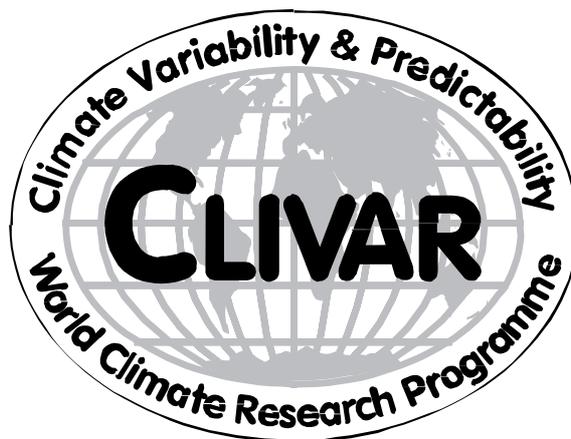


**INTERNATIONAL
COUNCIL FOR
SCIENCE**

**INTERGOVERNMENTAL
OCEANOGRAPHIC
COMMISSION**

**WORLD
METEOROLOGICAL
ORGANIZATION**

WORLD CLIMATE RESEARCH PROGRAMME



1st Session of the CLIVAR/Clic Southern Ocean Panel

Hobart, Australia, March 11-13, 2002

Mike Sparrow, Steve Rintoul and Eberhard Fahrback (Eds.)

August 2002

WCRP Informal Report No. 16/2002

ICPO Publication Series No. 65

CLIVAR is a component of the World Climate Research Programme (WCRP), which was established by WMO and ICSU, and is carried out in association with IOC and SCOR. The scientific planning and development of CLIVAR is under the guidance of the JSC Scientific Steering Group for CLIVAR assisted by the CLIVAR International Project Office. The Joint Scientific Committee (JSC) is the main body of WMO-ICSU-IOC formulating overall WCRP scientific concepts.

Bibliographic Citation

INTERNATIONAL CLIVAR PROJECT OFFICE, 2002: First Session of the CLIVAR/Clic Southern Ocean Implementation Panel, 11.-13. March 2002, Hobart, Australia. International CLIVAR Project Office, CLIVAR Publication Series No. 65, 38pp. (Unpublished manuscript).

TABLE OF CONTENTS

1.	ACTION ITEMS	3
2.	INTRODUCTION	6
3.	STRUCTURE AND PURPOSE OF MEETING	7
4.	OVERVIEW OF CLIVAR AND CLIC	7
	4.1 CLIVAR overview and status	7
	4.2 Overview of progress to date in implementation of Southern Ocean CLIVAR	8
	4.3 Overview of CliC, including elements relevant to the understanding of the Southern Ocean	10
5.	CLIVAR-CliC INTEGRATION	10
6.	SEA ICE	11
7.	METEOROLOGY, AIR-SEA COUPLING AND TELECONNECTIONS	11
8.	MODELLING ISSUES	14
	8.1 The 'mean state' of ocean models	14
	8.2 Variability in ocean models	15
9.	CARBON UPTAKE AND STORAGE IN THE SOUTHERN OCEAN	16
10.	SUMMARY OF NATIONAL PROGRAMMES	17
11.	SCIENCE SYMPOSIUM WITH ARGO SCIENCE TEAM: THE VALUE OF SOUTHERN OCEAN OBSERVATIONS	18
	11.1 CLIVAR's requirements for Argo observations	19
	11.2 Introduction: The Southern Ocean's role in climate	19
	11.3 Southern Ocean response to climate change	19
	11.4 Potential Impacts of climate change on the Southern Ocean's carbon cycle	20
	11.5 Modes of variability in the atmosphere-ocean system of the southern hemisphere	20
	11.6 Observed changes in the southern hemisphere oceans and the need for an expanded observing system	21
	11.7 Using Argo to study Southern Ocean circulation	21
	11.8 How to extend Argo into the high latitude Southern Ocean	21
	11.9 Ocean state estimation and operational oceanography: The need for southern hemisphere observations	22
	11.10 Discussion: Challenges and opportunities for implementation of Southern Ocean Argo	22
12.	SOUTHERN OCEAN TIME SERIES STATIONS	22
13.	REMOTE SENSING	23

14.	DATA MANAGEMENT ISSUES	24
15.	PALEO ISSUES	25
15.1	Southern Ocean variability: Lessons from ice cores	25
15.2	Southern Ocean variability: Lessons from sediment cores	25
16.	SUMMARY DISCUSSION OF NATIONAL/INTERNATIONAL PLANS	26
16.1	Air-sea fluxes	26
16.2	Oceanographic observations	26
17.	CROSS PANEL/PROJECT INTERACTIONS	27
17.1	CLIVAR regional panels	27
17.2	CLIVAR panels and working groups	29
17.3	CliC panels and working groups	29
17.4	WCRP programmes	30
17.5	Programmes outside of WCRP	31
18.	OTHER MATTERS	32
	APPENDIX 1. LIST OF ATTENDEES	33
	APPENDIX 2. MEETING AGENDA	35

1. ACTION ITEMS

- 1.** Draft implementation plan of CliC to be distributed for comment by rest of panel. (Ian Allison and Eberhard Fahrbach)
- 2.** Gurvan Madec to coordinate with CliC NEG (see Section 17.3) on issues of ocean and ice model development of common interest to CLIVAR and CliC. (Gurvan Madec)
- 3.** Arnold Gordon and Eberhard Fahrbach to prepare a brief white paper outlining a strategy for sustained and process observations in the sea ice zone. (Arnold Gordon and Eberhard Fahrbach, with input from rest of panel, Karen Heywood and Nathen Bindoff)
- 4.** The panel should investigate the possibility of including an oceanographic component to the meteorological RIME experiment in the Ross Sea. (Kevin Speer)
- 5.** Is there the potential for getting ice thickness and other relevant variables from Russian historical data? (Alexander Klepikov).
- 6.** A plan to box in the Adelie Land source with repeat hydrography, in coordination with the US Carbon sections, needs to be negotiated between the US, Australia and any other nations likely to be able to make a contribution to this work. (Steve Rintoul, Chris Sabine)
- 7.** Steve Rintoul and Chris Sabine to discuss who to contact about recommending a reoccupation of 43°S in the Pacific. (Steve Rintoul and Chris Sabine)
- 8.** The “chokepoint” section south of Africa remains somewhat of a gap. Germany, Russia and South Africa are encouraged to merge resources (and perhaps those of other collaborators like the USA) to see if more frequent hydrography or XBTs can be obtained to complement the present German efforts. (Eberhard Fahrbach, Alexander Klepikov, Chris Reason)
- 9.** Mike Sparrow to chase up national reports from other (e.g. Scandinavian) countries. (Mike Sparrow)
- 10.** Individuals to keep national reports updated annually. Mike Sparrow to send reminders. (National representatives and Mike Sparrow)
- 11.** Chair to write to Atlantic Panel and Edmo Campos emphasising the importance of the South Atlantic to CLIVAR science issues, supporting the planned South Atlantic Workshop, and NOAA efforts to establish an observing system at 30°S. (Steve Rintoul and Eberhard Fahrbach)
- 12.** Kevin Speer is to be the Argo contact point for the SO Panel, and coordinate the writing of a white paper for SO Argo. The paper will include contacts, schedules, and cruise tracks for Antarctic vessels capable of deploying floats. (Kevin Speer and rest of panel)
- 13.** SO Panel to update the white paper prepared for the Time Series Science Team (TSST) by requesting contributions from the panel members. For each site, a one page description of the scientific rationale, measurements proposed, investigators, and readiness is required. (Steve Rintoul to coordinate.)

14. TSST website will be up and running soon. ICPO to contact Uwe Send to ensure that details are posted on the SO website. (Mike Sparrow)
15. The SO panel endorses the GHRSSST project. The use of multiple sensors will be particularly useful in the cloudy Southern Ocean. The panel seeks guidance on the right mix of *in situ* measurements needed to complement and remove biases from satellite measurements in order to ensure the GHRSSST goals are met in the SO. (Steve Rintoul and Eberhard Fahrback to write to Neville Smith)
16. Once specific guidelines on data management are provided by ICPO, the Panel will communicate these guidelines to Principal Investigators to make sure they understand their responsibilities. (Stuart Cunningham, Shigeru Aoki)
17. Panel needs to identify data sets that have been collected since WOCE that should be archived as part of CLIVAR. (All panel, headed by Stuart Cunningham)
18. Katherine Bouton's draft CLIVAR data policy to be circulated to the rest of the panel for comment. (Mike Sparrow)
19. National representatives should assemble information on collection and availability of data sets resulting from the national programmes and forward to Stuart Cunningham and Shigeru Aoki. (All national representatives, Stuart Cunningham and Shigeru Aoki)
20. The SO Panel should liaise with the CliC DMIP (see Section 17.3) with regards data issues. (Stuart Cunningham and Shigeru Aoki)
21. The panel needs to let ICPO and the CLIVAR SSG know of any data concerns, in particular any difficulty in accessing data sets (All panel, headed by Stuart Cunningham and Shigeru Aoki)
22. The Panel should review the SO coring sites proposed by IMAGES/PAGES and provide guidance, if needed, on their oceanographic relevance. (Philip Froelich)
23. SO Panel to produce an evolving version on the web of the Implementation plan. To start with this should include a two or three page statement on the atmosphere (Ian Simmonds), carbon issues (Chris Sabine), paleo issues (Philip Froelich) and models (Gurvan Madec). (Ian Simmonds, Chris Sabine, Philip Froelich, Gurvan Madec and rest of panel)
24. The panel supports the formation of an air-sea flux group and seeks advice from them on the correct mix of SO observations that the Panel should advocate. (Steve Rintoul)
25. Chris Reason and Alexander Klepikov to provide maps summarising the cruise tracks of the South African and Russian vessels and investigate whether logistical support exists in South Africa for enhanced observations south of Africa. This information will then be forwarded to the SOOP. (Chris Reason, Alexander Klepikov)
26. The panel felt it would be useful to make the distinction on the CLIVAR hydrography/Carbon website between sections that are sustained commitments to multiple repeats and those that are one-off reoccupations. (Mike Sparrow)

- 27.** Chairs to write to Atlantic panel strongly endorsing plans for a 30°S observing system, and seeking clarification of present proposed and funded efforts. (Steve Rintoul and Eberhard Fahrback)
- 28.** Arnold Gordon to summarise arguments for re-occupation of WOCE lines in the South Atlantic, to forward to Atlantic panel. (Arnold Gordon)
- 29.** Chairs to write to AAMP to propose a “division of labor” between the two panels: The AAMP to cover the top-to-bottom circulation north of 20°S, while the SO panel extends its domain north to 20°S. (Steve Rintoul and Eberhard Fahrback)
- 30.** Explore with PAGES the possibility of a joint Southern Ocean workshop. (Philip Froelich)
- 31.** The SO panel needs to think about indices that provide useful benchmarks for models (e.g. transport of ACC, overturning cell, rate of bottom water formation, gyre circulation etc). It was suggested that modelling issues be a subtheme for the next panel meeting. (Gurvan Madec and rest of panel)
- 32.** Chairs to write to Judy Curry and Paul Stackhouse expressing the strong support of the panel for SEAFLUX and SRB and asking for suggestions as to how the panel might be of help. (Steve Rintoul and Eberhard Fahrback)
- 33.** The SO Panel webpage should be kept updated with information about other projects and panels. (Mike Sparrow)
- 34.** A list of scientific highlights, important and submitted papers to be included on the SO panel webpage. Details to be forwarded to Mike Sparrow. (All panel and Mike Sparrow)
- 35.** At least one representative from the panel should attend the South Atlantic Workshop (see Edmo Campos for details). (Steve Rintoul to seek a volunteer nominate)

2. INTRODUCTION

The CLIVAR Southern Ocean (SO) CLIVAR/CliC panel is charged with refining and implementing the science plans of CLIVAR and CliC in the SO Sector. The panel was formed as the result of a recommendation from a SO workshop held in Perth, Australia, in November 2000.

