CLIVAR WGOMD – GSOP Workshop on Decadal Variability, Predictability, and Prediction: Understanding the Role of the Ocean
NCAR, Boulder, Colorado, USA
20-23 September 2010

Workshop Scientific Steering Committee
Gokhan Danabasoglu (co-chair): National Center for Atmospheric Research, USA
Helge Drange (co-chair): University of Bergen, Norway
Detlef Stammer (co-chair): Institut für Meereskunde, Hamburg, Germany
Bernadette Sloyan (co-chair): CSIRO, Marine Research, Hobart, Australia

Magdalena Balmaseda: ECMWF, Reading, UK
Helene Banks: Hadley Center, UK Met Office, UK
Claus Boning: Leibniz Institute of Marine Sciences, Kiel, Germany
Eric Chassignet: Florida State University, USA
Rudiger Gerdes: Alfred Wegener Institut fur Polar- und Meeresforschung, Germany
Richard Greatbatch: Leibniz Institute of Marine Sciences, Kiel, Germany
Stephen Griffies: NOAA / Geophysical Fluid Dynamic Laboratory, USA
Keith Haines: Environmental Systems Science Centre, Reading, UK
Tony Lee: NASA Jet Propulsion Laboratory, Pasadena USA
Gurvan Madec: LODYC, Institute Pierre Simon Laplace, France
Simon Marsland: Commonwealth Scientific and Industrial Research Organization, Australia
Anna Pirani: CLIVAR Project Office, UK
Anne Marie Treguier: Laboratoire de Physique de Oceans, IFREMER, France
Hiroyuki Tsujino: Meteorological Research Institute, Japan Meteorological Agency, Japan
Josh Willis: NASA Jet Propulsion Laboratory, Pasadena USA

1 Motivation and goals for a workshop on understanding the role of the ocean in decadal climate variability

Some recent examples of regional scale climate variability and change such as the prolonged drought in the southwestern U.S., increased Atlantic hurricane activity, changes in commercial fish production in the North Pacific and northern North Atlantic and the recent melting of the outlet glaciers on Greenland have raised awareness about climate change and its impact on society on decadal time scales, including amongst decision and policy makers. On these 10-30 year scales, regional variations in climate and their impacts largely represent natural, i.e., internal, variability of the climate system primarily driven by the slowly varying oceans, significantly affecting the anthropogenic (forced) climate change signals.

Observational examples of decadal variability include the Pacific Decadal Oscillation or Inter-decadal Pacific Oscillation (PDO/IPO) and the multidecadal variability in the Sea Surface Temperatures (SSTs) in the Atlantic Basin, usually referred to as the Atlantic Multidecadal Oscillation (AMO). Coupled general circulation models used in climate studies usually exhibit significant decadal variability / oscillation in their Atlantic Meridional Overturning Circulations (AMOCs). Furthermore, some studies show a broad resemblance between the observed and model simulated SST variability patterns in the North Atlantic that is usually associated with the AMOC variability. The link between the AMO and AMOC cannot be verified by the observations due to the lack of long-term AMOC records. Nevertheless, presence of such long-lived variability as depicted by either the PDO or AMOC forms the basis for decadal prediction studies. Because of its prominent role in the Earths climate system, the AMOC variability and its potential predictability have received much recent attention. Decadal variability and prediction exists in other oceans including the Southern Ocean, Indian and South Pacific Oceans, although lack of long-term observational data severely limits detection of the decadal signal in these regions.

Decadal prediction is a new, but rapidly growing field. Some recent review articles (e.g., Meehl et al. 2009)

as well as white papers (Hurrell et al. 2010; Latif et al. 2010; Balmaseda et al. 2010) detail the need for and usefulness of such decadal predictions, and summarize the outstanding issues and challenges with both observations and models. A unique aspect of the decadal prediction problem is that it represents a joint initial and boundary value problem. This implies that best possible initial conditions of the climate system need to be provided. The global ocean is the primary source of the longer-term temporal 'memory' of the climate system. Therefore, robust decadal predictability and prediction assessment require that the ocean be initialized using observational information, synthesized into appropriate initial conditions. A suite of coordinated decadal hindcast and prediction experiments for the period 1960-2035 are being carried out as part of the Coupled Model Intercomparison Project Phase 5 (CMIP5) to improve our understanding of decadal climate variability and predictability. Results from these experiments, which partly are also initialized using ocean data or ocean syntheses, will be evaluated for the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5).

