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Preface

The Atlantic Implementation Panel (AIP) of WCRP's CLIVAR project met at IFM-GEOMAR in Kiel after the CLIVAR Workshop on the North Atlantic Subpolar Gyre. The workshop showed that impressive advances have been made in understanding the circulation in the subpolar gyre of the Atlantic and its connections to global climate. The Atlantic Implementation Panel reviewed the progress of implementation of observations and research in the Atlantic sector. The once data-void eastern tropical Atlantic, a region that shapes variability in the region, is now relatively well covered partly due to implementation of TACE. The RAPID mooring array at 26.5N is delivering its first data. The South Atlantic is still sparsely sampled, but plans are underway to monitor interbasin exchange. Synthesis products that optimally combine data and model information are becoming available to users now.

At the meeting a new theme emerged that focuses implementation of CLIVAR in the Atlantic: Decadal Predictability. It links the climate variability processes, with predictability, and anthropogenic climate change. It is on decadal timescales and regional spatial scales that internal variability and externally forced trends have comparable amplitude which implies that fluctuations can reverse local trends. Decadal predictions are potentially valuable to inform decision makers developing adaptation strategies and for detecting climate change. The meridional overturning circulation in the Atlantic and its potential predictability makes the Atlantic sector a natural focus for the decadal predictability problem.

The AIP meeting in Kiel was the first meeting in a long time without Martin Visbeck as chair. CLIVAR and the Atlantic Implementation Panel in particular are indebted to Martin's efforts to bring implementation of Atlantic observations and climate research forward. On behalf of the Atlantic Implementation Panel I would like to thank Martin for his leadership.

Wilco Hazeleger
co-chair AIP

ACTION ITEMS

1) Contact Arctic Climate community on the need for the CliC/CLIVAR Arctic Climate Panel for coordinate activities (R. Curry, S. Oesterhus, N. Koc)

2) Write a short document on the achievements of AIP and which climate science related issues wouldn't be addressed if AIP disappears in the next year or two. Send it to Jim Todd and ICPO (W. Hazeleger, M. Visbeck, R. Sutton, R. Boscolo and A. Piola)

3) Send feedback to the SSG on the AIP view on the future of CLIVAR and WCRP (W. Hazeleger and R. Curry)

4) Report to OOPC concern of maintenance of AX15 and report on its climate relevance (M. Visbeck, W. Hazeleger)

5) Get in touch with D. Stammer in obtain support for updating the AIP observations webpage (R. Boscolo)

6) Make a list (top 5) indices for the Atlantic Ocean based on the list already provided last year and with new additions (R. Curry, P. Brandt and B. Johns)

7) Write a CLIVAR AIP strategy for decadal predictions aiming at providing information for adaptation strategies (R. Sutton, W. Hazeleger, B. Johns and D. Stammer)

8) Communicate to the TACE modelling group the AIP's view that the group should narrow its scope to TACE observation-related ocean model development – concentration on the cold tongue and mixing - but that in the longer term that it should entrain atmospheric and terrestrial modelling experts (W. Hazeleger and P. Brandt)

9) Inform the TACE modelling group of the German modelling plan (C. Boening)

10) Ask the TACE modelling group to construct a webpage covering TACE modelling activities, duration and PIs etc (C. Eden)

11) Express the AIP's concern over the funding problem of PIRATA SE extension leading to a one-year interruption of data to OOPC (M. Visbeck)

12) Make the argument to funding agencies and non- participating PIs for enhanced deployment of instruments during the intense TACE obs period in 2009 (P. Brandt, B. Bourles, B. Johns)

13) Put information on AMMA data availability on the TACE observational webpage (P. Brandt)

14) Write a science plan for WAVEs jointly with VAMOS (P. Nobre, A. Piola and J. Marengo)

15) Ask whether appropriate RAPID PIs can attend the S. Atlantic workshop in Argentina to help with the OSSEs experiment as they did for RAPID (D. Marshall)

16) Produce a report of the meeting in Argentina and distribute to the AIP members (A. Piola)

17) Send summaries of European calls and proposals on AMOC and decadal predictability to US CLIVAR (W. Hazeleger, M. Visbeck, R. Sutton, D. Marshall)

18) Explore WGCM , WGSIP and GSOP activities on coupled ocean-atmosphere initialization for initial value predictions (W. Hazeleger and A. Pirani)

19) Provide input on speaker and themes for the IMBER/GLOBEC/SOLAS CLIVAR workshop to Wilco Hazeleger (all)

20) Reach out the IGBP community on AIP activities and future plans (i.e. decadal predictions) (W. Hazeleger)

21) Submit list of new members to the panel for input and submit final list to SSG (W. Hazeleger and R.Boscolo)

22) Ask the attendees of the 8th AIP meeting permission to place their presentations on the CLIVAR web site (R. Boscolo)

1. Introduction

The beginning of the 8th CLIVAR Atlantic Implementation Panel (AIP) meeting overlapped with last session of the CLIVAR workshop on North Atlantic Subpolar Gyre, 19-21 April, Kiel Germany (http://www.ifm-geomar.de/index.php?id=subpolar-gyre). The title of the session was "Past, present and future perspectives of Subpolar Atlantic variability in the CLIVAR context" and the two talks given by CLIVAR Panel members were:

- *Nalan Koc* - Centennial-millennial variability of the two main branches of the North Atlantic Drift through the Holocene
- *Detlef Stammer* - Present and Future Perspectives on Assimilation Efforts

W. Hazeleger, AIP chair, welcomed the participants (see APPENDIX A), especially the new panel members R. Curry, Y. Kushnir and S. Oesterhus and accepted the apologies of B. Barnier, L. Terray, C. Reason and C. Zhang for not being able to attend the meeting.

The goals of the meeting were:

- Assess the progress and problems in the continued implementation of CLIVAR research in the Atlantic sector
- Discuss CLIVAR research opportunities in the Atlantic sector and need for coordination (contribution to roadmap)

W. Hazeleger introduction to the meeting included the review of:

- the new Terms of Reference (http://www.clivar.org/organization/atlantic/atlantic_reference.php)
- Atlantic sustained observations, regionally enhanced observations and process studies
- agenda (see Appendix B)
- Action Items from last meeting (http://eprints.soton.ac.uk/19362/)

During last CLIVAR SSG (April 2006) both TACE (Tropical Atlantic Climate Experiment, http://www.clivar.org/organization/atlantic/TACE/tace.php) and CLIVAR co-sponsorship of the now CliC/CLIVAR Arctic Climate Panel (ACP, http://clic.npolar.no/org/acp.php) were endorsed. ACP endorsement followed consensus in the international community that a group like ACP is required because after the conclusion of the WCRP Arctic Climate System Study in 2003, there has been no group that would be coordinating Arctic climate research from a perspective of global change research. The ACP met for one day at the first CliC International Science Conference in Beijing in April 2005 to discuss its plans and ways of work and used opportunities of other meetings to enable at least some of its members, to meet to discuss their plans and ways of working. The CLIVAR SSG asked that the chair of ACP be an ex-officio member of AIP. However at present the ACP chair position is vacant, and CliC representation of the AIP remains to be resolved.

> **ACTION 1.** Contact Arctic Climate community on the need for the CliC/CLIVAR Arctic Climate Panel for coordinate activities (R. Curry, S. Oesterhus and N. Koc)

The SSG-14 in Buenos Aires also developed a CLIVAR "Forward Look" (http://www.clivar.org/organization/ssg/ssg14/ssg14.php) against the science themes: ENSO/Tropical Variability (TV), Monsoons, Decadal variability/Thermohaline Circulation (THC), Anthropogenic Climate Change (ACC), the role of the oceans in climate and global modelling and prediction. In addition attention was given to initial thoughts on the CLIVAR legacy when CLIVAR comes to its sunset date of the end of 2013. Applications were not specifically addressed as part of the Forward Look exercise per se. This remains a topic to be included in the future.

2. Overview of the WCRP strategic framework and its implementation

The World Climate Research Programme (WCRP, http://wcrp.wmo.int/) published in August 2005 its Strategic Framework: 2005-2015: Coordinated Observation and Prediction of the Earth System. The

document reiterates the WCRP objectives to determine the predictability of climate and the effect of human activities on climate. The strategic framework seeks to facilitate analysis and prediction of Earth system variability and change for use in an increasing range of practical applications of direct relevance, benefit and value to society. The key issues are:

- Move from physics-only to Earth-System models (with IGBP, http://www.igbp.net/)
- Prediction across all timescales: "seamless predictions"
- Develop sustained climate observing system with GCOS, GEOSS etc…
- Integration of models and data: 1) use of data assimilation to initialize models over widest range of climate prediction timescales possible; 2) synthesis through reanalysis (atmosphere, ocean, coupled)
- Link to applications through existing mechanisms (e.g. START http://www.igbp.net/ and the World Climate Applications Programme) and new ones

Roberta Boscolo informed the AIP that the 28th session of the WCRP Joint Scientific Committee will be held in Zanzibar, Tanzania, from 26 to 30 March 2007. The meeting aims to determine the future of the WCRP and review progress in implementing its Strategic Framework 2005-2015. She pointed out that all the documents prepared for the JSC-28 were available on the WCRP website: http://wcrp.wmo.int/TableDocs.html.

Particularly relevant to CLIVAR is the outcome of the JSC Task Team on Implementing the WCRP Strategic Framework which recommends WCRP to focus on cross-cutting issues aimed at meeting society's and stakeholder's needs. The cross-cutting activities identified by JSC are:

- Anthropogenic Climate Change
- Atmospheric Chemistry and Composition
- Monsoons and the Year of Tropical Convection
- Decadal Prediction
- Extreme Climate Events
- International Polar Year
- Sea-level Rise
- Seasonal Prediction

Roberta Boscolo also informed that as result of introducing cross-cutting activities within WCRP, the total budget allocated to CLIVAR activities will be reduced considerably (to about 1/4) for the period 2008-9. In this financial framework the SSG co-chairs and the ICPO feel urged to reorganize CLIVAR and introduce a new modus operandi.

The AIP raised a general concern on the choice of the WCRP cross-cutting activities: they are not optimal and present several overlaps. In addition it was felt that WCRP lacks of focus: what is the main driver for this set of cross-cutting activities?
It was suggested that WCRP should focus on Adaptation and Mitigation as a link between science and society. Within this focus WCRP should implement a much simpler structure in order to deliver to society.

Given the financial prospect an early sunset could be proposed (2010 instead of 2013)[1]. In any case, AIP should therefore start thinking about its legacy and producing an overall science assessment.

> **ACTION 2.** Write a short document on the achievements of AIP and which climate science related issues wouldn't be addressed if AIP disappears in the next year or two. Send it to Jim Todd, David Legler and ICPO (W. Hazeleger, M. Visbeck, R. Sutton, R. Boscolo and A. Piola)
>
> **ACTION 3.** Send feedback to the SSG on the AIP view on the future of CLIVAR and WCRP (W. Hazeleger and R. Curry)

[1] Post meeting note: At it's 28th meeting (Zanzibar, 26-30 March 2007, the JSC reaffirmed the sunset date for CLIVAR as 2013.

