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## **WORLD CLIMATE RESEARCH PROGRAMME**



### **Report of the 4th meeting of CLIVAR Atlantic Implementation Panel**

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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.

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## Action Items

- 1) Write an article for the next issue of the CLIVAR Exchanges Newsletter on assessing the present knowledge of MOC variability, and the status of the MOC observing system in the Atlantic.  
*(D. Marshall, T. Delworth, F. Schott and M. Visbeck)*
- 2) The panel is disappointed that WG1 has not submitted the recommendations of the CLIVAR Tropical Atlantic Variability workshop ([www.clivar.org/organization/atlantic/TAV](http://www.clivar.org/organization/atlantic/TAV)), 3-6 September 2001, Paris. We request immediate action to rectify this omission.  
*(S. Garzoli and R. Boscolo)*
- 3) Contact WGSIP and initiate discussions on holding a co-sponsored workshop focusing on Atlantic predictability in the near future depending on the outcome of the upcoming US workshop in the fall.  
*(Y. Kushnir and R. Sutton)*
- 4) Identify and submit to R. Boscolo short summaries of socio-economic applications within the CLIVAR activities in the Atlantic sector.  
*(all members of Panel + guests)*
- 5) Submit list of proposed new panel members to SSG for their consideration.  
*(M. Visbeck and R. Boscolo)*
- 6) Express concern to the ICPO on the effectiveness of SPRINT. Suggest to differentiate the core projects from the CLIVAR endorsed and CLIVAR related.  
*(R. Boscolo)*
- 7) Explore the possibility and format for a brochure about the science and implementation of CLIVAR in the Atlantic sector.  
*(R. Boscolo)*
- 8) Acknowledge the letter from VACS and encourage VACS to work together with the Atlantic panel on the implementation of AMMA. In particular, we would like to work with VACS on identifying the ocean role in the African climate variability at interannual to decadal time-scales.  
*(M. Visbeck and R. Boscolo)*
- 9) Establish a subgroup of the Atlantic panel to provide inputs to WGOMD on metrics and indices of climate variability in the Atlantic sector to be used for model-model and model-data comparison studies. The same group is tasked to jointly identify and/or develop model experiments to explore MOC responses and sensitivity.  
*(T. Delworth, W. Johns, D. Wright, D. Marshall and R. Sutton)*
- 10) Express interest in co-sponsoring a workshop in Kiel in 2004 on Atlantic Thermohaline variability from a synthesis point of view. The panel recommends that such a workshop should be a joint activity with WGCM and WGOMD.  
*(T. Delworth, C. Boening and M. Visbeck)*
- 11) Compile a table of MOC observables and pass it to WGCM  
*(D. Wright and T. Delworth)*
- 12) Express concern to the OOPC about weak surface drifter coverage in the eastern tropical South Atlantic area under the African stratus deck.  
*(M. Visbeck and R. Boscolo)*
- 13) Contact SOOP ([www.ifremer.fr/ird/soopip](http://www.ifremer.fr/ird/soopip)) and submit a well justified proposal to include the AX01 line (Shetlands-Greenland) in the plans for sustained high density XBT lines.  
*(S. Osterhus, B. Dickson and P. Koltermann)*
- 14) Express concern to OPCC and nations on the lack of a coherent / complete MOC observing system in the South Atlantic.

*(M. Visbeck and R. Boscolo)*

- 15) S. Oesterhus to contact the appropriate Norwegian group that operates a research vessel out of Namibia and explore the possibility of engaging them in support of sustained observations for climate and/or process experiments in the region and report back to panel.  
*(S. Oesterhus and M. Visbeck)*
- 16) Suggest that the ICPO implements a more interactive on-line tool for monitoring the implementation of the CLIVAR related observations network in the Atlantic and other basins. Include the ability to differentiate systems by the parameter that they measure, what is already known and how long the observations might be sustained.  
*(R. Boscolo)*
- 17) B. Dickson to provide a short white paper addressing the synergies between ASOF and CLIVAR which will then be forwarded with a request for ASOF endorsement to the SSG. (guidelines provided by ICPO)  
*(M. Visbeck and R. Boscolo)*
- 18) The panel welcomes the proposal for holding a CLIVAR/OOPC workshop on the South Atlantic Climate Observing System and encourages the organising committee to submit an updated proposal for review and hopefully endorsement. A subgroup of the panel is tasked to conduct this review in the near future and promises a fast turnaround time.  
*(J. Hurrell, A. Busalacchi, F. Schott, T. Delworth and S. Oesterhus)*
- 19) Contact the chairmen of the VACS, VAMOS and Southern Ocean panels and encourage their respective panels to become co-sponsors / reviewers of the CLIVAR/OOPC workshop on the South Atlantic Climate Observing System.  
*(M. Visbeck and R. Boscolo)*
- 20) C. Reason to explore with appropriate group in S. Africa how more CLIVAR related research can be conducted by joint ventures between S. Africa and other nations.  
*(C. Reason, H van Aken)*
- 21) Write to national funding agencies and inform them about the activities of CLIVAR in the Atlantic sector and ask them how they are contributing to those efforts.  
*(M. Visbeck and R. Boscolo)*
- 22) Propose holding the next Atlantic panel meeting back-to-back with the EGS-AGU annual assembly in April 2003 at a venue close to Nice, France. Likely dates are April 14-16 2003. The thematic focus could be on: data needs; synthesis/reanalysis/prediction systems; S. Atlantic research; connections to the Arctic.  
*(M. Visbeck and R. Boscolo)*

## 1. Background

The CLIVAR Atlantic Implementation Panel is a part of the CLIVAR organization. The panel is in charge of implementing the CLIVAR science plan in the Atlantic sector. More specifically its terms of references are:

1. To recommend and oversee the implementation of observations in the Atlantic Ocean sector, in order to meet the objectives outlined in CLIVAR's Science and Initial Implementation Plans, particularly with respect to the Principal Research Areas D1 (North Atlantic Oscillation), D2 (Tropical Atlantic Variability) and D3 (Atlantic Thermohaline Circulation).
2. To collaborate with JSC/CLIVAR Working Group on Coupled Modelling and CLIVAR Working Group on Seasonal-to-Interannual Prediction, in order to design appropriate numerical experiments, and to be aware of requirements set by these groups for data sets needed to validate models.
3. To liaise with the relevant CLIVAR panels, in particular Upper Ocean Panel and PIRATA Steering Group, to ensure that best use is made of resources from the global and equatorial research programs.
4. To liaise with Ocean Observation Panel for Climate and other relevant groups to ensure that CLIVAR benefits from and contributes to observations in GOOS and GCOS.
5. To report to the CLIVAR SSG.

### The members of the CLIVAR Atlantic Implementation Panel are:

M. Visbeck (Chair)	Lamont-Doherty Earth Observatory, Palisades, USA
A. Busalacchi	ESSIC, University of Maryland, USA
A. Clarke	Bedford Institute of Oceanography, Dartmouth, Canada
T. Delworth	GFDL-NOAA, Princeton, USA
R. Dickson	CEFAS-MAFF, Lowestoft, UK
J. Hurrell	NCAR, Boulder, USA
K.-P. Koltermann	Bundesamt Seeschifffahrt Hydrographie, Hamburg, Germany
Y. Kushnir	Lamont-Doherty Earth Observatory, Palisades, USA
A. Piola	Servicio de Hidrografia Naval, Buenos Aires, Argentina
C. Reason	EGS & Oceanography Depts., University of Cape Town, South Africa
G. Reverdin	Centre National d'Etudes Spatiales, Toulouse, France
F. Schott	Institut für Meereskunde, Kiel, Germany
R. Sutton	Centre for Global Atmospheric Modelling, Uni. Of Reading, UK
I. Wainer	University of São Paulo, São Paulo, Brazil

### ICPO Representative is:

R. Boscolo	ICPO SOC Southampton UK and IIM-CSIC Vigo Spain
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## 2. Opening Session

The 4<sup>th</sup> Atlantic Implementation Panel meeting started with the welcome remarks of Dr Knap, director of the *Bermuda Biological Station for Research* ([www.bbsr.edu](http://www.bbsr.edu)). The kind hospitality of Dr. Knap and his staff allowed the panel to have a productive and enjoyable stay in Bermuda. Dr. Knap gave an overview of the BBSR history and ongoing activities by stressing the importance of the Bermuda long-term observations for climate variability studies. He expressed enthusiasm for CLIVAR activities in the Atlantic and was pleased to host the CLIVAR meeting at the BBSR which he considered to be the most suitable place for discussing the Atlantic sector implementation. The CLIVAR Atlantic meeting also made it into the local news thanks to an interview of Dr Knap and Roberta Boscolo (see Appendix A and [www.bbsr.edu/Press\\_and\\_Pubs/pr\\_jul11\\_02/pr\\_jul11\\_02.html](http://www.bbsr.edu/Press_and_Pubs/pr_jul11_02/pr_jul11_02.html)).

Martin Visbeck (chairman of the CLIVAR Atlantic Panel) opened the session by welcoming the Panel members, invited experts and local participants (see Appendix B). Apologies were received from Drs Clarke, Kushnir, Reverdin and Sutton for being unable to attend the meeting. The Atlantic Panel's Terms of Reference ([www.clivar.org/organization/atlantic/index.htm#TOR](http://www.clivar.org/organization/atlantic/index.htm#TOR)) were briefly reviewed and the participants were reminded of the focus of the meeting. The Atlantic panel had the last two previous meetings focussing on the North Atlantic Oscillation (NAO) and Tropical Atlantic Variability (TAV). It was therefore decided to dedicate this meeting to the review of the Meridional Overturning Circulation (MOC) variability in the Atlantic and its interaction

with NAO and TAV. In particular, the participants were solicited to critically review the observational network presently in place in the Atlantic in order to find overlapping or gaps in long-time series and sustained observations as well as to propose process studies for developing further sustainable MOC observations. It was suggested that a subgroup of the participants would be in charge of writing an article for the next CLIVAR Exchange issue on the outcome of the meeting discussions.

**ACTION ITEM 1.** Write an article for the next issue of the CLIVAR Exchanges Newsletter on assessing the present knowledge of MOC variability, and the status of the MOC observing system in the Atlantic.

The review of the meeting agenda (see Appendix C) and a brief description of the local arrangements concluded the introduction to the meeting.

### **3. Review of the Panel relevant activities and developments**

#### **3.1 Last meeting's Action Items**

Martin Visbeck reviewed the status of the Action Items from last Panel meeting in Paris 7-8 September 2001 ([www.clivar.org/publications/wg\\_reports/atlantic/3rdmeet.pdf](http://www.clivar.org/publications/wg_reports/atlantic/3rdmeet.pdf)). Overall the members of the panel worked hard in order to address the assigned tasks and most of the action items were completed. The results of some of those completed actions are discussion items in the agenda of this meeting.

The following items needed further attention:

- Roberta Boscolo noted that the report of the CLIVAR-sponsored TAV workshop held in Paris on 3-6 September 2001 is still incomplete ([www.clivar.org/organization/atlantic/TAV](http://www.clivar.org/organization/atlantic/TAV)). The recommendations of WG1 are still missing.

**ACTION ITEM 2.** The panel is disappointed that WG1 has not submitted the recommendations of the CLIVAR Tropical Atlantic Variability workshop ([www.clivar.org/organization/atlantic/TAV](http://www.clivar.org/organization/atlantic/TAV)), 3-6 September 2001, Paris. We request immediate action to rectify this omission.

- Tony Busalacchi noted that no white papers for PIRATA extensions have been submitted yet to the PIRATA Steering Committee for endorsement.
- Yochanan Kushnir through Martin Visbeck let the panel know that the plans for organising an Atlantic predictability workshop are on a slow track. However he is holding an US workshop on TAV predictability in late September 2002 and depending on the outcome of this meeting he will seek support from the international community for proposing an international CLIVAR sponsored workshop.

**ACTION ITEM 3.** Contact WGSIP and initiate discussions on holding a co-sponsored workshop focusing on Atlantic predictability in the near future depending on the outcome of the upcoming US workshop in the fall.

- Martin Visbeck reported that planning of process research studies in the Atlantic in US has been encouraged and expects that the panel will hear more about the outcome next spring. At the international level there are some process studies that have been proposed for CLIVAR endorsement.
- Roberta Boscolo reported that other than the planning of the CLIVAR/Carbon hydrographic lines, there has been little interaction between CLIVAR and the Carbon community. There is no clear indication which organisation would be the main CLIVAR counterpart. Martin Visbeck asked Nick Bates from BBSR to participate actively in the meeting and raise issues, when appropriate, related to carbon studies in the Atlantic.
- The panel members and the ICPO staffer haven't taken actions yet toward identifying end-users and applications of CLIVAR Atlantic research activities. However Martin Visbeck stressed again the importance of this exercise in order to raise CLIVAR Atlantic profile and help PIs to write funding proposals. He also reported that this is one of the recommendations of the last CLIVAR SSG meeting.

**ACTION ITEM 4.** Identify and submit to R. Boscolo short summaries of socio-economic applications within the CLIVAR activities in the Atlantic sector.

### 3.2 Panel's Membership

Martin Visbeck reviewed the terms of the present members of the panel (see Appendix D). The two new members Dr. Ilana Wainer from S. Paolo, Brazil and Dr. Chris Reason from Cape Town, S. Africa were welcomed. Thanks went to the hard work of Drs Clarke, Reverdin and Dickson who have served on the panel since 2000 and their terms are finishing at the end of 2002.