The terms of references (TORs) of the panel are:

- To design a strategy to assess climate variability and predictability of the coupled ocean-atmosphere-ice system in the Southern Ocean region.
- To develop and refine an implementation plan for the Southern Ocean region which defines the process studies, sustained observations, and model experiments needed to meet the objectives of CLIVAR and CliC.
- To work in concert with relevant CLIVAR panels (e.g. regional panels, numerical experimentation groups), ACSYS/CliC Panels (DMIP, OPP, NEG) and other groups (e.g. Ocean Observation Panel for Climate, Argo Science Team) to integrate SO observations with those in neighbouring regions to ensure the objectives of CLIVAR/CliC are met and resources are used efficiently.
- To enhance interaction between the meteorology, oceanography, cryosphere, biogeochemistry and paleoclimate communities with an interest in the climate variability of the SO region.
- To serve as a forum for the discussion and communication of scientific advances in the understanding of climate variability and change in the SO region
- To work with the CLIVAR and CliC data systems on issues related to distribution and archiving of SO observations.
- To advise the CLIVAR and ACSYS/CliC SSGs on progress achieved towards implementation.

For further details see: <http://www.clivar.org/organization/southern/>

The members of the SO CLIVAR/CliC Panel are:

S. Rintoul - co-chair	CSIRO, Hobart, Australia
E. Fahrbach - co-chair	Alfred-Wegener-Institut für Polar und Meeresforschung, Bremerhaven, Germany
S. Aoki	National Institute for Polar Research, Tokyo, Japan
I. Allison	Antarctic CRC, Hobart, Australia
S. Cunningham	Southampton Oceanography Centre, Southampton, UK
P. Froelich	Georgia Institute of Technology, Atlanta, USA
A. Gordon	Lamont Doherty Earth Observatory, Palisades, USA
G. Madec	LODYC, Paris, France
D. Martinson	Lamont Doherty Earth Observatory, Palisades, USA
R. Morrow	LEGOS, Toulouse, France
C. Sabine	NOAA/PMEL, Seattle, USA
I. Simmonds	University of Melbourne, Melbourne, Australia
K. Speer	Florida State University, Tallahassee, USA
M. Sparrow	International CLIVAR Project Office (ICPO),

C. Ereño
Southampton Oceanography Centre, Southampton, UK
ICPO South American representative, University of
Buenos Aires, Buenos Aires, Argentina

Unfortunately Doug Martinson, Stuart Cunningham and Philip Froelich were unable to attend this first meeting. However Karen Heywood (University of East Anglia, UK) kindly stood in to represent UK interests and Will Howard and Vin Morgan attended to ensure that the paleo community were represented. In order to ensure a broad representation of the international community delegates from Russia, Brazil, South Africa, China, New Zealand, Italy and Norway were also invited. A full list of the attendees is given in Appendix 1.

3. STRUCTURE AND PURPOSE OF MEETING

The first meeting of the SO Panel was held at CSIRO Marine Research, Tasmania. The meeting structure was based on a series of discussions interspersed with science talks (see Appendix 2 for the full agenda).

The meeting started with Steve Rintoul welcoming the attendees and defining the purpose of the meeting:

- To update and fill gaps in the SO Science Plan (for example, carbon, sea ice, atmospheric processes, paleo studies etc.).
- Implementation: To summarise commitments, identify gaps and the strategies to fill them (including e.g. process studies, modelling, and time series/moorings).
- Implementation of SO Argo was singled out for particular attention. The meeting was organised to coincide with a meeting of the International Argo Science Team (IAST). A half-day joint science workshop on the scientific justification for SO Argo was held.
- Recommendations and questions for other panels.

4. OVERVIEW OF CLIVAR AND CliC

4.1 CLIVAR overview and status

The meeting continued with John Gould bringing the panel up-to-date on the status of CLIVAR. CLIVAR's aims 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 coupled climate system, in co-operation with other relevant climate-research and observing programmes.
- To extend the record of climate variability over the time-scales of interest through the assembly of quality-controlled paleoclimatic and instrumental data sets.
- To extend the range and accuracy of seasonal to interannual climate prediction through the development of global coupled predictive models.

- To understand and predict the response of the climate system to increases of radiatively active gases and aerosols and to compare these predictions to the observed climate record in order to detect the anthropogenic modification of the natural climate signal.

John described the structure, principal research areas and the organisation of CLIVAR. An important legacy of CLIVAR will be a better observing system and a much more comprehensive and extended climate record essential for understanding natural variability and human-induced change.

John reminded the panel of the importance of the SO connection to the other basins; in this sense, the SO component of CLIVAR can act as a bridge to help achieve a global perspective in CLIVAR. He encouraged the panel to consider issues of interaction with other programs for mutual benefit (e.g. GLOBEC), how to encourage closer collaboration between modellers and observationalists, and to identify data that was needed but not easily accessible.

4.2 Overview of progress to date in implementation of SO CLIVAR

Steve Rintoul gave an overview of the progress to date in the implementation of SO CLIVAR. The science has moved forward rapidly in the six years since the Science Plan was published. Due to these advances, SO CLIVAR has moved on from the “exploratory” approach advocated in the original Implementation Plan to a strategy focused on identifying and testing specific hypotheses regarding the connection between the SO and climate. The OceanObs99 conference and a CLIVAR SO workshop in Perth in 2000 made substantial progress in updating the scientific justification for SO CLIVAR and in securing resources for its implementation. The task for the SO panel is to build on this foundation. Steve also reminded the panel that our concern is the entire “Southern Ocean region,” i.e. including the atmosphere and cryosphere.

The OceanObs99 conference and the Perth workshop identified four themes of importance to the SO and climate: The “shallow” overturning cell, the “deep” overturning cell, interbasin exchange, and teleconnections and low-frequency variability. These themes provide a useful target for implementation. The relevance of each of these themes to CLIVAR and/or CliC can be summarised briefly as follows:

“Shallow” overturning cell:

- Formation and circulation of Subantarctic Mode Water (SAMW) and Antarctic Intermediate Water (AAIW)
- Sensitivity to changes in air-sea fluxes
- Link to the global overturning associated with North Atlantic Deep Water (NADW) formation and export
- Role in ventilation of the subtropical thermocline
- Exchange with lower latitudes
- Oceanic uptake of heat and anthropogenic CO₂

“Deep” overturning cell:

- Stability of the deep overturning circulation (e.g. in response to changes in freshwater flux)
- Rate of Antarctic Bottom Water (AABW) formation and sensitivity to change
- Freshwater balance at high southern latitudes
- Sensitivity of low latitude stratification to changes in AABW formation and export

Interbasin exchange:

- Antarctic Circumpolar Current (ACC) transport variability
- Exchange between the SO and the subtropical gyres
- Basin-scale heat and freshwater budgets
- Propagation of anomalies between basins and their impact on regional climate

Teleconnections and low-frequency variability:

- Interannual to centennial time-scales, including the Antarctic Circumpolar Wave (ACW)
- What are the relative roles of remote (e.g. tropical) and local forcing?
- Do the dominant modes of variability reflect coupled dynamics or a forced response?
- What is the impact of SO anomalies on regional climate? Predictability?

The SO (and southern hemisphere in general) is remote from the population and funding centres of the northern hemisphere. The need for observations of the southern hemisphere oceans therefore needs to be carefully evaluated to justify such an investment. Among the scientific questions that cannot be answered without southern hemisphere observations are: Variability of the overturning circulation; subtropical cells and low-frequency variability of El Niño/ Southern Oscillation (ENSO); ocean uptake of carbon; climate change detection and attribution; variability of southern hemisphere regional climate; basin-scale heat and freshwater budgets; global temperature response to greenhouse forcing (in particular the impact of sea ice changes in the southern hemisphere); centennial variability; and sea level rise.

To address these themes, sustained observations are needed. Argo is critical: The only way to obtain sustained observations in isolated regions like the SO is with profiling floats and satellites. However, Argo is not sufficient on its own, for example repeat sections are needed to measure transports, carbon storage, and changes throughout the full depth of the ocean. Time series stations and moorings have an important role to play, but require careful justification given the challenge of maintaining such observations in the SO.

Commitments now exist for a perhaps surprisingly large fraction of the proposed SO observing system, but a number of significant gaps remain. These include: Argo, air-sea flux measurements, hydrography in the Pacific sector, ACC monitoring, observing system design studies, South African “chokepoint” XBTs, and a strategy for sea ice thickness observations. One of the aims of the meeting is to make progress toward filling these gaps.

The following questions arose from the discussions:

- Arnold Gordon asked whether non-oceanic climate phenomenon are part of CLIVAR. John Gould answered that all physical climate phenomenon are part of CLIVAR or other WCRP programmes such as SPARC (Stratospheric processes and their effect on climate) or GEWEX (the Global Energy and Water Cycle Experiment).
- Ian Simmonds enquired if Argo floats make any atmospheric measurements. There was a general discussion on this topic. For the moment the answer is no (the main problem being designing an atmospheric sensor that can handle being submerged to 2000 m).
- Peter Sutton asked if the 3° by 3° spacing for the Argo floats was sufficient? It was suggested that in some cases it might be better to launch the floats together and let them scatter on their own (Arnold Gordon pointed out that the dispersion would be interesting in its own right). Further discussion on Argo implementation was postponed until after the Argo workshop.

4.3 Overview of CliC, including elements relevant to the understanding of the Southern Ocean

Ian Allison and Eberhard Fahrbach gave an overview of CliC, including the elements relevant to the understanding of SO CLIVAR.