3. Overview and recommendations from the CLIVAR Workshop on North Atlantic Subpolar Gyre

This workshop (http://www.ifm-geomar.de/index.php?id=subpolar-gyre) was sponsored by the CLIVAR Atlantic Implementation Panel to mark the ending of 10-year German programme Sonderforschungsbereich 460: "Dynamics of Thermohaline Circulation Variability". The workshop took stock of recent advances in observations, modeling and understanding of subpolar gyre dynamics, their interaction with the regional and global climate system, and impacts on the marine chemistry. The workshop was attended by about 60 scientists. R. Curry and D. Marshall reported on some key observational issues:

1. The dynamical processes of some boundaries are not well monitored both in space and time scales.
2. The variability is much larger than expect and is dominated by NAO
3. The overflow has been steady, no response to the large freshening (1970-95)
4. The freshening has diminished

Models show decadal propagation of anomalies, which introduce some predictability in the system. However fast communication down the boundaries is also present.
Special emphasis was placed to define the need for future coordinated efforts with regards to process and sustained observations, modeling and reanalysis. Which observations do we want to keep in the Sub Polar Gyre? Which measurements are the most efficient? Do we need boundary moorings? The AIP agreed that there is no unique observational system; it depends on the questions that need to be addressed.

4. Overview on Atlantic Observations

W. Johns reported on the current status of the Atlantic observing system with particular emphasis on gaps, new technologies and opportunities for funding/cooperation.

Drifters do not have good coverage over the tropical Atlantic (fig 1).

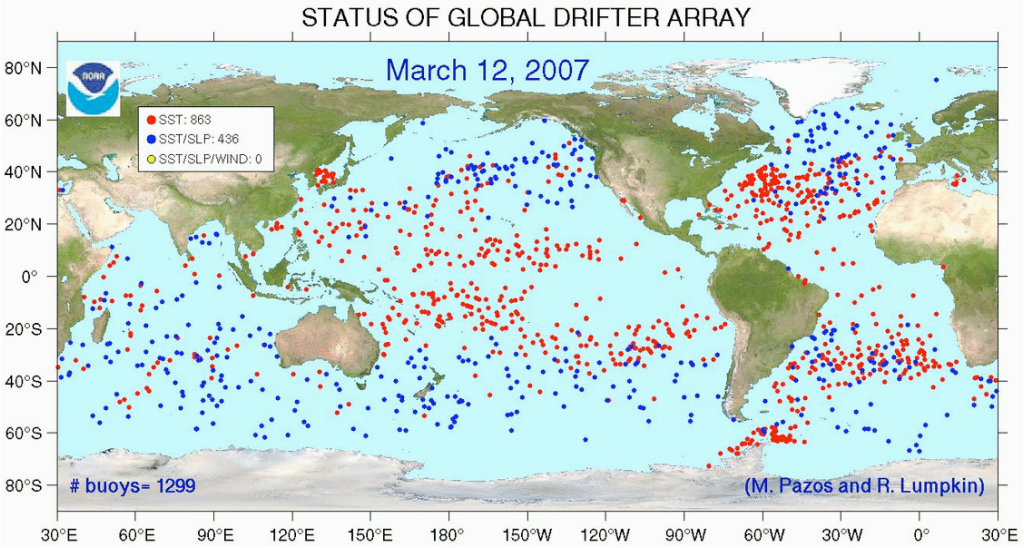

Figure 1. Status of global drifter array

This is probably due to the divergent current system rather than the deployment strategy. On the contrary the Argo float array (http://www.argo.ucsd.edu/) provides a good overall coverage and it is also the reason for the scaling down of some XBT low-density lines. High-density lines are still well

supported (fig 2). The JCOMM Ship Observations Team including the SOOP XBT program is meeting in Geneva in mid-April, and the AIP was asked to provide them with some feedback on the performance/requirements of XBT lines. It was agreed that the XBT lines in the Atlantic are very useful to monitor fronts and to capture variability something that Argo array is not able to resolve. Concern was raised on the maintenance of AX15 line (Cape of Good Hope – Europe) that is relevant to CLIVAR-TACE.

> **ACTION 4.** Report to OOPC concern of maintenance of AX15 and report on its climate relevance (M. Visbeck, W. Hazeleger)

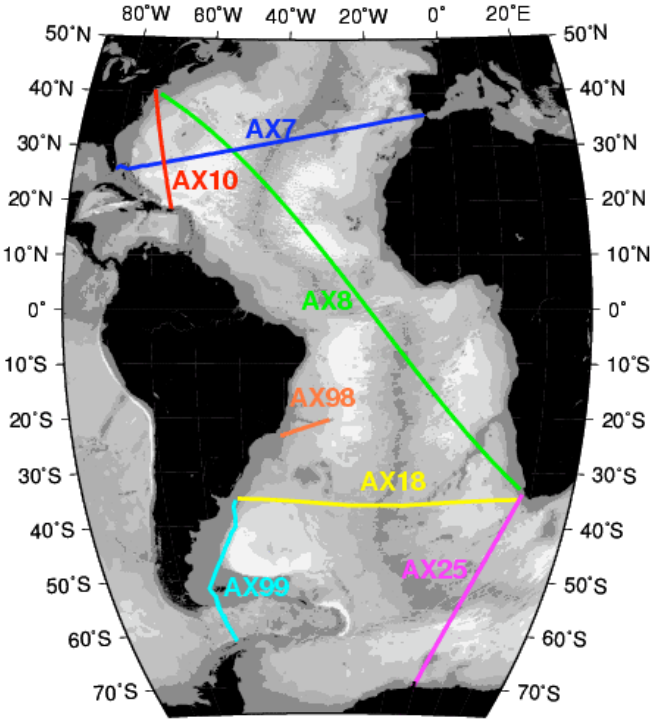

Figure 2. High Density XBT lines in the Atlantic Ocean

Several research-mode and sustained fixed-point measurement arrays are presently active in the Atlantic (http://www.oceansites.org/). However some of them will probably disappear before the CLIVAR sunset date.

The EU support to ASOF-East array (http://asof.npolar.no/) finished in 2006; although a few elements will continue under DAMOCLES (EU funded project) and IPY (International Polar Year, http://www.ipy.org/), some others like overflow monitoring and surface freshwater export will be under threat. In the ASOF-West region (http://asofw.apl.washington.edu/), the Davis Strait has been monitored since 2004 (moorings and gliders) and is proposed for continuation till 2010. The WHOI pilot effort (2004-2006) in the Hudson Strait is also under consideration for continuation. The ASOF group has now been able to produce a comprehensive synthesis map of the freshwater export in the Nordic seas (fig. 3).

The Subpolar Western Boundary Arrays supported by IfM-GEOMAR since 1997 will continue only partially till 2010. The Grand Banks Array will be discontinued. However the area will continue to be monitored by Canada as part of the Canadian Atlantic Zonal Monitoring Programme (AZMP, http://www.meds-sdmm.dfo-mpo.gc.ca/zmp/main_zmp_e.html).

The hydrographic line AR7W will continue with high priority within the Canadian monitoring programme and also the sections east of Labrador Sea (Orphan Basin and Grand Banks) should restart again.

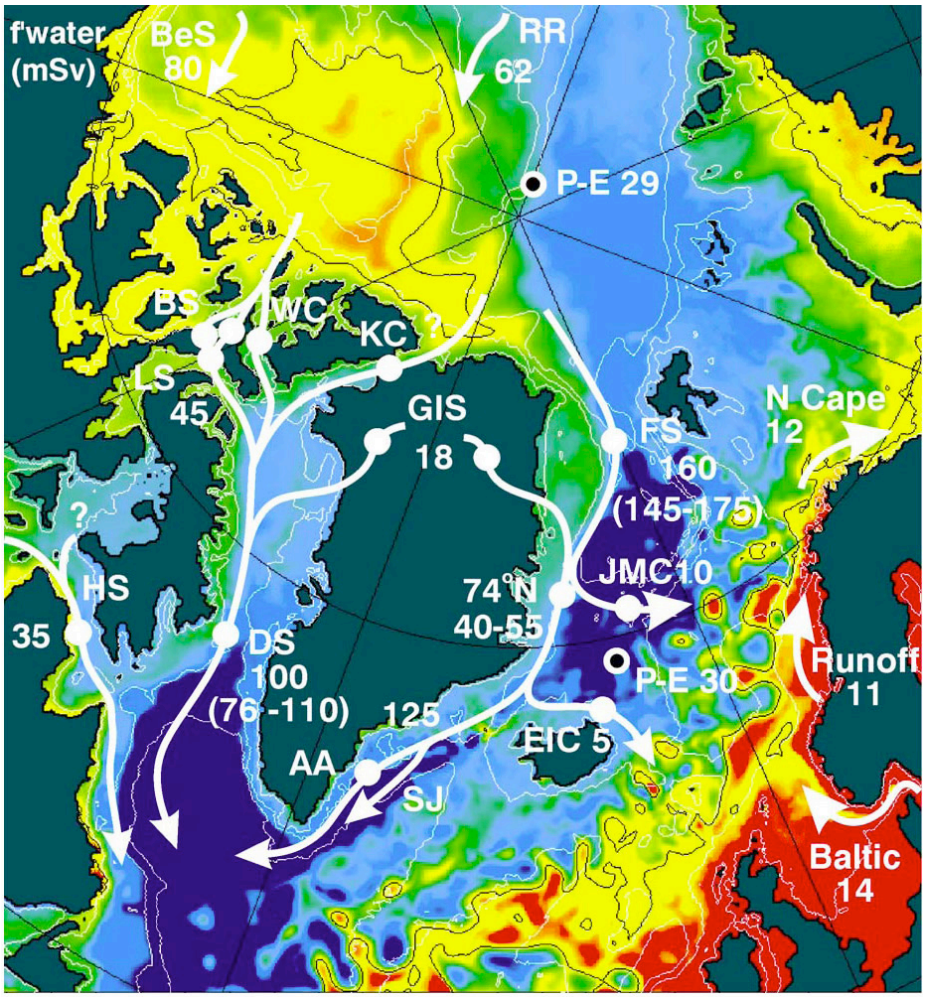

Figure 3. Estimate of freshwater transport in the Northern Seas (mSv)

The WHOI Line W array (http://www.whoi.edu/science/PO/linew/index.htm) that started in 2004 is funded till 2008 and proposed to continue till 2014, the same for the RAPID 26N array (http://www.noc.soton.ac.uk/rapidmoc/). RAPID is collaborating with NOAA Western Boundary Time Series (Florida current cable and semi-annual Abaco DWBC sections).