It was agreed to have four new members in 2003 to be chosen from the following (partial) list: W. Johns (USA), H. Mercier (FR), S. Oesterhus (NOR), D. Wright (CAN), D. Marshall (UK) and H. van Aken (NL). Martin Visbeck reported on his effort in trying to give a gender balance to the panel membership, unfortunately all the expert women scientists he approached, declined the invitation to serve on the panel. Tom Delworth also noted that the addition of a member from the paleo community would be very useful to the panel (Mike Man, USA, was proposed). The above list will be circulated among the present panel members for comments and the list of proposed four new panel members will be submitted to the CLIVAR SSG.

**ACTION ITEM 5.** Submit list of proposed new panel members to SSG for their consideration

### 3.3 Update on CLIVAR Organisation and ICPO activities

Roberta Boscolo gave an overview of the CLIVAR organisational developments ([www.clivar.org/organization/](http://www.clivar.org/organization/)) and ICPO relevant activities. During last year two new implementation panels were formed: the Pacific and the Southern Ocean panels. The Pacific panel oversees CLIVAR activities related to ENSO and the Indo-Pacific Decadal Variability, while the Southern Ocean panel addresses CLIVAR issues related to the climate variability and predictability of the coupled ocean-atmosphere-ice system in the Southern ocean. CLIVAR organisation up-to-now totals seven implementation panels. Clearly the Atlantic panel needs to develop and maintain close relationship with VAMOS (Variability of the American Monsoon Systems), VACS (Variability of the African Climate System) and the Southern Ocean Panels. CLIVAR also counts on several crosscutting panels that address the global approach of the CLIVAR science agenda. These are the three modelling working groups (seasonal to interannual prediction, coupled modelling and ocean model development) and the CLIVAR/PAGES intersection (past climate reconstruction). Of the two crosscutting panels on Ocean Observations and Data Strategy, the latter ceased to operate during last year whilst the role of the former is under review. The CLIVAR SSG is looking into finding a better way to address these issues perhaps jointly with other international organisations. Fritz Schott noted that no panel is addressing the Indian Ocean's role on climate variability at interannual to decadal time-scales. He asked whether the CLIVAR SSG would rectify this gap in the near future.

The ICPO based at SOC, UK ([www.clivar.org/organization/icpo/](http://www.clivar.org/organization/icpo/)), went through several changes during last year, the most relevant one is on the directorship. John Gould who has been the ICPO director since 1998, retires in August 2002 and Howard Cattle, head of the UK Met Office's Ocean Applications branch, will take over his position. Zhongwei Yan, based at SOC, is the new staffer for the Asian-Australian Monsoon Panel and the Expert Team on Climate Change Detection. Mike Sparrow, editor of the WOCE Atlases, has responsibilities on the newly formed Southern Ocean panel, he will be based in Beijing, China, from August 2002. Carlos Ereno, based in Buenos Aires, Argentina, co-ordinates CLIVAR activities in South America, especially in relation to VAMOS, and develops links with GEWEX. Roberta Boscolo who is based in Vigo, Spain, is the staffer for the Atlantic panel and will take responsibilities on VACS activities. Andreas Villwock, based in Kiel, Germany, is the most long-standing staffer. He co-ordinates CLIVAR modelling activities (WGSIP, WGCM and WGOMD), is the editor of CLIVAR Exchanges and the webmaster of the CLIVAR webpages. Daniela Turk who started in September 2001 as the Pacific Panel staffer, left the job at the end of April 2002. The ICPO is looking for her replacement.

Among the tools developed at ICPO for improving distribution of information and monitoring CLIVAR activities, the web pages ([www.clivar.org](http://www.clivar.org)), the Newsletter "Exchanges" and SPRINT were mentioned. In particular the panel were reminded that the topic of the September 2002 issue of Exchanges is CLIVAR Atlantic to which the panel should aim to submit the article on MOC (Action Item 1). Regarding SPRINT ([sprint.clivar.org](http://sprint.clivar.org)) the CLIVAR Searchable Program Information Network, the panel unanimously complained that the information contained is obsolete and that the system for updating information is not working. The panel also suggested



that there should be a flag in each entry in order to distinguish the CLIVAR-endorsed from the CLIVAR-related projects.

**ACTION ITEM 6.** Express concern to the ICPO on the effectiveness of SPRINT. Suggest differentiating the core projects from the CLIVAR endorsed and CLIVAR related.

Finally Roberta Boscolo reported on her work in updating the CLIVAR Atlantic web pages ([www.clivar.org/organization/atlantic](http://www.clivar.org/organization/atlantic)), developing a web-based tool for monitoring CLIVAR implementation in the Atlantic sector and promoting CLIVAR Atlantic science at international fora. She contributed to the AGU-ASLO Ocean Science 2002 meeting with a poster entitled "CLIVAR Variability in the Atlantic Sector: Three Phenomena One Challenge" and plans to contribute to the WOCE final conference in November 2002 with an Atlantic CLIVAR poster. She also suggested producing a brochure that would illustrate the CLIVAR activities in the Atlantic. The idea was welcomed but the panel suggested that the preparation of such a publication be coordinated with the other CLIVAR panels for consistency.

**ACTION ITEM 7.** Explore the possibility and format for a brochure about the science and implementation of CLIVAR in the Atlantic sector.

### 3.4 Report on CLIVAR SSG-11

Tony Busalacchi firstly reviewed the issues of concern which had emerged at the last WCRP Joint Scientific Committee meeting regarding CLIVAR activities:

- Effective links to IGBP in terms of joint interests in the intersection of climate variability and biogeochemistry
- Free exchange and access to data, especially at regional scales, and access to coupled model solutions/ensembles
- Funding for participation of developing nations
- WCRP approach to data management
- WCRP leadership/presence in joint IGBP/IHDP/VERITAS activities
- Co-ordination of the WCRP research agenda and the operational activities of WMO (data request to NMHS, sustained observations and support to SALLJ)

Considerable time at the last JSC was dedicated to the concept of an overarching "WCRP Banner on Predictability" in response to statements that there is no single organisational structure within the WCRP to provide opportunities for all WCRP components to interact on the question of the nature and predictability of the entire physical climate system.

Based on the feedback of the JSC, the most pressing issue discussed at the SSG meeting in Xi'an, China, was the CLIVAR approach to global integration. The vital activities in this regard are the modelling groups (WGCM and WGSIP) and reanalysis of atmosphere, ocean and land. It was decided that COOP (CLIVAR Ocean Observation Panel) would focus on global reanalysis for both ocean and atmosphere and that observational issues would be taken care of by the OOPC (Ocean Observation Panel for Climate). The SSG agreed on the need for a closer relationship between its WGs on Coupled, Ocean and Seasonal-Interannual (SI) predictive modelling and its more observationally focused regional panels. Plans were welcomed for a pan-CLIVAR workshop on monsoon modelling. The SSG also asked the WGSIP to review the techniques which can be used to establish the dependence of SI predictions on existing ocean data and the possible future ocean observing system and to assess the current capability and principal limitations of the SI prediction groups to perform such studies.

Tony Busalacchi also reported on the Review of Tropical Moored Buoy Programs, a workshop held at the Pacific Marine Environmental Laboratory in Seattle USA, from 10-12 September 2001. About 12 ATLAS moorings form the Atlantic array called PIRATA, a joint French, Brazil and USA effort. This array was begun in 1997 and many research groups are using the data in modelling and empirical studies of tropical Atlantic phenomenology. In addition institutions like NCEP, ECMWF, IFREMER (through CORIOLIS) regularly utilise PIRATA data in their operational analysis and forecast products. Adequacy of ship time is an issue: buoys are serviced once a year by French and Brazilian ships. Data return was 75% during last year, an improvement on previous years but lower than in the Pacific array (serviced twice per year). Vandalism by fishing fleets continues to adversely affect data return and equipment return particularly in the Gulf of Guinea. France, Brazil and USA signed a MoU in August 2001 to continue PIRATA for a 5-year "consolidation phase" (2001-2005). Plans are to be proposed for array extensions at north-east, south-east and north-west sites. There have been also some discussions about instituting a

Brazilian base of operation in Natal to support long-term operations for PIRATA and other elements of GOOS.

#### **4 BBSR Current Projects in Support of Climate Research: seminar by N. Bates**

The Bermuda Atlantic Time-series Study (BATS) is the long-term time-series study of biogeochemical cycles in the western North Atlantic Ocean near Bermuda. BATS ([www.bbsr.edu/Labs/co2lab/nickbats.html](http://www.bbsr.edu/Labs/co2lab/nickbats.html)) is one of two oceanographic time-series sites (the other one is located in the North Pacific near Hawaii) that have been supported by a large interdisciplinary and international program (JGOFS). The purpose of both time-series studies is to understand the role of the ocean in large-scale processes of global change, especially their role in affecting greenhouse gases such as CO<sub>2</sub>. The formation of cold, dense waters drives an overturning ocean circulation that transfer heat, CO<sub>2</sub> and oxygen into the deep ocean. After several thousand years, deep water, which has high levels of CO<sub>2</sub>, returns to the surface in upwelling regions such as the Equatorial Pacific. However episodic events such as hurricanes can temporarily reverse the direction of carbon dioxide exchange, short-circuiting the pathway back into the atmosphere. Upper ocean physical properties and biogeochemical signals at BATS are being related to changes in NAO.

#### **5. The Tropical Atlantic Variability Workshop Follow up.**

Fritz Schott listed a series of initiatives that stemmed from the recommendations put forward by the WGs at the TAV workshop, Paris 3-7 September 2001:

- Based on the recommendations of the "WG2: climate impacts and predictions", a US CLIVAR workshop will take place in late September 2002 on the Dynamics and Predictability of the Atlantic ITCZ and its Regional Climatic Influence. The meeting will be held at IRI, Palisades NY with Y. Kuhnir and S. Zebiak as chairmen (<http://iri.columbia.edu/outreach/meeting/CLIVARWS2002/>).
- Based on the recommendations of "WG3: links between the upper tropical Atlantic, the deep ocean and other basins", a PIs meeting took place on 13-15 May 2002 at the University of Maryland. Chaired by S. Garzoli and co-ordinated jointly with Paola Malanotte-Rizzoli and Jim Carton, the meeting helped to formulate a proposal for process studies in the Tropical Atlantic. The proposal was submitted to US CLIVAR SSC for review.
- A workshop on Circulation and Variability of the Tropical Atlantic will be held at IfM in Kiel, Germany on 19-22 August 2002 ([www.clivar.org/organization/atlantic/wksp\\_trop\\_atl.htm](http://www.clivar.org/organization/atlantic/wksp_trop_atl.htm)). The meeting is chaired by F. Schott and B. Molinari with the aims of bringing together observational groups for joint papers on recent observational programs; comparing observations with recent model results; encouraging co-operation in model-observation synthesis groups; formulating objectives for future observational foci.
- A special GRL issue will be published with papers from the talks and posters presented at the CLIVAR TAV workshop. There have been 20 papers submitted and some already published.
- Specific requests have been submitted to the WGCM on the importance of understanding the role of MOC in climate variability and change as well as the value of co-ordinated experiments to elucidate the mechanism, sensitivity and impacts of the MOC. The WGCM met in early February 2002 and endorsed the CLIVAR Atlantic panel suggestions. A set of experiments on MOC response to GHG forcing and different components of the surface fluxes is already underway and a WGCM subgroup will develop a proposal for a set of experiments aimed at better understanding the natural variability of the MOC. The subgroup will liaise with the Atlantic panel members.

The panel welcomed the progress on TAV studies made at national level and particularly encouraged the initiative led by Kushnir on establishing predictability in the TAV region. Fritz Schott noted that the US lack of interest in the TAV region is hindering a truly international commitment in the area.

#### **6. Status of the Winds Data Products**

The quality of surface wind analyses in the Tropical Atlantic (TA) region was discussed at the previous panel meeting in September 2001. An action item was generated to report on the status of surface winds analysis products in the Atlantic sector, with emphasis on the TA region, highlighting the problems and biases for the different products. Of particular interest is the degree

to which the space and time variations in the surface climate of the TA are captured in the observations and analysis. Ilana Wainer gave a presentation on this assignment with contributions from Y. Kushnir and J. Hurrell.

The major source of historical surface marine winds data is NOAA Comprehensive Ocean Atmosphere Data Set (COADS, [www.cdc.noaa.gov/coads/](http://www.cdc.noaa.gov/coads/)). The COADS includes all in situ observations from ships of opportunity and surface buoys. In recent years other marine wind products became available, which are derived from satellite remote sensing instruments (<http://manati.wwb.noaa.gov/doc/oceanwinds1.html>; <http://winds.jpl.nasa.gov/>). Global remote-sensed wind speed data are derived from the passive microwave radiometer sensors. Several efforts are underway to prepare ocean surface turbulent flux data sets from satellites (HOAPS: Hamburg Ocean Atmosphere Parameters from Satellite Data; GSSTF-1: Goddard Satellite-Based Surface Turbulent Fluxes; J-OFURO: Japanese Ocean Flux Data Sets with Use of Remote Sensing Observations). However the scatterometer sensors which measure backscatter from the sea surface provide most promising data stream for vector winds (<http://www.coaps.fsu.edu/scatterometry/Nscat/gridded.shtml>). All these data need to be analysed in order to produce regularly gridded fields, appropriate diagnostic studies, ocean model forcing fields and atmospheric model evaluations. A list of global data products available can be found at IRI/LDEO Climate Data Library web page (<http://ingrid.ldeo.columbia.edu/SOURCES>) and other relevant data sets are listed at the WOCE SAC ([www.coaps.fsu.edu/WOCE/SAC](http://www.coaps.fsu.edu/WOCE/SAC)).