The principal goal of CliC is to:

“Assess and quantify the impacts of climatic variability and change on components of the cryosphere and their consequences for the climate system, and determine the stability of the global cryosphere.”

Its supporting objectives are to:

- Enhance the observation and monitoring of the cryosphere in support of process studies, model evaluation, and change detection
- Improve understanding of the physical processes and feedbacks through which the cryosphere interacts within the climate system
- Improve the representation of cryospheric processes in models to reduce uncertainties in simulations of climate and predictions of climate change

Further details may be obtained from the ACSYS/CliC website at: <http://www.clic.npolar.no/>.

Areas where SO CLIVAR and CliC interests intersect include: The impact of a change in the thermohaline circulation (THC) on sea ice cover and vice-versa; the influence of the ocean on ice shelves and vice-versa; the high-latitude freshwater budget and stability of the THC; and ocean-atmosphere-ice interaction in the SO.

The ocean measurement requirements for CliC have not been finalised. A draft implementation plan has recently been completed, but was not available at the meeting. Ian noted that while some quantities of importance to CliC (and CLIVAR) are not observable now (e.g. sea ice divergence), it is likely that advances in technology will permit this in the 15 year lifetime of CliC.

ACTION: Draft implementation plan of CliC to be distributed for comment by rest of panel. (Ian Allison and Eberhard Fahrbach)

5. CLIVAR-CliC INTEGRATION

The panel felt that since there are many members of both CliC and CLIVAR in the SO Panel that the integration of the two projects should not be a problem. One aspect that may benefit from further coordination is modelling. The SO Panel (in particular Gurban Madec) has a role to play as a bridge between the CLIVAR and CliC numerical experimentation groups to ensure that SO issues are addressed.

ACTION: Gurban Madec to coordinate with CliC NEG (see Section 17.3) on issues of ocean and ice model development of common interest to CLIVAR and CliC. (Gurban Madec)

There was some discussion of the right mix of process and sustained observations required in the sea ice zone (interaction between the atmosphere sea-ice and land-ice) to meet the needs

of CLIVAR/CliC. It was agreed that a short white paper outlining a proposed ‘straw man’ plan should be prepared for further discussion by the panel.

ACTION: Arnold Gordon and Eberhard Fahrback to prepare a brief white paper outlining a strategy for sustained and process observations in the sea ice zone. (Arnold Gordon and Eberhard Fahrback, with input from rest of panel, Karen Heywood and Nathen Bindoff)

ACTION: The panel should investigate the possibility of including an oceanographic component to the meteorological RIME experiment in the Ross Sea. (Kevin Speer)

6. SEA ICE

Ian Allison led a discussion on the issue of sea ice. The aims of CliC in this respect may be summarised as: What are the past and future patterns of variation and change in sea-ice distribution and mass balance in the polar regions?

Ian talked about ASPeCt (Antarctic Sea Ice Processes and Climate), a SCAR (Scientific Committee on Antarctic Research) affiliated project that seeks to understand and model the role of sea ice. This project has compiled ice and snow thickness distribution (16,000 observations from 63 voyages with another 10 voyages planned soon) and is producing sea ice core data in a standardised format. For further details see:

<http://www.antrc.utas.edu.au/scar>.

Two other relevant projects discussed were the International Programme for Antarctic Buoys (IPAB) <http://www.antrc.utas.edu.au/antrc/buoys/buoys.html> and the Antarctic Ice Thickness Research Programme (AnSITP):

<http://www.awi-bremerhaven.de/Research/IntCoop/Oce/ansitp.html>.

Ian described the prospects for remote sensing of sea ice thickness, in particular CRYOSAT. The panel strongly endorses the CRYOSAT mission, and will need to work with the CRYOSAT team to identify requirements and opportunities for validation. It is particularly important that calibration and validation projects include the Antarctic as well as the Arctic. The satellite is due for launch in 2004, for a four year mission. The likelihood is that gridded sea ice thickness fields will not be available until after the CLIVAR period.

ACTION: Is there the potential for getting ice thickness and other relevant variables from Russian historical data? (Alexander Klepikov to explore).

7. METEOROLOGY, AIR-SEA COUPLING AND TELECONNECTIONS

The panel recognised that meteorology and air-sea interaction was not adequately represented in the CLIVAR science and implementation plans. To fill this gap, Chris Reason was invited to present a science talk on “The Impact of the mid/high latitude ocean on southern hemisphere regional climate (a South African example),” and Ian Simmonds led a discussion on meteorology, air-sea coupling and teleconnections.

Chris presented evidence that winter rainfall variability in southwestern Australia may be linked to large scale circulation changes that appear to be related to the Antarctic Oscillation or Southern Annular Mode (Ref: Ansell, T.J., C.J.C. Reason, I.N. Smith and K. Keay, 2000: Evidence for decadal variability in southern Australian rainfall and relationships with regional pressure and sea surface temperature. *Int. J. Climatol.*, 20, 1113-1129.)

In the SW Cape region of South Africa that (like southwestern Australia) receives predominantly winter rainfall, wetter winters seem to be associated with an Antarctic Oscillation type circulation anomaly. During drier winters, a shift in the wave number 3 pattern seems to be the dominant anomaly pattern in the mid-latitude atmospheric circulation. SST anomalies in the mid-latitude South Atlantic also appear to be associated with anomalous rainfall in the SW Cape. During wet winters, the warmer SST tends to be found in the SW Atlantic (an important area of cyclogenesis) and in the SE Atlantic to the south of Africa near the Agulhas Current retroflexion. Cool SST anomalies tend to be found in the central mid-latitude South Atlantic and may act to increase the local baroclinicity as well as shift the storm tracks further north via potential vorticity conservation. Experiments with atmospheric GCMs forced by these South Atlantic SST anomalies indicate circulation and rainfall anomalies over the SW Cape consistent with the observational results (Ref: Reason, C.J.C., M. Rouault, J.-L. Melice and D. Jagadeesha, 2002: Interannual winter rainfall variability in SW South Africa and large scale ocean-atmosphere interactions. *Met. Atmos. Phys.*, Special Issue on Atmosphere-surface interactions, 80 (1-4), 19-29)

Ian's presentation briefly considered three topics with respect to the Southern Ocean: Synoptic activity, air-sea interaction and teleconnections.

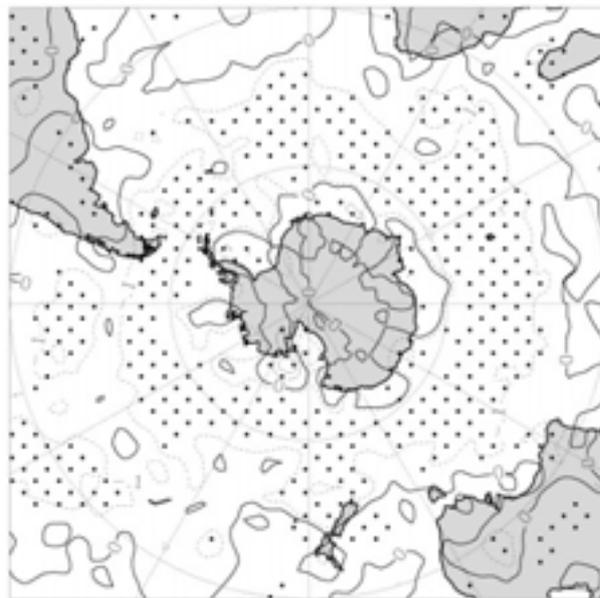


Figure 1 – Change in mean annual density of southern hemisphere cyclonic systems between 1958 and 1997, from NCEP reanalyses. Dots indicate changes that are significant at 95% confidence.

The mean annual density of southern hemisphere cyclonic systems exhibits a maximum in the high southern latitudes, particularly in the Indian Ocean sector. This system density has exhibited a significant (95% confidence level) decrease over much of the SO in the NCEP reanalyses over the period 1958-1997 (Fig. 1). However Fig. 2 shows that, over this period, the mean depth of cyclones (an important measure of cyclone vigour (see Simmonds, I., and K. Keay, 2000: Mean Southern Hemisphere extratropical cyclone behaviour in the 40-year NCEP-NCAR reanalysis. *Journal of Climate*, **13**, 873-885)) has shown a significant increase over the SO. That is, cyclones are becoming fewer but more vigorous.

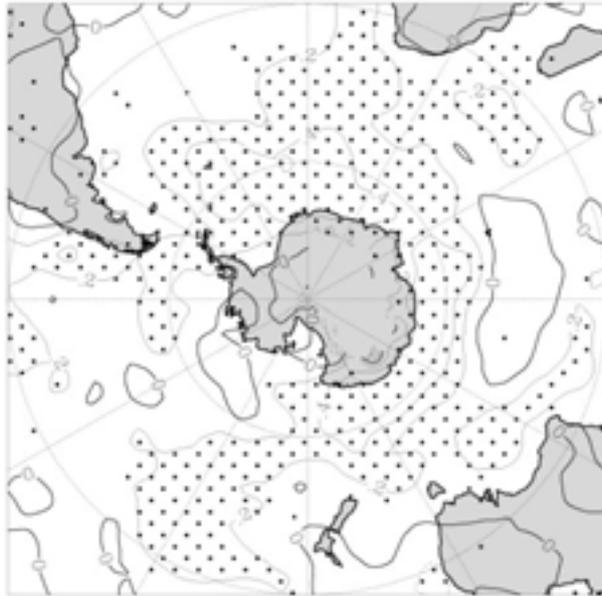


Figure 2 – Mean depth of cyclones has increased between 1958 and 1997 in the NCEP reanalyses. Dots indicate changes that are significant at 95% confidence.

The complex interaction between sea ice cover and cyclonic activity was discussed. An important point was raised in that the perceived nature of the interaction depends strongly on the time scales being considered. Hence, in particular, there can be no single statement on the interaction that holds for synoptic and interannual periods.

An important aspect of the interaction between the sea ice and the general circulation was observed to be related to the relative latitude of the sea ice edge and the circumpolar trough. This determined whether the Ekman transport of ice at the ice edge was to the north or south, which in turn influences ice growth/retreat and concentration characteristics. The ‘semiannual’ oscillation in surface pressure dictates the timing during the year of the crossovers of the ice edge and trough position. There are considerable implications to the fact that the amplitude of the semiannual oscillation has undergone considerable variability over the last forty years.

The fact that the SO cyclones have displayed, on average, greater vigour over the last four decades would lead one to believe there would be an increase in the rate at which mechanical energy is being imparted to the ocean (this rate is proportional to the mean cube of the low level wind speed), and hence changes in the wave climate. Fig. 3 shows that over much of the mid latitude oceans and the Southern Ocean this mean rate has increased by significant amounts since 1957, particularly in the Indian and western Pacific sectors. No significant change is revealed over the eastern Pacific sector.