Despite an increasing number of studies, many important aspects of decadal variability and prediction remain controversial. For example, the amplitude and period of the AMOC variability differ considerably across ocean models and the associated SST variability patterns, magnitudes, and periods do not match the observational AMO properties in most models. This holds also for ocean models constrained by ocean observations and a detailed study is required to determine why those differences remain and what observational database is required to better constrain and understand them. Furthermore, an understanding of decadal variability mechanisms is severely lacking. Some recent studies indicate that proper initialization of oceanic indices, e.g., the AMOC and the global upper-ocean heat content, is important for predictability of the climate system. However, the robustness of such initialization approaches – attempting to accurately represent present-day low frequency variability in the ocean – across different models remains unclear.

Decadal predictions of the climate system, associated initializations of coupled models using ocean reanalyses or hindcast products, and the estimation of uncertainties of predictions are among the incentives defined by CLIVAR as core activities to be pursued over the next decade. In organizing this workshop, the CLIVAR Working Group on Ocean Model Development (WGOMD) and Global Synthesis and Observations Panel (GSOP) are leading what is actually a far more widely spanning community meeting, covering the cross cutting topics of decadal variability, predictability, and prediction. The invited speakers include representation from the CLIVAR basin panels, the US CLIVAR Decadal Predictability Working Group, the Ocean Observations Panel for Climate (OOPC), and the CMIP panel. We envisage that all these groups will coordinate future research directions as a community-wide effort, each providing leadership in its area of focus.

WGOMD has recently finalized an experimental protocol for the Coordinated Ocean-ice Reference Experiments (CORE-II) forced with interannually varying surface data sets for the period 1948-2007 from Large and Yeager (2008). The CORE-II hindcast simulations provide a highly anticipated framework to evaluate ocean model performance, to study mechanisms of ocean phenomena and their variability from seasonal to decadal timescales, to identify forced variability changes, and to develop mechanistic descriptions of observed climate variability and change. Furthermore, CORE-II experiments will serve as a useful direct comparison to observational studies, and they can be used to optimize the ocean observing systems for the present climate. The natural variability differences amongst models participating in CORE-II experiments will be interesting for understanding and evaluating the robustness of modeled ocean variability and the formation, propagation and decay of anomaly signals that has been observed during the 20^{th} Century. Given the reliability of data assimilation prior to the Argo period is under question, initializing decadal predictions from CORE-II hindcast simulations without data assimilation can be an option. Similarly, anomalies can be extracted from the CORE-II climatology and then applied to the decadal prediction simulations.

An alternative approach is being followed by GSOP: The synthesis of all available ocean data sets by merging them over many years with ocean circulation models. Results of mathematically consistent approaches are dynamically self-consistent and can serve as a complementary basis to study the dynamics of ocean variability, to improve ocean and coupled models, to improve the observing system and to initialize coupled forecast models. GSOP performed now for several years an evaluation of existing ocean

syntheses (Lee et al. 2010; Heimbach et al. 2010; Stammer et al. 2010). A next step includes the use of those syntheses for initialization, but especially also for studying ocean decadal variability. Part of those efforts needs to be to assess the adequacy of ocean syntheses for such studies as well as identifying and improving existing shortcomings.

Despite its prominent role in decadal variability and predictability, understanding of the underlying physical mechanisms of oceanic natural variability is clearly missing. As indicated above, so far many efforts have focused on the Atlantic Ocean, with the AMOC as a key player, although the Pacific Ocean also contains intriguing variability on the decadal time scales. There are of course significant difficulties with the decadal variability and prediction problem associated with a paucity of observational data, the long time scales involved, and ocean (and climate) model limitations. The CLIVAR WGOMD and GSOP are motivated to hold a joint workshop on decadal variability, predictability, and prediction, specifically focusing on the oceans role in understanding and modeling the decadal variability. In particular, we believe that the availability of the CORE-II hindcast simulations and the recent advances in ocean syntheses will be of significant help in addressing these issues.

The main goals of the workshop are:
- To assess how well the ocean models and ocean syntheses reproduce observed decadal variability,
- To understand and evaluate the robustness of simulated ocean internal variability,
- To identify the underlying physical mechanisms in the ocean in decadal climate variability,
- To evaluate the outcomes of the CMIP5 decadal prediction experiments.

2 Topics and key questions

The following provides a list of topics and some key questions. We hope that the workshop participants will address these and other related questions in their presentations, posters, and discussions.

1. Observed decadal variability: What is the observed decadal variability in the climate system (observations and syntheses)? What are the observed climate impacts? What do the paleoclimate records show? What are the observed signals in the ocean? Are the present ocean observations adequate for decadal variability studies? What new observations are needed?

