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Action Items

1) Put together a workshop report with the outputs/recommendations from the 4 sessions and the extended abstracts of the invited speakers

(S. Griffies and R. Boscolo)

2) Provide regular updates on AOMIP activities and ensure good interaction between AOMIP and WGOMD intercomparison activities.

(R. Gerdes)

3) Write a user guide document that describes in detail the NCAR dataset and provides information on how to access it.

(B. Large and S. Griffies)

4) Update P-OMIP protocol for WGOMD-CORE which is comprehensive enough also for the involvement of new groups by September 2004

(A.M. Treguier)

5) Update the CLIVAR WGOMD webpage with the new protocols for CORE, leave the old P-OMIP protocol but say that it is obsolete

(R. Boscolo)

6) Write a CORE protocol for the experiments with the interannually varying forcing by September 2004

(H. Drange)

7) Write an article for the December issue of the CLIVAR Exchanges in order to officially launch the WGOMD-CORE. The article should contain selected results from currently running experiments

(C. Boening and S. Griffies)

8) During the first experimentations in CORE, establish the needs for exchanging/archiving the outputs

(E. Chassignet, S. Griffies, F. Bryan and rep. PCMDI)

9) write a protocol for perturbation experiments on the response of the sub-Arctic Atlantic to increase of freshwater fluxes

(R. Gerdes)

10) The basin panels to continue developing indices for models to use

(C. Boening, D. Wright, K. Richards and S. Rintoul)

11) Contact Peter Gent to request he makes available the specifications of the IPCC ocean component models to be put in the CLIVAR WGOMD webpage

(A. M. Treguier and R. Boscolo)

12) Suggest to the SSG the following replacements for F. Bryan and T. Hirst: Marika Holland (NCAR, USA) and Andreas Schiller (CSIRO, AUS)

(C. Boening and R. Boscolo)

13) Suggest to the SSG to hand over chairmanship from C. Boening to S. Griffies; more specifically, to nominate both as co-chairs for 2005 (leading up to the 2005 meeting), and Boening to retire afterwards.

(C. Boening and R. Boscolo)

14) Suggest holding the next meeting in November 2005 in Hobart, Tasmania, in conjunction with a CLIVAR workshop on Southern Ocean dynamics organized jointly with the CLIVAR SO Panel.

(C. Boening and R. Boscolo)

1. Opening of the Meeting

The chair of the CLIVAR WGOMD, Claus Boening, opened the panel's 5th session by welcoming the participants and thanking S. Griffies for hosting the meeting at NOAA-GFDL. The meeting included with the presence of representatives from the CLIVAR basin panels (Pacific, Atlantic and Southern Ocean), from the Arctic Ocean modelling community, from the Program for Climate Model Diagnosis and Intercomparison (PCMDI), from the Coupled Model Intercomparison Project (CMIP) "special response experiment" and from major ocean and climate modelling groups (see Appendix I). The WGOMD chair also welcomed the new panel members: H. Drange, R. Greatbach and H. Banks as well as accepted apologies from T. Hirst and R. Greatbach for not being able to attend the meeting.

While reviewing the meeting agenda (see Appendix II), Claus Boening highlighted the objectives of the joint session with the Arctic Ocean Models Intercomparison Project (AOMIP) which was having its meeting at the same time in GFDL building. The WGOMD was interested to learn the achievements of AOMIP as well as be aware of problems and issues that such activity raised among the modelling community. It was felt that good coordination between AOMIP and any future MIPs activity proposed by WGOMD would be beneficial to both groups. In particular Claus Boening noted several issues for further discussion:

- To set the same kind of data and protocol
- To have a joint diagnostic strategy
- To look at some physical processes (spreading of the Atlantic water, Denmark Strait etc…)

It was also noted that the CLIVAR workshop on Ocean Modelling (http://www.clivar.org/organization/wgomd/OMworkshop.html) organized by WGOMD should help to formulate a strategy for a future OMIP activity and the analysis of the models for IPCC AR4.

2. Update on recent CLIVAR and WCRP activities

Roberta Boscolo reported on the relevant CLIVAR and WCRP activities. First she reminded the group that Andreas Villwock, after serving the ICPO for 9 years, left its duties within CLIVAR to take up responsibilities directly with WCRP. Andreas acted as ICPO representative for WGOMD since its establishment and this role has now been taken over by Roberta Boscolo. In the last year two new CLIVAR panels have been formed: the Indian Ocean Panel (IOP) and the Global Synthesis and Observation Panel (GSOP). The IOP addresses the need for high-quality ocean observations and applications in the Indian Ocean. The IOP is supported by CLIVAR and GOOS (through Indian Ocean GOOS and the Perth Office of the IOC) with the following terms of reference

- To provide scientific and technical oversight for a sustained ocean observing system for the Indian Ocean and Indonesian Throughflow in order to provide ocean observations needed for climate variability research and to underpin operational ocean applications and services relevant to the region, particularly with regard to ocean-state estimation and climate prediction.
- To develop, coordinate and implement a plan for a sustained ocean observing system for the Indian Ocean to (a) meet the common requirement of CLIVAR research themes and regional initiatives, particularly those identified by AAMP and VACS and the CLIVAR modelling panels, (b) satisfy the common requirements of GOOS and its modules, and (c) coordinate implementation activities in collaboration with relevant regional and global bodies and IOGOOS and JCOMM in particular.
- Liaise with relevant research Panels of CLIVAR and implementation Panels of GOOS and JCOMM and provide a focal point for coordination of ocean observing networks in the region.

An Indian Ocean Modelling workshop has been organized at IPRC, Honolulu USA on 29 Nov. – 3 Dec. 2004 (http://www.clivar.org/organization/indian/docs/IOM1stCircular.htm).

The GSOP was established in order to:

- Develop, promote and seek to implement strategies for a synthesis of global ocean, atmosphere and coupled climate information through analysis and reanalysis efforts and through the use of other techniques where appropriate. Initial emphasis will be on global ocean synthesis efforts, building on previous experiences and developments.
- Be responsible for the definition and fulfilment of CLIVAR's global needs for sustained observations and for the development of a strategy for their evolution/optimization based on new science and reanalysis insights, and fostering the use of resulting data sets in global synthesis efforts.

- Promote activities to develop the surface flux data sets required by CLIVAR in liaison with the WGNE, global atmospheric reanalysis efforts and the WCRP Working Group on Surface Fluxes.
- Provide an overview of and directions to CLIVAR data management and information activities in collaboration with other WCRP projects and in liaison with CLIVAR-relevant data centres and DACS and the ICPO.
- Liaise and collaborate with CLIVAR Panels and Working Groups in identifying the requirements for and coordinating the development of an observing system for CLIVAR.

GSOP is planning to hold a CLIVAR Ocean Reanalysis workshop at NCAR Boulder USA on 8-10 November 2004 (http://www.clivar.org/organization/gsop/implementation/ocean_reanalysis.html). It will have its first meeting immediately following this (from 10-12 November).

The ICPO has initiated a mid-term self-assessment in order to measure the achievements to date against the CLIVAR objectives and to provide the CLIVAR Scientific Steering Group (SSG) with input to determine what steps might be necessary to ensure future progress. The review has been organized by CLIVAR streams: GOALS, DecCen and ACC and by unifying themes, i.e. "Data and Modelling". Each panel/group provided some background information to the reviewers (D. Anderson for WGOMD), based on a common set of questions. The reviewers will comment on relevance/progress and assess the effectiveness of the organizational structure at the next SSG meeting in Baltimore 2004.