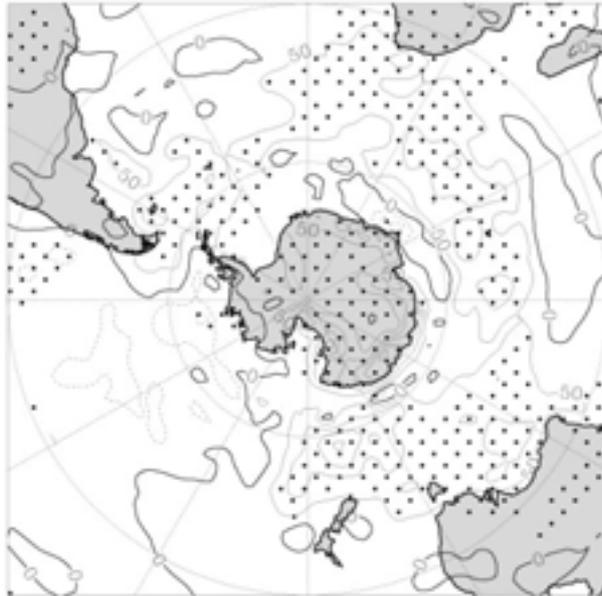


Figure 3 – Changes in the cube of the low level wind speed, which is proportional to the rate at which mechanical energy is imparted to the ocean, based on 1958-1997 NCEP reanalyses. Dots indicate changes that are significant at 95% confidence.

Teleconnections are seen to strongly influence the SO environment. Simmonds and Jacka (1995, Relationships between the interannual variability of Antarctic sea ice and the Southern Oscillation. *Journal of Climate*, **8**, 637-647) documented strong associations between Antarctic sea ice extent and the Southern Oscillation Index. Garreaud and Battisti (1999, Interannual (ENSO) and interdecadal (ENSO-like) variability in the Southern Hemisphere tropospheric circulation. *Journal of Climate*, **12**, 2113-2123), among others, have revealed a robust ‘Pacific South American’ teleconnection pattern originating in the tropics, and exhibiting poles in the Amundsen / Bellingshausen and the Weddell Seas.

The presentation also considered the robustness and stability of the ACW which may be a manifestation of air-sea interaction and responses to remote forcing (probably El Niño). Much of the analysis of this phenomenon has been confined to the period from the mid 1980s to the mid 1990s. Analyses conducted with a longer period of data (Simmonds (2002: Modes of atmospheric variability over the Southern Ocean. *Journal of Geophysical Research*, (in press)) reveals that outside this period the ACW assumes rather different characteristics, and is found to explain only modest amounts of variance.

8. MODELLING ISSUES

Gurvan Madec started the discussion of modelling issues by talking about the results of coupled and ocean-only models relevant to SO CLIVAR/CliC and observations needed to test and improve such models.

8.1 The ‘mean state’ of ocean models

To reproduce the mean state, models must simulate water mass formation (requires good forcing data and sea ice and mixed layer models), circulation (need to resolve or parameterise eddies), and consumption (mixing). Models now have some success in representing the basic structure of SO Water masses.

However, there are two major problems encountered in many coupled models run with no flux correction:

- The disappearance of sea ice in the models, due to a small imbalance in the seasonal cycle.
- warm SST anomaly in the 50-60°S band, due to the mixed layer being too shallow.

In passing, Gurban noted that geothermal heating can be an important term in driving upwelling of AABW. This is neglected in present models.

Advances in diagnostics have made a significant contribution, including “Walin” type water mass formation calculations and Lagrangian techniques to determine water mass residence times and to quantify interbasin exchange rates and pathways.

Observations needed for improved understanding of the mean state of the Southern Ocean:

- For water mass formation
 - A description of the seasonal cycle of the mixed layer
 - better constrained freshwater budget
- For water mass consumption
 - Microstructure analyses
 - Tracer release experiments in AAIW and SAMW
- For water mass circulation
 - The absolute transport of the ACC, preferably using current meters

8.2 Variability in ocean models

The ACW is now generated in models. Interestingly, the wind anomaly is sufficient to generate the ACW, whereas the thermohaline anomalies on their own fail.

In coupled mode models the ACW is almost always present and seems to be a robust feature of the SO. However, in some models it is generated with a longer time period and with a wave number of 2 or 3 (as opposed to 2 in the ‘real world’). If advection is an important element of the ACW, then coarse resolution models with a broad and slow ACC might be expected to result in a longer period. The simulation of the ACW in a coupled model may depend on the extent to which the particular model has a wind response to an SST anomaly.

Is the energy source for the ACW ocean available potential energy (APE) or atmospheric APE? It is known that the ACC advects the anomalies and sets the period. Is it excited by ENSO? Is it phase locking only, or does the ENSO teleconnection drive the ACW?

Observations required to improve our understanding of Southern Ocean variability:

- variability in temperature and salinity of SAMW and AAIW (e.g. using profiling floats). Repeat sections also contribute to this goal.
 - Variability of interbasin exchange
 - Time series in different ocean sectors to detect dominant time scales and processes
- Proxies to determine the ACW time series back more than the roughly 20 years of available satellite data

9. CARBON UPTAKE AND STORAGE IN THE SOUTHERN OCEAN

The carbon cycle was another issue that was not well represented in the initial science and implementation plans. In his role as the Carbon representative for the SO Panel, Chris Sabine gave the panel an overview of the SO's role in carbon chemistry.

During WOCE/JGOFS, substantial progress has been made in understanding the carbon system in the ocean (e.g. during GEOSECS, 6000 samples were obtained globally; during WOCE/JGOFS, about 100,000 samples were obtained, with an order of magnitude increase in accuracy).

The Ocean Carbon Model Intercomparison Project (OCMIP) showed that two large opposing terms largely cancelled each other in the SO: The solubility pump results in a large sink in the SO, while upwelling of "biological" CO₂ results in a source. Present estimates suggest the two terms roughly cancelled in pre-industrial times, but the SO now acts as a net sink. One of the main conclusions of OCMIP was that the largest difference between the models appears in the SO, largely due to differences in the physics in each model.

Roughly 60% of the total oceanic inventory of CO₂ is found in the southern hemisphere; about 40% is found south of 40°S. The largest accumulation is in the SAMW and Subtropical Mode Water in the southern hemisphere. On the SR3 section south of Australia, anthropogenic CO₂ has been detected in AABW for the first time. Models also suggest that the SO becomes increasingly important in the future for uptake of anthropogenic CO₂. Since the solubility and biological pumps are both large in the SO, changes in either one could have a large impact on the net oceanic sink of CO₂.

Chris presented the plan of repeat sections proposed by the US Carbon program. The sections largely coincide with repeat hydrographic sections already proposed by CLIVAR (see Figure 4). The panel strongly endorses the US Carbon program plan, which will meet the need to monitor changes in the deep ocean inventories of temperature, salinity and tracers as well as carbon parameters. The repeat sections need to be complemented by making pCO₂ measurements on ships of opportunity.

Discussion focused on possible gaps in the program of repeat hydrography. One issue is the reoccupation of S4, the circumpolar zonal section. The US plan is to "box in" the main AABW formation regions, but not repeat the entire S4 line. The panel felt that overall this approach was justifiable, given the difficulty of reoccupying the complete zonal section. However, the Adelie Land Bottom Water source (a location where anthropogenic CO₂ has already been detected) is not boxed in by the US plan.

ACTION: A plan to box in the Adelie Land source with repeat hydrography, in coordination with the US Carbon sections, needs to be negotiated between the US, Australia and any other nations likely to be able to make a contribution to this work. (Steve Rintoul, Chris Sabine)

There was also discussion of the need to repeat the 43°S section in the Pacific. While present estimates suggest the inventory of anthropogenic CO₂ is larger south of the proposed repeat line at 30°S (P6), there is no high quality recent carbon data from this line to serve as a baseline against which to measure future change. Much of the mode water in the Pacific recirculates south of 30°S, and the panel feels that reoccupation of the 43°S line would be a valuable addition to the international carbon program.

ACTION: Steve Rintoul and Chris Sabine to discuss who to contact about recommending a reoccupation of 43°S in the Pacific. (Steve Rintoul and Chris Sabine)

NCAR Model Anthropogenic CO₂ for 2005 with proposed repeat lines
Black = proposed US lines; White = committed international lines
Black and White = international lines where US involvement may be needed

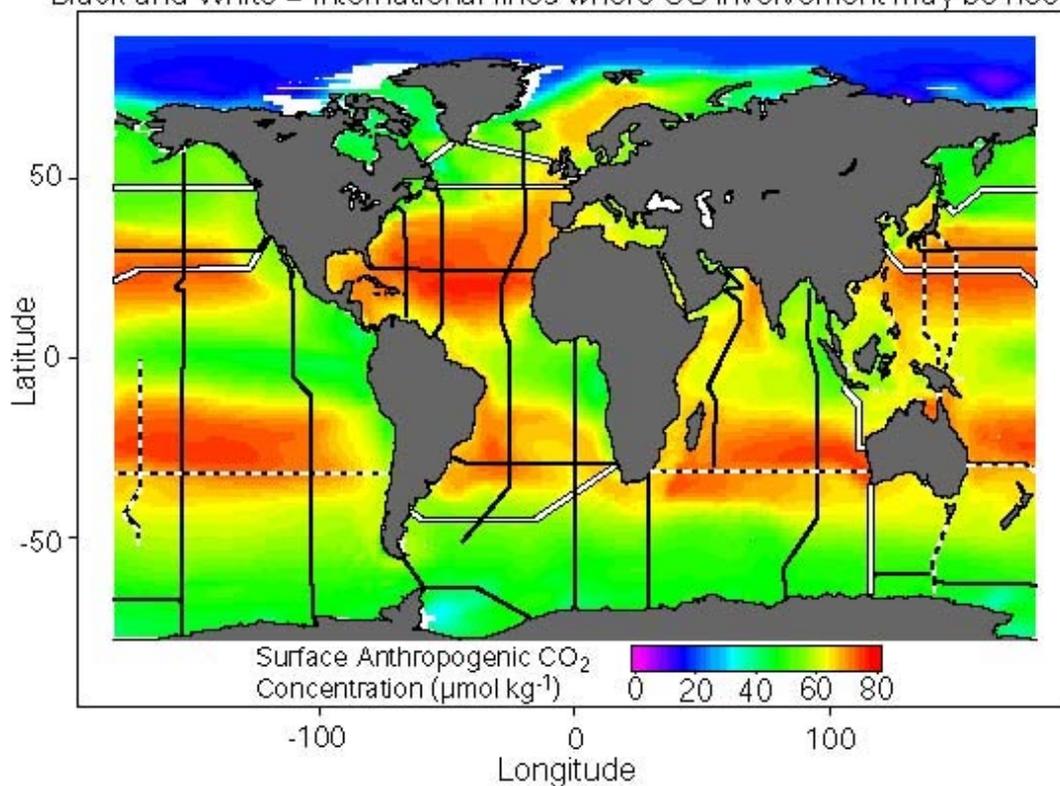


Figure 4

10. SUMMARY OF NATIONAL PROGRAMMES

As an international collaborative effort it is extremely important to have input from as many interested countries as possible. For this first meeting the following representatives were given the opportunity to discuss their countries involvement in SO research:

- Australia (S. Rintoul)
- China (Z. Dong)
- France (R. Morrow)
- Germany (E. Fahrback)
- Italy (G. Spezie)
- Japan (S. Aoki)
- New Zealand (P. Sutton)
- Russia (A. Klepikov)
- South Africa (C. Reason)
- South American activities (E. Campos)
- United Kingdom (K. Heywood)
- United States (A. Gordon)

Emphasis was placed on the speakers explaining the motivation for their research and areas of possible collaboration. The national reports may be accessed on the web at http://www.clivar.org/organization/southern/national_reports/index.htm.