As far as the TA is concerned, there are 5 major sources of analysed surface marine data products, including winds:

- NCEP/NCAR Reanalysis Project (<http://wesley.wwb.noaa.gov/reanalysis.html>). Data available from 1949 to present
- ECMWF Reanalysis Project ([www.ecmwf.int/research/era/](http://www.ecmwf.int/research/era/)). Data available for the period 1<sup>st</sup> Jan 1979 to 28<sup>th</sup> Feb 1994.
- Navy Operational Global Atmospheric Prediction System (NOGAPS) surface wind stress analysis ([www.coaps.fsu.edu/woce/html/models/fnoc.htm](http://www.coaps.fsu.edu/woce/html/models/fnoc.htm)). Data available from 1982 to 2001.
- Atlas of Surface Marine Data (SMD94) developed by A. da Silva and collaborators based on COADS data ([www.nodc.noaa.gov/OC5/asmdesm.html](http://www.nodc.noaa.gov/OC5/asmdesm.html)). Data available from 1945 to 1993.
- Tropical Atlantic Pseudostress and SST Analyses produced by J. Servain and collaborators at centre ORSTROM, France ([www.coaps.fsu.edu/woce/html/servain.htm](http://www.coaps.fsu.edu/woce/html/servain.htm)). Data available from 1964 to 2001.

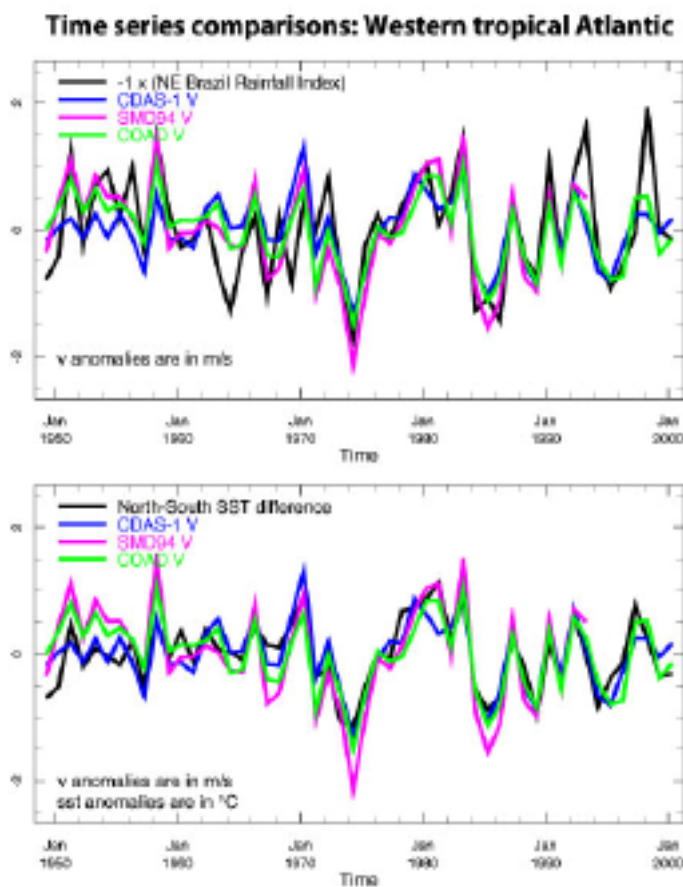
Among these data sets the first four are global in area and the last is regional. The first three are assimilation products based on numerical weather prediction models with input data that vary in type, coverage and quality. The last two data sets are based on in-situ marine data (COADS) analysed in a statistical procedures. A notable difference between numerical assimilation products and the statistical analysis of in situ data is in the temporal resolution of the procedures. In the numerical products the time step is consistent with the observational interval, which is 6 hr. The statistical analyses use a time step of one month.

A global surface wind comparison performed by McDermott et al. (NOAA TM PMEL-110, 1997) on three data sets: US Navy data, ECMWF analysis and NCEP/NCAR Reanalysis, reports that the analysis quality is lower in all areas where data availability is low. That includes the TA region that displays a low signal-to-noise ratio compared even to the data sparse regions of the Southern Hemisphere (SH). The comparison between the Servain data set and the operational product of ECMWF in the TA region points at some noticeable differences between the two data sets. While the climatologies are qualitatively similar the ECMWF trade winds were found stronger than the Servain ones but displayed a less well-defined ITCZ than the latter. Subtle differences were also found in the leading patterns of windstress variability and their temporal evolution, particularly in the case of the zonal component where the statistical analysis fields are less energetic and to some extent more localized in areas where data are available. These differences are magnified in the ocean model simulations particularly in the SH domain where the numerical analysis produced an overall better agreement with observables than the statistical analysis product.

In situ marine meteorological data sets based on ship and buoy observations suffer from space/time sampling problems. Data are denser in the Northern Hemisphere than in the Southern Hemisphere as can be clearly seen in the map of the VOS surface marine network in the Atlantic ocean (<http://www.clivar.org/organization/atlantic/IMPL/data.htm#ocean10>). The middle of the Atlantic basin, particularly in the Southern Hemisphere, is poorly sampled and in the tropical Atlantic the data sampling is highly uneven. The COADS coverage in the TA region is characterised by the

concentration of data along two major ship lanes stretching from West Africa towards South America and towards South Africa. A secondary lane runs along the north-eastern coast of South America from the Caribbean to Northeast Brazil. Most of the TA is inadequately sampled by ship of opportunity data. Temporal changes in the number of observations per month along the ship tracks are also very large. The uneven temporal coverage, even over the relatively frequently visited ship tracks is a cause for concern regarding temporal variations in the quality of any historical analysis of the region's climate variables.

Comparison and evaluation of two analyses, namely NCEP-NCAR Reanalysis surface wind field (hereafter CDAS-1) and the da Silva et al. product (SMD94) was performed by Y. Kushnir and co-workers for this report. The differences between the two analyses are quite small over much of the basin. This is encouraging and should provide some confidence for users of the data. The evaluation of the data quality was based on the correlation between two rainfall indices for Northeast Brazil ([http://tao.atmos.washington.edu/data\\_sets/brazil/](http://tao.atmos.washington.edu/data_sets/brazil/)) and the Gulf of Guinea ([http://tao.atmos.washington.edu/data\\_sets/guinea/](http://tao.atmos.washington.edu/data_sets/guinea/)) and SST and surface winds, by season. Figure 1 shows the timeseries of rainfall anomalies together with the boreal spring meridional wind anomalies averaged in the box 25-40°W and 5°S-10°N as calculated from the three different data sources: CDAS-1, SMD94 and COADS monthly summaries.



*Figure 1.*  
*Top: time series of NE Brazil rainfall anomalies plotted with the boreal spring meridional wind anomalies of CDAS-1, SMD94 and COADS data sets averaged in the box 25-40°W and 5°S-10°N.*  
*Bottom: same wind time series plotted with the anomalies of SST difference north and south of the equator (SSTA averaged in a box 5-20°N/25-55°W minus SSTA averaged in the box 0-15°S/0-30°W)*

The overall agreement between the different time series of meridional wind is very good. The agreement is better during the more recent half of the data series and between the SST gradient and the wind. A similar comparison was applied to verify the quality of the zonal wind component in the centre of the basin using the connection between rainfall on the northern coast of the Gulf of Guinea and winds and SST in the eastern equatorial region (not shown). It was found that the agreement among the three data sets is not so good as in the NE Brazil rainfall example. Apparently the dynamical model assimilation creates a superior representation of the rainfall-SST-wind relationship in the data sparse region of the middle of the basin. Comparison of wind components derived from the Community Climate System Model (CCSM), NWP analyses and COADS (Comprehensive Ocean-Atmosphere Data Set) with in situ data of weather stations in the SH shows visible discrepancies in spatial resolution and in the amplitude of the variability. The highly uneven and poor data sampling in TA and SH respectively leads to visible differences between analyses in spatial resolution and in the amplitude of the variability. Overall the quality of

the dynamical and statistical analyses is comparable but differences that appear small in diagnostic studies can lead to large errors when the data are used to force ocean models. There is no clear advantage to numerical simulation over a statistical approach in data rich regions. Further study is needed to confirm that the seemingly better performance in data sparse region is robust and reliable. For this reason it is difficult to assess the best product particularly in the tropical Atlantic. It was suggested that the scientific community point out the wind errors and the Atlantic panel make recommendations to OOPC for additional air-sea flux stations or VOS lines. However ocean surface wind data derived from spatial blending of high-resolution satellite data (QSCAT) and global weather centre analyses (NCEP) provide better wind products with higher temporal and spatial resolution.

To improve the understanding and determination of ocean surface turbulent flux products, the GEWEX Radiation Panel has initiated the SEAFLOW Project (<http://paos.colorado.edu/~curryja/ocean/>) with the aim of evaluating and improving the global flux products in the context of applications (e.g. forcing ocean models, partitioning of heat transport in the atmosphere and ocean). The project provides an extensive library of *in situ* data sets from research ships and buoys for validation of the global flux products and a library of satellite data sets co-located with the *in situ* data sets, covering an area of approximately 200km around each *in situ* point. A book entitled "Wind Stress over the Ocean" edited by I.S.F. Jones and Y. Toba has been recently published as the final report of a SCOR working group. The parameterisation of windstress (drag) over the ocean is still a controversial issue in numerical analysis of ocean-atmosphere interactions due to the lack of understanding of the processes involved.

## 7. The West African Monsoon Experiment: AMMA

A large group of French scientists has recently produced a white book ([http://medias.obs-mip.fr/amma/english/doc/livre\\_blanc\\_en.html](http://medias.obs-mip.fr/amma/english/doc/livre_blanc_en.html)) synthesising the current knowledge and open questions regarding the various components of the West-African Monsoon (WAM) and the regional impacts of its variability. This white book suggests that a large international programme should be established to study this climate system involving African American and European scientists and promoting enhanced observations covering a large spectrum of scales. A couple of meetings were organised, one in Boulder, USA, November 2001 and one in Niamey, Nigeria, February 2002 in order to convene American and African scientists respectively, interested in being involved in the project. The project is known as AMMA (African Monsoon Multidisciplinary Analysis) and comprises four major fields of studies for a full and integrated picture of the climate and water cycle variability in West Africa (Figure 2):

- Atmospheric Dynamics (internal variability of the WAM)
- Continental water cycle
- Atmospheric chemistry
- Surface conditions (land and ocean)

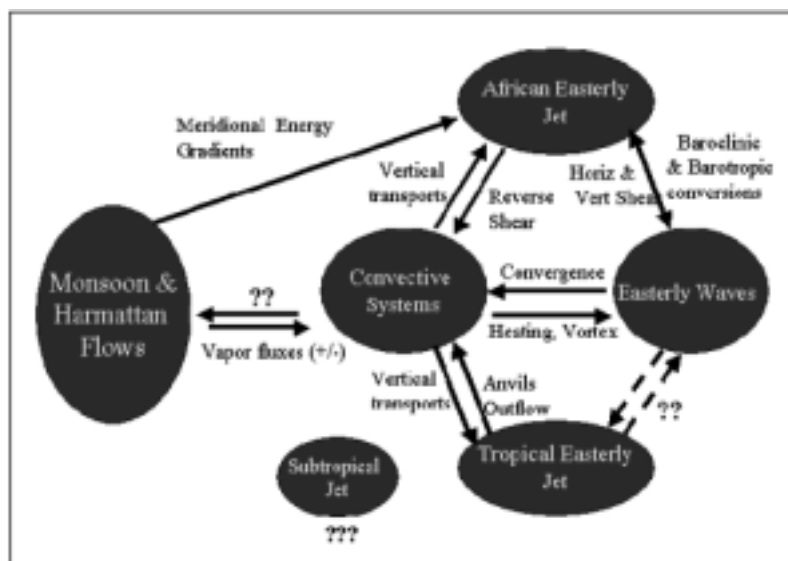


Figure 2. Main interactions among dynamical features of the West African Monsoon.

The field campaign includes both a long-term multi-year component and a year with more intensive observing periods focused on key periods of the annual cycle of the WAM, such as the rainfall onset and other periods when weather systems such as easterly waves and mesoscale convective systems are most active. Currently the field campaign is planned to begin in 2004 and intensive observing periods are provisionally planned for 2005.

Chris Thorncroft (VACS chairman) made it known in a letter to the Atlantic Panel that VACS seeks collaboration for exploring potential mutual benefits of combining AMMA and extra tropical Atlantic observations. Also, since extra observations are planned in the tropical Atlantic through AMMA, it is important that the Atlantic panel be aware of this activity in order to advise accordingly and again potentially indicate where potential PIs may wish to collaborate. This refers to the French funded project called EGEE (<http://medias.obs-mip.fr/amma/english/ocean.html>) that will address the oceanic circulation and its variability in the upper layers of the eastern Tropical Atlantic, mainly in the Gulf of Guinea (GG). EGEE will be associated to AMMA given that the intensity of WAM seems to depend *inter alia* upon the meridional energy gradients between the GG and the continental regions. EGEE plans 2 hydrographic campaigns per year during 3 years (2003-2005) while it will also service the PIRATA ATLAS buoys in GG.

Chris Reason mentioned that the main focus of AMMA appears to be on mesoscale through to intraseasonal time-scales. If possible, it would be desirable to also devote significant attention to seasonal and interannual scales, and in particular consider linkages between Atlantic Ocean variability and the West African Monsoon

**ACTION ITEM 8.** Acknowledge the letter from VACS and encourage VACS to work together with the Atlantic panel on the implementation of AMMA. In particular, we would like to work with VACS on identifying the ocean role in the African climate variability at interannual to decadal time-scales.