At the last meeting of the Joint Scientific Committee (JSC) for WCRP (Moscow, 1-6 March 2004) Tim Palmer was nominated to be the new CLIVAR co-chair to replace Jurgen Willebrand, who finished his term. Tony Busalacchi accepted to continue co-chairing CLIVAR SSG for another two years. A substantial part of the JSC meeting was devoted to further develop the concept of the WCRP Coordinated Observation and Prediction of the Earth System (COPES). COPES was first conceived as a major overarching and integrating initiative that would set future directions for WCRP. Now COPES represents a new strategy of WCRP for the period 2005-2015, reflecting the existing needs and possibilities and the maturity of WCRP's development, to convert theoretical and practical achievements into tangible support to governance on the basis of a global seamless observing, forecasting and projection system spanning timescales from weeks to centuries. The main aim is to facilitate prediction of climate variability and change so as to strengthen and broaden the range of applications of direct relevance, benefit and value to society. The two goals are:

- to provide society with a tangible result on what is, and what is not, predictable at weekly, seasonal, interannual and decadal time scales.
- to provide the research community with a central theme for building climate observation systems, developing climate system models and climate data assimilation techniques, and computing and data processing systems.

Initial specific objectives are:

- to determine the feasibility and expected skill of seasonal climate prediction in all regions of the globe with currently available models and data (this important exercise should be repeated periodically as observational systems and models evolve)
- to further develop and test the techniques for ensemble prediction of climate variability and change
- to determine the scientific basis for, the best approaches to, and current skill of projections of regional climate change at several time-scales
- to develop well-tested, detailed chemistry-climate prediction and projection models and related procedures (IGBP-IGAC)

A Task Force on Seasonal Prediction has been established under the chairmanship of B. Kirtman. He already organized a workshop on seasonal prediction in Hawaii in November 2003. Also a task force (chairs B. Hoskins and J. Church) has been recently established to further develop COPES strategic framework. WCRP is planning a major international conference as part of its 25th anniversary where COPES will be officially launched.

3. Joint meeting with AOMIP

The joint session with the AOMIP meeting was structured around three presentations. First Steve Griffies gave a short presentation on the CLIVAR workshop on evaluating the ocean component of the IPCC-class models (16-18 June 2004, GFDL/NOAA Princeton USA). The workshop motivations were:

- The climate modelling centres are in the process of freezing their coupled models used to address IPCC 2007 questions. Most are focusing on roughly a 1-degree class of global ocean model, with enhanced resolution in regions such as the tropics. Such synchronization of efforts presents the climate community with a valuable opportunity to compare state-of-the-art simulations, debate methodologies, and discuss strategies for improvement.
- Considerable experience has been obtained in recent years with the parameterization of important physical processes in ocean climate models. For example, processes such as gravity current entrainment and the interactions between mesoscale eddies and the mixed layer are the focus of major collaborative efforts in the US. Other processes have been identified as well, with clear need for their proper incorporation into climate models.

The workshop goals were:

- To foster a candid and critical evaluation of the state-of-the-art in ocean models used in the IPCC class of climate models.
- To provide guidance towards the evaluation and documentation of the models.
- To discuss and debate strategies for improving the physical integrity of the simulations.

The workshop was divided in 4 sessions. Each of the sessions was organized by a facilitator who coordinated the talks within the session. Furthermore, the facilitators were in charge of coordination between sessions so to allow sessions to complement one another. The 4 sessions were:

A **State of the art in ocean climate models**. Representatives from climate centres detailed aspects of their models used for IPCC assessments. Focus was placed on the ocean component from fully coupled ocean-atmosphere-land-ice models, as well as coupled ice-ocean simulations as proposed for the ocean model intercomparison project (OMIP). Speakers highlighted details of their ocean component related to the key processes discussed in Session C, and they presented analysis of key metrics identified in the pilot-OMIP protocol of Session B. They also presented analysis of the natural variability found in the model (e.g., ENSO, THC fluctuations, the oceanic response to simulated NAO, etc.). Presenters were encouraged to expose the "underside" of their models so, the workshop participants could learn what are the key biases and problems requiring improvements. Discussion of "problem attribution" was also encouraged, whereby participants attempted to answer whether the biases reside wholly in the ocean, or represent a problem with simulating the coupled system.

B **Ocean Model Intercomparison Project** How can we systematically compare coupled ice-ocean model simulations? What sorts of comparisons are relevant and interesting? The ocean climate modelling community continues to struggle with these questions. Can the community coalesce around protocols, and associated datasets, for running the models, such as within the context of an Ocean Model Intercomparison Project (OMIP)? How valuable will an OMIP be for evaluating the ocean and sea ice components of coupled climate models? Does OMIP provide a useful venue for comparing model sensitivities to parameterizations arising from the process studies? Can the community coalesce around an OMIP protocol that is sufficient for running repeating seasonal climatological runs (OMIP-1), interannaually varying integrations (OMIP-2), and/or experiments with strong perturbations such as fresh water pulses added to the North Atlantic (OMIP-3)? What sorts of datasets are useful to assess the physical integrity and relevance of these simulations? Overall, this part of the workshop solicited discussions/debates of the proposed OMIP protocol, including forcing datasets, bulk formulae, and key metrics to be used for evaluating the ice-ocean simulation. It also solicited experience in running pilot-OMIP simulations.

C **Key Physical Processes.** This session aimed to address the questions: What are key physical ocean processes that must be explicitly represented and/or parameterized in order to reduce uncertainty in the climate's response to anthropogenic forcing? How well do the global 1-degree class of models do with these processes? Will enhanced resolution resolve problems? What sorts of resolution are required for the different processes? This part of the workshop allowed experts in ocean processes, and their numerical representations, to discuss ways and means to increase simulation integrity.

D **Future Directions.** The final session focused on new paradigms for improving the physical and numerical integrity of ocean climate simulations. In particular, what are the key goals for future IPCC ocean models? What about model resolution? Should mesoscale eddies be explicitly represented in models used in the fifth assessment (post-2010)? Why? What resolution is really needed? What about straits, throughflows, mixed layers, sub-mesoscale eddies, biology, coastal zones? What is (are) the best vertical coordinate(s) for ocean climate simulations? Will the sensitivity of global climate be altered substantially by models explicitly representing eddies? How are we to address the needs of the regional impacts community, which includes the coastal zones? This Session solicited presentations from those developing new model classes (e.g., hybrid vertical coordinates; alternative horizontal grids), high-resolution models, and those presenting coastal impacts perspectives.

ACTION ITEM 1. Put together a workshop report with the outputs/recommendations from the 4 sessions and the extended abstracts of the invited speakers *(S. Griffies and R. Boscolo)*

Frank Bryan reported on the Pilot Ocean Model Intercomparison Project (POMIP) that WGOMD established in order to determine the feasibility and merit of a coordinated investigation of the performance of the ocean and sea-ice components of global coupled climate models. More specifically the pilot phase was proposed for determining:

- the feasibility of deriving a common forcing data set and applying it to a broad range of models. This is substantially more difficult for OMIP than for CMIP or AMIP
- the feasibility of writing a broadly usable and useful integration protocol
- the feasibility of establishing the administrative and technical infrastructure required to support such an intercomparison
- the merit of an intercomparison aimed specifically at the ocean components of coupled climate models beyond those ocean model intercomparisons already completed or underway (OCMIP, DYNAMO, DAMEE, DOME, …).