The following points arose from the discussions:

- The Australians are keen to collaborate on a time series mooring in the Subantarctic Zone south of Australia. The mooring would include a surface flux buoy and fine resolution physical and biological measurements in the upper water column. International collaboration and funds would be required to carry out this project.
- Kevin Speer asked if it would be possible to carry out CTD measurements in the Kerguelen area during the Chinese cruises. Zhaoqian Dong replied that unfortunately time constraints would not allow this. Zhaoqian also pointed out that they were going to gather all the Chinese historical hydrographic data in his institute.
- Regarding the French proposal to put a series of moorings across Drake Passage, Eberhard Fahrbach, Arnold Gordon and Kevin Speer suggested moving the bottom row of current meters closer to the bottom to better resolve the barotropic component of the flow.
- The Russians would like to carry out tracer and CO₂ measurements on their cruise transects, but currently lack the people with the relevant expertise to do so.
- There was some concern (echoed by the Atlantic Panel) that research in the South Atlantic is being somewhat left out. A South Atlantic Workshop is currently being organised by Edmo Campos to try to redress this problem.

ACTION: The “chokepoint” section south of Africa remains somewhat of a gap. Germany, Russia and South Africa are encouraged to merge resources (and perhaps those of other collaborators like the USA) to see if more frequent hydrography or XBTs can be obtained to complement the present German efforts. (Eberhard Fahrbach, Alexander Klepikov, Chris Reason)

ACTION: Mike Sparrow to chase up national reports from other (e.g. Scandinavian) countries. (Mike Sparrow)

ACTION: Individuals to keep national reports updated annually. Mike Sparrow to send reminders. (National representatives and Mike Sparrow)

ACTION: Chairs to write to Atlantic Panel and Edmo Campos emphasising the importance of the South Atlantic to CLIVAR science issues, supporting the planned South Atlantic Workshop, and NOAA efforts to establish an observing system at 30°S. (Steve Rintoul and Eberhard Fahrbach)

11. SCIENCE SYMPOSIUM WITH ARGO SCIENCE TEAM: THE VALUE OF SOUTHERN OCEAN OBSERVATIONS

Argo is particularly important for the SO. Autonomous floats represent the only realistic means of obtaining regular, repeated, *in situ* measurements of temperature, salinity and currents in such a remote region. The remoteness of the SO also means that an investment in SO Argo needs to be carefully justified. To make progress towards implementation of SO Argo, a joint symposium was held between the Argo Science Team and the SO panel. This consisted of a series of talks presenting the scientific justification for SO Argo.

11.1 CLIVAR's requirements for Argo observations (John Gould)

CLIVAR, together with the ocean carbon programmes, will re-occupy during the next decade many of the hydrographic sections occupied during WOCE. These re-occupations will provide direct calibration data for Argo floats and will become the basis of new global temperature/salinity climatologies.

CLIVAR is expected to end in 2010 and will thus be the main global ocean programme during the early phases of Argo. Thus a close link between Argo and CLIVAR will be fruitful, with Argo providing data to CLIVAR and CLIVAR providing new scientific insights on which Argo deployment and sampling strategies can be based.

Salinity sensor stability remains an issue. In addition, CLIVAR's links to ocean carbon programmes highlight the potential for Argo floats to carry other sensors for biogeochemical parameters. For the SO the question has been raised as to whether Argo floats could measure atmospheric pressure. There has also been an expression of interest in monitoring pressure, temperature and salinity during the submerged portions of the float trajectories in order to provide more stable deep climatologies

There is an urgent need to expand the scientific use of Argo and similar profiling float data and to exploit the complementary nature of Argo and satellite remote sensing data.

Finally it was noted that the IPCC Third Annual Report report projected, for the coming decades, global temperatures that lie far outside the temperatures experience during the past 1000 years. Argo will be a crucial tool for documenting the impacts of these changes on the oceans.

11.2 Introduction: the Southern Ocean's role in climate (Steve Rintoul)

To provide an overview for the workshop, Steve Rintoul summarized the Southern Ocean's role in climate. See section 4.2 of this report.

11.3 Southern Ocean response to climate change (Siobhan O'Farrell)

Siobhan O'Farrell talked about the ocean response of the CSIRO Mark 2 and Mark 3 models to the IPCC A2 scenario. The study of signal to noise in the HADCM3 model showed best indices for detection were SST, sea surface salinity (SSS), SAMW at 32°S. Poor indices were heat transport, the strength of the polar gyres, overflow water and with the overturning streamfunction. Detection of climate change may be possible within 30 years by Argo observations at individual water masses in key locations, which are currently data sparse. The SO has a particularly high signal to noise ratios in the HADCM3 model, making it a good location for Argo deployment.

Issues for Argo deployment and data analysis in SO CLIVAR/CliC:

- High priority for seeding floats into SAMW and AAIW for climate change detection. These integrate changes in surface fluxes which are more difficult to measure.
- Need to have floats in regions that are currently data sparse in SO (the ACC may concentrate floats).

- Need to measure changes in salinity and temperature over a range of time scales to understand the variability of SO, ACC strength, ACW-like anomalies etc.
- Need to deploy floats that store data while operating under seasonal ice cover.
- Integrate Argo data with satellite data by assimilating into SO model for seasonal-interannual changes
- Don't neglect deep hydrographic/tracer sections for measuring changes in AABW, shelf waters etc.

11.4 Potential Impacts of climate change on the SO carbon cycle (Chris Sabine)

The ocean is a net sink of carbon. How will temperature changes due to global warming affect the carbon cycle? A 1°C increase will change the partial pressure by about 4%. However, the CO₂ flux depends on the biology as well as the physics of the ocean, which is also affected by climate change.

Models of CO₂ flux estimates disagree most in SO, though the SO is the most important area for the uptake of CO₂ (the Atlantic is more efficient, but SO has much larger surface area).

The GFDL (Geophysical Fluid Dynamics Laboratory) model suggests that the amount of CO₂ taken up by the ocean could decrease by 50% in the next 50 years. In order to model the uptake of CO₂ correctly, models need to be validated with observations.

What can Argo tell us about carbon cycling?

- Changes in temperature and salinity density structure will directly impact CO₂ air-sea exchanges
- Better characterisation of water mass formation rates
- Documentation of spatio-temporal patterns of variability in physical properties of the SO will assist carbon chemists in designing their programmes.

In the future it may be possible to fit CO₂ sensors to Argo floats, which would help greatly to answer many questions with regard to carbon cycling.

11.5 Modes of variability in the atmosphere-ocean system of the southern hemisphere (Ian Simmonds)

The atmospheric circulation of the southern hemisphere is one of the most variable in the world at all time scales. Studies of cyclone variability have shown that cyclones are becoming deeper and more intense, though their frequency has decreased. (see notes in Section 7 from Ian Simmond's earlier talk).

The semi-annual oscillation (SAO) can explain a large proportion of the variance in the southern hemisphere climate, though the actual amount has changed with time: From >80% in the late 1970s, to <50% in the 1980s to 1990s. The reasons for the change are unclear. Van Loon explains the SAO as resulting from the difference in thermal inertia between 40°S (where land masses exist) and 65°S (dominated by the ocean and sea ice). If so, the change in the SAO may reflect a change in ocean heat storage. Argo would provide the kind of measurements needed to test his hypothesis.

11.6 Observed changes in the southern hemisphere oceans and the need for an expanded observing system (Nathan Bindoff)

The properties of many water masses of the SO can be seen to be changing with time:

- SAMW seems to be changing throughout the SO
- AAIW has become fresher
- Circumpolar Deep Water (CDW) unchanged north of the Subantarctic Front, but has warmed and become saltier to the south

In trying to monitor changes in the properties of water masses in the SO, Argo offers the following advantages:

- Year-round monitoring
- Can follow evolution of freshwater fluxes (surface and depth)
- Monitoring of key water masses (CDW, SAMW, AAIW)
- Natural variability in the SO is 'low' compared to other oceans
- Anthropogenic changes are likely to be detected first in the SO
- Data from 500 PALACE floats already available in the SO - historical data base
- 10 years of operation can really look at variability
- Complements altimetry

There are the following limitations to using Argo in the SO:

- No profiles in sea-ice zone (although many groups are working on ways to overcome this)
- Can't directly sample AABW
- Issues related to calibration
- Still need WOCE-type lines (albeit less frequently)
- Need to sustain at least 500 floats

11.7 Using Argo to study Southern Ocean circulation (Kevin Speer)

Argo can provide estimates of *absolute* dynamic height, and so is of particular interest in the SO where the barotropic flows may be large. In particular, three particular circulation issues can be addressed using Argo trajectories: The circulation of SAMW, the study of cross ACC eddy fluxes in the CDW density class, and the largely barotropic gyres near the Antarctic continent.

11.8 How to extend Argo into the high latitude Southern Ocean (Eberhard Fahrbach)

Eberhard Fahrbach described his group's efforts to obtain profiling float data at high southern latitudes in the sea ice zone. From hydrography and moorings, they have observed variations in the temperature of inflowing Warm Deep Water and outflowing bottom water. But the circulation pattern and rates remain poorly known.

Attempts to measure this circulation have encountered a number of problems. There is a tendency for the Ekman drift of floats at the surface to move the float off the streamline on which they were originally deployed. They presently handle the problem of ice damaging the profiling floats by stopping the profile at 20 m depth if the temperature is at the freezing point. The next step is to store the profiles for later transmission, if it is not possible to surface. They are working on a Hybrid Arctic Float Observing System (HAFOS), which combines RAFOS and Argo technology. Profiling floats are positioned by acoustic tracking using RAFOS sound sources. This system is expected to be operational in five years.