Specific activities and needs were submitted for consideration by VACS to the Atlantic panel in support of AMMA observational strategy:

- Availability of R/V Ron Brown for AMMA especially in 2005 for monitoring the processes leading to monsoon onset between May and June.
- PIRATA SE and NE extensions are viewed as extremely important for monitoring the evolution of WAM
- Linkages of hurricane research community, including NOAA HRD, with AMMA projects for addressing tropical cyclogenesis

## **8. Update on VAMOS activities in S. America**

Together with the Large-scale Biosphere-Atmosphere (LBA) experiment, the South American Low-Level Jet (SALLJ) experiment is going to be the most important VAMOS activity in S. America in the next 12 months. It involves a relatively intense field program to be carried out in Peru, Bolivia, Paraguay and Argentina. The low-level jet is a northerly flow observed east of the Andes centred at about 1500m. This flow is believed to be the main route for water vapour transfer from the Amazon into the Plata basin (Figure 3) and it may explain a substantial part of the precipitation variability in spring and summer. A conference held in Bolivia in February 2002 addressed several scientific issues related to the structure and variability of SALLJ, its role in the precipitation and hydrology of central S. America and the role of SST and land-surface processes in modulating SALLJ (<http://www-cima.at.fcen.uba.ar/sallj/>). Particularly interesting is the study on canonical correlation between monthly precipitation and S. Atlantic SST (Barros and Doyle 2002). Enhanced precipitation over south-eastern S. America during summer is related at interannual time-scales to positive SST anomalies over south-western Atlantic Ocean. The SALLJ experiment is an intense observational period planned to begin in November 2002. It will contribute an increase in the network of rain gauges (600 new installations in Argentina, Bolivia, Paraguay and Peru) and vertical profiling stations (temperature, humidity and wind profile measurements). Intense profiling at selected dates and flight patterns designed to measure the LLJ 3D structure will be part of the field-work.

There is no oceanographic measurement component included in the experiment. However VAMOS is interested in repeating the measurements to contribute to the establishment of sustainable observations for monitoring interannual variability.



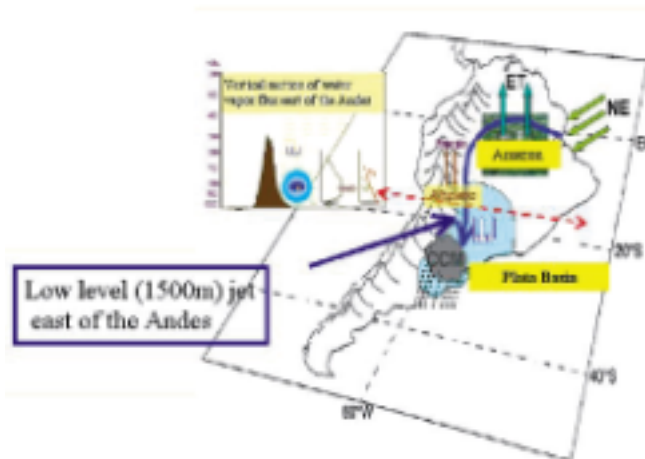


Figure 3. The South American Low Level Jet

### 9. South Atlantic CLIVAR related activities - links with the Southern Ocean Panel

Alberto Piola gave an overview of the current CLIVAR-related activities in the South Atlantic including the Atlantic sector of the Southern Ocean (Figure 4):

- A moored observing system has been maintained by AWI (Germany) since 1996 in the Weddell Sea along longitude 0°. The moorings are equipped with current meters, temperature and conductivity sensors and are planned to be continued until 2003 (PI H. Sabine).
- A moored observing system is maintained by LDEO (USA) since 1999 south of the South Orkney Islands to document interannual variability in Weddell Sea Deep and Bottom water formation (PIs M. Visbeck, A. Gordon, P. Schlosser and B. Smethie). This effort follows 10 years of an array slightly to the south-west maintained at the time by AWI (Germany).
- ARGAU is a long-term (10 years) France-Argentina co-operation programme consisting of oceanographic cruises (summer and winter) from Buenos Aires to the Weddell Sea onboard of the Argentinean Icebreaker "Almirante Irizar". The programme's objective is to describe, explain and model the trend and variability of CO<sub>2</sub> fluxes in this area at various time scales, the physical-chemical characterisation of the different water masses is being studied together with the biological communities present in the water column, within a multidisciplinary approach (PI A. Piola).
- An array of current meter moorings has been located in the region of the Malvinas Current at 41°S since 1999 to evaluate the water mass transport associated with the Malvinas Current and the exchange of subantarctic waters between the Antarctic and the Atlantic Ocean. The mooring array is going to be extended from 2002 with an additional cross-shelf mooring in order to monitor the interannual variations. A moored YO-YO with CTD plus nutrients sensors will also be deployed late in 2002 and tested for 6 months. The programme is funded until March 2003 (PI C. Provost).
- In situ, remote and air-borne observational and modelling efforts in the Plata basin and Brazil Current in order to study the seasonal variability of the Plata plume over the continental shelf and slope and the role of the WBC in the export of shelf waters towards the open ocean (SACC group)
- A Brazilian proposal for an extension of the PIRATA array in the western tropical/subtropical Atlantic. The objectives of the proposal include:
  - understand the role of the upper ocean circulation (0-500m) on the regional and global climate, as well as, the heat and mass exchanges over the western tropical Atlantic;
  - monitor the variability of the salinity maxima in the western tropical S. Atlantic (link to STC and partition of warm SEC into BC and its flux northward);
  - real-time measurements of air-sea fluxes for prediction of atmospheric variability leading to flooding conditions over SE and NE Brazil and associated with the SACZ and easterly waves seasonal activity.
- High density XBT lines AX08 and AX18 (PI Goni). The AX08 line crosses the tropical and S. Atlantic Ocean from Miami to Cape Town. Measurements started in 2000. However it is from 2002 that the line is fully operational with 4 cruises per year that will continue to be funded until 2005. AX18 crosses the S. Atlantic from Buenos Aires to Cape Town at 30°S.

Measurements started in 2002 and so far only one line has been visited in July 2002. The line is planned to be visited twice per year and is funded until 2004.

- The long-term monitoring of ACC barotropic transport at Drake Passage is a UK ongoing effort that started in 1993. Presently there are 3 Bottom Pressure Recorders (BPR) and an Inverted Echo Sounder. There is also a long-term BPR close to Signy Island which will be kept in position. The WOCE SR1 hydrographic section onboard of RRS James Clarke Ross will be maintained with an annual occupation (PI B. King). There is a French proposal to deploy 9 current meters across the Drake passage at T/P altimeter crossover points along T/P groundtrack. The deployment is planned for December 2003 till April 2005 (PI C. Provost).

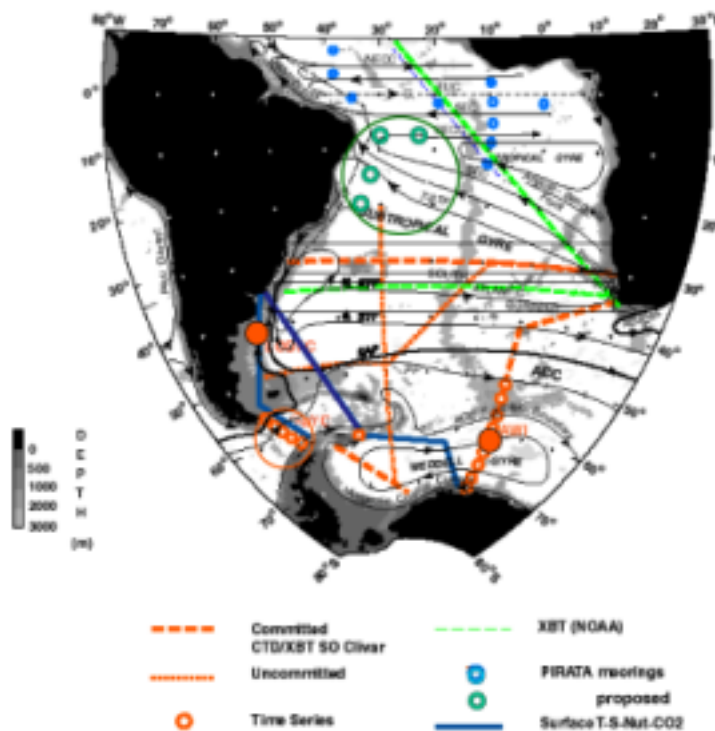


Figure 4. South Atlantic observational network: present and planned.

## 10. Review of MOC Theory and Highlights of Critical Issues

After a short introduction to MOC as a global phenomenon, Martin Visbeck focused on the Atlantic sector where the MOC transports approximately 20 Sv of warm water northward in surface layers with compensating southward flow at depth. Associated with this overturning is a northward heat transport, peaking at about 1 PW in the subtropical N. Atlantic. It is widely accepted that this heat is an important factor in determining surface air temperature over much of the North Atlantic sector. A large number of projections of greenhouse gas induced climate change over the next century indicate a weakened MOC in the North Atlantic due to freshening of the subpolar ocean, although there is little consensus on the rate and magnitude of the projected change (IPCC, 2001). Observations reveal consistent evidence of long-term changes in the properties of the overflows and in convectively renewed water masses in the Labrador Sea; the present observational network seems inadequate, however, to directly determine whether the strength of the MOC is in the process of decreasing by 10-20% as anticipated. In addition, even with perfect observations it would be difficult to detect an MOC climate change signal without an adequate understanding of the natural variability of the MOC.

David Marshall was in charge of reviewing the theoretical aspects of MOC and its variability. The thermohaline circulation responds to surface forcing on a range of time-scales. The initial dynamical adjustment occurs via the propagation of Kelvin waves and Rossby waves on the time-scale of months-decades; in contrast thermodynamic equilibrium is approached over several centuries. It is still necessary to employ relatively coarse-resolution models in order to study the time-mean circulation and anthropogenic climate-change scenarios. However these models not only fail to resolve the geostrophic eddy field, but also fail to adequately resolve the narrow boundary currents and their recirculation within which most of the heat transport occurs; thus the



results of such coarser models need to be treated with caution. Even in eddy-permitting models there remain several important processes that require careful parameterisation such as shelf and open-sea convection, overflows and sea-ice. The role of the tropics in modulating the MOC is still not well understood. It has been shown that the equator acts as a low pass filter to MOC anomalies. In contrast to the time-mean, where there is some debate over whether the MOC is "pushed" by convection in the high-latitude North Atlantic, or "pulled" by Ekman transports in the Southern Ocean and/or diapycnal mixing in the ocean interior, temporal anomalies in MOC likely to be confined to the hemisphere in which they are generated on decadal and shorter time-scales. However the Atlantic MOC may still have a rapid global impact and changes in high-latitude ocean conditions are likely to involve a combination of oceanic and atmospheric teleconnections, with coupling occurring likely in the tropical belt.

### 11. 3-D Modelling of the Atlantic's MOC and links to WGOMD

Claus Boening showed recently obtained ocean-model output for the Atlantic MOC's interannual-decadal variability and addressed critical issues related to sensitivity studies (for more details see article in CLIVAR Exchanges No. 25, page 34). The study of Atlantic MOC's fluctuations using output from numerical models describes the underlying mechanism as a superimposition of a fast, barotropic response to changes in the wind field over the North Atlantic and a delayed reaction to modifications in the surface heat fluxes over the Labrador Sea. During a positive (negative) NAO phase, the former reduces (enhances) the meridional overturning rate, whereas the latter tends to reinforce (weaken) the overturning. Preliminary results of a model intercomparison study with emphasis on low-frequency variations in MOC show the mechanisms for interannual variability of extra-tropical MOC fluctuations to be of similar nature as for seasonal variations: a direct response to wind forcing. Different models driven by the same wind-stress (NCEP/NCAR reanalysis) show very similar results. The oceanic response to atmospheric fluctuations is a robust feature in ocean models which in principle does not depend on model characteristics but represents a physical phenomenon that should be inferable from models given precise wind fields. Changes in the overturning are basically vertically coherent and are aligned with those in zonal wind stress. The modification of the overturning circulation is a manifestation of the changes in the Ekman transport due to enhanced or reduced zonal winds. On decadal and longer time-scales a trend towards increased buoyancy driven changes is expected. The results of these model intercomparison studies should be taken into consideration when designing an observing system for meridional ocean transports of mass and heat. The model results can be used to provide information on where the transport changes are concentrated.

Being the Chair of the WOCE/CLIVAR WG on Ocean Model Development (WGOMD), Claus Boening also reported on the WG activities and their link to the Atlantic Panel. The WGOMD stimulates the development of ocean models for research in climate and related fields with focus on decadal and longer time scales at mid-high latitudes. It reports on its activities to the JSC/CLIVAR WGCN and WOCE SSG (more details can be found at [www.clivar.org/organization/wgomd/](http://www.clivar.org/organization/wgomd/)). The first meeting of the WGOMD was held in March 2000 and reviewed the developments of ocean models ([www.clivar.org/publications/wg\\_reports/wgcm/developments.pdf](http://www.clivar.org/publications/wg_reports/wgcm/developments.pdf)). During its 3<sup>rd</sup> annual meeting in May 2002, the group has discussed the usefulness of an Ocean Model Intercomparison Project (OMIP) by launching a pilot phase. The main objectives of this initiative are:

- Assess the general performance of ocean and ice model components used in coupled models to study climate and tracers uptake
- Assess the quality of the forcing fields: identify limitations and critical issues linked to air-sea flux datasets
- Improve understanding of the sensitivity of models to parameterisations and forcing aspects

During the pilot phase the list of activities is limited because no infrastructure is available at this stage to collect model results and produce diagnostics. WGOMD also proposed a possible OMIP Phase II on the response of the Atlantic Ocean to THC shutdown; the Atlantic panel input on experimental setup is sought.