POMIP was the answer to several calls: from IPCC requiring a quantitative evaluation of the models participating in climate assessments and from WGCM asking for a coordinated intercomparison among the models whose outputs are in the PCMDI IPCC/CMIP archive. By pooling and disseminating community resources, establishing a common reference point for investigating sensitivities to model formulation and making models results more readily available to the broader research community it also fulfilled the WGOMD terms of reference:

- to encourage investigations of the effects of model formulation on the results of ocean models, making use of sensitivity studies and intercomparison
- to stimulate the development of ocean models for research in climate and related fields, with a focus on decadal and longer timescale at mid- and high-latitudes

The POMIP protocol included as forcing a dataset based on ERA-15 developed by F. Roeske at MPI. The dataset provides a comprehensive specification of heat, freshwater and momentum fluxes at the air-sea and air-ice interfaces, it is globally balanced in heat and freshwater when used with accompanying turbulent bulk formula and observed SST and includes synoptic variability for a single synthetic year: no forced inter-annual variability. The experiments were to be conducted with an ocean model coupled to prognostic sea-ice component, run for 100 years. Table 1 lists the models that participated to POMIP.

INSTITUTE	MODEL	VERT. GRID	HORIZ. GRID	ICE
CCSR	COCO	Z(40)	Rotated Spherical B-grid (1.5˚x1.5˚)	EVP
LANL/RSMAS	MICOM	□(16)	Tripole C-grid (3.6˚x 0.9-1.9˚)	thermodynamic
LANL/RSMAS	HYCOM	□/z(16)	Tripole C-grid (2.0˚x 2.0˚cos□)	thermodynamic
LODYC	OPA	Z(31)	Tripole C-grid (2˚x 2˚ cos□)	VP
MPI	HOPE	Z(23)	Dipole C-grid (225-375km x 24-235 km)	VP
MRI/JMA	MRI.COM	Z(48)	Spherical B-grid (2.0˚x 1.0˚)	VP
NCAR/LANL	POP	Z(25)	Dipole B-grid (3.6˚x 0.9-1.9˚)	none

Table 1. Models participating to POMIP

POMIP proved the feasibility of designing a protocol that can be used by several centres. However serious shortcomings remained in the forcing data (objections and non-compliance on one aspect or another of the forcing specification). It was also difficult to motivate model developers to run the experiments and undertake diagnostic analysis projects. Several issues thus need to be addressed for moving forward:

- How do we motivate groups to participate (obligation or attraction)?
- How do we motivate groups to take on analysis?
- What is the "stable" lifetime for a forcing data set?
- Mean climate versus variability experiments?
- Open ended or hypothesis driven experiments?
- How do we secure the technical and administrative infrastructure required to expand to a full-blown OMIP?

Andrey Proshutinsky reviewed the lessons learned so far in AOMIP. The overarching project goal is to determine major directions for Arctic Ocean model improvements based on coordinated numerical experiments and intercomparisons across an international suite of participating models. One of the most difficult tasks is to identify causes of differences among model results and causes of differences between model results and observations. Once done, the models can be improved with the implementation of new physics and parameterizations. Another goal of AOMIP is to investigate the variability of the Arctic Ocean climate at seasonal to decadal time scales based on model results and observations. A community-based modelling approach provides the unique opportunity to coordinate the investigation of different aspects of Arctic Ocean dynamics and thermodynamics because it allows for the purposeful design of a set of carefully planned numerical experiments covering the most important processes and interactions. A clear advantage is that each PI will be able to work with his or her specific research theme using simulation results from all AOMIP models, and will be able to analyze differences among all model results. This approach will allow AOMIP PIs to carry out comprehensive studies of different processes and interactions, and to investigate their temporal and spatial variability. AOMIP objectives for model intercomparison and improvement studies are:

- Run and analyze 50-year and 100-year coordinated AOMIP model simulations and determine major differences among model results and differences between model results and observations;
- determine major causes of model errors and propose model improvements;
- design a set of idealized numerical experiments in order to test improved models; and
- repeat 50-year and 100-year coordinated experiments with improved models.

AOMIP is addressing some research questions in Arctic Ocean science, in particular:
- Accumulation and release of freshwater in the Arctic Ocean
- Processes of shelf-basin interactions in different regions of the AO based on high and very high-resolution results
- Role of thermohaline and wind-driven forcing in the Arctic Ocean Circulation
- Processes of mixing in the Arctic Ocean
- Processes of sea ice dynamics and thermodynamics
- Origin and variability of the Atlantic water circulation in the Arctic Ocean
- Interactions with the North Atlantic in collaboration with global ocean circulation projects

The webpage of AOMIP (http://fish.cims.nyu.edu/project_aomip/overview.html) provides regular updates on the project activities. The most important element of the web site is the Live Access Server (LAS). This is a node of the National Virtual Ocean Data System (NVODS) that allows efficient model-data exchange among AOMIP participants. The common-forcing data sets are available through the AOMIP-LAS as well as the model results are directly accessible through the same system.
The PI/group responsible for the intercomparison activity for one/two parameters or processes, should collect the data from all models, analyse the results and propose model improvements. Major results, plans and project activities are discussed at annual workshops. To ensure an accurate intercomparison experiment, and to eliminate ambiguities in interpretation of model results all the models have been forced and validated with the following data sets:
- For bathymetry, a global merged data product was created with a blend of the International Bathymetric Chart of the Arctic Ocean data and the Earth Topography Five Minute data (Holland, 2000).
- For river-runoff, the hydrographic data product for the arctic region developed at the University of New Hampshire (Lammers et al., 2000) is used. The data sets archived at the National Snow and Ice Data Center (NSIDC) are used for sea-ice
- For hydrography, a global merged data product was produced, where various high-quality Arctic Ocean data sets have been blended with the World Ocean Atlas (Steele et al., 2001).
- For atmospheric forcing, derived reanalysis products from the National Centers for Environmental Protection (NCEP) are used.

The first AOMIP experiment involved an intercomparison of the seasonal cycle of the various AOMIP models. That experiment did not involve common forcing, but rather each AOMIP model was run using forcing data sets exactly as had been used by any given model prior to the beginning of the AOMIP. The second (and current) AOMIP experiment involves a coordinated intercomparison of the last 50 years (1948 - present) as simulated by the various AOMIP models using a carefully defined common forcing data set. The experiment consists of a coordinated spin-up phase (1948 - 1978) and a coordinated analysis phase (1979 - 2004). In the future, a third AOMIP experiment will be carried out involving a coordinated intercomparison of the last 100 years (1901 - present).

The WGOMD recognised the importance of using actual forcing (not the climatological cycle) to provide a more scientific approach to the project and also the use of interannual forcing. The benefit for a good communication/interaction between the AOMIP community and WGOMD was highlighted. R. Gerdes was asked to ensure a good flow of information and link between the two groups.

> **ACTION ITEM 2.** Provide regular updates on AOMIP activities and ensure e good interaction between AOMIP and WGOMD intercomparison activities *(R. Gerdes)*

4. Reports on Status and Plans of Modelling Activities

NOAA/GFDL (S. Griffies, USA)

The major activities at GFDL on ocean climate models during the past year include the following:

(A) Completing the ocean component for the 4th IPCC assessment report. Details of the model were reported at the 2003 WGOMD meeting in Villefranche sur Mer, France. The coupled model was frozen in spring 2004, with multi-century integrations ongoing, with the bulk of the IPCC committed runs to be completed in Fall 2004. Some notable elements of this model include:

1. No flux adjustments, with a stable meridional overturning for multiple centuries;
2. Use of real fresh water fluxes rather than the commonly used virtual salt flux;
3. Flow dependent neutral diffusivity;
4. The same coupled model used for IPCC scenario runs is also being used for seasonal-interannual prediction at GFDL.