11.9 Ocean state estimation and operational oceanography: The need for southern hemisphere observations (Neville Smith)

There are a variety of applications for “operational ocean services”, including risk management in the marine environment, transport safety, recreational users, commercial operators, boundary conditions for coastal management, information for living resources management and research, and support for sustainable development of the SO marine ecosystem and resources. Argo has an important role to play in operational oceanography by providing repeated, routine ocean observations.

The applications of SO data assimilation are likely to emphasise nowcasts/hindcasts over “predictions”. One model for such activity in the SO involves a hierarchy of related models:

- A global model, with the aim of estimating the current ocean state (non-eddy resolving). Argo will provide an important direct constraint. Applications include climate re-analysis and provision of boundary and initial conditions for regional models.
- An embedded regional, eddy-resolving model, with additional attention to the upper ocean, mixing, and the vertical circulation (because these are the key issues for users such as those interested in the marine ecosystem). Satellite data is critical, but limited. A sea ice model would be important.
- An embedded, coupled ecosystem model, which may be off-line.

11.10 Discussion: challenges and opportunities for implementation of Southern Ocean Argo (Steve Rintoul and Dean Roemmich)

The IAST participants felt the scientific presentations provided a useful and convincing scientific justification for SO Argo. To move forward, it was agreed the SO panel would summarise these arguments in a white paper for further distribution. As shipping is limited in the SO, Antarctic research and supply ships are likely to play an important role. The SO Panel has a role to play in identifying ships capable of deploying floats and communicating this information to the rest of the community.

ACTION: Kevin Speer is to be the Argo contact point for the SO Panel, and coordinate the writing of a white paper for SO Argo. The paper will include contacts, schedules, and cruise tracks for Antarctic vessels capable of deploying floats. (Kevin Speer and rest of panel).

12. SOUTHERN OCEAN TIME SERIES STATIONS

Uwe Send talked to the panel about the Time Series Science Team (TSST). The TSST was formed by request of OOPC (Ocean Observations Panel for Climate) and the CLIVAR observations panel. It consists of around fifteen interdisciplinary scientists from around the world and has just had its second meeting after the Hawaii AGU meeting.

The TSST is concerned with observations of:

- Air-sea heat flux, precipitation/evaporation, wind stress (high accuracy reference sites)
- Changes in the major water-mass formation processes
- Changes in the ocean state

- Transport changes in major current systems
- Flow through critical straits, passages and choke points
- The oceanic uptake of greenhouse gases
- The relationship between upper-layer ecosystem productivity and downward carbon export
- The linkages between physical/climatic and bio-geochemical conditions and variability in the water column
- Ground-truthing/verification of remote-sensing, modelling, forecasting
- Geophysical (seismic etc) and bottom pressure (including tsunamis) data
- Acoustic observations (tomography, biology)
- Pollution monitoring
- Test beds for new instrumentation

The definition of an ocean time series site in the global systems (requirements):

- Sustained in-situ observations at fixed geographic locations ocean/climate related quantities at a sampling rate high enough to unambiguously resolve the signals of interest
- Transport sections (using whatever technique) are included in choke points and major boundary current systems (moorings, gliders, ship ADCP etc.)
- Coastal time series are included when they are instrumented to have multidisciplinary impact on the global observing system and if they are not part of a national coastal buoy network
- Any implemented site fulfilling criteria will become part of the system but has to deliver its data into the system and to demonstrate successful operation and value after 5 years
- Real time data telemetry of operational variables will be pursued i.e. make every effort if technically feasible and/or if there are operational users
- Data should be made public in near real-time for real-time data or as processed and post-calibrated for other data; certain quality control standards, data formats and data centres need to be established

A preliminary list of Southern Ocean time series sites was prepared and forwarded to the TSST meetings. This list needs to be updated and expanded.

ACTION: SO Panel to update the white paper prepared for the Time Series Science Team (TSST) by requesting contributions from the panel members. For each site, a one page description of the scientific rationale, measurements proposed, investigators, and readiness is required. (Steve Rintoul to coordinate.)

ACTION: TSST website will be up and running soon. ICPO to contact Uwe Send to ensure that details are posted on the SO website. (Mike Sparrow)

13. REMOTE SENSING

Ian Barton gave the panel a general introduction to remote sensing applications in CLIVAR, with particular emphasis on SST measurements.

A SST accuracy of around 0.25°C is required for climate applications. When using SSTs from satellite data it must be remembered that there are three types:

- Skin SST - measures temperature to a depth of around 20 micrometers, the actual depth being dependent on wavelength
- Bulk SST – temperature beneath the skin layer (often equal to mixed layer SST)

- Mixed layer SST – the SST of the top 1 or 2 metres of the ocean. At night this is usually the same as the Bulk SST

Wind speeds are required to validate SST as the wind mixes up the skin temperature.

Summary of satellite measurements:

- AVHR atmospheric correction and cloud clearing now well modelled
- The ATSR series giving skin SST
- The GODAE High resolution SST (GHRSSST)
- Novel uses of sat data – currents from cross-correlation
- Water vapour analysis
- GODAE High resolution SST pilot project (2003-2005)
- GIFTS (on EOS 3 satellite) to study atmospheric gases and SST
- Feature tracking/ water vapour distribution

ACTION: The SO panel endorses the GHRSSST project. The use of multiple sensors will be particularly useful in the cloudy Southern Ocean. The panel seeks guidance on the right mix of *in situ* measurements needed to complement and remove biases from satellite measurements in order to ensure the GHRSSST goals are met in the SO. (Steve Rintoul and Eberhard Fahrbach to write to Neville Smith).

14. DATA MANAGEMENT ISSUES

The SO Panel confirmed Shigeru Aoki and Stuart Cunningham as the data representatives. There was a great deal of concern from the panel that data issues were not being addressed by ICPO as well as they could be. ICPO needs to work out clearer guidelines for data handling. There was also concern of the loss of funding to the WOCE Data Assembly Centres (DACs), especially the current meter DAC.

John Gould pointed out that after the dissolution of the Data Task Team ICPO is concentrating its efforts to sort out the problems with data handling in CLIVAR. It is envisaged that efforts will be concentrated on WOCE-like data rather than atmospheric or real time data. A major task is to preserve the funding for the DACs.

As the SO community is relatively small, in most cases it makes little sense to have separate SO data centre. The WOCE model of a central hydrography data centre has been a great success, and the continuation of the WHPO in some form is seen as a high priority. In particular, the WHPO provided rigorous quality control as well as archiving and distribution.

ACTION: Once specific guidelines on data management are provided by ICPO, the panel will communicate these guidelines to Principal Investigators to make sure they understand their responsibilities (Stuart Cunningham, Shigeru Aoki).

ACTION: Panel needs to identify data sets that have been collected since WOCE that should be archived as part of CLIVAR. (All panel, headed by Stuart Cunningham)

ACTION: Katherine Bouton's draft CLIVAR data policy to be circulated to the rest of the panel for comment. (Mike Sparrow)

ACTION: National representatives have responsibility to provide information on collection and availability of data sets resulting from the national programmes to ensure all relevant data sets are “captured” by the CLIVAR data system. (All national representatives, coordinated by the data reps Stuart Cunningham and Shigeru Aoki)

ACTION: The SO Panel should liaise with the CliC DMIP (see Section 17.3) with regards data issues. (Stuart Cunningham and Shigeru Aoki)

ACTION: The panel needs to let ICPO and the CLIVAR SSG know of any data concerns, in particular of any difficulty in accessing data sets (All panel, headed by Stuart Cunningham and Shigeru Aoki)

15. PALEO ISSUES

Before the general discussion of paleo issues, there were two science talks by Vin Morgan and Will Howard.

15.1 Southern Ocean variability: Lessons from ice cores (Vin Morgan)

Vin gave a talk about the use of ice cores in climate studies. He made an interesting comparison between the functioning of electronic circuits and the switching to higher temperature regimes caused by increased Methane concentrations.

The troposphere is well mixed on a time scale of about a year or so. Matching e.g. methane concentrations in trapped air provides a means of synchronizing records from the northern and southern high latitudes.

Ice is porous down to about 60 m. Therefore, the age of ice at depths above this is older than the age of air in the ice. (The ice-air difference in the Vostok core is different by about 6000 years. In other areas the difference is as low as 30 years – this depends on accumulation rate).

The high accumulation rate core at Law Dome (66°44' S, 112°50' E) suggests that the temperature rise in the south at the transition to the interglacial *leads* the changes in the northern hemisphere. This argues against the recent hypothesis of a "bi-polar see-saw" between the north and south.

15.2 Southern Ocean variability: Lessons from sediment cores (Will Howard)

Will started off by giving an overall view of using paleo data. He showed some examples of what has been learned from paleo data and the operation issues involved.

- The subantarctic ocean was once the place where pCO₂ was being modulated.
- Changes in CO₂ concentrations in the Vostok core were driven by the ocean, although the mechanism is not yet clear.
- Many models show the ocean driving changes in temperature, CO₂ etc. from the Vostok core.
- There were sharp step changes in properties in the SO: Sea surface temperature changed by up to 5°C in a few years over the South Tasman Rise, at 8000 years before present. A shift in ocean currents?
- The history of sea ice extent in the SO can be obtained from paleo analysis of diatoms.

- How did the deep water circulation during glacial intervals differ from today? $\Delta^{14}\text{C}$ concentrations were less than today. NADW contributions less than in modern ocean. The rate of the overturning circulation depends on which tracers you look at, i.e. there is no consensus among the paleo community at present on this topic.
- Because the SO ventilates the deep ocean, it is a “window” that must be involved in 100k year glacial CO_2 cycles.
- In the sediment record, the contributions of the solubility, biological and alkalinity pumps to past changes in CO_2 can be isolated.

ACTION: The Panel should review the SO coring sites proposed by IMAGES/PAGES and provide guidance, if needed, on their oceanographic relevance. (Philip Froelich)

16. SUMMARY DISCUSSION OF NATIONAL/INTERNATIONAL PLANS

ACTION: SO Panel to produce an evolving version on the web of the Implementation plan. To start with this should include a two or three page statement on the atmosphere (Ian Simmonds), carbon issues (Chris Sabine), paleo issues (Philip Froelich) and models (Gurvan Madec). (Ian Simmonds, Chris Sabine, Philip Froelich, Gurvan Madec and rest of panel)

16.1 Air-sea fluxes

Improved air-sea fluxes in the SO are crucial to meet CLIVAR/CliC goals. In the OceanObs99 volume (Rintoul et al., 2001), a combination of measurements is proposed to improve flux estimates. The rationale is that our best estimates of fluxes will come from either atmospheric reanalyses or satellite measurements. The role of *in situ* measurements is to remove biases and provide validation data sets for these products. However, the SO Panel lacks the expertise to decide on the optimal mix of *in situ* observations (e.g. surface flux reference sites, meteorological observations from VOS ships, sea level pressure from surface drifters, etc.).