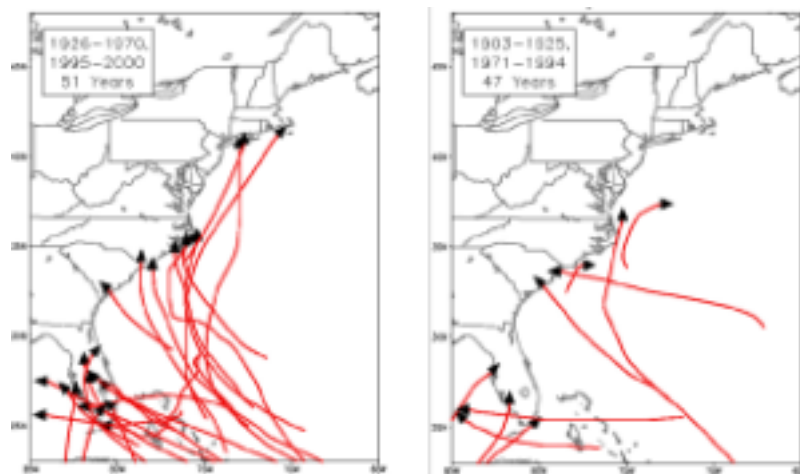
**ACTION ITEM 9.** Establish a subgroup of the Atlantic panel to provide inputs to WGOMD on metrics and indices of climate variability in the Atlantic sector to be used for model-model and model-data comparison studies. The same group is tasked to jointly identify and/or develop model experiments to explore MOC responses and sensitivity.

On the nature of the relationship between WGOMD and WGCM, Claus Boening said that a representative of WGOMD participated to the last WGCM meeting. Although WGCM is mainly atmospheric dominated it seems that a synergy of the two WGs is expected to be very productive in the future.

**ACTION ITEM 10.** Express interest in co-sponsoring a workshop in Kiel in 2004 on Atlantic Thermohaline variability from a synthesis point of view. The panel recommends that such a workshop should be a joint activity with WGCM and WGOMD.

## 12. Coupled Model Results and Assimilation Activities.

Tom Delworth was asked to summarise the recent work on the role of MOC in Dec-Cen Climate variability with relevance to the atmospheric component. The decadal scale variations of the thermohaline circulation may give rise to some (modest) predictability in the NAO. This is a result of an atmospheric response study to a particular SST pattern and shows that the predictability is a strong function of the ocean state. Fully coupled AOGCMs have not seen such predictability. Multi-decadal fluctuations of SST in the Atlantic have been observed in both the instrumental and proxy records, and modelling studies suggest these are related to MOC fluctuations. Changes in precipitation pattern are associated with THC weakening/strengthening in climate model simulations which suggests that on decadal and longer time scales THC fluctuations may have an important atmospheric impact by perturbing the ITCZ in the tropical Atlantic. In turn this signal can then have a global influence. A direct impact of MOC fluctuation can be found in Atlantic hurricane activity (Figure 5). The number of intense (major) hurricanes that hit the US coast is statistically significantly higher when the THC is stronger (warm N. Atlantic).



*Figure 5. US East Coast Major Hurricanes: Warm Atlantic (left) and Cold Atlantic (right) (Courtesy of C. Landsea)*

The WGCM at its last meeting endorsed a set of co-ordinated experiments to explore the nature of the MOC response to GHG forcing, and the role of different components of the surface fluxes. This effort is already underway and several institutions are participating: Hadley Centre, GFDL, NCAR CCSM2, U. Victoria) as part of the Coupled Model Intercomparison Project (CMIP). A protocol has been design in order to determine unambiguously the role of heat and freshwater fluxes for the MOC changes. Important related issues are the atmospheric water cycle and how that responds to climate change. A crucial issue is the partitioning of precipitation into Atlantic and non-Atlantic drainage basins. WGCM also agreed that experiments aimed at better understanding the natural variability of the MOC could be a useful complement to the above. To this end, a subgroup (involving T. Delworth, A. Weaver and M. Latif) was invited to develop a concrete proposal for consideration at the next WGCM meeting. The subgroup will liase with R. Sutton and the Atlantic Panel

It was recognised during the panel discussions that a fundamental contribution that CLIVAR could initiate on the MOC studies is a synthesis of available data and model results. The data need to be constrained in a climate context in order to improve accuracy and design a sustainable and consistent observational system and thus reduce costs. Wright discussed a method used in the

synthesis of data and models where model drift is reduced by adding terms to the momentum equations that nudge the velocity field towards a state consistent with the climatological temperature and salinity fields. The approach is well suited to studying the evolution of tracers under present-day conditions and is presently being used to study the transport of passive tracers through the N. Atlantic. He also discussed an alternative assimilation approach in which the climatologies of the model's temperature and salinity fields are constrained, without directly constraining the variability at timescales not included in the climatologies. This method is presently being used in a study of the feasibility of using sea-level observations to constrain the variability in basin-scale models. In the latter case, the model-data misfits can be examined to gain insight into the nature of the model limitations and how these might be reduced or eliminated. Ocean data assimilation activities are the main focus of GODAE ([www.bom.gov.au/bmrc/ocean/GODAE](http://www.bom.gov.au/bmrc/ocean/GODAE)) but the emphasis is more on real-time data. The main contribution of CLIVAR for MOC synthesis could be on assimilating the historical data accordingly collected and archived in the data structure that CLIVAR will adopt. Data and model synthesis can already start by comparing model results with the ongoing and historical observations, thus CLIVAR should encourage the modelling groups (WGCM) to make the model data available for comparison.

**ACTION ITEM 11.** Compile a table of MOC observable and pass it to WGCM.

### **13. The Atlantic observing system as it pertains to MOC**

The panel reviewed the information gathered by Roberta Boscolo on the Atlantic observing system (available on the web at [www.clivar.org/organization/atlantic/IMPL/index.htm](http://www.clivar.org/organization/atlantic/IMPL/index.htm)) with the aim of evaluating whether the present network is adequate for the CLIVAR research agenda and identifying geographical areas where priority to new/continued measurements should be given.

- Many of the elements of the Fixed Point Time Series network (which include Transport, Observatory and Air-Sea Flux Reference Sites) were discussed in details by the invited PIs at the meeting (see following sections).
- The drifter displacement maps show poor coverage in the eastern tropical South Atlantic area, even though there is an ongoing project that has deployed approximately 80 drifters per year in the tropical Atlantic since 1997.

**ACTION ITEM 12.** Express concern to the OOPC about weak surface drifter coverage in the eastern tropical South Atlantic area under the African stratus deck.

- 1) The subsurface float coverage is well underway in the Atlantic thanks to the ARGO project and several process studies that have float deployments as part of their measurement system. The South Atlantic is much less well covered than the North Atlantic. However ARGO is planning several deployments along the south routes of VOS XBT lines.
- 2) The future plans for sustained XBT lines in the Atlantic have left out some of the ongoing high-density lines that are presently supported by national resources.

**ACTION ITEM 13.** Contact SOOP ([www.ifremer.fr/ird/soopip](http://www.ifremer.fr/ird/soopip)) and submit a well justified proposal to include the AX01 line (Shetlands-Greenland) in the plans for sustained high density XBT lines.

- Including the repeat hydrography measurements and the VOS Surface Marine network, the map of the Atlantic observation system shows the inadequacy of the present ongoing measurements as it pertains to monitoring and understanding the variability of the MOC in the South Atlantic. Suggestions on how to improve the situation and support sustained observations for climate and/or process experiments in the S. Atlantic region were solicited from the panel members and participants.

**ACTION ITEM 14.** Express concern to OPCC and nations on the lack of a coherent / complete MOC observing system in the South Atlantic.

**ACTION ITEM 15.** S. Oesterhus to contact the appropriate Norwegian group that operates a research vessel out of Namibia and explore the possibility of engaging them in support of sustained observations for climate and/or process experiments in the region and report back to panel.

- Regarding GCOS surface and upper air networks, Jim Hurrell complained that there is no real control on those stations and that data are not smoothly going to the GTS system and onto operational centres. A flag that identify problematic stations should be introduced in the maps created by Boscolo.

Overall it was felt that this exercise of reviewing the Atlantic observational network as presented by Roberta Boscolo is a very useful tool for making progress on CLIVAR implementation. However the method that Boscolo uses for displaying the information doesn't give the possibility of interacting with the database and sorting the information by choosing different parameters. It was felt that this feature would be very useful and that it should be suggested to the ICPO that such a development activity be initiated.

**ACTION ITEM 16.** Suggest that the ICPO implements a more interactive on-line tool for monitoring the implementation of the CLIVAR related observations network in the Atlantic and other basins. Include the ability to differentiate systems by the parameter that they measure, what is known already, and how long the observations might be sustained.

#### 14. ASOF Observations and the Atlantic MOC

Bob Dickson as chairman of the Arctic Subarctic Ocean Fluxes study (ASOF) updated the panel on the recent ASOF developments (<http://asof.npolar.no/>). ASOF aims to measure and model the variability of the fluxes between the Arctic Ocean and the Atlantic Ocean with a view to implementing a longer term system of critical measurements needed to understand the high-latitude ocean's steering role in decadal climate variability. ASOF will contribute to shed light on several pieces of theoretical and observational evidence on the MOC variability:

- Modelling and paleo-evidence that the anthropogenic effects on the stability of the thermohaline circulation may be rapid in their onset;
- New understandings based on model output on what the "fingerprint" of anthropogenic climate change should look like in the ocean;
- A recent analysis of long hydrographic records shows that the system of overflow and entrainment that ventilates the deep Atlantic steadily changed over the past four decades resulting in a sustained and widespread freshening of the deep and abyssal ocean.

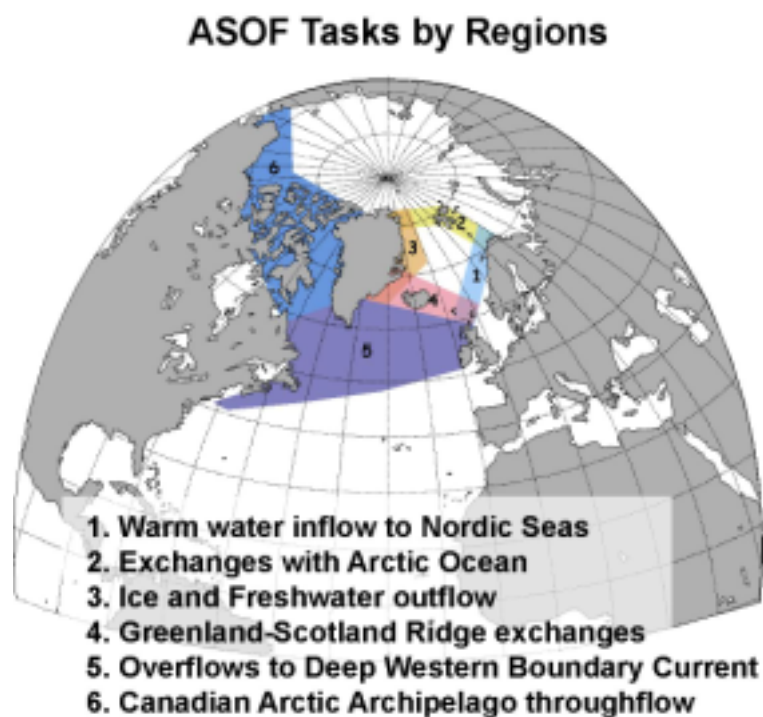


Figure 6. The ASOF domain

ASOF has moved from the Science Plan towards implementation. The ASOF International Science Steering Group (ISSG), which is structured in two groups --ASOF-west and ASOF-east- reflecting the sources of their funding --, will continue to oversee the overall implementation of ASOF. However it has been proposed that ASOF activities should be divided into 7 main tasks reflecting the ASOF regional domain (see Figure 6) and the integrated modelling effort. ASOF does not intend to cover the whole or even a large part of the thermohaline circulation of the North Atlantic but certainly will attempt to cover all of the main ocean fluxes that connect the Arctic Ocean to the North Atlantic through these waters. ASOF will implement new techniques and innovative instrumentation in order to put in place a decadal-long observational system and will conform to the data management model for CLIVAR (when this is in place) in order to ensure wide distribution of ASOF generated data sets and access to multidisciplinary datasets generated within CLIVAR. Many agencies and projects are currently contributing to ASOF implementation *inter alia* the UK's RAPID thematic programme (see following section), the NOClim project and Polar Climate Research initiative of the Norwegian Research Council, aspects of the FV programme of EC, and program solicitations of the NSF Office of Polar Programs and the interagency SEARCH program (<http://psc.apl.washington.edu/search/>). The ASOF ISSG will meet in Hamburg on 18-19 October and will select chairmen and teams for each regional task. The Atlantic Panel has followed ASOF progress with great interest over the last two years and recognised its contribution to CLIVAR scientific goals in particular to the MOC variability Principal Research Area. Martin Visbeck and the Atlantic panel proposed to start the process of endorsing ASOF as part of the CLIVAR programme. From time to time CLIVAR is asked to "endorse" research (and other activities) and to consider including new research foci in its portfolio.

The objectives of these requests are varied but include:

- helping a project to obtain national recognition and funding
- establishing a formal mechanism to enable the representatives of a project to engage discussions with a CLIVAR panel or WG to assist co-ordination
- to broaden CLIVAR's scientific scope to include a new emerging research area.