Plans for this model include continued research, as well as incremental upgrades, including the use of a new atmospheric dynamical core, which resolves many of the biases associated with wind stress.

(B) In collaboration with NCAR, the development of a protocol for running ocean and sea ice models using the Large and Yeager (2004) forcing fields. Initial experiments with this protocol indicate that the GFDL model's meridional overturning collapses, whereas NCAR's does not. Differences in model parameters are being investigated to determine what is the reason for the widely varying model behaviour. This experience illustrates the power of running ocean climate models with the same protocol in order to understand model sensitivities.

(C) MOM4 continues to evolve, with three major releases occurring in 2004. Development presently is focused on two-way nesting capabilities and generalized vertical coordinates with quasi-Eulerian capabilities. The nesting effort is aimed at better representing many of the critical areas of ocean climate system, which require enhanced resolution, yet without a global increase. Generalized vertical coordinates will assist in the representation of upper ocean processes, shelf processes, and bottom boundary layer processes. MOM4 will not include an isopycnal option, as that is reserved for HOME.

(D) HOME-the Hybrid Ocean Model Environment: This effort represents a merger of all isopycnal model developers in the world to bring together the best of their algorithms into a single code. This project remains to be funded. However, GFDL is committed to this project and has a scientific programmer focused on HOME starting Sept 2004.

(E) Alistair Adcroft and Sonya Legg join Princeton University in Sept 2004. They bring to GFDL and Princeton expertise in numerical algorithms and physical processes. They will focus on leading GFDL into the next generation of ocean climate models, as well as enhance GFDL's participation in the NOAA/NSF funded Climate Process Teams (CPTs). Particular effort will be focused on merging the key features of the MIT ocean GCM with MOM.

CCSR (H. Hasumi, JAPAN)

The ocean component model at CCSR (COCO) has the following characteristics:

- Spherical coordinate system (including its rotation) in the horizontal, hybrid of z and sigma (sigma only for the upper ocean, between the free surface and a fixed depth in the upper ocean) in the vertical
- Third-order upstream tracer advection scheme
- Nakano and Suginohara (2002), for bottom boundary layer parameterization
- Noh and Kim (1999) turbulence closure for surface mixed layer: based on Mellor-Yamada’s level 2.5 and different in the estimation of the turbulence length scale. The dependence of the Prandtl number on the Richardson number has been newly introduced. The dependence is taken from a study on the atmospheric boundary layer, and it improves the mixed layer depths in subpolar regions (which were too shallow previously) and around the equator (which were too deep previously).

Note: Although the latest version of COCO is formulated on the generalized horizontal curvilinear coordinate system and a relevant flux coupler has already been developed, the currently used coupled GCMs include an older version, which is formulated on the spherical coordinate system.

A lower-resolution version is used for the coupled GCM: 1.4 degree (long), 0.5-1.4 degree (lat), 43 levels. The IPCC runs consist of a control run (external forcing fixed at 1850), 20th century run, 1%/yr CO_2 increase run and some related climate stabilization runs, and some of the SRES scenario runs. Three-member ensemble is intended at least for the 20th century run, 1%/yr CO_2 increase run, and scenario runs. The total integration time is >5000 yr, ~1500 yr of which has been finished as of 10 June.

A higher-resolution version has been also used for coupled the GCM 1/4 degree (long), 1/6 degree (lat), 47 levels. The IPCC runs were: control run (external forcing fixed at 1900), 20th century run, 1%/yr CO_2 increase run, and two of the SRES scenario runs. The total integration time is ~500 yr, ~100 of which has been finished as of 10 June.
The planned activities are: higher-resolution coupled GCM: 1/10 degree resolution ocean coupled to T213 atmosphere and update of the ocean component to the latest version of COCO in the coupled GCM

NCAR (F. Bryan, USA)
The CCSM-3.0 code was frozen in late May 2004, and will be released to the public, along with documentation and selected output from control runs, on the CCSM web site (http://www.ccsm.ucar.edu) in late June 2004.

The ocean component of CCSM-3.0 is based on the POP 1.4 code from Los Alamos National Laboratory. Two standard grid configurations are supported: a low resolution version with a nominal horizontal resolution of 3 degrees, and 25 vertical levels, and a moderate resolution version with a horizontal resolution of approximately 1 degree and 40 vertical levels. Both versions are dipole grids with the grid north pole displaced into Greenland and meridional resolution enhancement on the equator.

Over the past year the majority of the CCSM effort has gone into configuring the IPCC coupled model and carrying out control runs with the new model and beginning IPCC scenario runs. Control and CMIP runs have been carried out with the 1 degree ocean model in combination with T42 and T85 versions of the atmospheric component model and the 3 degree ocean model coupled to a T31 atmosphere. The initial research focus of the ocean behaviour in these solutions includes identification and attribution of biases, variability and secular trends of the overturning circulation, tracer based measures of ocean ventilation, and the resolution dependence of the simulated variability and climate change response. To facilitate this research ideal age is include in nearly every coupled mode experiment and CFC-11 and CFC-12 have been included in selected historical (1870-2000) experiments according to the OCMIP protocol.

Met Office/Hadley Centre (H. Banks, UK)
The current Hadley Centre coupled model is HadGEM1 (Hadley Global Environmental Model). We plan to submit results from this model to IPCC. The model details are:
Ocean model

- Based on the same ocean model as used in HadCM3
- 1^{o} resolution with higher meridional resolution in the tropics
- 40 vertical levels
- 4th order advection with upwind at bottom
- Some changes to vertical mixing (Peters et al coefficients, entrainment at base of mixed layer)

Sea ice model:

- Elastic-Viscous-Plastic rheology
- Multiple ice thickness categories
- Improved albedo schemes

Atmosphere model:

- ‘New dynamics’: semi-implicit, semi-Lagrangian
- 1.875^{o} x 1.25^{o} (N96) resolution
- New physics schemes relative to HadAM3

The Hadley Centre is also involved in collaboration on a project called UK-HiGEM. This is a NERC (UK academic community) project to develop a high-resolution version of HadGEM1. It is planned to set up an N144 Atmosphere and to run the ocean (and sea ice) model at 1/3^{o} resolution, 40 vertical levels. The 3 year project began in January.

The Met Office also runs ocean models for operational and seasonal forecasting:

- FOAM (Forecasting Ocean Assimilation Model): Global and limited area models are run. Forecasts are produced up to five days using winds, heat flux and freshwater flux from atmosphere operational forecasts
- GloSea: Coupled model based on the Hadley Centre climate model HadCM3. Ocean analyses are produced by assimilating sub-surface temperature in the ocean model. The ensemble predictions are produced using wind stress and SST perturbations designed to estimate uncertainty in the observations. A six month forecast is produced.

In the longer term, the Met Office plans to transition all deep ocean modelling (climate, FOAM and GloSea) to use NEMO (based on the French OPA model). The Met Office plans to develop FLUME (Flexible Unified Model Environment) which will enable them to run NEMO (and other non-Unified Model components) for operational and climate forecasts.