The JSC/SCOR working group on air-sea fluxes has proposed an air-sea flux group. This has been considered by the JSC and, if formed, will be connected to SOLAS.

ACTION: Support the formation of an air-sea flux group, and seek advice from them on the correct mix of SO observations that the Panel should advocate. (Steve Rintoul)

16.2 Oceanographic observations

Rick Bailey of the Ships of Opportunity Programme (SOOP) commented on the general trend towards a smaller merchant fleet, and hence fewer ships of opportunity available for ocean observations. The panel had been concerned about gaps in the set of repeat XBT sections in the SO including zonal lines near 30°S in the Indian and Atlantic basins, and a meridional section south of Africa. Rick informed the panel that XBT lines at 30S in the Indian and Atlantic Oceans have recently been initiated.

Chris Reason (South Africa) and Alexander Klepikov (Russia) suggested ships from their countries might be used to obtain XBT sections south of Africa, provided the XBTs could be supplied by someone else. Given the length of the section, the possible non-repeating nature of the ship track, the complexity introduced by the Agulhas Current at the northern end, and

logistical challenges, some thought needs to be devoted to whether the scientific pay-off from deploying XBTs on this line is higher than devoting the same resources to Argo floats.

ACTION: Chris Reason and Alexander Klepikov to provide maps summarising the cruise tracks of the South African and Russian vessels and investigate whether logistical support exists in South Africa. This information will then be forwarded to the SOOP. (Chris Reason, Alexander Klepikov)

The French are going to deploy moorings in Drake passage (see French national report at <http://www.clivar.org/organization/southern/>)

ACTION: The panel felt it would be useful to make the distinction on the CLIVAR hydrography/Carbon website between sections that are sustained commitments to multiple repeats and those that are one-off reoccupations. (Mike Sparrow)

17. CROSS PANEL/PROJECT INTERACTIONS

A document about possible cross panel/project interaction was prepared and circulated by Mike Sparrow prior to the meeting. The panel then used this as a base for discussion.

An important aspect of WCRP programmes such as CLIVAR and CliC is the interaction with other panels and projects. The communication of ideas and results as well as efficient use of resources in overlapping areas of interest are just some of the benefits.

17.1 CLIVAR regional panels

The Atlantic, Pacific and Indian Oceans are the responsibility of the Atlantic, Pacific and Asian-Australian Monsoon panels, respectively.

There are areas of responsibility of the SO panel that are of concern to all the above regional panels. For example, variability in the formation or circulation of the water masses ventilating the Southern Hemisphere thermocline (SAMW and AAIW) is likely to influence sea surface temperature, heat and freshwater storage at lower latitudes and is therefore important to decadal variability of all three ocean panels. There is obviously going to be overlap between SO Argo and the other basin panels.

i) The Atlantic Panel (chair Martin Visbeck; ICPO contact Roberta Boscolo)

- Global models suggest that anomalies carried by the ACC may influence the variability of overturning in the North Atlantic. The overturning cells within the SO itself also ‘recycle’ NADW to close the thermohaline circulation.
- Both the SO and Atlantic panels are concerned with the same atmospheric forcing due to the Southern Annular Mode (SAM) i.e. the NAO of the south.

Martin Visbeck informed the SO panel that the general interest (and hence funding) of the Atlantic panel is focused on the North Atlantic, but that the panel are trying to ‘reprogram’ as much of their resources as possible into the South Atlantic. For example, they are trying to make a strong case for a 30°S observing system with high resolution XBTs, a five-year hydrography revisit and ideally a boundary current/transport mooring array.

ACTION: Chairs to write to Atlantic panel strongly endorsing plans for a 30°S observing system, and seeking clarification of present proposed and funded efforts. (Steve Rintoul and Eberhard Fahrback)

There was some discussion of which lines in the South Atlantic were most important to repeat (e.g. the A11 and A17 lines, as well as A10).

ACTION: Arnold Gordon to summarise arguments for re-occupation of WOCE lines in the South Atlantic, to forward to Atlantic panel. (Arnold Gordon)

ii) The Pacific Panel (chair Kelvin Richards)

- Heat and freshwater anomalies carried between basins by the ACC appear to be linked to variability on shorter time scales via the ACW. It has been suggested that the ACW anomalies migrate to lower latitudes to form an ocean teleconnection with interannual climate fluctuations, including ENSO.
- The coldest, freshest and thickest SAMW is found in the Pacific, where it subducts into the South Pacific subtropical gyre, forming the low salinity core of AAIW.

The SO panel also sees areas of joint interest in a repeat 43°S section, Argo in the South Pacific and in various time series sites.

iii) The Asian-Australian Monsoon Panel (AAMP) (chairs Julia Slingo & Peter Webster; ICPO contact Zhongwei Yan)

The AAMP is also responsible for the Indian Ocean. The SO panel are concerned that as the Indian Ocean does not have its own basin panel CLIVAR has to ensure that some aspects of research, especially in the mid-latitudes, are not overlooked.

Gary Meyers, who is on the AAMP, gave a talk on Indian Ocean – SO interactions. He reiterated that there is a danger that some research might be left out because it doesn't fit in the areas of interest of either the AAMP or the SO panel. He suggests that the AAMP should ensure it looks into the deeper and slower circulation patterns. Gary identified the Indian Ocean Zonal (Dipole) Mode circulation as a 'hot topic' dealing with the low-latitudinal and larger scale climate variability that may be of interest to both panels.

ACTION: Chairs to write to AAMP to propose a "division of labor" between the two panels: The AAMP to cover the top-to-bottom circulation north of 20°S, while the SO panel extends its domain north to 20°S. (Steve Rintoul and Eberhard Fahrback)

iv) Other regional panels

The other two regional panels are Variability of the American Monsoon Systems (VAMOS) and Variability of the African Climate System (VACS) panels.

At the moment VAMOS seems to be mostly concerned with monsoons, although a joint area of interest with VAMOS is the ocean's impact on climate in southern South America.

There seems to be potential for interaction with VACS in the SO's impact on the climate of southern Africa.

17.2 CLIVAR panels and working groups

i) PAGES-CLIVAR Panel (chairs J-C. Duplessy and J. Overpeck; ICPO contact Andreas Villwock)

PAGES/CLIVAR seeks to improve understanding of decadal to century scale climate variability by extending the instrumental record of climatic variables using high-resolution paleoclimatic data.

In the minutes of the second meeting of the PAGES-CLIVAR working group they state that ‘...PAGES-CLIVAR will try to initiate activity on paleo data in the Southern Hemisphere. The Working Group felt that this activity should be co-ordinated with the SO Panel...’

The SO Panel agree with this. The general opinion seemed to be that for the SO getting some of the higher frequency data from the paleo record would be extremely useful (e.g. records of decadal variability in the past).

ACTION: Explore with PAGES the possibility of a joint workshop. (Philip Froelich)

iii) CLIVAR Modelling Panels

There are two crosscutting (global) panels involved with modelling issues: The Working Group on Coupled Modelling and the Working Group on Seasonal to Interannual Prediction. The SO panel should liaise with these groups with regard to modelling issues.

ACTION: Gurban Madec to keep the panel up-to-date on modelling issues. The SO panel needs to think about indices that provide useful benchmarks for models (e.g. transport of ACC, overturning cell, rate of bottom water formation, gyre circulation etc). It was suggested that modelling issues be a subtheme for the next panel meeting. (Gurban Madec and rest of panel)

17.3 CliC panels and working groups

ACSYS-CliC has a number of panels and groups that the SO panel should be prepared to work and liaise with. These include:

i) The Data Management and Information Panel (DMIP) (Chair, James Moore)

The principal objective of the DMIP is to make available relevant datasets to users as efficiently as possible within the procedures and protocols that govern international data exchange. Their principal ‘target groups’ are modelling and process-orientated research groups with a thematic relation to ACSYS and CliC research priorities.

ii) The Observation Products Panel (OPP) – Koni Steffen, Chair

The OPP was set up to evaluate the user requirements for observational products and data obtained by in-situ and remote-sensing observations. A full list of the terms of references (TORs) may be found at <http://acsys.npolar.no/impplan/tor.htm>.

iii) The Numerical Experimentation Group (NEG) – Greg Flato, Chair

The general TORs of the NEG are to:

- Address modelling issues of single components and the high-latitude coupled system (atmosphere, sea ice, ocean, hydrology) relevant to ACSYS (and CliC)
- Promote the investigation and improvement of the parameterisation of specific high-latitude processes in climate models
- Distribute the improved parameterisations

Full details of the TORs may be found at <http://acsys.npolar.no/impplan/tor.htm>.

17.4 WCRP programmes

SO CLIVAR will build on the base established by the World Ocean Circulation Experiment (WOCE). The panel will have strong links to ACSYS because it is a CliC as well as a CLIVAR panel. Links with the Stratospheric Processes And their Role in Climate (SPARC) project and the Working Groups on Air Sea Fluxes and Numerical Experimentation (WGASF and WGNE, respectively) will be pursued.

Surface fluxes provided by GEWEX will be particularly important for the SO, where existing estimates are poor. GEWEX has two projects designed to evaluate and produce global surface fluxes:

- i) The Surface Radiation Budget (SRB) project will produce by mid 2002 (approximately 2 years are available now) a global 1 by 1 degree data set of surface radiative fluxes from 1983-1995 (initially). More resources may be required to extend this data set through to 2002.
- ii) The SEAFLUX project is seeking to provide a high-resolution satellite data set of surface turbulent fluxes over the global oceans (to include the SO). The SEAFLUX project (<http://paos.colorado.edu/~curryja/ocean/index.html>), includes the following elements:

- Extensive library of *in situ* data sets from research ships and buoys for validation of the global flux products
- Development and evaluation of a new skin sea surface temperature product that resolves the diurnal cycle
- Evaluation and improvement of bulk turbulent flux models
- Evaluation and improvement of methods to determine surface air temperature and humidity from satellite
- Production and evaluation of global high-resolution satellite-derived surface turbulent fluxes for 1999
- Evaluation of the global flux products in the context of applications (e.g. forcing ocean models, partitioning of heat transport in the atmosphere and ocean)

For the *in situ* validation cases, SEAFLUX has several deployments from the SO, mostly buoys, with one deployment having direct turbulent flux measurements. This project is operating on essentially no resources and consolidation of requirements from WCRP projects for these types of data would be of great help in obtaining support for producing these data sets on a more consistent and predictable basis.