The German MOVE array at 16N started in 2000 and will be funded till 2008. Funding for continuation is being sought. An eastern mooring was added off Cape Verde in order to extend to a full-basin geostrophic array. Good progress in monitoring the tropical Atlantic has been made thanks to TACE (http://tace.ifm-geomar.de/index.html) while still little activity is in place in the South Atlantic.

In summary in the Atlantic:

- The drifter/float coverage is good (a part from the divergent equatorial drifters)
- The basinwide heat content change is now being adequately monitored by Argo
- Time series sites/sections at key locations (Nordic Seas) are monitoring water mass changes
- Overflows (until recently) are well measured
- Meridional Overturning Circulation (MOC) monitoring array(s) are now well established
- Tropical time series arrays have been enhanced –becoming closer to adequate

More attention/planning is needed for:

- continuation of overflow monitoring (how much can we rely on use of indirect measures, e.g. reservoir conditions?)
- measurement of Arctic-Atlantic freshwater inflows
- long-term maintenance of tropical arrays (PIRATA + enhancements)
- the carbon sampling network (adequate?)

- improvement of surface fluxes (status/plans for reference sites?)
- maintenance of key satellite measurements (esp. altimetry)
- strategy for MOC monitoring (efficient systems, distribution of sites, southern hemisphere line?)
- strategy for validation of synthesis products
- identifying emerging needs for process studies

Opportunity for funding/cooperation can be sought at:

- U.S. Ocean Research Priorities Plan (ORPP) – MOC monitoring a high immediate priority
- U.S. Decadal Predictability Initiative -> coordination with EU 7th Framework activity
- U.S. CCSP "Synthesis and Assessment" activity:
    - Product 3.1 Climate Models: An Assessment of Strengths and Limitations for User Applications
    - Product 3.2 Climate projections for research and assessment based on emissions scenarios developed through the Climate Change Technology Program
    - Product 3.3 Weather and Climate Extremes in a Changing Climate
    - Product 3.4 Abrupt Climate Change
- Strategic "grass-roots" collaboration and leverage, e.g. TACE (German/French/US; French/S.Africa)

It was pointed out that the Atlantic observing system web page created by R. Boscolo and hosted in the CLIVAR website, is out-of-date. R. Boscolo reported that she find it difficult to dedicate time to this task given her additional responsibilities on the Pacific and Indian Panels.

ACTION 5. Get in touch with D. Stammer in obtain support for updating the AIP observations webpage (R. Boscolo)

5. Synthesis Activities in the Atlantic

D. Stammer reported on several global ocean data assimilation products that are available for climate applications. Those efforts can be summarized as having three different goals:

- Climate-quality hindcasts
- High-resolution nowcast
- Best initialization of forecast models

Synthesis evaluation efforts are needed to determine the quality of existing global ocean analysis/synthesis products and to assess their usefulness for climate research. Those efforts should be oriented along global science questions and, from a CLIVAR point of view, their usefulness for climate research purposes, both globally and regionally. They also need to be done in close collaboration with CLIVAR's basin panels, process modelling and IPCC communities.

GSOP and GODAE held the 1st workshop in synthesis evaluation in August 2006 (for more information see http://www.clivar.org/organization/gsop/synthesis/synthesis.php).

The outcome of the workshop was:

- Quantitative statement of the skill of available global synthesis products and their usefulness for CLIVAR
- Identification of common strength and weakness of systems and the differences among them
- Prototype synthesis support of global and regional CLIVAR research (will be extended as work progresses)
- Basis set of recommendations with regard to future synthesis resource planning.
- Recommendations for CLIVAR data processing and management
- The CLIVAR GSOP web site to present climate indices from ocean syntheses over last 50 years (counterpart to OOPC indices from data alone)
- Stimulation for WGOMD, WGSIP and WGCM to join in

ACTION 6. Make a list (top 5) indices for the Atlantic Ocean based on the list already provided last year and with new additions (R. Curry, P. Brandt and B. Johns)

A discussion followed on the question: what should a *sustained global ocean climate* observing system look like? The solution is a weighted choice involving potential coverage, cost, ease of deployment and maintenance and information content. Almost surely required are:

- Extended Argo (full depth highly desired)
- T/P-Jason class altimetry (wide swath mesoscale resolution desired)
- Scatterometry winds (synoptic coverage highly desirable)
- SST (combined system)

Worth debating:

- sea surface salinity
- space-borne gravity (bottom pressure) changes
- gliders
- Argo-mounted nutrient/oxygen/… sensors
- Argo-mounted tomography

Ancillary to the ocean observation problem:

- Land ice volume (laser altimetry). Sea ice thickness, concentration and extent
- Land hydrology (water storage). Land carbon.

Two questions that need to be addressed are:

- What is the strategy to engage to make significant progress with ocean synthesis in 5 years?
- What key variables need to be observed do constrain climate predictions?

GSOP together with OOPC is planning a follow up of OceanObs99 in Sept/Oct 2009. OceanObs09 would focus on the evolution of the observing system, its impact on operations, science and societal needs, new sensors and observing component.

6. Seasonal to Decadal Predictability and Prediction

R. Sutton reported on the follow up of the workshop on Atlantic Predictability held in April 2004. The two overarching challenges identified were:

- To exploit fully the seasonal predictability of climate in the tropical Atlantic region
- To take a lead in the development of decadal climate prediction

This offered an agenda for Atlantic climate prediction over the next 5-10 years. Namely:

1) Significant enhancement of sustained observations in the ocean, at the land surface, and in the free troposphere - ARGO is an extremely important development for monitoring changes in the ocean and for initialising climate predictions. It is of course a very high priority for it to be continued in a sustainable way
2) Major effort to reduce the systematic errors in simulation of tropical Atlantic climate in models used for seasonal prediction - There has been some progress here, for example, in the simulation of the stratocumulus region. Higher resolution coupled models (e.g. UK-HIGEM model) show reduced systematic errors for reasons, which are still being unravelled. Nevertheless major errors still remain
3) Research to better understand the fundamental ocean-atmosphere-land processes that control the climate of the tropical Atlantic region, its variability and predictability, including the statistics of sub-seasonal variability.
4) Improvement of data assimilation systems for the Atlantic Ocean (especially the treatment of salinity) - There has been progress in exploring a range of approaches. Anomaly assimilation methods, such as used in the new UK Met Office Decadal Prediction Systems have been shown to have some advantages in being less sensitive to model biases. A variety of approaches is being explored for the handling of salinity

5) Development of reliable methodologies for making seasonal forecasts relevant and useful to decision makers.
6) Development of an observational system for monitoring the MOC – This has been addressed thanks to the RAPID programme
7) Understanding the limits of predictability in the MOC and the mechanisms that determine predictability - The first multimodel assessment of decadal predictability has been made at UK Met Office. Progress is gradually being made in understanding the mechanisms that govern predictability and in relating model results to observations.
8) Development of data assimilation methods for initialisation of decadal MOC forecasts - The work by Smith et al, (to appear in Science) at the Met Office is a landmark achievement towards operational decadal prediction.
9) Identifying which aspects of the oceanic initial conditions most constrain the future behaviour of the MOC - This is work in progress at Reading. Results are encouraging but nothing published yet
10) Understanding how initial conditions and changing external forcings combine to determine climate evolution on decadal timescales, and (belatedly) development of suitable ensemble techniques for sampling forecast uncertainty – The work of Smith et al. (abovementioned) is also an important stepping stone here, much still to do
11) Understanding and quantifying the regional climate impacts of MOC change and the predictability of these impacts - It is increasingly understood that the impacts of MOC change are not limited to the Atlantic region. They may include global changes in the Asian monsoon and in ENSO. The detailed mechanisms involved are only partially understood and further work is required.

Widespread acceptance of climate change is generating growing demand for the best possible information about near term, regional climate trends. This information is needed to inform adaptation decisions. It is on decadal timescales and regional spatial scales that internal variability and externally forced trends have comparable amplitude which implies that fluctuations can reverse local trends. Decadal predictions could be further helpful for detecting climate change. They could potentially separate the impact of the internal variability components of the climate system and the impact of anthropogenic emissions of greenhouse gasses and aerosols. Figure 4 illustrates that scenario uncertainty is not the dominant factor in the uncertainty for near (decadal) predictions.

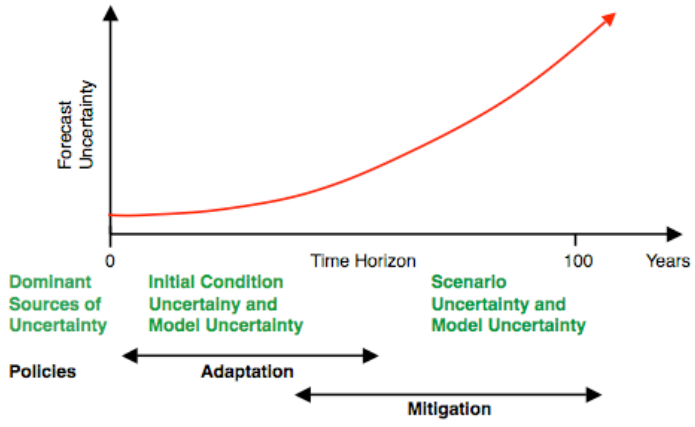

Figure 4. Sources of Uncertainty in Climate Forecasts.

Decadal prediction will be useful for policymakers who need to take decisions on adaptation and mitigation is under consideration by the JSC for WCRP to become one of its cross cutting topics. It links the climate variability processes, with predictability, and anthropogenic climate change.

The Atlantic sector is a natural focus for the decadal prediction problem. There is evidence of predictability in the overturning (AMOC) and associated predictability of near surface temperatures

over western Europe, however a lack of consistency in Atlantic ocean reanalysis (especially for transports and salinity) poses a fundamental issue for initialization and verification of forecasts. There is a role for AIP in joining earth observations with detection, attribution and prediction:

- Observations are central not only for initialisation and evaluation of predictions, but also for detection and attribution of climate signals
- Increasingly, observations are being used directly to constrain climate predictions, narrowing *model-related* uncertainty
- The long term goal (for CLIVAR and WCRP) could be a joined up system where the latest observations are analysed in real time, both to initialise predictions and also continuously to evaluate and improve models, thereby refining predictions.

ACTION 7. Write a CLIVAR AIP strategy for decadal predictions aiming at providing information for adaptation strategies (R. Sutton, W. Hazeleger, B. Johns and D. Stammer)

7. TACE Modelling Activities

Carsten Eden presented the recent white paper distributed by the TACE Modelling group. Many studies suggest that on interannual time scales Tropical Atlantic Variability (TAV) is a combination of remote forcing from ENSO, NAO and the South Atlantic, and of local processes like the Atlantic zonal mode. On intraseasonal time scales easterly waves in the atmosphere and Tropical Instability Waves (TIW) in the ocean are the dominant features. Less is known about the physics that determines the mean and seasonal cycle of the Atlantic ITCZ (AITCZ). Therefore the TACE modeling group decided that it will have the greatest impact on seasonal to interannual climate prediction if it solves the two following questions:

a) What determines the mean position of the AITCZ?
b) What determines the seasonal cycle of the AITCZ?