CSIRO (A. Schiller, AUSTRALIA)

The leading Australian large-scale ocean modelling groups (CSIRO, Bureau of Meteorology/BoM, and Tasmanian Partnership for Advanced Computing/TPAC) have agreed to support two core model streams in the foreseeable future, one for climate applications (AusCOM, Australian Community Ocean Model) and the other one for short-range ocean forecasting applications (OFAM, Ocean Forecasting Australia Model). Both models are based on GFDL's MOM4 code. There are additional synergies between the models. Due to the advanced stage of OFAM (currently run in spin-up mode, June 2004) the development of AusCOM benefits from experiences gained with OFAM, e.g. lessons learnt from various choices of sub-grid scale parameterizations.

The AusCOM model will meet most of the climate applications of interest to the Australian ocean modelling community. Main applications driving the development of AusCOM are the implementation of the next-generation operational seasonal-to-interannual prediction system (POAMA II, Predictive Ocean Atmosphere Model for Australia), the ocean component of a new-coupled climate change model and the implementation of biogeochemistry for ecosystem research. The model is based on GFDL MOM4 code with enhancements added by Australian researchers such as a Hibler-type sea-ice model, the Chen mixed-layer model and the OASIS flux coupler. Two options exist in AusCOM to avoid potential numerical problems at the North Pole: either the tripolar grid (Murray, 1996) as implemented in MOM4 or a displaced pole (Roberts et al., 2004) can be used. The aim is to make the model available for testing to the Australian user community by 2005.

OFAM is a global coarse-resolution model (~2º) with eddy-resolving resolution (1/10º) around Australia has been developed as part of the BoM/CSIRO/RAN (Royal Australian Navy) partnership for the development of an Australian ocean forecasting system. OFAM will be made operational by 2006, including real-time data assimilation.

LODYC/IFREMER (A.-M. Treguier FRANCE)

The ocean code OPA developed at LODYC (Paris) is evolving into a modelling environment (NEMO) including other components such as tracers, biogeochemistry, etc. The latest version of the ocean-ice code, OPA9, is being used for global forced ocean experiments at 1/2 degree and 1/4 degree. There will be an interest for the various groups involved in the "DRAKKAR" modelling project (www.ifremer.fr/lpo/drakkar) to participate in model intercomparisons.

Two laboratories in France (IPSL and CERFACS) are using coupled models to run IPCC scenarios. The French coupled models have the OPA model as their ocean component, with a 2 degree grid and a meridional refinement to 0.5 degree at the equator. However, the exact grid and parameterizations differ between the two versions. The ice and atmospheric components are also different. The two groups have a coordinated strategy for the analysis of their experiments.

The French MERCATOR project also uses the OPA code and its global configurations for operational oceanography. New developments for OPA are under way in the framework of the European project MERSEA, like for instance the improvement of the upper layer physics, or an explicit free surface. The MERCATOR group will provide ocean reanalysis for the recent years. As already noted, the use of such reanalyses for climate will be the subject of a CLIVAR workshop in Boulder in November 2004.

RSMAS (E. Chassignet, USA)
The HYbrid Coordinate Ocean Model (HYCOM 2.1) has been configured globally and has been coupled to the Los Alamos CICE ice model using the NCAR coupler. The present configuration has an horizontal resolution of 2 degrees with 26 hybrid vertical layers. Over the past year, most of the effort has gone into the coupling of the ocean model to the sea ice model and into evaluating the model's performance using the Large and Yeager corrected "normal" year forcing. Using 100-year long simulations, RSMAS are presently (or will be) investigating the impact of a) the sea ice model's choice (i.e. CICE vs. energy loan model), b) of relaxation to surface salinity (presently none), and c) of natural boundary conditions vs. virtual salt flux.

Collaboration has also been initiated with NCAR (W. Large, N. Norton) to bring HYCOM into compliance with the CCSM environment. Ultimately, comparison of CCSM experiments with HYCOM as the ocean component to experiments using POP as the ocean component should provide some indication as to whether the design of the ocean model is of significant importance in IPPC scenario runs. Comparison to other IPCC coupled ocean-atmosphere-ice simulations using HYCOM as the ocean model [i.e. the GISS atmospheric model (S. Sun) or the FSU atmospheric model (S. Wacongne)] will then be performed to assess the robustness of the results.

MPI (J. Jungclaus, GERMANY)
Technical details of the Max-Planck- Institute for Meteorology (MPI-M) ocean model MPI-OM and the parameterizations that have been implemented during the transition from the Hamburg Ocean Primitive Equation (HOPE) model (Wolff et al., 1997) to the MPI-OM model can be found in Marsland et al. (2003)[1]. The vertical discretization is on z-levels and the bottom topography is resolved by way of partial grid cells (Wolff et al., 1997[2]). The spatial arrangement of scalar and vector variables is formulated on a C-grid and a free surface formulation is used. The Hibler-type dynamic and thermodynamic sea ice model is similar to the earlier HOPE model (Wolff et al., 1997). The effect of snow accumulation on sea ice is included, along with snow-ice formation when the snow/ice interface sinks below the sea level due to snow loading.

The orthogonal curvilinear grid allows for an arbitrary placement of the grid poles. In the current set-up, the model's North Pole is shifted to Greenland and the South Pole is moved toward the center of the Antarctic Peninsula. This approach not only removes the numerical singularity associated with the convergence of meridians at the geographical North Pole but also produces higher resolution in the deep water formation regions near Greenland (Greenland Sea, Labrador Sea) and in the Weddell Sea. Several grid set-ups are available. Coupled ocean-atmosphere experiments are either run in the IPCC set-up with an ocean resolution of nomaly 1.5° together with a T63 (ECHAM5) atmosphere or in a coarse resolution version with 3° in the ocean and a T31 atmosphere. In both cases the coupled model produces a stable climate without the need of any flux adjustment.
Considerable improvement of the Equatorial Pacific cold bias problem was achieved by taking into account the ocean surface velocity in the calculation of the wind stresses in the atmosphere (Luo et al., 2004[3], Jungclaus et al., submitted to J. Climate[4]).

The HAMOCC5 carbon cycle model is implemented in the ocean model (optional) and has been tested in a number of forced stand-alone and coupled ocean-atmosphere experiments (Maier-Reimer et al., submitted to J. Climate[5])

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[1] Marsland, S.J., H. Haak, J.H. Jungclaus, M. Latif, and F. Röske, 2003: The Max- Planck- Institute global ocean/sea ice model with orthogonal curvilinear coordinates. Ocean Modelling, 5, 91-127
[2] Wolff, J.O., E. Maier-Reimer, E., Legutke, S., 1997: The Hamburg Ocean Primitive Equation Model HOPE. Technical Report No. 13, German Climate Computer Center (DKRZ), Hamburg, Germany.
[3] Luo, J.-J., S. Masson, E. Roecker, G. Madec, and T. Yamagata, 2005, Reducing climatology bias in an ocean-atmosphere CGCM with improved coupling physics, accepted J. Climate
[4] J. H. Jungclaus, M. Botzet, H. Haak, N. Keenlyside, J.-J. Luo, M. Latif, J. Marotzke, U. Mikolajewicz, and E. Roeckner: Ocean circulation and tropical variability in the coupled model ECHAM5/MPI-OM, submitted to J. Climate.