Contact points are:

- Judy Curry for SEAFLUX (curryja@cloud.colorado.edu) and

- Paul Stackhouse for SRB (P.W.STACKHOUSE@LaRC.NASA.GOV)

ACTION: Chairs to write to Judy Curry and Paul Stackhouse expressing the strong support of the panel for SEAFLUX and SRB and asking for suggestions as to how the panel might be of help. (Steve Rintoul and Eberhard Fahrback)

17.5 Programmes outside of WCRP

Both the SCAR and the Scientific Committee on Oceanic Research (SCOR) have established SO programmes: The SCAR programme is called Antarctic Sea-Ice Processes, Ecosystems and Climate (ASPeCt); International Antarctic Zone (iAnZone) is a SCOR affiliated programme. Both of these programmes are directly concerned with the coupling of the SO and atmosphere in the regions covered by year-round and by seasonal sea ice.

The paleoclimate records from the Antarctic ice sheet, and from the circumpolar belt are of particular interest to the SO component of CLIVAR and CliC. As well as PAGES-CLIVAR, there are other projects such as IMAGES (a joint project between PAGES and SCOR), which is currently planning a major SO cruise to obtain long sediment cores for climatic and environmental reconstruction. The primary contacts for this effort are Rob Dunbar (dunbar@stanford.edu) and Andreas Mackensen.

The scientific focus for the Surface Ocean Lower Atmosphere Study (SOLAS) programme is the interaction between the atmosphere, climate and marine biogeochemical processes. SOLAS is sponsored by the International Geosphere-Biosphere Program (IGBP), SCOR and the Commission of Atmospheric Chemistry and Global Pollution (CACGP).

In remote regions of the SO, monitoring changes in upper ocean temperature and salinity is only possible using drifting platforms due to the lack of merchant shipping. Profiling floats with temperature and salinity sensors provide a cost-effective means of monitoring such regions. In addition, the floats provide a measure of the absolute velocity field. Thus SO Argo is something that will be actively encouraged by the SO panel.

Some observations required for SO CLIVAR-CliC (e.g. repeat XBT/XCTD sections) will likely form part of the Global Ocean Observing System (GOOS).

Wherever possible links will be explored with projects in IGBP and possibly even in with the International Human Dimensions Programme (IHDP).

ACTION: The SO Panel webpage should be kept updated with information about other projects and panels. (Mike Sparrow)

18. OTHER MATTERS

Eberhard Fahrback pointed out that the ICPO suffers from a shortage of funding, and therefore even small contributions from the nations involved in SO research can be helpful (e.g. by providing funds for brochures etc.)

ACTION: A list of scientific highlights, important and submitted papers to be included on the SO panel webpage. Details to be forwarded to Mike Sparrow. (All panel and Mike Sparrow)

ACTION: At least one representative from the panel should attend the South Atlantic Workshop (see Edmo Campos for details). (Steve Rintoul to seek a volunteer)

Finally the timing and venue of the next meeting of the SO panel was discussed. It was felt that the next meeting should be in about eighteen months. Eberhard offered Bremerhaven as a possible venue. To advance the integration of Southern Ocean Projects he suggested having a joint meeting with iAnzone and ASPeCt in late summer 2003, during which time all three groups would have their meetings and a joint session to discuss overlapping issues. The presently envisioned time is the week of 8 to 12 September 2003.

APPENDIX 1. LIST OF ATTENDEES

S. Rintoul	CSIRO, Hobart, Australia	Steve.Rintoul@marine.csiro.au
E. Fahrbach	Alfred-Wegener Institut für Polar und Meeresforschung, Bremerhaven, Germany	efahrbach@awi-bremerhaven.de
I. Allison	Antarctic CRC, Hobart, Australia	ian.allison@aad.gov.au
S. Aoki	National Institute for Polar Research, Tokyo, Japan	shigeru@nipr.ac.jp
A. Gordon	Lamont Doherty Earth Observatory, Palisades, USA	agordon@ldeo.columbia.edu
G. Madec	LODYC, Paris, France	gm@lodyc.jussieu.fr
R. Morrow	LEGOS, Toulouse, France	rosemary.morrow@cnes.fr
C. Sabine	NOAA/PMEL, Seattle, USA	sabine@pmel.noaa.gov
I. Simmonds	University of Melbourne, Melbourne, Australia	i.simmonds@earthsci.unimelb.edu.au
K. Speer	Florida State University, Tallahassee, USA	kspeer@ocean.ocean.fsu.edu
K. Heywood	University of East Anglia, Norwich, UK	K.Heywood@uea.ac.uk
A. Klepikov	Arctic and Antarctic Research Institute, St. Petersburg, Russia	klep@aari.nw.ru
E. Campos	Instituto Oceanografico, Universidade de Sao Paulo, Sao Paulo, Brazil	edmo@usp.br
C. Reason	University of Cape Town, Rondebosch, South Africa	cjr@egs.uct.ac.za
Z. Dong	Polar Research Institute of China, Shanghai, China	zhaoqian@stn.sh.cn
W. Howard	University of Tasmania, Tasmania, Hobart, Australia	Will.Howard@utas.edu.au
V. Morgan	University of Tasmania, Tasmania, Hobart, Australia	Vin.Morgan@utas.edu.au
P. Sutton	National Institute of Water & Atmospheric Research, Wellington, New Zealand	p.Sutton@niwa.cri.nz
G. Spezie	Università di Napoli "Parthenope" Istituto di Meteorologia e Oceanografia, Napoli, Italy	giancarlo.spezie@uninav.it
G. Budillon	Università di Napoli "Parthenope" Istituto di Meteorologia e Oceanografia, Napoli, Italy	budillon@unina.it
A. Bergamaso	CNR, Istituto Dinamica Grandi Masse Venezia, Italy	andreab@isdgm.ve.cnr.it
E. Zambianci	Università di Napoli "Parthenope" Istituto di Meteorologia e Oceanografia, Napoli, Italy	enrico.zambianchi@uninav.it

C. Dick	ACSYS-CliC Project Office, Tromso, Norway	chad.dick@npolar.no
M. Sparrow	International CLIVAR Project Office (ICPO), Southampton Oceanography Centre, Southampton, UK	mdsp@soc.soton.ac.uk
J. Gould	International CLIVAR Project Office (ICPO), Southampton Oceanography Centre, Southampton, UK	wjg@soc.soton.ac.uk
G. Meyers	CSIRO, Hobart, Australia	Gary.Meyers@csiro.au
S. O'Farrell	Div. of Atmospheric Research, CSIRO, Aspendale, Australia	siobhan.ofarrell@csiro.au
W. Cai	Div. of Atmospheric Research, CSIRO, Aspendale Australia	wenju.cai@csiro.au
N. Bindoff	CSIRO, Hobart, Australia	n.bindoff@utas.edu.au
U. Send	Institut für Meereskunde, Duesternbrooker Weg 20, Kiel, Germany	usend@ifm.uni-kiel.de
Ian Barton	CSIRO Marine Research, Hobart, Tasmania, Australia	ian.barton@csiro.au

APPENDIX 2. MEETING AGENDA

Monday, March 11, 2002

- 0845-0900 Welcome and purpose of the meeting (Rintoul)
0900-0930 Overview and status of CLIVAR (Gould)
0930-1030 Overview of progress to date in implementation of SO CLIVAR (Rintoul)
1030-1100 Coffee break
1100-1130 Overview of CliC, including elements relevant to the understanding of the Southern Ocean (Allison, Fahrback)
1130-1200 Discussion: CLIVAR/CliC integration
1200-1230 Sea ice (Allison, Martinson)
1230-1400 Lunch
1400-1430 Science talk: Impact of the mid/high latitude ocean on southern hemisphere regional climate: A South African example (Reason)
1430-1530 Meteorology, air-sea coupling and teleconnections (Simmonds)
1530-1600 Coffee break
1600-1645 Modelling: recent results of coupled and ocean-only models relevant to SO CLIVAR; observations needed to test and improve models (Madec)
1645-1730 Carbon uptake and storage in the Southern Ocean (Sabine)

Tuesday, March 12, 2002

- 0830-1230 Summary of national programmes:
- Australian programme (Rintoul)
 - Chinese programme (Dong)
 - French programme (Morrow)
 - German programme (Fahrback)
 - Italian programme (Spezie)
 - Japanese programme (Aoki)
 - NZ programme (Sutton)
 - Russian programme (Klepikov)
 - SA programme (Reason)
 - South Atlantic and South American activities (Campos)
 - UK programme (Heywood)
 - US programme (Gordon)
- 1230-1330 Lunch
1330-1800 Science symposium with Argo Science Team: The value of Southern Ocean observations:
- 1330-1355 CLIVAR's requirements for Argo observations (Gould)
1355-1420 Introduction: the Southern Ocean's role in climate (Rintoul)
1420-1445 Southern Ocean response to climate change (O'Farrell)
1445-1510 Potential Impacts of climate change on the Southern Ocean carbon cycle. (Sabine)
1510-1535 Modes of variability in the atmosphere-ocean system of the southern hemisphere (Simmonds)
1535-1600 Coffee

- 1600-1625 Observed changes in the southern hemisphere oceans and the need for an expanded observing system (Bindoff)
- 1625-1650 Using Argo to study Southern Ocean circulation (Speer)
- 1650-1715 How to extend Argo into the high latitude Southern Ocean (Fahrbach)
- 1715-1740 Ocean state estimation and operational oceanography: the need for southern hemisphere observations (N.Smith)
- 1740-1800 Discussion: challenges and opportunities for implementation of Southern Ocean Argo (Rintoul, Roemmich)
- 1800 Drinks with Argo Science Team at CSIRO

Wednesday, March 13, 2002

- 0830-0930 Southern Ocean time series stations (Send, Speer)
- 0930-0950 Science talk: Improved SST from multiple satellite sensors (Barton)
- 0950-1010 Remote sensing: Discussion of panel actions required
- 1010-1040 Data management issues (Aoki, Fahrbach)
- 1040-1100 Coffee break
- 1100-1120 Science talk: Southern Ocean variability: Lessons from ice cores (Morgan)
- 1120-1140 Science talk: Southern Ocean variability: Lessons from sediment cores (Howard)
- 1140-1200 Paleoceanography discussion (Rintoul; paper from Froelich)
- 1200-1300 Lunch
- 1300-1500 Summary discussion of national/international plans and the way forward:
 - Identify gaps and strategy to fill them
 - Particular logistical/technological constraints in the SO
- 1500-1530 Coffee
- 1530-1600 Science talk: Indian Ocean - Southern Ocean interactions (Meyers)
- 1600-1645 SO panel interaction with other basin panels, working groups and programmes.
- 1645-1730 Review action items, writing assignments, plans for next meeting
- 1830 Dinner at Meadowbank Vineyard (with Argo Science Team)