Based on the results and the experiences gained by answering these questions, it will make recommendations for targeted observations by November 2007. The following hypothesis will be addressed:

- The mean ITCZ position is determined remotely by Indian and Pacific climate (R. Murtugudde, M. Jochum)
- The cold bias in the warm pool is caused by insufficient representation of barrier layer dynamics (P. Chang)
- Rainfall biases in the simulated ITCZ are not caused by SST biases, but by unresolved low-level convergence in African Easterly Waves (A. M. Jochum, R. Murtugudde)
- Mean wind biases in the tropical Atlantic are caused by unresolved coastal upwelling (W. Wang, P. Malanotte-Rizzoli, M. Jochum)
- Open ocean upwelling in the Guinea and Angola domes determines the asymmetry of the ITCZ (A. Lazar)
- Properly representing the tropical eddy field will improve the ITCZ position (C. Eden / Sheinbaum)
- The latitudinal assymmetry of the ITCZ is caused by the MOC (P. Chang)

The Panel noted that C. DeWitt will explore the parameter space in intermediate coupled models and identify key processes that determine the ITCZ position whilst
J. Carton will use forced AGCM studies to determine what causes the biases in surface winds

The panel complimented the WG for the nice perspective of TACE modelling proposal. In the discussion two issues came up: (i) the TACE modelling proposal does not seem to link well with the enhanced observations in the cold tongue region; (ii) the role of aerosols is not addressed.

ACTION 8. Communicate to the TACE modelling group the AIP's view that the group should narrow its scope to TACE observation-related ocean model development – concentration on the cold tongue and mixing - but that in the longer term that it should entrain atmospheric and terrestrial modelling experts (W. Hazeleger and P. Brandt)

C. Boening informed of the German plan to develop a hierarchy of ocean models simulating the lateral (isopycnic) and vertical (diapycnic) ventilation of the tropical ocean and the biogeochemical cycles relevant for oxygen. The goal is to provide a realistic model framework for a synthesis of the combined observational and experimental effort and for improvement of coarser resolution circulation/biogeochemical models.

ACTION 9. Inform the TACE modelling group of the German modelling plan (C. Boening)

ACTION 10. Ask the TACE modelling group to construct a webpage covering TACE modelling activities, duration and PIs etc (C. Eden)

8. TACE Observational Activities

The TACE observations working group (http://tace.ifm-geomar.de/index.html) coordinates observational activities in the tropical Atlantic for understanding key ocean-atmosphere processes and improving initialization and assimilation of coupled predictive systems. The WG works with the TACE Modeling and Synthesis WG and other involved research groups (e.g., the PIRATA program and various operational centers) to help design an optimal observing system for the tropical Atlantic and to determine the necessary sustained observation network in the tropical Atlantic to meet future climate forecasting needs.
The TACE projects and programmes include:

- BMBF – Nordatlantik (http://www.ifm-geomar.de/index.php?id=bmbf-ap1_2&L=1%2F)
- Dispycnal mixing processes in the upwelling regions of the tropical Atlantic (http://www.ifm-geomar.de/index.php?id=3259&L=1)
- EGEE program (http://www.brest.ird.fr/actualites/EGEE-3.htm)
- TACE – EUC (http://www.rsmas.miami.edu/users/tace/)

These projects and programmes are strongly linked with the following international programmes

- AMMA (http://amma-international.org/index)
- CORIOLIS (http://www.coriolis.eu.org/english/project/project.htm)
- PIRATA (http://www.pmel.noaa.gov/pirata/)

Simultaneous oceanic cruises were carried out during May-June 2006 in the framework of AMMA, PIRATA and TACE. The Meteor cruise (BMBF-Nordatlantik) deployed 4 moorings at the equator, 23W. The next deployment will be in April 2008 with 6 moorings. The total observation period will span June 2006 - spring 2011. The mooring array was intensively tested using the 1/12 degree FLAME model to get an optimum distribution of instruments for the observation of the eastward temperature transport. The effects and predictability of TAV will be analyzed by means of a global ocean-atmosphere model.

In the framework of TACE-EUC, equatorial current meter moorings at 0-10W will be first deployed in September 2007 during the EGEE 6 cruise. The observational period will span Sep. 2007 – Sep. 2010.

The German TACE mixing process study will quantify the impact of diapycnal mixing processes on the variability of SST in the equatorial cold tongue and eastern upwelling regions of the tropical Atlantic. The measurement programme consists of microstructure shear and temperature observations and CTD and current observations to be collected on several cruises within the equatorial cold tongue and the upwelling region off Northwest Africa during 2006 – 2010.

There are also several biogeochemical programmes to be carried out in the same area:

- The German project on biogeochemical cycle and air-sea matter exchange (2007-2009) which includes several research cruises in the Mauritania upwelling region
- Physical and biogeochemical study of Oxygen Minimum Zones, 2008-2011. This is a tracer release experiment to study horizontal and vertical mixing processes, moored oxygen and current observations along 23W between the equator and Cape Verde

Argo is now up to it's targeted global network of nearly 3000 floats. However there are still gaps in the eastern upwelling regions. To resolve the equatorial radius of deformation (~130km) a doubling of the nominal resolution is needed in the tropical Atlantic region.

There are serious gaps in surface drifter coverage due to circulation features. If the funding is sustained, 175 drifters will be deployed in the Atlantic between 30N and 40S.

The AX8 XBT line (see fig. 2) is done 4 times per year. It was again noted that AX15 line is relevant to TACE observations as well.

The PIRATA SE Extension (SEE) has a funding problem. The project will be interrupted at least one year because the local resources were not enough to fund buying an extra mooring. The PIRATA committee endorsed a one-year demonstration project funded by BCLME. However BCLME has now ended and an intergovernmental Benguela Current Commission is being set up around management issues. It is unlikely that further funding for PIRATA SEE will come from this body. The PIRATA SEE has a new 3-year long pilot project submitted to PIRATA for endorsement. The PIRATA SEE is important for studying the connection between tropical SE Atlantic SST anomalies in the PIRATA SEE region and West African monsoonal rainfall. The PIRATA SEE committee is continuing looking for potential sponsors.

> **ACTION 11.** Express the AIP's concern over the funding problem of PIRATA SE extension leading to a one-year interruption of data to OOPC (M. Visbeck)

With regard to the equatorial cold tongue, the WG suggests a TACE Intense Observing Period in 2009 supported by several ongoing programs and research cruises and glider surveys.

> **ACTION 12**. Make the argument to funding agencies and non- participating PIs for enhanced deployment of instruments during the intense TACE obs period in 2009 (P. Brandt, B. Bourles, B. Johns)

It was suggested that AMMA be contacted to find out information on its project database and data availability

> **ACTION 13.** Put information on AMMA data availability on the TACE observational webpage (P. Brandt)

An AMMA-Ocean/TACE/PIRATA meeting will be embedded in the 2nd International AMMA Conference, 26-30 November 2007, Karlsruhe Germany (http://amma-international.org/meetings/internationalConferences/karlsruhe2007/). The meeting will focus on ocean studies particularly discussing the role of the Tropical Atlantic Ocean in the climate system. Meeting sessions (oral and poster) will be devoted to papers that address the following topics:

1) Atlantic ITCZ and TAV
2) Air-sea coupling, sea surface temperature & ocean mixed layer heat budget
3) Prediction and predictability of TAV
4) Tropical ocean circulation (including oxygen minimum zones, TIWs and equatorial wave dynamics)

9. PIRATA assessment, status and CLIVAR/OOPC review

The PIRATA project (http://www.pmel.noaa.gov/pirata/) is a tripartite programme among PMEL & AOML (USA), INPE & DHN (Brazil), and IRD & MeteoFrance (France) to generate an ocean-atmosphere database over the tropical Atlantic to understand the two main modes of Tropical Atlantic seasonal to decadal variability; the equatorial and the meridional mode. Established in 1997/98 with 12 ATLAS moorings, the array went through a pilot phase until 2001. The consolidation period lasted until 2006, with 10 moorings. Three extensions (SW, NE, and SE) to the original PIRATA backbone have been implemented since 2005, with six additional moorings already in place (SW- 3 moorings, September 2005; NE - 2 moorings, June 2006; and SE - 1 mooring, July 2006), and two extra moorings of the NE extension planed to be deployed in 2007 (see Fig 5).

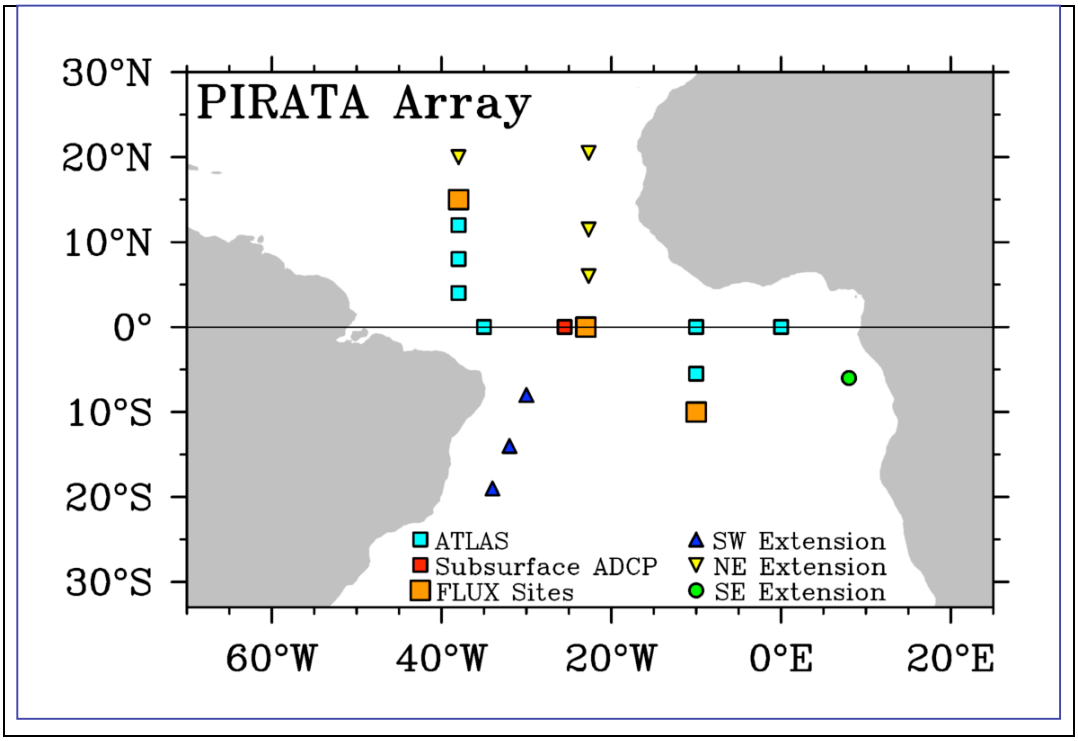

Figure 5. PIRATA array status

In total, the PIRATA array presently consists of 16 moorings. The SE extension is planned to stay in the water until the end of 2007. The PIRATA extensions were proposed and scientifically justified to expand the study of processes and climate related phenomena affecting the Tropical Atlantic and neighbouring continents.
All ATLAS moorings data are collected by Service ARGOS. In addition, the Brazilian SCD satellites collect the data of the westernmost sites of the PIRATA array.
The data transmitted via ARGOS is quality controlled at PMEL and distributed worldwide via the GTS. During maintenance oceanographic cruises, XBT and CTD profiles are done and meteorological data is collected, in addition to ship mounted ADCP measurements. All the data are available from the PIRATA website (http://www.pmel.noaa.gov/pirata/); data transmitted via GTS are used in data assimilation programmes like the French Mercator and Coriolis projects.

