the ocean area of the South East Pacific is sorely insufficient. The Joint Group concluded that ocean buoys are obviously needed in the region to monitor the evolution of El Niño, so as to provide inputs for the Regional Prediction Models presently being developed to mitigate the impact of the phenomenon in the coastal areas of the four CPPS countries.

The scientists who attended the Joint Group accordingly appointed a working party which drafted a preliminary proposal (Annex 1 hereto) of a monitoring system based on coastal and oceanic buoys to be installed along the South East Pacific Coast. Some of the countries of the region already have plans for their buoys and are seeking local and/or international funding whilst others are now finalising their proposals. Needless to say, our Commission strongly supports this important initiative of the IOC-WMO-CPPS Joint Group on El Niño. It would obviously greatly assist the region in better understanding the El Niño phenomenon and would also allow better preparation of mitigation measures for the future.

Our Commission would appreciate that information about this CPPS project be made available to the CLIVAR meeting, stressing its importance for studies on Climate Variability and Predictability and for the entire Ocean Sciences community, as well as its urgency for the countries of the South Pacific Region.
It has been agreed that the delegate of Chile will make the general presentation of the above mentioned CPPS project at the CLIVAR meeting.

Annex III Report of the Working Group: South-East Pacific Monitoring and Warning System

Introduction

The South-East zone of the Pacific Ocean, which comprises the coasts of Colombia, Ecuador, Peru and Chile, where the most severe effects of the El Niño Phenomenon take place, is devoid of sea-based meteorological on the surface temperature of the sea and its level. This situation does not assist understanding of the ocean phenomena occurring on the coastal zone, such as upwelling patterns of Kelvin waves on the continental platform which impact fishing and the coastal climate.

The Toga buoys system

As a part of the TOGA project, a string of ocean buoys was laid along a line of the Equatorial Pacific between 5º South, and from the date line to 90º East. These buoys provide surface meteorological information and oceanographic data to a depth of 500 metres. The information gathered by the TOGA monitoring system has proven of great value for evaluating the unfolding of the El Niño phenomenon, and as an input to prediction models. However, the system extends only to 95º West, leaving the coastal zone near South America without the data needed to monitor subsurface anomalies which propagate the length coast from Colombia to Chile.

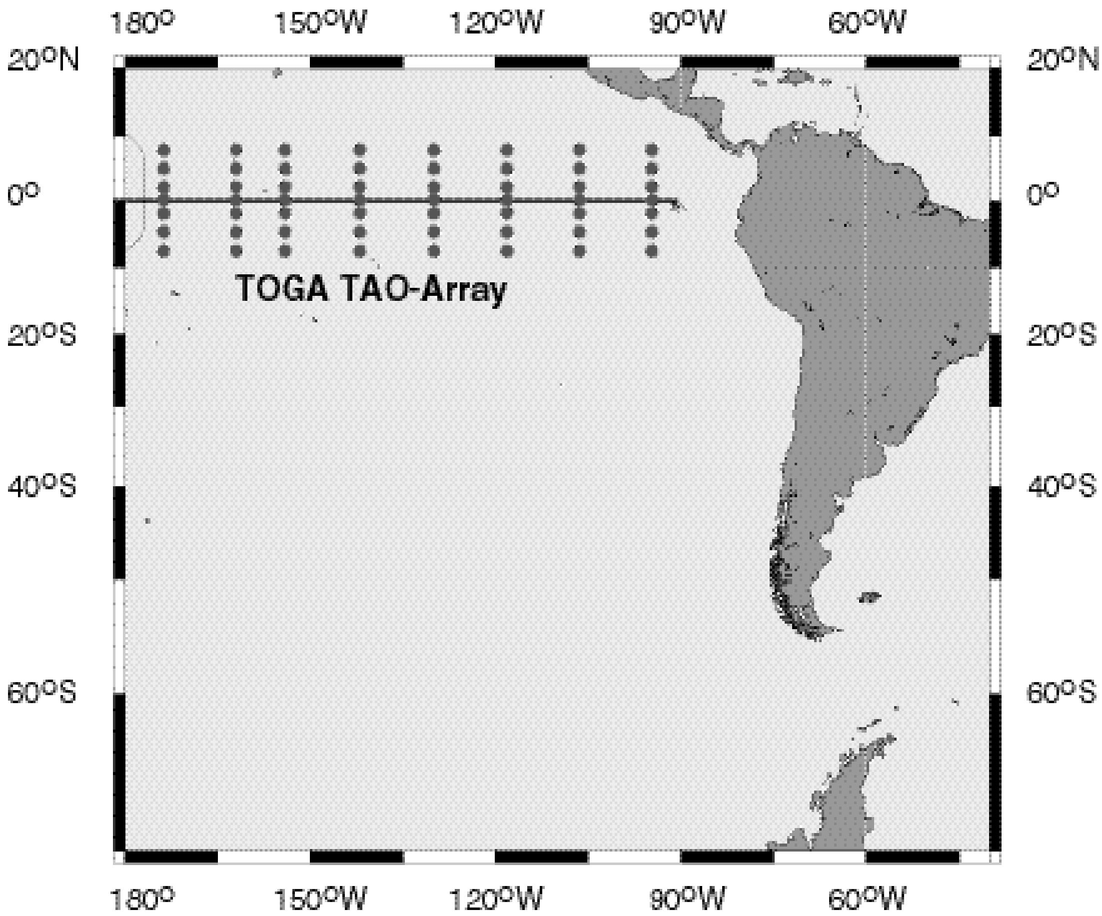

Figure 2

The region's requirements

The strength of the El Niño 1997-1998 phenomenon and the usefulness of the buoys system of the TOGA project aimed at covering the entire Equatorial Pacific has highlighted the absolute need to extend the monitoring and watch buoys system towards the West Coast of the Pacific, and along that Coast. The installation of ocean buoys with meteorological sensors and depth sensors of temperature, salinity and the strength of currents would enable the region to keep the phenomena affecting the coastal climate and fishing under permanent scrutiny.