Presently, the sea ice model is being updated to allow for the simulation of multi category sea ice (Haapala, 2000[6]). In the near future also a multi-layer sea-ice formulation will be implemented.
On the longer term MPI-M plans to build a new ocean model that will share several properties of the ICON atmosphere model presently developed in a cooperation of the MPI-M, the German Weather Service (DWD) and other groups. ICON has a completely new dynamical core and the grid is based on the icosahedron, a regular Platonian body with 12 points spanning 20 triangles. This grid is refined by iterative triangulation of the initial triangles until the required level of resolution is reached.

5. High Resolution Ocean Modelling for Climate Studies

Several groups (U. Tokyo CCSR, Hadley Centre) are currently conducting coupled climate system simulations of century timescale or longer with ocean component models with resolutions in the "eddy-permitting" regime (20-30 km). These groups and others (e.g. CCSM) are working to develop coupled climate models incorporating ocean components with resolutions of 10km or better, i.e., just entering the "eddy-resolving" regime. The motivations for undertaking these studies in light of the very high computational cost are to understand how the climate (its mean, variability, and response to external forcing) differ when the ocean mesoscale eddies are explicitly resolved rather than parameterized, to investigate the role of processes which are excluded from eddy parameterizations (e.g., eddy-mixed layer interactions, non-local transport by coherent structures such as meddies, Agulhas rings or West Greenland Current eddies,), to improve our understanding of the role of small scale features in the time mean flow (e.g. western boundary currents and narrow straits or channels of the coastline geometry), as well as to investigate the dynamics of ocean eddies in a system in which the feedbacks to the atmosphere are included more realistically than can be achieved with a prescribed atmospheric state.

A major area of research in this high resolution modelling activity is to develop sub-grid scale closures that are suitably adiabatic for long term climate integrations, yet non-dissipative enough to retain the highly energetic mesoscale structures and their interaction with the mean flow. Each of the groups mentioned above are pursuing different variations of Gent-McWilliams (GM) type parameterizations for closure of the tracer equations. The Hadley Centre eddy-permitting coupled model HadCEM uses the Roberts-Marshall formulation of GM, the CCSR model uses a latitude dependent combination of biharmonic diffusion and GM, and the CCSM model uses an anisotropic formulation of GM with stronger diffusion in the along flow direction than the cross-stream direction. Early indications are that the representation of both the mean flow and variability in the model simulations (both local flow features and integral properties) can be quite sensitive to these choices. As many realizations of experiments will be necessary to quantify the sensitivity of the solutions to these closure choices, and the cost of this class of experiments, it is likely to be some time before we have a clear picture of the best choices of approach or magnitude of the closure parameters.

A recent paper by Maltrud and McClean (2004, Ocean Modeling) demonstrated that many aspects of the ocean general circulation and its variability are significantly better represented in a global ocean model with resolution of approximately 0.1°, than in a similarly configured model with a resolution of 1/3°. However, several significant biases, principally in western boundary current regions, remain even at this high resolution. This may seem somewhat discouraging from the point of view justifying the expense of high-resolution ocean models in climate studies. It must be kept in mind however, that our experience with this class of models is still very limited and that it could take some time to develop the understanding necessary to tune the sub-grid scale closures for this resolution regime. In the mean time, coupled experiments with models of this class will allow us to begin addressing many of the questions about the role of mesoscale ocean processes that are mentioned above. Roberts et al (2004, J. Clim) have already demonstrated progress in this regard by showing improvements in the simulation of tropical Pacific SST when tropical instability waves are explicitly resolved in HadCEM versus parameterized in HadCM3. It is reasonable to expect further stepwise improvements as finer scale ocean eddies are explicitly resolved on the path to fully "eddy-resolving" ocean component models.

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[5] Maier-Reimer, E., P. Wetzel, M. Botzet, J. Jungclaus, and N. Keenlyside: Effects of ocean biology on the penetrative radiation in a coupled climate model, submitted to J. Climate.

[6] Haapala, J., 2000: On the modeling of ice-thickness redistributions, J. Glaciology,46(154), 427-437.

6. Future of OMIP: The Coordinated Ocean-ice Reference Experiments (CORE)

The model intercomparison activities AMIP and CMIP are built on experimental designs that were considered established "standard practice" in the atmospheric and coupled modelling communities. The model output that is submitted to the public archive comes from runs that the groups carry out as part of their regular model development, testing, and tuning process. Thus, participation in this type of activity is generally not especially onerous for the groups submitting data.

Within the ocean modelling community, there are examples of a number of successful named intercomparison activities such as OCMIP, DYNAMO, DAMEE, and DOME that are organized around particular research questions with protocols designed specifically to address those questions. There has not, as yet, been a more general open-ended "OMIP" of the AMIP/CMIP type. This may be attributed in large part to the lack of an established "standard practice" or "reference" experiment commonly conducted by a broad cross section of the modelling groups. This, in turn, results from the difficulty of the problem of specifying comprehensive surface forcing for global ocean and ocean-ice models of sufficient generality to meet the needs of a wide variety of investigations.

The discussions at the Princeton Workshop, and within the WGOMD over the last several years lead us to conclude that it is necessary to establish a level of common practice within the community before proceeding to the declaration of an OMIP, and before soliciting modelling groups to submit standard output to a central archive.

The WGOMD therefore decided to establish experimental protocols for a series of "Co-ordinated Ocean-ice Reference Experiments" (CORE) that can become the basis for PI driven collaborations between groups and potentially serve as a basis of a broader ocean model intercomparison activity of the AMIP/CMIP class at some future date.

CORE will use the recently developed merged NCEP reanalysis / remote sensing data set of Large and Yeager (2004) as forcing. The dataset is well documented, comprehensive, globally balanced, and includes both a "normal year" and interannually varying forcing (please visit http://data1.gfdl.noaa.gov/nomads/forms/mom4/CORE.html).

> **ACTION ITEM 3**. write a user guide document that describe in details the NCAR dataset and provides information on how to access them (*B. Large and S. Griffies*)

Several groups have already begun using this data set, and an informal survey indicated much broader interest in the ocean modelling community than in the case of POMIP during the last couple of years.
The experiments specified in the CORE framework include:

- a normal year forcing control
- an interannually varying forcing
- and a special climate perturbation experiment addressing the response to a perturbation in freshwater fluxes over the sub arctic Atlantic

The experimental protocols draw on experience from POMIP (for the normal year forcing) and the EU-PREDICATE project (for the interannually vaying forcing); WGOMD will publicize the protocols through its webpage; it also plans to publish selected results from currently running experimentation for the December issue of CLIVAR Exchanges.

> **ACTION ITEM 4** update P-OMIP protocol for WGOMD-CORE which is comprehensive enough also for the involvement of new groups by September 2004 (*A.M. Treguier*)

> **ACTION ITEM 5** update the CLIVAR WGOMD webpage with the new protocols for CORE, leave the old P-OMIP protocol but say that it is obsolete (*R. Boscolo*)

> **ACTION ITEM 6** write a CORE protocol for the experiments with the interannually varying forcing by September 2004 (*H. Drange*)

ACTION ITEM 7 write an article for the December issue of the CLIVAR Exchanges in order to officially launch the WGOMD-CORE. The article should contain selected results from currently running experiments *(C. Boening and S. Griffies*)

PCMDI is likely to get involved in archiving the CORE outputs for the analysis. However it was felt that a standard practice for the experiments needed to be established first.