The backbone array is maintained by yearly cruises undertaken by Brazil and France, with the ATLAS mooring sensors recalibration and reassembly done by PMEL. The deployment and maintenance of the PIRATA extensions are responsibility of the proponent countries (i.e., SW – Brazil; NE – USA; and SE – South Africa). The PIRATA moorings are also used as platforms of opportunity to support scientifically targeted research, as for example the measurements of dissolved oxygen and carbon dioxide currently being measured and transmitted via service ARGOS at the 10S, 10W site. Experiments to measure biologic activity and diffusivity were also done at 8N, 28W in the past.

At the PIRATA X (Fortaleza 2004) and PIRATA XI meeting (Toulouse 2005), the Brazilian, US and French partners in the PIRATA program expressed their desire to extend the program, but decided that an assessment should take place by CLIVAR and GOOS. Members of the Atlantic Implementation Panel of CLIVAR and the Ocean Observations Panel for Climate of GOOS performed the review based on the document "PIRATA; accomplishments of PIRATA : 1997-2005. Status and Perspectives".

Paulo Nobre reported on the outcome of the review. In general CLIVAR and OOPC endorsed sustaining the PIRATA program. According to CLIVAR *"it is of the foremost importance to maintain the current mooring array and to strongly support the currently planned extensions. This would enable PIRATA to be firmly established as the main backbone of the tropical Atlantic observing system. The failure to do so would be a disaster for climate science community."* The new Northeast, Southwest and Southeast extensions of the mooring array are also strongly supported. Some of the concerns are of practical nature, in particular the issue of vessel support and vandalism. OOPC expressed specific comments on technical issues: procedures, calibration, sampling and observational challenges. A re-assessment is needed on critical observations and cost-effective technologies, a regional design should capture:

- The meridional mode
- Gulf of Guinea upwelling + Coastal Trapped Waves (CTW)
- Connections to Benguela upwelling + CTW
- Equatorial Wave Guide
- Eastern equatorial upwelling
- North Brazil Current
- Zonal inflow in the South Atlantic

PIRATA should also show that it contributes to improved estimation of oceanic state with independent data. "*PIRATA should not be stand-alone, but be part of an integrated observing system and research leading to better state-estimation and predictions"* (in situ, modelling, data assimilation, satellite observations, etc).This would be important in terms of setting priorities for new actions to be launched in the future.

A new Memorandum of Understanding among the founding countries of the PIRATA Project will be signed during 2008. It defines new strategies and incorporates the CLIVAR and OOPC reviews into consideration. Among such recommendations is the need of the already established moored array of the PIRATA Project to be integrated with other programs taking place in the tropical Atlantic during the coming years.
To move from a research-based, time-limited observing initiative to a sustainable observing system, the PIRATA array shall become part of an internationally sponsored ocean observing network. Current maintenance arrangements (basically, the backbone serviced by Brazil and France only) is not sustainable on the long run and shall be part of the new MOU signed among the supporting countries/institutions.

10. Tropical Atlantic Meeting Paris, Oct 2006

An overview of the workshop was given by W. Johns. The workshop was organized in 5 sessions:

1) Tropical Basin circulation
2) Equatorial waves and currents
3) Equatorial SST and currents
4) Upper Ocean Processes
5) Air-sea coupling

On the mean Tropical Atlantic (TA) circulation several issues/questions are still open:

- Issue 1: Pathways of the MOC through the tropics
    - What is the partitioning between western boundary (including rings) and interior pathways?
    - Models still suggest a lesser role for rings in MOC than observations suggest
    - MOC pathways through and outside of Carribbean sea?
    - How does Sub Tropical Cell (STC) variability influence the MOC pathways (and vice-versa)?
    - Is there a positive feedback between the ocean circulation in the tropics (e.g. STC convergence) and the meridional mode?

- Issue 2: Role of zonal equatorial currents (and other circulation features) in supplying waters to the eastern upwelling zones
    - What are the climatological transports and seasonal cycles of the EUCs -South EUC and North EUC- and where/how do they terminate?
    - How do they vary interannually in relation to TAV (e.g., does the EUC's transport and eastward penetration vary systematically during Atlantic Nino events?)
    - Role in ventilation (and export) from the oxygen minimum zone

Further observational and modelling studies on the dynamics, structure, and termination of the currents feeding the eastern upwelling zones need to be undertaken as well as their interannual variability in relation to TAV. Observational enhancements from moorings to be deployed during TACE will help to improve the data coverage in the east but targeted programs involving floats and drifters would also be very useful.

Measurements of currents, temperature, and salinity at the 0, 23W PIRATA site, as well as additional velocity measurements planned within a few degrees of the equator at 23W, will help to quantify the role of Tropical Instability Wave (TIW) in the mixed layer heat balance.
Satellite measurements and possibly the new PIRATA mooring at 12N, 23W, will help to quantify the roles of wind stress curl and oceanic circulation in driving surface chlorophyll variability.

Continued measurements at the PIRATA sites along 38W and at the North Tropical Atlantic site at 15N, 51W will help to diagnose SST variability in the tropical North Atlantic. Additional current meter(s) (one at 30-60 m depth for example) and salinity measurements (at ~80 m) on the 15N PIRATA mooring would help to better quantify the roles of horizontal heat transport, entrainment, and barrier layer formation in the mixed layer heat balance.

The main topic of the session on equatorial SST and currents was the equatorial current system, its mean and seasonal to interannual variability, with focus on its relation to the mixed layer heat budget in the cold tongue region. New moored and shipboard observations particularly regarding the eastward EUC and the westward flow below were presented that yield better estimates of the mean flow and its variability needed as reference for numerical models. The heat budget of the mixed layer in the eastern tropical Atlantic and its relation to the equatorial flow field are analysed using high-resolution numerical models to obtain a better understanding of the interannual cold tongue variability and its possible predictability.

The largest variability in the cold tongue region was found to be related to the West African monsoon onset in June. Accordingly, a discussion addressed the coordination of a special observing period in 2009. In this period, equatorial current meter arrays at 23°W, 10°W and 0°W will be installed. Several research vessels (US, French and German) will be in the region. A combined coordination of the individual field programs will lead to an optimum coverage of surface drifters, floats and gliders to obtain a better understanding of the cold tongue heat content variability and the role of intraseasonal waves. A mooring at 2°N (to be deployed at 23°W in April 2008), will be important for understanding of TIWs. Equatorial current meter moorings in the eastern equatorial Atlantic will address the termination of the EUC. The combination of atmospheric flux and oceanic microstructure measurements should be still one of the main foci of the observational program to close the mixed layer heat budget in the cold tongue region.

On Tropical Atlantic Variability the main issues were:

- Intra-seasonal
  - What is the cause/dynamics of the "14-17" day variability in the equatorial waveguide (most pronounced in the east)? Does it have rectified effects?
  - What is the cause of the strong interannual variability in the intraseasonal band (i.e., TIW's)?
  - Synoptic air-sea coupling over TIWs tends to damp the waves, but at small fraction (~10%) of energy production rate.

- Seasonal
  - What is the EUC seasonal cycle across the basin and extent of its eastward penetration?
  - Barrier layers are extensive not only in the Gulf of Guinea (Eastern Tropical Atlantic) but also in the western North Tropical Atlantic (warm pool) region. There is a need to better understand their role in seasonal (and interannual) heat storage and memory.
  - Climate models still mostly get the seasonal cycle wrong (in terms of both ITCZ movement and timing) – there is a need to focus on this for improved forecast capability

- Interannual
  - ECCO shows a strong correlation between Ekman transport divergence, STC convergence, and EUC transport on interannual time scales; the range is about 5 Sv, with apparent increasing trend over the past 20 years.
  - STC convergence is correlated with meridional SST mode (esp. NTA anomaly). Is there a positive feedback between the ocean circulation (e.g. STC convergence) and the meridional mode? Where does the memory of a boreal spring meridional mode event reside into the following spring?
  - Anomalous warm advection (from the south) has been shown to be major factor in initiating and sustaining the warm SSTs in the NTA during 2005. The annual cycle may be principally 1-D but not interannual.
  - There is growing evidence for remote forcing of anomalies in the Benguela and NW Africa upwelling regions by equatorial Kelvin waves. How do the zonal equatorial currents vary interannually in relation to TAV (e.g., does the EUC's transport and eastward penetration vary systematically during Atlantic Nino events?)

The workshop key recommendations were:

- Observational and modelling studies focused on determining the persistence mechanism of the SST gradient mode, and particularly the NTA SST anomaly pattern, are needed
- Further observational and modelling studies on the dynamics, structure, and termination of the currents feeding the eastern upwelling zones need to be undertaken as well as their interannual variability in relation to TAV. Observational enhancements from moorings to be deployed during TACE will help improve the data coverage in the east, but targeted programs involving floats and drifters are also needed.
- Coordination of a special observing period in the cold tongue during 2009 should be pursued, involving a detailed case study of its evolution, and roles of various processes (fluxes, advection, equatorial waves, mixing, TIWs) in the heat budget.
- Next Tropical Atlantic workshop should be held joint with PIRATA/AMMA meeting (on track for Nov. 2007?)