The economic impact of these phenomena for the South American West-Coast nations call for a response from the scientific community to allow them to take adequate action in the future. The establishment of a Monitoring and Warning System for the South-East Pacific would not only contribute to a better scientific understanding of the phenomena but help the responsible authorities to design better concrete measures for prevention of disasters and the taking of emergency action.

Proposal for a Monitoring System

The proposed System would constitute an extension of the present buoys system of the TOGA project, along the coasts of Colombia, Ecuador, Peru and Chile and into the open sea, to detect the meteorological and oceanographic factors which unfold in that region during phenomena such as El Niño and La Niña, but also during periods of normal conditions. The aim is to better understand these phenomena and their interaction with the coastal climate and fishing within the region, as they concern each of the coastal nations.
The proposal includes the need to establish:

- In Colombia: 2 buoys facing the coasts of Tumaco and one near the Island of Malpelo.
- In Ecuador: 3 buoys on the Equatorial line between 95° West and the coast of Ecuador, one near the Galapagos Islands; one between the Galapagos Islands and the coast; and one near the coast on the line

the Equator.

- In Peru: 3 buoys off the coasts of Bayovar (6º South) where the Humboldt current distances itself from the coast turning West (one coastal and 2 ocean buoys), and 3 buoys facing the coast of Callao (12º S). The latter include one coastal; one approximately 60 miles from the coast, where monitoring of the thermic structure has been taking place over a number of years and where cruise ship monitoring is frequent; and one off Callao to detect ocean phenomena associated with ENOS.
- A buoy at 18ºS 85ºW, financed by the PACS Project and due to be installed in the year 2001.
- In Chile: buoys between Iquique and the south of Chile (at 3, 20, 100 and 1000 miles from the coast).

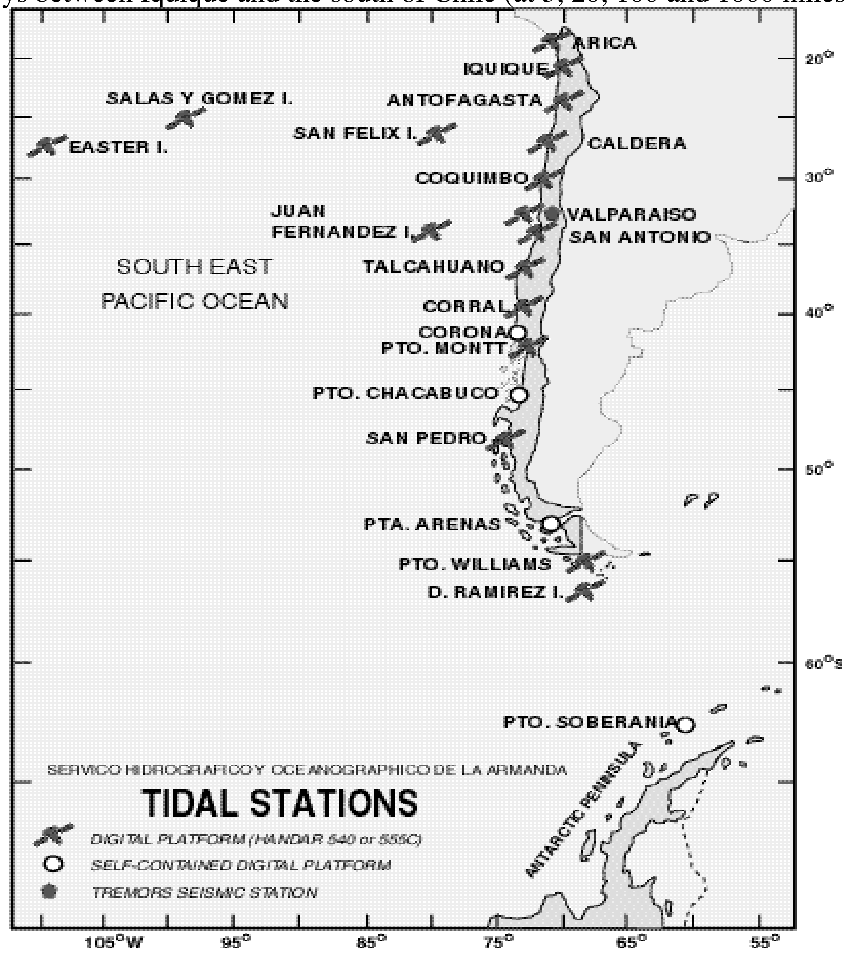

Figure 3

Recommendations

In view of the importance that the region should benefit in the future from a surveillance system of fixed buoys, it is hereby recommended that the countries of the region and the CPPS through ERFEN promote the proposed activity amongst the governments, that they seek the technical backing of the IOC and the OMM as necessary, and that they study the prospects of financing from national sources as well as other sources available through international entities.

It is recommended, moreover, that this activity be evaluated within the work of programmes such as CLIVAR/VAMOS and other initiatives which require information on the region as inputs for their own development.

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