ACTION ITEM 8 during the first experimentations in CORE, establish the needs for exchanging/archiving the outputs (E. Chassignet, S. Griffies, F. Bryan and rep. PCMDI)

7. Sensitivity Experiments: Subarctic melt water response
Ruediger Gerdes reported on the protocol for perturbation experiments in the framework of CORE. Most coupled climate models show a decreasing THC in response to increasing GHG concentrations. However, the degree of this weakening is very different. A few models show no noticeable weakening of the THC. This different behaviour was motivation for the Coupled Model Intercomparison Project (CMIP) to launch so called water hosing experiments where a fresh water flux anomaly of 0.1 Sv (in additional experiments 1.0 Sv) were added to the northern North Atlantic between 50°-70°N for 100 years. A similar spread of reactions of the THC was documented as characterized the IPCC warming scenarios. It is noteworthy that the combination of an ocean GCM with a simple atmospheric energy balance model can reproduce important aspects of the coupled GCMs. This motivated WGOMD to look into the response of ocean-sea ice models to changes in fresh water fluxes into the northern North Atlantic.

Several experiments with an ocean-sea ice model (a version of MOM4) were conducted at GFDL to investigate the oceanic circulation response to increased freshwater flux into the northern North Atlantic. A fresh water flux anomaly was introduced around Greenland, its total volume flux rate is 0.1 Sv, slightly higher than the average increased melt rate from Greenland over the next 500 years as estimated by Huybrechts & deWolde (1999). Increased fresh water export from the Arctic would have a similar distribution or would lead to sea surface salinity anomalies that are compatible with this fresh water flux anomaly. The anomaly may thus also be taken as describing a general fresh water input into the northern North Atlantic, be it from glacial melt, enhanced precipitation over the Arctic catchment area, or drainage of the Arctic fresh water reservoirs. The experiments started after a spin up of 100 years by switching on the fresh water flux anomaly around Greenland. Four different approaches were used: The boundary conditions vary from the classical restoring of surface values to climatology, mixed boundary conditions where the fresh water flux is prescribed, and a method where the salinity forcing consists of two parts of which only one is restored to climatology while an "anomaly" part receives the anomalous fresh water flux and is not damped. The fourth approach is to couple an atmospheric EBM with the ocean-sea ice model.

How do the models cope with rather localized input of fresh water? How does their sensitivity vary with the type of surface boundary conditions, i.e. what kind of surface boundary conditions should we use to most closely emulate the response in the coupled system – without losing the ability to essentially prescribe the atmospheric conditions?

In the control run, fresh water of Arctic origin does not progress very far into the interior near the surface; it is carried to greater depths and eventually exported into the Southern Ocean with the DWBC. An active fresh water flux anomaly can reduce the ability of the North Atlantic to transport fresh water downwards. This not only affects the anomaly but also the export of fresh water from the Arctic. The ocean is under a strong constraint: At equilibrium, it has to transport fresh water equatorward to compensate for the atmospheric poleward transport. After a transient storing of freshwater in the subpolar gyre, southward transport of fresh water is enhanced in mode waters that follow the subtropical recirculation. A new Northeast Atlantic Intermediate Water (NEAIW) forms and reaches the western boundary in the second half of the experiments. There it moves southward at intermediate depths where remnants of the DWBC are still present. While all experiments agree in the general features of the response huge quantitative differences exists depending on surface boundary conditions.

ACTION ITEM 9 write a protocol for perturbation experiments on the response of the sub-Arctic Atlantic to increase of freshwater fluxes (*R. Gerdes*)

8. Links to CLIVAR Basin Panels

Advice from the CLIVAR basin panels (Pacific, Atlantic, and Southern Ocean) has been sought for experiment designs.

Kelvin Richard, chair of the Pacific panel, reported on the main scientific and implementation issues that the Pacific panel is addressing. Observational activities are well reported in the CLIVAR Pacific web page (http://www.clivar.org/organization/pacific/implementation/pacdatanew.htm). They include several XBT lines, TAO moorings and several process studies. There is the potential for long-term monitoring of the throughflow, but far from being operational.

Pacific decadal variability or ENSO decadal variability is hard to predict so it would be interesting for the Pacific panel that WGOMD explores the low frequency variations with the ocean models. Theories suggest that low frequency ENSO has tropic and subtropic connections, as well as connections with south Pacific. Ultimately the analysis should be done with a coupled model in order to explore possible teleconnection in the atmosphere with feedback from the ocean. The Argo floats in the Gulf of Alaska showed an abrupt change in the position of the north Pacific current during 2002-2003.

The main issues to be addressed are:

- Could CORE use proper interannual forcing instead of a fictitious mean seasonal cycle?
- If CORE is set up to do long (century +) integrations, can it nonetheless be designed so that shorter integrations (e.g. last 20 years) are a specified option? This argues for detailed comparisons with observations
- Can the data aspects be as open as possible, so that all the different groups across CLIVAR and beyond can share the same protocol and data analysis/comparison framework to the greatest extent feasible?

There is a shared WGSIP/Pacific Panel project on tropical Pacific simulations and mixing starting up, but it would be beneficial that the framework for such a study could be coordinated with a wider WGOMD work. Also ECMWF is promoting diagnostics for ocean reanalysis. Magdalena Balmaseda is looking at observable quantities in order to assess annual mean, seasonal cycle and intraseasonal/interannual variability. CORE could help with accessibility of data so that anybody can perform their own diagnostic and provide feedback when necessary. Within this framework the basin panels can suggest process study experiments. GODAE also are doing an ocean reanalysis.

Dan Wright represented the Atlantic panel. He stressed the importance of model-model intercomparison for determining both robustness and areas of uncertainty. The main issues for WGOMD to consider are:

- Need for model results to provide evidence of the role of the MOC in decadal climate variability
- Guidance on how to design an appropriate sustained observation programme
- Identification of indices of MOC (and heat flux) variability.

Robust correlations, under realistic forcings, between indices of climatic relevance and indices easily monitored are anxiously anticipated. Some questions that the Atlantic panel would like to answer with WGOMD help are:

- What controls the damping timescale of decadal oscillations? Are the processes reliably represented?
- How important are nonlinear effects in determining decadal variations? (Dewar, J. Clim., 2001)
- Sensitivity to source of freshening: Canadian Archipelago throughflow, East Greenland Current, Denmark Strait Overflow, NE Atlantic Deep Water and surface fluxes
- Can model comparisons identify the root cause of biases in water mass properties? Do different models agree on the causes? Can biases be reliably reduced?
- How well do models represent overflows and deep flows? How steady or intermittent are these flows?
- Where are the best monitoring locations?
- Why is the Gulf Stream separation so different in different models? Are improvements reliable?

Sea ice has been identified as an important element in determining surface salinities and temperatures in the NW Atlantic and model studies suggest that it can influence the THC. In addition the THC affects the surface heat transport and hence the extent and volume of sea ice. Observations show dramatic changes in the Nordic Seas and Labrador Sea. The dense water mass formed in the early 90s in the Labrador Sea has not been renewed after 1994. The drainage of this water mass out of the region provides an opportunity to test model representations of mixing and advection, and exchange between the subpolar and subtropical gyres. The section off the Grand Bank (42N) is also of interest because it has been occupied several times (1957, 1982, and 7 times since 1993) and because the Canadians and the Germans have maintained current meter moorings along this line (Aug. 93 - May 95 and Aug 99 - May 2001).