The CLIVAR International Project Office has recently established guidelines on how such requests should be submitted to CLIVAR, and how the project should assess them and formulate a response:

- A request for CLIVAR "endorsement" for a research project, conference/meeting/workshop should be addressed or forwarded to the ICPO. The ICPO will then seek clarification from the proposer that will request:
  - A description of the activity
    - its objectives (what is it seeking to achieve), its scope, what countries/groups are involved, what activities are planned
    - its duration
    - its relevance to CLIVAR's present activities (and to those of other WCRP projects)
  - The proposer's view of the benefits to the proposed activity, and to CLIVAR/WCRP, of the endorsement that is sought.
  - The proposed form of joint activities with CLIVAR
  - Description of any financial implications
  - How the project might interact with CLIVAR
- The information will be passed to the SSG and to members of appropriate CLIVAR Panels and WGs for comment.
- The ICPO will pass to the proposer (in the name of the SSG co-chairs), CLIVAR's response describing the form of the collaboration/endorsement that CLIVAR is willing to provide.

Bob Dickson welcomed the Panel proposal for CLIVAR endorsement and stressed the fact that CLIVAR provides a global structure but it is not a funded project as a whole. However the smaller-scale funded projects within CLIVAR, like ASOF, contribute to give CLIVAR international credit. It is therefore important to establish the mutual benefits and state in a clear way what CLIVAR can do for the endorsed projects.

**ACTION ITEM 17.** B. Dickson to provide a short white paper addressing the synergies between ASOF and CLIVAR which will then be forwarded with a request for ASOF endorsement to the SSG. (guidelines provided by ICPO).

## 15. Update on Fixed Station Time Series, the MOVE transport array and the Netherlands' efforts to study MOC variability.

An update on Fixed Station Timeseries was given by Hendrik van Aken with information and graphical material provided by Uwe Send (who could not be present at the meeting). A global ocean timeseries observatory system is now under development. The initiative is sponsored by GOOS, CLIVAR and POGO (via the OOPC and COOP panels) and an international Science Team provides guidance, co-ordination, outreach and oversight for the implementation, data management and capacity building (Uwe Send and Bob Weller are the co-chairmen). This Pilot Project is focused on the development of a global network of multi-disciplinary timeseries stations, providing high-quality fixed-point data sets for testing and developing models and monitoring changes. Data are publicly available as soon as received and quality-controlled by the owner/operator. The Science Team met in Hawaii in February 2002, a pilot system (2001-2006) has been defined consisting of all operating sites and those planned to be established within 5 years, subject to evaluation in terms of the qualifying criteria set by the Science Team. The Science Team for the project is in the process of developing an implementation plan.

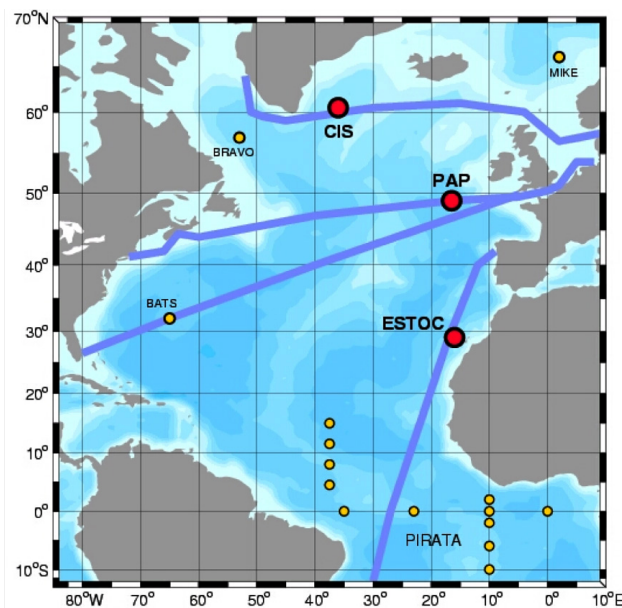


Figure 7. Location of the ANIMATE and other related CO<sub>2</sub> observing sites (current and planned). Lines are VOS CO<sub>2</sub> observations.

Focusing on the Atlantic ocean, the panel was briefed on the progress of ANIMATE (Atlantic Network of Interdisciplinary Moorings and Time-series for Europe; [www.soc.soton.ac.uk/animate/main/home.html](http://www.soc.soton.ac.uk/animate/main/home.html)) an EU-funded project for setting up a multidisciplinary time-series observatory infrastructure. The project started in 2002 with 3 key sites in different regimes of the eastern North Atlantic (Figure 7):

- CIS: Central Irminger Sea
- PAP: Porcupine Abyssal Plain
- ESTOC: Canary Island

All sites will implement physical measurements (T, S, dynamic height, ADCP, CO<sub>2</sub>, nutrients, fluorescence and sediment traps). Implementation of real-time telemetry of subsets of the data collected will be in place for immediate dissemination to the general public through the web site. ANIMATE contributes to a North Atlantic carbon observing system (together with time-series planned at BRAVO, MIKE and in PIRATA array) and VOS lines (CAVASSOO project; <http://envsol.env.uea.ac.uk/temp/tracer/e072/>) which pass very near the ANIMATE sites.

The 16°N Atlantic MOC Transport Array (MOVE) is a German contribution to CLIVAR. The main objectives include the monitoring of the strength (mean and variability) of the southward limb of the Atlantic MOC and changes in the deep water masses on a range of time-scales (monthly to interannual). The location was chosen on the basis that the southward flow is concentrated in a not-too-long section between very steep bathymetry on both sides, eddy noise is expected to be small and the MOC variability is expected to be sufficiently large to represent an observable signal. MOVE aims to develop, test and demonstrate suitable observing techniques for



transport time-series through long deep sections. The array consists of 3 CTD moorings and bottom pressure sensors at the ends and centre of the 1000km section (data telemetry being implemented on the outer CTD moorings), plus 2 current meter moorings on the very steep western slope. The array is co-located with the GAGE current meter array (PI McCartney WHOI) (Figure 8). The design of the array and the accuracy of the instruments should allow baroclinic transport estimates with accuracy of 1-2Sv. The bottom pressure needs to be measured to 1-2mm if the same accuracy is required for the barotropic component. The measured bottom pressure gradients only provide a measure of the fluctuations in the total transport so a reference level is still required from independent measurements. Preliminary results from the first year deployment show a mean total transport of -12Sv +/- 5Sv (accuracy expected to improve later). The second phase of the transport measurement has been funded for the period 2003-2006, this phase will see the outer CTD moorings extended to the surface and the addition of acoustic tomography to monitor the heat content across the section.

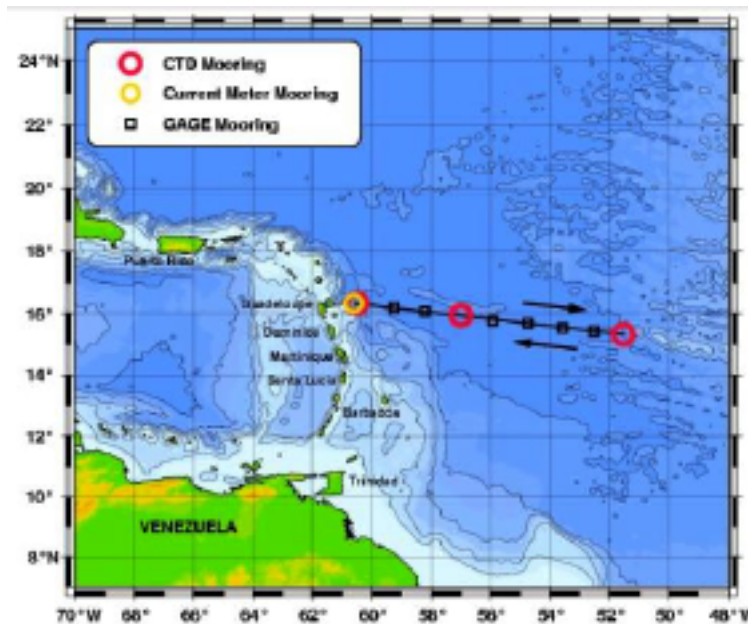


Figure 8. The MOVE array

Finally the Netherlands contribution to the CLIVAR activities in the Atlantic focuses on the variability of the large-scale circulation in the eastern North Atlantic (Iceland Basin and Bay of Biscay) and its water mass distributions. Presently on-going observations include:

- Long-term current meter moorings on the continental slope in the Bay of Biscay
- Bi-annual hydrographic surveys of the Ireland-Greenland section (AIE WHP line in 2003 and 2005)

A proposal has been submitted by NIOZ and KNMI to the Dutch Research Foundation called LOCO (Long-term Ocean Climate Observation) which consists of the deployment of long-term subsurface moorings (at least 5 years) in some key areas of the world oceans. Three moorings equipped with CTD profilers will be deployed in the Irminger Sea thus complementing the two moored profilers deployed in August 2001 by Bob Pickart.

## 16. Heat transport variability at 48°N

Since 1993 the German agency BSH (PI Koltermann) has routinely measured the transports of heat and freshwater in the North Atlantic Ocean across the English Channel and Grand Banks of Newfoundland (48°N). The German research vessels "Gauss" and "Meteor" have performed 7 high-resolution hydrographic surveys, the last one in June 2002. Including two historical cruises made in 1957 and 1982, a data set is presently available to determine the temporal and spatial variability of the thermohaline structure along 48°N and the MOC variability at interannual and decadal timescales.

First analyses of the coherent hydrographic dataset along the WOCE-section A2 during the 90s show significant interannual changes in the climate relevant key parameters of the large-scale

circulation in the North Atlantic such as heat and freshwater transport. With a phase lag of one year the transport values show an almost linear correlation with changes in the dominant mode of low-frequency atmospheric variability in the North Atlantic (NAO). The values for the two historic cruises confirm this behaviour. The line of zero wind stress curl shifts its position in concert with the NAO exciting long baroclinic Rossby waves. This builds a sink of potential energy of the large-scale ocean circulation; the superimposition of these Rossby waves leads to intense mesoscale variability. Along A2 this variability manifests itself in the meandering of the North Atlantic Current in the central Newfoundland basin. One year after a low NAO-index (weak westerlies and a south shift of the line of zero wind stress curl) the heat transport drops by 60%. It seems also that the "dynamic ocean response" is more sensitive to a weakening of zonality of the westerlies than the strengthening.

Long Rossby waves are forced in the eastern North Atlantic through the meridional movement of the line of zero wind stress curl. The westward propagation of these waves could explain the spatial structure of the variability in the upper 1000m along line A2 and the phase lag of one year between changes in the NAO and the oceanic dynamical response (such as the variability of heat and freshwater transports). At intermediate depth (the depth of LSW) the transport variability can be linked with a time lag of 3-4 years to the atmospheric variability in its source region. With the hydrographic data along 24°N and 36°N the decadal variability in the N. Atlantic is described in the form of a bimodal structure of the vertical profile of the MOC: single meridional cell in 1982/83 with higher volume transports on the upper and deeper layers than on the intermediate layer of the LSW; and two meridional cells in 1957/58 and 1992/93 with more pronounced LSW transport, whilst the upper and deeper transports are drastically reduced. To relate the flip between the two modes to just one controlling mechanism is difficult, at least in part because the variability at deeper levels is influenced by forcing in remote regions, and so the two modes reflect variability with different phase lags relative to the atmospheric forcing.

## 17. Boundary Current Transport Arrays

The SFB460 project was established in 1996 at University of Kiel, Germany, with the aim of investigating fluctuations of water mass formation and transport processes in the subpolar North Atlantic and gaining better understanding of their significance for the dynamics of the thermohaline overturning and oceanic uptake of anthropogenic CO<sub>2</sub>. Since its establishment the SFB460 has carried out extensive experimental fieldwork using shipboard measurements, moored stations and deep floats within the subpolar North Atlantic (Figure 9)

A current meter array has been deployed at the exit of the Labrador Sea since 1997. During the first deployment period from 1997 to 1999, five moorings were installed to determine the mean transport of the Deep Labrador Current (DLC) and its variability on time-scales from weeks to years. The mean flow reveals two current cores, a shallow core at the shelf break associated with the Labrador Current, and a deep core associated with Denmark Strait Overflow water. Between these cores the DLC transports LSW and GFZW southward. From 1999 to 2001 the array consisted of three moorings, of which only two were successfully recovered. Presently there are three moorings, which will be recovered in 2003. In summer 1999 a deep water current meter array was deployed at the tail of the Grand Banks, approximately the transition between the cyclonic subpolar circulation and the anticyclonic subtropical circulation. Cold water arriving with the Deep Western Boundary Current exits the subpolar N. Atlantic (SPNA) at depth, and warm and saline water enters the SPNA with the North Atlantic Current. The array can be seen as a follow up of a Canadian mooring effort (BIO, A. Clarke). The array was recovered in May 2001 and immediately redeployed for another two-year period. First data reveal a rather narrow DWBC and sluggish flow in the deep layers of LSW and GFZW. Changes in the water mass characteristics were observed from the cruises since 1996 in the LSW as well as in the GFZW and the DSOW on 4 repeated sections at about 56°, 53°, 48° and 44° N off Canada. For the LSW, changes in potential temperature at 1500 m depth and the thickness of the density layer in the central LS are described in relation to the NAO index. The focus of the subprogram has been extended towards the determination of NADW export out of the subpolar gyre into the tropics. Recent analysis of data showed surprisingly large variability in the cold water outflow along the topography. The North Atlantic Current appears to play an important role for the observed DWBC export and there are indications that the deep NAC extension hinders the profiling floats to exit the subpolar gyre via the boundary current route. In addition, models indicate that there might be other routes for the deep-water export, probably located in the interior of the basin. It is therefore planned to add an



offshore mooring in the next deployment phase (2003-2005) and further extend the array by a geostrophic mooring near the MAR for integral measurements of the baroclinic flow.