11. The AIP-VAMOS southWestern Atlantic climate Variability Experiment - WAVEs

WAVEs is a joint AIP-VAMOS proposal for field experiment and coupled modelling research program to study ocean-atmosphere-biosphere interactions leading to South Western Atlantic - South America climate variability and change. WAVEs aims to study the physical mechanisms that cause the SST variability on intraseasonal to interdecadal timescales in the South Atlantic.
The basic research foci are:

- South Atlantic Convergence Zone (SACZ) and related seasonal rainfall predictability (intraseasonal to interannual)
    - SST-SACZ coupled interactions
    - ITCZ-SACZ correlations
    - Amazon rainfall and Atlantic/Pacific SST variability
    - Remote forcings
- SST variability and change and meridional heat fluxes (interannual to decadal)
    - SST – solar radiation – rainfall feedback processes
    - Barrier layers due to SACZ rainfall over the ocean and river discharges
    - Amazon soil moisture – rainfall memory: ITCZ-SACZ-Low Level Jet (LLJ) interactions?
    - Teleconnections from the South Pacific Convergence Zone (SPCZ)
    - Density anomaly (T-S) advection by the South East Current (SEC)
    - SEC bifurcation
    - MOC-STC pathways
    - Brazil-Malvinas confluence zone
    -

WAVEs will promote the analysis of historical data, numerical modelling and observations to generate a better estimate of meridional heat flux in the South Atlantic. It will also carry out observational diagnostic studies and numerical simulations to better understand the land-air-sea interactions in different regions of the South Atlantic basin with the aim of designing and implementing a sustained monitoring system.

> **ACTION 14.** Write a science plan for WAVEs jointly with VAMOS (P. Nobre, A. Piola and J. Marengo)

12. South Atlantic (SA) observations status and SA workshop

A. Piola noted that observations in the South Atlantic are still sparse and limited in time-scale. A new estimate of the SA meridional heat flux is emerging from the AX18 HD XBT line. Figure 6 shows the heat transport at 35S from data collected from July 2002 to May 2006 (14 sections). In addition a model study shows that the South Atlantic, South Indian and South Pacific subtropical gyres are intimately connected: 3 Sv of upper branch water wrap around the three local gyres.

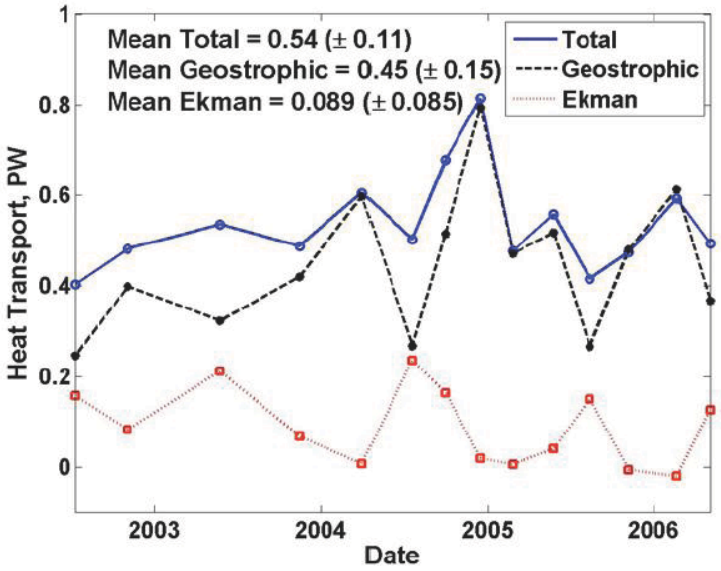

Figure 6. Estimate of South Atlantic Meridional Heat Flux (Garzoli and Baringer, submitted).

A workshop on "A monitoring system for heat and mass transports in the SA as a component of the MOC" will be held in Buenos Aires, Argentina on 8-10 May 2007 (for more information please visit the workshop website http://www.aoml.noaa.gov/phod/SAW/). The main objective of this workshop is to get together scientists with current or proposed programs in the South Atlantic to foster collaborations leading to the establishment of a monitoring system for meridional heat and mass transports in the South Atlantic and inter-ocean exchanges as a component of the MOC. The importance of the measurements was established at the CLIVAR South Atlantic meeting that took place in Angra dos Reis, Brazil in February 2003 see http://www.clivar.org/organization/atlantic/SACOSreport.pdf).

ACTION 15. Ask whether appropriate RAPID PIs can attend the S. Atlantic workshop in Argentina to help with the OSSEs experiment as they did for RAPID (D. Marshall)

ACTION 16. Produce a report of the meeting in Argentina and distribute to the AIP members (A. Piola)

13. US Decadal Predictability initiative

W. Johns reported on the US activities focusing on decadal predictability. The rationale is the linkage suggested by models between multi-decadal (perhaps decadal) SST variability and the Atlantic MOC together with the relevant societal consequences (hurricane activity, droughts etc…). Ocean observing systems and synthesis efforts are progressing to the point where they can provide useful nowcasting capabilities for model initialization. Decadal variability in the Atlantic will likely provide the basis for the first successful decadal forecasts.

Initial planning of a US MOC and decadal predictability program began after the US CLIVAR Summit in 2005. The first workshop (GFDL, June 2006) focussed on model results/phenomenology and the second workshop (AOML, January 2007) on the observational record, synthesis capabilities and needs. An implementation "roadmap" will be produced in fall 2007 and will be distributed among the US/International CLIVAR community.

The specific questions that this initiative wants to address are:

- What are the physical mechanisms and morphology of the variability on 10 year and longer time scales?

- Do self-sustained coupled modes exist in the Atlantic, ocean modes that are stochastically forced by the atmosphere, or damped coupled modes forced by the atmosphere?
- What are the regional impacts and their predictability?
- What are the links to the MOC?
- What is the influence of global warming on the MOC and its decadal variability?

The components of the programme are:

- Diagnostic studies of decadal/multidecadal variability including model-data comparison and Model Intercomparison Projects (MIPs)
- Predictability studies; statistical and model-based (IPCC class)
- Experimental decadal predictions
- Prototype outlooks/forecasts
- Improved nowcasting capabilities (synthesis)
- Specification of observing system required

David Legler informed the panel of the US "Ocean Research Priorities Plan", which was recently published as the guide for the next 10 years. It contains 20 ocean research priorities including 4 near-term priorities (next 2-5 years):

- Forecasting the response of coastal ecosystems to persistent forcing and extreme events
- Comparative analysis of marine ecosystem organization
- Sensors for marine ecosystems
- Assessing meridional overturning circulation variability: implications for rapid climate change

Abrupt Climate Change and the Atlantic Meridional Overturning Circulation (AMOC) is mentioned as near-tem priority. The anticipated outcomes are:

- Enhanced understanding of the MOC system
- Design of a comprehensive MOC observation and monitoring program
- New forecasting capabilities
- Improved ocean models, coupled models, and ocean analyses for their initialization
- Characterization of the impacts and feedbacks of changes in the MOC on ecosystems, carbon budgets and regional climate

The funding perspective is a modest increase in the budget in 2008 and a more substantial one in 2009. A writing team will be appointed to write a brief implementation plan. The draft plan will be completed in June and reviewed by individuals and groups (including AIP). The final version will be out in late September. International linkages are especially critical; therefore actions by AIP to coordinate US and EU research efforts would be very helpful.

Building on investments that agencies have already made in ocean observing systems and ocean and climate modeling capabilities, the following advances are planned by 2012:

- A routine capability to assess changes to the AMOC will be implemented. A climate history of Atlantic and global ocean changes will be developed for the past 50 years to enable recent changes to be put into the historical context of changes to climate in general.
- A firmer understanding will be established of the origins and structure of AMOC variability and trends, the implications of these on regional and global climate, and their predictability will be assessed.
- Working with interagency and international partners an objectively based design will be established for the sustained ocean observing system required for an early warning system and the economic and social benefits to be derived from this estimated.

- A prototype early warning system for some possible rapid climate changes will be implemented based on projections of likely future changes out to a decade or more (in partnership with the Administration's CCSP).

ACTION 17. Send summaries of European calls and proposals on AMOC and decadal predictability to US CLIVAR (W. Hazeleger, M. Visbeck, R. Sutton, D. Marshall)

ACTION 18. Explore WGCM , WGSIP and GSOP activities on coupled ocean-atmosphere initialization for initial value predictions (W. Hazeleger and A. Pirani)

14. Decadal Predictability EU FW7 proposal

Detlef Quadfasel is coordinating an European proposal in response to the European Union Framework Programme 7 (EU FW7) call on the stability of thermohaline circulation. The EU is promoting: *"Integrated observation and process studies in key regions (e.g. the Arctic and sub-Arctic), modelling and palaeo-studies to assess the risk of the breakdown or sudden reduction of the thermo-haline circulation. Feedback with stability of ice-sheets in polar regions, changes and variability in atmospheric circulation and the hydrological cycle should be included. The participation of international cooperation partner countries (e.g. Russia) is encouraged."* The expected outcome is:

- much improved quantification of risk, time horizon and possible scenarios for thermohaline circulation breakdown and related abrupt/rapid climatic change
- understanding of the influence of ice sheets melting on THC
- predictions of the THC in the future
-

The funding scheme encourages collaborative projects (large-scale integrating projects) with budgets from 4 to 10 M euros.

The AIP is aware of a number of proposals in this call, one on risk assessment, one on convection, small-scale processes and water masses and one on decadal variability and predictability (THOR). D. Quadfasel presented THOR. This proposal will address:

1. Quantifying and modelling MOC variability using paleo observations and simulations.
   - 1a Analyses of millennium-scale simulations with coupled atmosphere-ocean general circulation models
   - 1b MOC and related climate variables during the last Millennium from paleo observations
2. Ocean reanalysis and hindcasts
   - 2a. Evaluating MOC analyses (past 50 years)
   - 2b. Assessing uncertainty arising from the limitations of current climate models
3. Observations of the North Atlantic MOC
   - 3a. Sustained observations of ocean properties and fluxes through key sections
   - 3b. Monitoring water mass formation in convection regions south of the ridge: Irminger and Labrador Seas
   - 3c. Process studies on entrainment into overflow plumes and freshwater dispersion north of Iceland
4. Decadal Predictability of the MOC
   - 4a. Decadal predictability (20 years)
   - 4b. Impact of Ocean Observations on MOC predictions
5. New Technologies for MOC observations and coupled assimilation atmosphere-ocean

15. National Process Studies

15.1 UK RAPID

The RAPID science community and international participants met in Birmingham, 24-27 October 2006, to discuss the past, present and future states of the Atlantic MOC, its underlying mechanisms and predictability, and the RAPID and other monitoring efforts. The conference was preceded by a PAGES/CLIVAR workshop focused on the 8.2 ka event.
The conference was split into 4 themes:

1. Is the MOC changing?
Keynote talks were given by Harry Bryden on the first full year of data from the 26.5N RAPID array and from Fritz Schott on a northern perspective on the MOC during the past decade. The 26.5N array has revealed intense variability in the MOC, consistent with (and exceeding) that found in models and state estimation calculations such as ECCO. This led to an unfortunate article in the Guardian newspaper reporting that the MOC "shut down" for 2 weeks in November 2004 and a subsequent letter from Martin Visbeck rebutting the article. Science subsequently published a short and well-balanced article articulating the majority view that the variability is far too large to detect any trend as inferred by Bryden et al. (2005).