CFCs have a well-defined history and provide information on both advection and diffusion. The ability to reproduce the evolution of such passive scalars seems to be a prerequisite to being able to accurately model the evolution of T and S (hence rho, u, v, w). The timescale on which tracers move from the Labrador Sea to the Equator and the reduction in the strength of the signal from the Labrador Sea to the equator are very useful constraints for models. Passive scalars get transferred southward in the DWBC at a speed of about 1 or 2 cm/s, which is much slower than expected from isolated direct current measurements. Recirculations are at least part of the explanation. Do parameterizations represent these?

Observed quantities in the northern Atlantic that WGOMD can use for validating ocean models include:

- Spatial and temporal variation of tracers
- Variations in sea ice and relation to SST
- Response to the Great Salinity Anomaly(ies)
- Major gyre transports (Curry and McCartney)
- Upper ocean shelf-slope transports (Dickson and Yashayaev)
- Transport through A2/AR19 section (Grand Bank to England)
- Florida Current transport
- Transport through full A5/AR1 section (24°N)
- Sections across 10°N (MOVE/GAGE), 10°S, 30°S
- “Drainage” of Greenland Sea deep water
- Production and drainage of Labrador Sea (and deeper) Waters
- Watermass pathways into the South Atlantic
- The magnitude and structure of the ocean warming over past 50 years revealed by Levitus et al. (Science, 2000)
- The spatial structure of the changes in Atlantic fresh water content revealed by Curry, Dickson and Yashayaev (Nature, 2003)

In the southern hemisphere there has definitely been some work done that models could be compared with: the temperature variations in Vema Channel and the moored current meter array (5 moorings) maintained by Fritz Schott at 11S in the NBUC are good examples. More information can be found at: http://www.clivar.org/organization/atlantic/IMPL/index.htm

Steve Rintoul co-chair of the Southern Ocean Panel highlighted the importance of water mass formation and variability in the ACC transport. How is the freshwater treated in the model? Is the variability in the source water region smoothed out in the evolution of the mode water? The SO has somehow a different physics, or behaves differently from the other basin. It would be interesting to perform some experiments that show why.

Claus Boening noted that the CORE protocol with interannually varying forcing is expected to be of interest regarding the mechanisms of low-frequency variability in the ocean, and will help, due to identification of robust model behaviours and manifestations of this variability, in the design of observing systems. Further development of CORE, particularly with respect to model diagnostics and reference datasets for model evaluation, should proceed as a joint activity of WGOMD, the CLIVAR basin panels, and WGSIP. The establishment of CORE as a framework for coordinated ocean model experimentation will provide a useful starting point for a host of modelling studies or diagnostic subprojects more closely tied to investigations of specific processes or research questions.

ACTION ITEM 10 the basin panels to continue developing indices for models to use (C. Boening, D. Wright, K. Richards and S. Rintoul)

Eric Chassignet informed the group that GODAE is doing intercomparison projects in the N. Pacific and N. Atlantic. Hydrographic sections are chosen for intercomparison as well as choke points and TAO moorings. Models are high-resolution at regional scale and this is to assess how they perform with data assimilation. In the N. Atlantic this is MERSEA and includes the Mediterranean. A mechanism to connect the basin panels and GODAE for setting up experimental reference design could be valuable.

9. Inputs to IPCC

Frank Bryan informed the group that there is no more time to send inputs for the ocean component for IPCC and suggested looking at the list of the required runs (PCMCI webpage) to be sure that everything is clear

Anne Marie Treguier suggested updating of the model specification webpage with the IPCC ocean component specifications:

> **ACTION ITEM 11** contact Peter Gent to make available the specifications of the IPCC ocean component models to be put in the CLIVAR WGOMD webpage (A.M. Treguier and R. Boscolo)

10. Membership

F. Bryan and T. Hirst end their term at the end of 2004. The suggested replacements are:

- Marika Holland (NCAR, USA) Expert on various coupled model systems, polar climate processes and variability, link to polar modelling, link to NCAR CCSM
- Andreas Schiller (CSIRO AUS) Expert on tropical Pacific and Indian oceans, data assimilation, operational oceanography, link to Australian ocean climate community

> **ACTION ITEM 12** Suggest to the SSG the following replacements for F. Bryan and T. Hirst: Marika Holland (NCAR, USA) and Andreas Schiller (C. Boening and R. Boscolo)

C. Böning suggested handing over the chairmanship to S. Griffies; more specifically, he proposed S. Griffies to be co-chair together with him till the end of 2005. Afterwards C. Böning will retire and S. Griffies will be chairman. (Note that S. Griffies will spend a sabbatical in Hobart during 2005)

> **ACTION ITEM 13** Suggest to the SSG to hand over chairmanship from C. Boening to S. Griffies; more specifically to nominate both as co-chairs for 2005 (leading up to the 2005 meeting), and Boening to retire afterwards. (C. Boening and R. Boscolo)

11. Next meeting

The group discussed the proposal of holding a CLIVAR workshop on Southern Ocean dynamics. WGOMD would be a sponsor jointly with the CLIVAR SO Panel. Steve Rintoul suggested Hobart (Tasmania) as venue for the workshop in November 2005. Claus Boening suggested holding the next WGOMD meeting in conjunction with this workshop.

> **ACTION ITEM 14** Suggest holding thenext meeting in November 2005 in Hobart, Tasmania, in conjunction with a CLIVAR workshop on Southern Ocean dynamics organized jointly with the CLIVAR SO Panel. (C. Boening and R. Boscolo)

APPENDIX I. List of Participants

Panel Members:

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APPENDIX II. Meeting Agenda

Day 1 - Tuesday 15th June

12:00 Lunch

13:00 Opening

- Review of Meeting objectives and Agenda (C. Boening)
- Review of Relevant CLIVAR and WCRP Activities (R. Boscolo)

14:15 Joint meeting with AOMIP

- Objectives and Motivation of the CLIVAR Ocean Modelling workshop (S. Griffies)
- Brief Introduction to POMIP (F. Bryan)
- Lessons from AOMIP (A. Proshutinsky)

15:30 Coffee breaks

16:00 Developments in Ocean Climate Models: brief reports on status and plans from the different centres:

- GFDL (S. Griffies)
- NCAR (F. Bryan)
- OPA (A.M. Treguier)
- HYCOM (E. Chassignet)
- Hadley (H. Banks)
- MPI (J. Junclaus)
- CCSR (H. Hasumi)
- CSIRO (A, Schiller)

17:30 Status and Lessons from the "eddying" global (coupled) model (M. Roberts, F. Bryan and H. Hasumi)

18.00 Adjourn

Day 2 - Friday 18th June

15:30 Coffee Break

16:00 The future of OMIP (all, leading C. Boening and S. Griffies)

- General Aspects: merits and feasibility
- forcing protocol
- Timeline: coordination with CMIP and IPCC requests
- Model Output: recommendations from CLIVAR basin panels and AOMIP. Diagnostic sub-projects
- CMIP-3: Recommendations for ocean component output
- Infrastructure and Organization: PCMDI support

18:00 Adjourn

Day 3 - Saturday 19th June

9:00 Sensitivity studies: Subarctic meltwater response experiments (R. Ruediger)

9:45 Suggestions from Pacific Panel (K. Richards)

10:30 Coffee Break

11:00 Suggestions from Atlantic Panel (D. Wright)

11:45 Suggestion from Southern Ocean Panel (S. Rintoul)

12:30 Lunch

13:30 WGOMD Panel business (C. Boening)

- Membership
- Next Meeting
- Input to SSG

15:00 Adjourn

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