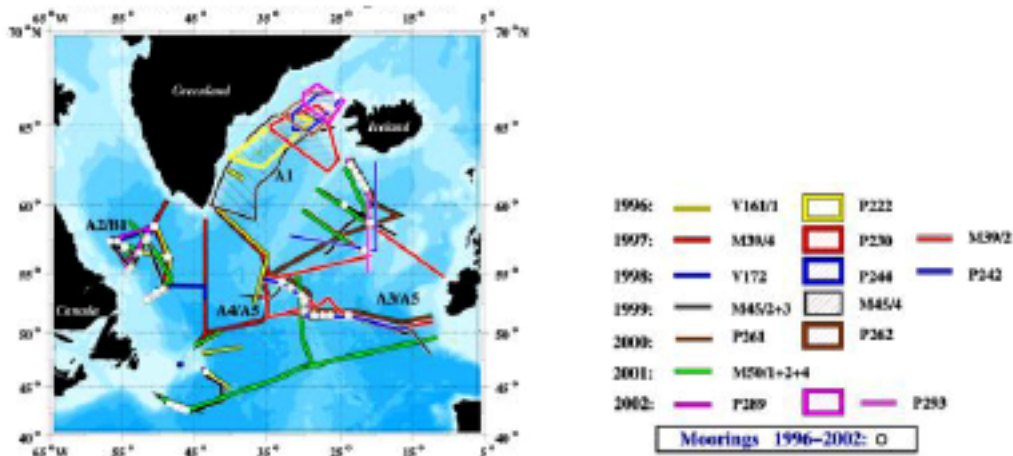


Figure 9. SFB460 cruises and moored stations during 1996-2002.

The tropical-subtropical interaction in the Atlantic Ocean is a German contribution to CLIVAR (PI F. Schott) aiming at understanding the tropical-subtropical coupling of the warm circulation in the western South Atlantic. The main topics are the ocean-atmosphere interaction and the role played by the ocean with regard to the climate variability in the tropical Atlantic Ocean. The observational program includes ship cruises, a long-term mooring program and the use of profiling floats ([www.ifm.uni-kiel.de/allgemein/research/projects/clivar/ta/clivar-ta.html](http://www.ifm.uni-kiel.de/allgemein/research/projects/clivar/ta/clivar-ta.html)). A current meter array (5 moorings) was deployed near 11°S at the Brazilian shelf break (Figure 10) with the aim to measure transport variability of the North Brazil Current on time-scales from intraseasonal to interannual. The moorings are equipped with Acoustic Doppler Current Profilers for near-surface measurements in the boundary current, with a variety of current meters in deeper levels, and with T/S probes for the determination of water mass variability. Two of the moorings were exchanged after 7 months and the first data show the intensity of the NBUC flow that reveals a subsurface maximum near 200m. The array was recovered and redeployed in February 2002.

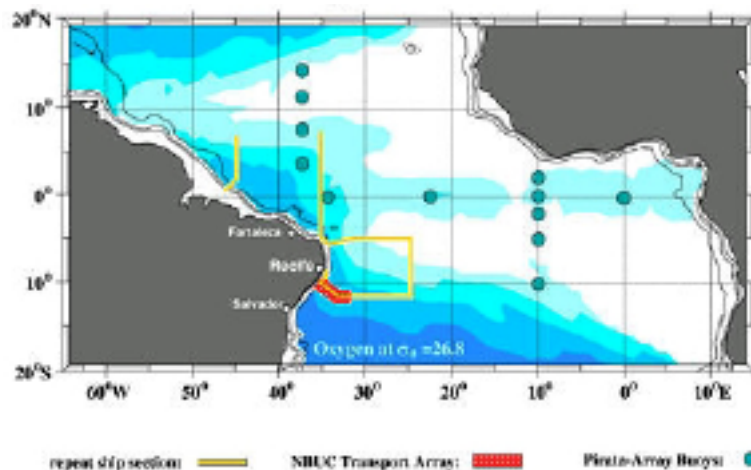


Figure 10. Location of the NBUC moored array.

Several US activities are contributing to the MOC monitoring the Atlantic. The Florida Current (FC) is the western boundary current for the subtropical gyre of the N. Atlantic. In addition to transporting water masses originating in the northern hemisphere, the FC advects water from the southern hemisphere that has crossed both the equator and the North Atlantic's tropical/subtropical gyre boundary. Ultimately, a portion of the FC transport becomes entrained in the subpolar gyre where it contributes to the formation of the deeper water masses. Beginning in the early 80s, submarine cable observations of voltage differences across the Straits have been calibrated with direct current data to estimate FC transport. Recently a new program consisting of weekly

observations of velocities with an ADCP started. The mean annual transport of the FC at 27°N over the cable record is 32Sv. The variability is less than 4Sv and this signal is correlated with the NAO index.

The AOML also supported a 10-year observational program to determine the quantity of transport between the Atlantic Ocean and the Caribbean Sea. This transport includes the upper ocean portion of the MOC of the N. Atlantic. This program sought to better understand the mechanisms and pathways of upper ocean warm water inter-hemispheric transport, since the resultant heat flux into the northern hemisphere is thought to be a key determinant affecting climate in the N. Atlantic and adjacent regions. The observational program consisted of repeated sampling in the southern Caribbean passages on seasonal time-scale over a period of 10 years ([www.aoml.noaa.gov/phod/wimp/](http://www.aoml.noaa.gov/phod/wimp/)). The water mass and velocity characteristics of the DWBC at 26.5°N, east of Abaco Island, the Bahamas, have been monitored by AOML and RSMAS since 1984.

The section has been occupied from one to four times per year with observations of temperature, salinity, and dissolved oxygen on all sections, direct velocity measurements and CFCs on several sections. The water mass formed in the LS is advected in the DWBC to 26.5°N. The T/S characteristics at the depth of LSW can be correlated to the late 90s cooling and freshening at its formation region. The comparison indicates the arrival of LSW at Abaco some 8 to 10 years after formation thus suggesting more rapid advective velocities or more direct pathways. NOAA is considering committing more resources for continuing the Abaco time-series.

## 18. NOAA's Commitments to Atlantic MOC monitoring

The NOAA missions of detecting, attributing and forecasting long-term climate changes address both components of the oceanic circulation: wind-driven and thermohaline circulation. Many early NOAA programmes were searching for indices of critical N. Atlantic MOC features to monitor thus considering also the contribution of Southern Hemisphere features to the MOC. The inter-oceans exchange takes place through the Benguela/Agulhas system, south of S. Africa. The Agulhas Current at its retroflexion sheds energetic rings that carry salt and warm water into the South Atlantic. Satellite altimetric measurements have been calibrated to provide estimates of the transport of the Agulhas current and the separated rings. The time-series of this transport starting in 1993 indicates the mean annual transport of the current from the coast to 40°S and above the 10°C isotherm to be 15.7 +/- 1.5 Sv. The number of rings shed at the retroflexion is between 4 and 7 per year and the transport of the rings varies between 0.8 and 2.4 Sv. Strong interannual variability in the transport is primarily related to ring shedding.

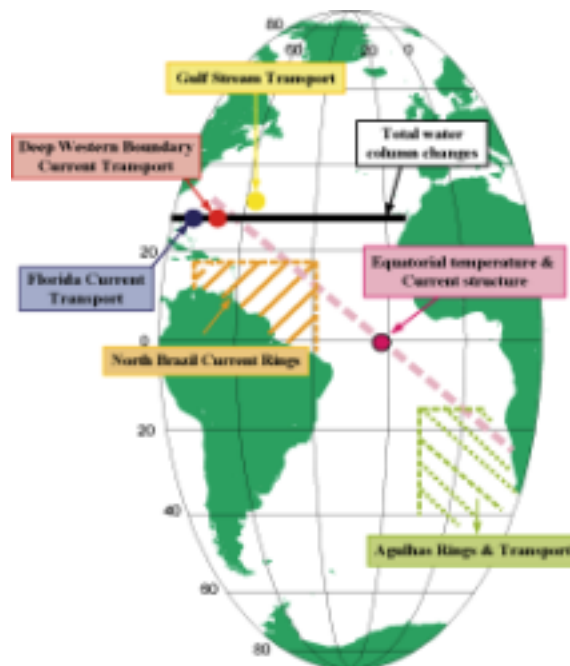


Figure 11. Benchmarks for Atlantic Circulation.

The pathways of the upper limb MOC transport are complicated by the wind-driven circulation features along the western boundary and the interior tropical Atlantic. Models suggest that the 14 Sv of upper limb MOC is partitioned among three pathways connecting the equatorial and tropical wind-driven gyre: a frictional western boundary current accounting for 6.8 Sv; a diapycnal pathway involving wind-forced equatorial upwelling and interior Ekman transport, 4.2 Sv; and the North Brazil Current (NBC) rings shed 3 Sv. As part of the NBC study, an analysis of altimetric data was made and the record indicates that ring shedding is nearly a factor of two (9 Sv) greater than previously estimated even though the altimeter does not track all the rings formed at the retroflection. Based on the result of this work, a monitoring strategy is being developed to monitor ring formation and propagation.

In the North Atlantic time-series of both the upper layer temperature structure within the subtropical gyre and total water column changes across the basin are being maintained (cable observations at the Straits of Florida and transects at Abaco). NOAA has collected data over the past 10 to 50 years thus contributing to observational benchmarks (i.e. indices) for the various components of MOC. These benchmarks collectively (Figure 11) will provide a useful tool for detection and attribution of climate change ([www.aoml.noaa.gov/benchmarks/index.html](http://www.aoml.noaa.gov/benchmarks/index.html)).

## **19. UK Rapid Climate Change Programme**

Meric Srokosz introduced the new UK-funded initiative called the RAPID programme aiming at investigating and understanding the causes of rapid climate change, with a main (but not exclusive) focus on the role of the Atlantic Ocean's THC. Paleo climate records indicate that abrupt climate change has occurred in the Northern Hemisphere, especially during and just after the last cold stage with THC change as the most plausible mechanism. Similar changes might occur in the future as model results suggest that the human-induced increase in the atmospheric concentration of CO<sub>2</sub> and other greenhouse gases will lead to a significant reduction in strength of the Atlantic THC. It is possible that changes could occur rapidly, perhaps over a 10-20 year period. Such rapid climate change would make adaptation to, and mitigation of, the impacts exceedingly difficult for the affected countries.

Using a combination of present day observations, paleo data and a hierarchy of models, the RAPID programme intends to improve understanding of the roles of the THC and other processes in rapid climate change. As a result, the ability to monitor and predict future rapid climate change, particularly in the North Atlantic region, will be enhanced. RAPID has been funded at a level of \$30M over a period of 6 years, the first round of proposals has been submitted in July 2002. One of the proposals was specifically focussed on the design and implementation of a prototype Atlantic MOC monitoring system, which is considered a key component of the RAPID programme. Funding decisions will be made in November 2002, with studies beginning early in 2003. More details of the programme, including the science and implementation plans and proposed project titles can be found at <http://rapid.nerc.ac.uk/>.

RAPID is actively developing international collaborations that will complement and enhance the work carried out in the UK. As a result of this, an Expression of Interest for the EU framework 6 integrated project was submitted in June 2002 (WATCHER= Will the Atlantic Thermohaline Circulation Halt; is Europe at Risk?). A key collaboration also has arisen with the Norwegian Ocean Climate Project NOCLIM ([www.noclim.org](http://www.noclim.org)). The RAPID programme will contribute to CLIVAR and PAGES (IGBP).

## **20. The CLIVAR/OOPC/IAI Workshop on the South Atlantic Climate Observing System**

The idea was brought up during the OOPC VI meeting and further discussed at a 2-hour meeting during IAPSO, Mar del Plata. The motivation lies in the strong belief that the S. Atlantic plays an important role in the Global Climate but it is still one of the less studied part of the world oceans. In this respect the contributions of the South Atlantic countries are essential in properly addressing the problem: due to their strategic locations these countries can greatly contribute in the development of the observing system for their part of the world. The proposed observations should be considered as a way to fill crucial gaps in the observations, to form partnerships especially with and within the countries of the southern hemisphere and to promote capacity building.

The workshop goals are:

- To discuss the observing system requirements for understanding the role of the South Atlantic in the climate system both on regional and global scales:
  - Identify common interests in an ocean observing system
  - Identify social and economic applications of data of joint/common interest
  - Provide an overview of scientific understanding of South Atlantic oceanic and climate variability
  - Identify the key locations and processes which need to be addressed in the next few years
- To develop multinational action-plans to:
  - Review national commitments and plans for research and operational observations
  - Survey the need for data management activities, including historical data
  - Develop joint actions and seek co-operation in proposals
  - Agree on the principle of the long-term strategy

The workshop will be structured around a series of Discussion and Review papers. The papers will be prepared by groups of leading authors selected for their expertise. The preliminary list of proposed subjects is:

- Review of South Atlantic intraseasonal to interdecadal variability (*C. Vera, C. Thorncroft, B. Bourles, I. Wainer*)
- The South Atlantic role in the global thermohaline circulation (*A. Piola, A. Gordon, P. Chang, E. Campos*)
- Interocean Exchanges (*W. deRuijter, R. Matano, A. Piola, J. Lutjeharms, S. Cunningham*)
- South Atlantic links and impacts to regional and global climate (*P. Nobre, A. Robertson, C. Reason*)
- The South Atlantic Observing System (*S. Garzoli, A. Piola, C. Provost, K. Heywood*)
- Overview of ongoing and planned modelling efforts (*R. Matano, B. Barnier, E. Chassignet, E. Campos*)
- The role of the South Atlantic in the variability of the ITCZ (*Y. Kushnir, P. Chang, P. Rizzoli*)
- Applications, services and commercial opportunities (*M. Andriolli, C. Nobre*)

The possible venue of the workshop is Rio de Janeiro or S. Paulo, Brazil and the proposed period is February/March 2003.