2. What does the past tell us about rapid change?
Keynote talks were given by Eric Wolff and Bette Otto-Bleisner on "8.2k and Dansgaard-Oeschger events in ice core and other paleorecords" and "Freshwater in the North Atlantic and rapid climate change: modelling of the 8.2 ka and Heinrich events". There was also a panel discussion on how paleo studies help us to improve models and predictions of rapid climate change.

3. THC, climate and weather in the 21st century.
Richard Wood and Henk Dijkstra gave keynote talks on predicting the MOC and stability of the MOC. There was also a panel discussion on what society wants to know about rapid climate change.

4. Outlook and challenges
Finally there were keynote talks from Jonathan Rougier on how probability can be used to quantify uncertainty in climate predictions, from Peter Haugan on polar mechanisms of rapid climate change, and from Jochem Marotzke on from MOC observations to climate predictions.

Sir David King (Chief Scientific Advisor to the UK Government) also gave a keynote talk in which he highlighted the recent Stern report that argues the future economic cost of adapting to climate change will far exceed that of immediate mitigation measures. He also stressed the need to narrow the range of uncertainties in climate change predictions. In addition there were many excellent posters and some contributed oral presentations. Overall, the meeting was considered a great success by the participants.

The RAPID-WATCH proposal (Bryden, Marshall, Sutton, Wood, Marotzke and Srokosz) was submitted to the UK Natural Environment Research Council (NERC) in April 2006, in parallel with the Oceans 2025 proposal to fund core-strategic work across the NERC Marine Science Centres. At its meeting on 29 November 2006, NERC Council agreed, in principle, to earmark £15.1M for the RAPIDWATCH programme for the period 2008/09 to 2013/14 subject to further observing system evaluation.

A review of the observing system took place in February 2007. The impressive results from the first year of 26.5N data were discussed in some detail. Preliminary results from the WAVE array (Western Atlantic margin Variability Experiment) were also discussed (data have only been available since last autumn) but there were unfortunately substantial equipment losses (8 out of 10 moorings and 10 out of 18 Bottom Pressure Recorders). In the meantime, a strong working collaboration with the Bedford Institute of Oceanography has been established and the proposal is to move forward by focusing on a full-depth western boundary array along the Halifax line to provide a second estimate of the MOC to the north of the Gulf Stream (to compliment 26.5N), along with maintaining the RAPID contribution to Line W (Toole et al.) at the intergyre boundary.

The objectives of RAPID-WATCH are:

- To deliver a decade-long time series of calibrated and quality-controlled measurements of the Atlantic MOC from the RAPID-WATCH arrays
- To exploit the data from the RAPID-WATCH arrays and elsewhere to determine and interpret recent changes in the Atlantic MOC, assess the risk of rapid climate change, and investigate the potential for predictions of the MOC and its impacts on climate.

The latter will be carried out via an open call for proposals addressing one or more of the following key science questions:

1. How can we exploit data from the RAPID-WATCH arrays to obtain estimates of the MOC and related variables?
2. What do the observations from the RAPID-WATCH arrays and other sources tell us about the nature and causes of recent changes in the Atlantic Ocean?
3. What are the implications of RAPID-WATCH array data and other recent observations for estimates of the risk due to rapid change in the MOC?
4. Could we use RAPID-WATCH and other observations to help predict future changes in the MOC and climate?

15.2 USA CLIMODE

CLIMODE (CLIvar MOde Water Dynamic Experiment, http://www.climode.org) is focused on a region of huge ocean to atmosphere annual mean heat loss (>200 Wm^{-2}) which occurs over the separated Gulf Stream in the North Atlantic. The region of most intense wintertime ocean heat loss corresponds to an area with relatively warm surface waters that are carried there by the Gulf Stream. Late winter SST's fall to approximately 18˚C as water parcels move east under this cooling. The associated buoyancy loss from the ocean is believed to trigger ocean convection on the northern rim of the subtropical gyre to form what is known as Eighteen Degree Water (EDW) the North Atlantic Subtropical Mode Water. The region of EDW formation is particularly relevant to wider CLIVAR goals because, first, the annual mean ocean to atmosphere heat flux over the EDW formation region might be crucial for the maintenance of the Atlantic Storm track. Second, EDW and the associated Gulf Stream recirculation and thermal structure occur over a key region where oceanic timescales can possibly imprint themselves on the atmosphere. Seasonal to interannual timescales are introduced by the thermal inertia of the ocean mixed layer/EDW layer system, whose evolution through the annual cycle is strongly connected to the re-emergence of SST anomalies from winter to winter. On longer timescales the intensity and path of the Gulf Stream affects air-sea exchange and mode water formation through interannual variations in low-frequency flow as well as lateral eddy heat fluxes. How exactly such oceanic influences on climate work is a subject of great importance, controversy and subtlety. Finally, CLIMODE should also be seen as making an important contribution to tying down the basin scale air-sea heat budget and, by implication, quantifying the meridional transport of heat in the Atlantic basin. CLIMODE is motivated by the fact that there is presently a major disconnect between the best available estimates of EDW formation rates based on air-sea fluxes and what we (think we) know about likely dissipation rates. The most likely possibility for the disconnect between estimates of mode water formation and dissipation rates described above are we believe: (a) neglect of eddy processes acting in the mixed layer in and near the Gulf Stream which result in significant lateral transport and (b) incorrect estimates of air-sea fluxes.

CLIMODE has been constructed around a two-year period of field measurements (2006, 2007) with particular emphasis on the late winter/ early-spring periods, times when EDW 'formation' is highest. Observations have been collected at high spatial resolution over the top 500 m of the ocean to capture the processes associated with mode water formation in the context of the meandering front. Simultaneously, the evolving marine boundary layer was measured in order to document the air-sea fluxes that drive the two fluids. On longer time scales, the subsequent capping and initial injection of the mode water into the subtropical thermocline was also observed, as well as its eventual dispersal. The seagoing element of CLIMODE begun in November 2005, when moorings and floats were deployed. The intensive winter observational periods followed in February 2006, 2007. For the two-year observation period, moorings (one surface, two subsurface) were maintained in the EDW transformation region surrounded by an array of profiling floats. Continuous remote sensing of the

ocean surface properties (SST, winds, sea level anomalies) were also carried out, in conjunction with an array of surface drifting buoys. In parallel with the observational program, modeling and theoretical studies have been carried out. A combination of regional and process ocean models were used to address the phenomenology of EDW formation and dissipation.

15.3 German CLIVAR activities

Several CLIVAR activities have been funded under the project "The North Atlantic as part of the Earth system: the path from understanding the system to regional impact analysis". Past CLIVAR/marine effort (1999-2005) provided contributions to the following subjects:

- Observations of the changing Atlantic circulation in several key regions, including aspects of the MOC
- Development of new technologies, e.g. MOVE array
- New insight into role of the shallow subtropical overturning cells and of the tropical horizontal circulation through joint observational and modeling studies
- Identification of decadal fluctuations in the source regions of the MOC, i.e., the subpolar North Atlantic and the Arctic Ocean.

The new phase will focus on:

- Quantitative understanding of key processes, including freshwater budget of North Atlantic and water mass formation rates
- Identification of vital observing elements in key regions than can form the backbone of a North Atlantic observing and diagnosis system
- Development of approaches suitable to detect seasonal to decadal climate changes, including the improvement of coupled models and the use of the consortium's observations for initialization
- Estimation of impacts of large-scale Atlantic circulation changes on European continental shelf regions, on the uptake of CO_2 as well as regional sea level changes in the Atlantic
- Estimation of the impact of modified thermohaline circulation on primary production and the fish stock of the Atlantic through numerical scenario run
- Construction of pilot diagnosis and evaluation system.

Several tasks will be performed using the following methods:

- Expansion of analysis methods to study changes of Atlantic circulation over the last 50 years.
- Mix of observational and modelling efforts.
- New regional observations will be used as initial conditions for global models and as constraints in synthesis systems.
- Results from model and synthesis efforts will be tested against new observations from key regions.
- Coupled ocean-atmosphere models will be improved and used to understand key regions and key processes.
- Regional observations jointly with those from other observing systems and in combination with models will form the basis for an early warning system.

There are four work packages and each of them include several projects:

AP1: Understanding of key regions and key processes in Atlantic Ocean Circulation.

- AP1.1: Role of freshwater changes for the development of the thermohaline - Latif (IFM-GEOMAR)

- AP1.2: Role of the equatorial Atlantic as key region for climate changes observed in Atlantic Ocean - Brandt, Boening, Latif, Stramma (IFM-GEOMAR)
- AP1.3: Changes of freshwater transports from the Nordic Sea into the North Atlantic – Schauer, Gerdes (AWI).

AP2: Development of components of an early warning system for seasonal to decadal climate changes.

- AP2.1: Large-scale changes in the North Atlantic subpolar gyre - Rhein (University Bremen)
- AP2.2: Changes of the deep boundary current circulation in the Labrador Sea - Visbeck, Fischer (IFM-GEOMAR)
- AP2.3: Causes for climate-relevant heat transport changes across the Greenland-Scotland ridge - Quadfasel/Kaese (IfM-HH).

AP3: Improving models and provide linkages to products

- AP3.1: Changes in the circulation and the ecosystem of the North Atlantic and the European North Sea and the feedback of both with the European Shelf analyzed in a regional coupled ocean-biology model – Maier-Reimer und Mikolajewicz, (MPI-HH)
- AP3.2: Changes of the thermohaline circulation determined in an eddy-resolving model with focus on mechanisms, observability and impact on carbon up take – Böning, Eden (IFM-GEOMAR).

AP4: Construction of pilot diagnosis and assessment system

- AP4.1: Determination of the North Atlantic Circulation through data assimilation - Stammer, Koehl (IfM HH)
- AP4.2: Initialization of a coupled global climate model through ocean reanalyses - Marotzke, Jungclaus (MPI-M)

16. CLIVAR workshop on Multidecadal to Centennial Global Climate Variability

This workshop, organised by Axel Timmermann and Henk Dijkstra, was held in Honolulu 15-17 November 2006. Most talks addressed either a) Atlantic multidecadal variability, or b) Pacific decadal-multidecadal variability (PDV). A few talks addressed interactions, e.g. the influence of the Atlantic on the Indo-Pacific on multidecadal timescales.

In the case of the Atlantic there was general agreement that the term “Atlantic Multidecadal Variability” (AMV) is preferable to “Atlantic Multidecadal Oscillation”, in view of the lack of clear evidence (at least from the observational record) for a preferred timescale beyond “red noise”. However, there is persuasive evidence that variability in the MOC contributes to Atlantic Multidecadal Variability, and that the associated spatial pattern is reasonably well defined (inter-hemispheric dipole with largest amplitude in high latitude North Atlantic). Nevertheless, clearly separating this contribution from the influence of changing external forcings over the last ~100 years is a challenging and as yet unsolved problem. It is likely that the changing external forcing is relatively more important at lower latitudes, but uncertainty in the aerosol forcing, especially before 1960, is an issue for attribution studies.