**ACTION ITEM 18.** The panel welcomes the proposal for holding a CLIVAR/OOPC workshop on the South Atlantic Climate Observing System and encourages the organising committee to submit an updated proposal for review and hopefully endorsement. A subgroup of the panel is tasked to conduct this review in the near future and promises a fast turnaround time.

Tony Busalacchi suggested that the involvement of VAMOS and VACS panels should be sought for achieving a successful meeting.

**ACTION ITEM 19.** Contact the chairmen of the VACS, VAMOS and Southern Ocean panels and encourage their respective panels to become co-sponsors / reviewers of the CLIVAR/OOPC workshop on the South Atlantic Climate Observing System.

## 21. Interactions with other CLIVAR panels

**WGCM.** R. Sutton reported on feedback regarding the role of Atlantic MOC in climate variability and change. Other feedback from the same group included:

- the panel members were urged not to focus too narrowly on the North Atlantic. The upwelling in the equatorial Atlantic of Antarctic Intermediate water from the South Atlantic was highlighted specifically
- it was noted that some of the issues surrounding better understanding of the MOC may best be addressed using ocean-only models rather than coupled models
- WGCM are particularly interested in the spread of MOC behaviour in GHG scenarios. There is a need for more detailed comparison and synthesis of the existing results in this area, Better understanding of the uncertainties is a priority for the next IPCC assessment
- The Working Group express caution about the use of results from existing coupled models to guide observational programmes, given the problems of low resolution etc... Model studies may generate hypothesis that can be tested through new observations but more specific guidance may have to await future model improvements
- CLIVAR Atlantic should consider links with the Paleoclimate Modelling Intercomparison Project in this area.

**VACS** Chris Reason attended the last VACS meeting in March 2002. Regarding decadal variability in the African climate system, Chris Reason agreed to provide a summary of issues and research priorities, including recommendations on the way forward. This should include analysis of the available multi-year model integration that have been made at various institutions. The need to have ongoing activities to assess what is the optimum observing network for VACS research and prediction was also noted.

**ACTION ITEM 20.** C. Reason to explore with appropriate group in S. Africa how more CLIVAR related research can be conducted by joint ventures between S. Africa and other nations.

**PAGES** Y. Kushnir put together a report on PAGES ([www.pages-igbp.org](http://www.pages-igbp.org)) Atlantic interest after an initial consultation with K. Alverson (director of the IPO). PAGES interest in the Atlantic stems, in part, from the hypothesis that past millennial scale climate variability is related to changes in THC in the Atlantic. PAGES have 5 foci of which two are relevant to the CLIVAR Atlantic Panel: PAGES/CLIVAR Intersection and IMAGES. PAGES/CLIVAR Intersection aims to improve the understanding of decadal to century scale climate variability. Six themes are considered:

- Dynamics of low-latitude climate change
- Global ocean thermohaline variability
- Regional-to-global scale hydrologic variability
- Dynamics of abrupt climatic change
- Model evaluation and improvement
- Climate change detection

Only research involving high-resolution paleoarchives such as corals, tree-rings, varved sediment and ice cores are grouped in this focus ([www.clivar.org/organization/pages/](http://www.clivar.org/organization/pages/)).

IMAGES has been initiated to respond to the challenge of understanding the mechanisms and consequences of climatic changes using oceanic sedimentary records. The aim is to quantify climate and chemical variability of the ocean on timescales of oceanic and cryospheric processes, to determine its sensitivity to identified internal and external forcings, and to determine its role in controlling atmospheric CO<sub>2</sub>. IMAGES proposes to co-ordinate a global programme and defines several working groups ([www.images-pages.org/wgroups.html](http://www.images-pages.org/wgroups.html)) of which 3 appear relevant to the CLIVAR Atlantic panel:

- *North Atlantic Ultra High Resolution*: focused on the preparation of the Marion Dufresne 1999 cruise in the North Atlantic, Labrador Sea, Norwegian Sea and numerous fjords and estuaries along the track
- *Terminal Millennial Synthesis of Decadal-to-Millennial-Scale Climate Records of the last 80kyr*: aims at 1) creating a common canonical time series of short-term and abrupt climatic events documented in marine sediment record; 2) tying the ultrahigh-resolution marine climate records to ice and other varved records of climate change measured on calendar-year timescale; 3) constraining the temporal and spatial variability of both the oceanic C14-reservoir effect and cosmogenic C14 production to develop C14 as an high-precision tracer in paleoceanography and improve chronological resolution in sediment records; 4) better understanding teleconnection processes in global transfer of climatic change.
- *Holocene Climate Variability*: investigating submillennial climate fluctuations during the Holocene, at both low and high latitudes, regional teleconnections, amplitude of variability and linkages between oceanic and climatic changes.

## 22. Implementation Activity

**ACTION ITEM 21.** Write to national funding agencies and inform them about the activities of CLIVAR in the Atlantic sector and ask them how they are contributing to those efforts.

## 23. Next Meeting

**ACTION ITEM 22.** It was proposed that the next Atlantic panel meeting be held back-to-back with the EGS-AGU annual assembly in April 2003 at a venue close to Nice, France. Likely dates are April 14-16 2003. The thematic focus could be on: data needs; synthesis/reanalysis/prediction systems; S. Atlantic research; connections to the Arctic.

## Boffins analyse climate change

By JEANNINE KLEIN

SCIENTISTS from around the world are holding high level talks this week in Bermuda to ensure countries bordering the Atlantic Ocean cooperate on studying the effects of climate change on the ocean.

Dr. Anthony Knap, Director of the Bermuda Biological Station (BBSR) told the Bermuda Sun that the meeting is of extreme importance because temperature changes in the Atlantic affect the world.

"Climate change affects weather, climate patterns worldwide and when there is rainfall in areas from Bermuda to Africa to everywhere else, you get winds, hurricanes — you name it. The ocean is the moveable heat of the world, not the atmosphere, so determining where that goes and how that is going to change is essential for everybody."

The experts hope to establish a common strategy to measure and understand how changing climate alters oceans and how the oceans will affect local climates and weather patterns.

"Climate and weather are, other than senior management scandals in companies, probably one of the greatest reasons for price changes for commodities worldwide. If you have an extra warm winter, ski resorts won't do well, a strong la Nina in the Pacific that will mean hurricanes in North America," Dr. Knap said.

The 20 scientists are members and guests of the Council for Science and the Intergovernmental Oceanographic Commission (CLIVAR), an international research programme that studies global climate variability and predictability.

BERMUDA

SUN

weekend

July 12, 2002

## APPENDIX B: List of Attendees

Busalacchi Tony	ESSIC, Maryland, USA	tonyb@essic.umd.edu
Delworth Tom	GFDL, Princeton, USA	td@gfdl.gov
Dickson Bob	CEFAS, Lowestoft, UK	r.r.dickson@cefas.co.uk
Hurrell Jim	NCAR, Boulder, USA	jhurrell@ucar.edu
Koltermann Peter	BSH, Hamburg, GER	koltermann@bsh.d400.de
Piola Alberto	SHN, Buenos Aires, ARG	apiola@hidro.gov.ar
Reason Chris	EGS, Cape Town, SA	cjr@egs.uct.ac.za
Schott Fritz	IfM, Kiel, GER	fschott@ifm.uni-kiel.de
Visbeck Martin	LDEO/Columbia Univ, USA	visbeck@ldeo.columbia.edu
Wainer Ilana	Univ. Sao Paulo, BR	wainer@usp.br
Bates Nick	BBSR, Bermuda	nick@bbsr.edu
Boening Claus	IfM, Kiel, GER	cboening@ifm.uni-kiel.de
Johns Bill	RSMAS, Miami, USA	johns@rsmas.miami.edu
Marshall David	Uni. Reading, UK	D.P.Marshall@reading.ac.uk
Molinari Bob	AOML, Miami, USA	molinari@aoml.noaa.gov
Oestehus Svein	Univ. Bergen, NOR	Svein.Osterhus@gfi.uib.no
Van Aken Hendrix	NIOZ, Netherland	aken@nioz.nl
Wright Dan	BIO, Dartmouth, CA	WrightDG@mar.dfo-mpo.gc.ca
Boscolo Roberta	ICPO, UK	rbos@iim.csic.es
Srokosz Meric	SOC, RCC IPO, UK	mas@soc.soton.ac.uk
Todd Jim	NOAA-OGP, USA	james.todd@noaa.gov

## APPENDIX C: Meeting Agenda

### Wednesday 10th July

- 9:30 - 10:00** Introduction to the Meeting:
- Welcome (*Visbeck and Knap*)
  - Meeting arrangements (*Visbeck and Boscolo*)
  - Review of agenda (*Visbeck*)
- 10:00 - 12:00** Executive Panel Session:
- Review of the Action Items from last meeting (*Visbeck*)
  - Review of the Membership (*Visbeck*)
  - Update of CLIVAR/ICPO activities (*Boscolo*)
  - Report on WCRP JSC in Hobart and CLIVAR SSG-11 in Xi'an (*Busalacchi*)

Lunch at BBSR

- 13:30 - 14:30** Scientific seminar: Nick Bates from BBSR
- 14:30 - 15:00** Follow up of TAV Workshop (*Schott, Busalacchi and Wainer*)
- 15:00 - 15:30** Status of winds data products (*Wainer, Reverdin and Hurrell*)
- Coffee Break
- 16:00 - 16:30** West African Monsoon Experiment AMMA (*Reason and Hurrell*)
- 16:30 - 17:00** Update on VAMOS activities in S. America (*Piola and Wainer*)
- 17:00- 17:30** Review of "South Atlantic Climate Observing System" and links to the Southern Ocean Panel (*Piola input from Ereños*)
- 18.00** Sun Downer at BBSR

### Thursday 11th July

- 9:00 - 9:15** Introduction to the meeting theme "Atlantic MOC" (*Visbeck*)
- 9:15 - 10:00** Review of MOC Theory and highlight of critical issues (*Marshall, Wright and others*)
- 10:00 - 10:45** 3D-Modelling of the Atlantic Ocean's MOC. Links to WGOMD (*Boening*)

Coffee Break

- 11:15 - 12:00** Comments and additions to 3D-ocean Modelling: assimilation and coupled models results. Links to WGCM (*Delworth, and others*)

Lunch at BBSR

- 13:30 - 14:15** The Atlantic observing system as it pertains to MOC (*Boscolo*)
- 14:15 - 14:45** ASOF observations and the Atlantic MOC (*Dickson and Oesterhus*)
- 14:45 - 15:15** Update on Fixed Stations Time Series, MOVE Transport array and Netherlands activities on MOC variability (*Van Aken, Schott with input from Send*)

Coffee Break

- 15:40 - 16:00** Heat transport variability at 48°N (*Koltermann*)



- 16:00 - 16:30** Boundary Current Transport arrays (*Schott and Johns*)
- 16:30 - 17:00** NOAA's "renewed" focus on MOC (*Molinari*)
- 17:00 - 17:30** UK Rapid Climate Change Programme (*Srokosz, Dickson and Marshall*)
- 17:30 - 18:00** Discussion on status, plans and expected effectiveness of observing systems as it pertains to expected change and variability including CO2 uptake (*Delworth, Visbeck*)
- 19:00** Panel Dinner at Carriage House, St George

### **Friday 12th July**

- 9:00 - 10:00** Review of MOC issues highlighted the previous day and establish action items (*Visbeck leading, all involved*)
- 10:00 - 10:30** Interaction with other panels:
- WGCM (*Delworth*)
  - WGSIP (*Visbeck, input from Zebiak*)
  - WGOMD (*Boening*)
  - PAGES (*Visbeck, input from Kushnir*)
  - VACS (*Reason*)
  - S. Ocean (*Visbeck input from Rintoul*)

Coffee Break

- 10:45 - 11:00** Review of guidelines for CLIVAR endorsement of multinational projects not included in the initial CLIVAR Implementation Plan. Endorsement of ASOF (*Visbeck and Dickson*)
- 11:00 - 11:30** Introduction to CLIVAR/OOPC Workshop on the "South Atlantic Climate Observing System" (*Piola, Reason and Wainer*)
- 11:30 - 12:30** Discussion on Panel Business:
- Future activities
  - Future meetings
  - Next Panel meeting
  - wrap up
- 12:30** Adjourn

## APPENDIX D. Panel Members Terms

### Present Members

T. Busalacchi	USA	2000-2003
A. Clarke	Canada	2000-2002 (FINISHING)
T. Delworth	USA	2000-2003
B. Dickson	UK	2000-2002 (FINISHING)
J. Hurrell	USA	2000-2004
P. Koltermann	Germany	2000-2004
Y. Kushnir	USA	2000-2003
A. Piola	Argentina	2000-2004
C. Reason	S.Africa	2001-2005 (NEW)
G. Reverdin	France	2000-2002 (FINISHING)
F. Schott	Germany	2000-2003
R. Sutton	UK	2000-2004
M. Visbeck	USA	2000-2004
I. Wainer	Brazil	2001-2005 (NEW)

### Past Members

M. McCartney	USA	2000-2001 (RESIGNED)
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### Suggested New Members (4 to be selected)

B. Johns	USA
H. Mercier	France
D. Wright	Canada
D. Marshall	UK
S. Oesterhus	Norway
H. van Aken	NL

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