In the Pacific region there is evidence for both decadal and multidecadal variability, which may be associated with distinct mechanisms. Spatial patterns are somewhat sensitive to analysis method. Changes in tropical SST (and associated diabatic heating) in the Indian Ocean and West Pacific are implicated in the multidecadal variability seen in North Pacific SLP (transitions around 1926, 1947, 1976 and possibly 1997) but simulations with AGCMs do not consistently capture the observed variations. The Kuroshio extension region appears to be associated with enhanced decadal variability. Fluctuations in this region arise from both internal ocean processes and in response to variations in

wind stress curl. There is some evidence for weak ocean-atmosphere coupling. It is hypothesised that (large-scale) decadal variability in the Pacific Ocean is largely a deterministic response to changes in wind. The direct influence of changing external forcings on the Pacific Ocean has received less attention than is true of the Atlantic and Indian Oceans, possibly because the signal-to-noise (relative to the internal variability) is lower.

There is considerable evidence that both AMV and PDV are associated with important climate impacts, including those on: fisheries, sea level and precipitation patterns. It is highly likely that Atlantic and Pacific Multidecadal Variability cannot be understood independently from each other, but involve important interactions. It has been demonstrated, for example, that changes in the Atlantic MOC can influence the Pacific both through oceanic and atmospheric teleconnections. Furthermore there is important palaeo-evidence of correlations between the Atlantic and Pacific basins. Nevertheless, there is no clear understanding of the relationships between the basins on multidecadal timescales. For the recent period, understanding of this issue is complicated by changing external forcings. Some issues for the future:

Atlantic:

- potential for new proxy SST reconstructions to better characterise AMV prior to instrumental record (and onset of significant anthropogenic forcing).
- Mechanism for Atlantic Multidecadal Variability – what determines timescale (even if just red noise)? Do Rossby waves have any significant role? Relationship of modes found in simpler models (e.g. stochastically excited linear normal modes) to "statistical" modes found in GCMs? Internal ocean modes versus coupled modes (e.g. Vellinga and Wu).

Pacific:

- Are decadal and multidecadal variability really distinct or is it just red noise?
- Mechanisms – relevance of basin modes and how these are modified by ocean-atmosphere coupling, especially in the tropics; nature of tropical-extratropical interactions in ocean and atmosphere.
- What is the role of the Indian Ocean in PDV?

Common issues:

- Even if low frequency variability is best described as red noise, a good theory should be able to predict the associated timescale based on an understanding of the relevant processes
- Understanding inter-basin interactions on multidecadal timescales.
- Separating the influence of internal variability from the influence of changing external forcings
- Climate impacts, including seasonal variation of patterns and impacts
- Predictability

17. Status of the COREs: report from the WGOMD

Coordinated Ocean-ice Reference Experiments (COREs) have been defined by the Working Group for Ocean Model Development (WGOMD) as an effort to address various issues in modelling the global ocean circulation. Of particular concern is the formulation of the momentum, thermal, and hydrological fluxes required for simulations of coupled ocean-ice system on multi-decadal and longer time scales. The basic approach followed in the COREs is to prognostically compute turbulent fluxes for heat, moisture, and momentum from bulk formulae as a function of the ocean state (SST and surface currents) and a prescribed atmospheric state (air temperature, humidity, sea level pressure, and wind speed), in addition to applying radiative heating, precipitation, and river runoff. While being closest to what is used in climate (earth system) models, there are fundamental problems of this approach in ocean-only (or, ocean-ice only) models, related to the use of a prescribed and nonresponsive atmosphere. The COREs' goal is to highlight the difficulties, and to provide a means to lift disparate modelling efforts onto a common plateau from which alternative model designs and forcing data sets can be systematically explored.

In order to be widely applicable in global ocean-ice modelling, a flux data set should produce near zero global mean heat and freshwater fluxes when used in combination with observed SSTs, a criteria

precluding the direct use of atmospheric reanalysis products. The choice for the COREs is to adopt the forcing data sets of Large and Yeager (2004), based on a combination of NCEP/NCAR reanalysis and remote sensing products. The WGOMD has proposed three COREs:

- CORE-I: aimed at investigations of the climatological mean ocean and sea ice states, realized using the idealized, repeating "normal" year forcing of Large and Yeager, with models ideally be run to quasi-equilibrium of the deep circulation.
- CORE-II: aimed at investigations of the ocean variability during the last four decades, realized as the forced response of the interannually varying dataset of Large and Yeager.
- CORE-III: a perturbation experiment addressing the response to increased meltwater runoff distributed around the Greenland coast, following Gerdes et al. (2006).

The present status of CORE simulations is that modelling groups at GFDL, Kiel, KNMI, MPI and NCAR have explored the CORE-I set-up, focusing on the difficulties associated with the salinity or fresh water forcing; a paper providing a comprehensive discussion of the CORE proposal and analyses of this suite of experiments is in preparation.

Studies of global ocean-ice response to interannually varying atmospheric forcing have been taken up in various groups, adopting either the Large and Yeager forcing proposed for CORE-II (e.g., Kiel), or other, recent developments involving corrections of individual flux components (e.g., the effort by the DRAKKAR consortium).

18. Climate driving of ecosystem changes - making the connection: a CLIVAR-IMBER-GLOBEC initiative for a "hands-on" workshop

At the meeting of the Atlantic Implementation Panel of CLIVAR (Venice, Oct 2005) a GLOBEC representative was invited and informed the Atlantic Implementation Panel on the importance of climate variability for the marine environment. A list of questions from the GLOBEC community was delivered to CLIVAR. These questions concern impacts of patterns of climate variability, such as the North Atlantic Oscillation and the El Nino Southern Oscillation, on marine systems. At the SSG meeting of CLIVAR (Buenos Aires, April 2006) it was proposed to organize a small open science meeting together with the marine programs of SCOR/IGBP to address the issues mentioned above. This plan was positively received at the SSG meeting of IMBER (Brest, May 2006) at which representatives of SOLAS and GLOBEC were present. The goals of such a small open science conference should be.

1. To exchange information on climate variability impacts and marine impacts between physical climate science and marine biogeochemistry and ecosystems communities
2. To foster cooperation between WCRP and SCOR/IGBP projects
3. To take stock of IPCC-AR4 results where relevant for impacts on the marine environment.

A planning meeting was held at the SCOR Project Summit in December 2006 in London with CLIVAR, GLOBEC, IMBER and SOLAS representatives:.
The agenda included a science lecture on "Climate Variability and Change in the Atlantic Sector and its Global Context" by Rowan Sutton (University of Reading). It was decided that the conference should be a "hands-on" workshop focusing on informing young researchers from the marine sciences. The workshop will consist of Science Talks in the morning and exercises on the use of climate data in the afternoon. The science talks will discuss the data and its quality (such as reanalysis, in situ data and climate model data). In the afternoon web-based tools will be demonstrated. Kiel and Brest were proposed as potential venues. The time line for further planning is:
31-1: Finalize science team
31-3: Finalize questions and themes
30-4: List of confirmed speakers
31-5: First circular with invitation to community
30-6: Finalize program
30-9: Close registration

ACTION 19. Provide input on speaker and themes for the IMBER/GLOBEC/SOLAS CLIVAR workshop to Wilco Hazeleger (all)

ACTION 20. Reach out the IGBP community on AIP activities and future plans (i.e. decadal predictions) (W. Hazeleger)

19. AIP Membership and co-chair

The AIP members that are due to rotate off at end 2007 are B. Bourles, W. Hazeleger, N. Koc, D. Stammer, D. Marshall, C. Zhang.

It was suggested W. Hazeleger and N. Koc to stay for another two years.
The panel recognized the importance of a link with GSOP and synthesis activities. It was therefore suggested to ask D. Stammer to stay another two years or to be an ex-officio member.

R. Curry was asked to become co-chair

ACTION 21. Submit list of new members to the panel for input and submit final list to SSG (W. Hazeleger and R.Boscolo)

ACTION 22. Ask the attendees of the 8th AIP meeting permission to place their presentations on the CLIVAR web site (R. Boscolo)

APPENDIX A: List of Attendees

Panel Members

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ICPO

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Panel Members not present

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APPENDIX B. Agenda

Wednesday 21st March

Overlap with last session of the North Atlantic Subpolar Gyre Workshop - Past, present and future perspectives of Subpolar Atlantic variability in the CLIVAR context

9:30 Centennial-millennial variability of the two main branches of the North Atlantic Drift through the Holocene *(Nalan Koc)*

10:00 Present and Future Perspectives on Assimilation Efforts *(Detlef Stammer)*

10:30 Coffee break

11:30 Welcome and Introduction *(W. Hazeleger)*
- Introduction and Welcome to guests and new members
- Introduction to CLIVAR roadmap development
- Review of the Agenda
- Review of Action Items

12:30 Overview and recommendations from the meeting Subpolar Gyre workshop just finished (R. Curry and D. Marshall)

12:45 Lunch

13:30 WCRP and CLIVAR Forward look *(R. Boscolo)*

Discussion Sessions: CLIVAR Atlantic perspective on future climate research (up to 2013)

14:00 Atlantic Observations: introduction *(Bill Johns)*
15:00 Synthesis and status ocean reanalysis *(D. Stammer)*

16:00 Coffee Break

16:30 Seasonal to decadal predictability: introduction *(Rowan Sutton)*

17:30 Wrap up discussion

19:30 Panel dinner – chez Visbeck

Thursday 22nd March

Tropical Atlantic Session

9:00 Report + activities TACE modelling *(C. Eden)*
9:30 Report + activities TACE observations *(P. Brandt)*
10:15 PIRATA assessment: status and CLIVAR/OOPC review *(P. Nobre)*
10:30 PIRATA + Extensions status *(P. Nobre)*
10:40 Tropical Atlantic workshop in Paris, Oct 2006 *(B. Johns)*

10:45 Coffee Break

South Atlantic Session

11:10 Status + interaction WAVES-VAMOS *(P. Nobre)*

11:30 Status South Atlantic observations and workshop *(A. Piola)*

North Atlantic session

12:00 Decadal Predictability US initiative *(B. Johns)*
12:30 AMOC Variability: a near-term US Ocean Research Priority *(D. Legler)*

13:00 Lunch

13:45 Decadal Predictability EU FW7 proposal *(D. Quadfasel)*
14:15 German CLIVAR activities *(D. Quadfasel)*
14:45 RAPID conference, Oct 2006 and RAPID II status (D. Marshall)
15:15 CLIVAR workshop on multidecadal to centennial variability *(R. Sutton)*

15:30 Coffee Break

Interactions with other panels and programs

16:00 WGOMD and status CORE *(C. Boening)*
16:15 IMBER/SOLAS/GLOBEC –CLIVAR joint workshop *(W. Hazeleger)*

AIP Business

16:40 Memberships, new co-chair, proposal for future workshops, next meeting

17:30 ***End Meeting***

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