2. Predictability and state of the ocean models: Is there any predictability in the climate system? What are the sources of such predictability? What are the roles of natural and forced variability? Are the ocean models up to the task? What are the CORE-II hindcast simulations and ocean syntheses showing? How sensitive are small/regional changes to the ocean initial state? Are all the participating models in CORE-II reproducing the observed and synthesized variability robustly? How sensitive are the model results to model resolution? Are the ocean models robust in their internal variability? How is the internal variability affected by ocean model parameterization choices?

3. Physical Mechanisms: What are the sources of decadal variability? What determines the propagation and decay of decadal anomalies? What are the physical mechanisms in the ocean for decadal variability? How robust are these mechanisms? How are CORE-II experiments and ocean data assimilation improving our understanding of oceanic decadal variability mechanisms?

4. Initial conditions, predictions, and verification: What initialization techniques are used in the community? Are they robust in their outcomes across different models? What fields should be carefully initialized in the ocean? Can the CORE-II hindcast simulations be successfully used to initialize the ocean state for prediction experiments? Are they as useful as ocean syntheses? Is any one of the initialization approaches clearly superior to the others? What are the common verification techniques?

5. CMIP5 decadal prediction experiments: What do the early results show? Do the models agree? Is there any predictability? Are the ocean models capturing observed variability during the hindcast period? Do the hindcast experiments show that it is meaningful to run projection / prediction experiments?

3 Workshop format

The four-day workshop will consist of sessions formed around the above topics. In addition to the invited talks, we will have contributed talks and posters. The invited speakers will be asked to review the current state of research related to a particular topic with candid and critical comments, rather than focusing on their own research. These presentations should be conducive to discussions and these will be expanded on in explicitly scheduled discussion sessions.

While there is no doubt that decadal issues are a hot topic, this will be yet another decadal themed workshop dominated by talks (risk of show and tell, and repetitiveness). More time has been allocated in the agenda for participants to discuss future directions, how the community should move forward together (for example on the analysis of CMIP5, on a strategy to assess initialization techniques, the development of state of the art assimilation systems, etc.). The participants will be organized into break out groups of order 30 people and that will be charged with the same discussion topics. The smaller groups will render the discussions more productive and keeping the same topics will avoid participant disappointment in not being able to attend simultaneous discussions on different topics. The session discussion sessions will seek to assess consensus within the community and outline the key areas of research that need to be addressed by future coordinated activities.

The final discussion session at the end of the meeting will gather all the participants together to summarize the connectivity between the different session topics and to develop a way forward for the community. Those charged with leading the break out discussions will gather beforehand the main issues and points from their sessions and these will be brought together in the final discussion, working towards forming a straw-man plan for what could be achieved by a joint effort, looking at whether the community could develop a common framework.

4 Venue and logistical details

The National Center for Atmospheric Research (NCAR) will host this workshop over the four days 20-23 September 2010. Subsequent to the workshop, WGOMD and GSOP will hold panel meetings, including a joint session between the two groups. The workshop is open to all registered participants, with registration via the meeting website:
http://www.clivar.org/organization/wgomd/decadal/decadal.php

_ Registration is required, with space limitations necessitating that registration close after 100 people have registered. Registration will close no later than 1 August 2010. There may be a small registration fee.

_ Those wishing to present talks and / or posters must apply during registration, and decisions will be made soon afterward.

- The organizers are working to secure funding for this workshop. We would especially like to help support young scientists, whereby candidates go through an application procedure that includes submitting an abstract, which will be reviewed by a selection committee.

5 Workshop products

A key outcome of the workshop is the interaction that it will facilitate among various groups that are working on the decadal variability and prediction problem. Specifically, the members from the US CLIVAR Atlantic Meridional Overturning Circulation (AMOC) program, the CLIVAR WCRP Decadal Prediction Working Group, various CLIVAR basin panel communities, and GSOP will be participating in this workshop. The workshop will aim to strengthen collaborations between various different projects and activities, e.g., AMOC, CORE-II, CMIP5. It will provide the wider community guidance on both how to evaluate ocean models, e.g., for CMIP5 decadal experiments and robustness of decadal variability in ocean

(and climate) models. We will have some funding available for graduate students, post-docs, and early career scientists to attend the workshop.

The outcomes of the discussions and session summaries will form the basis for a peer-reviewed publication (BAMS-type) focused both on the state of the art and coordinated future efforts for research in decadal variability, predictability, and prediction. We currently stop short of aiming to develop a common framework, in particular for the analysis of CMIP5 near term simulations. This is premature, particularly in light of the community being only in the early stages of this analysis by the time we will meet in September 2010. In terms of CMIP5, we will encourage the speakers to look at what is available where possible as part of their talks.

6 Past WGOMD and GSOP Workshops

The WGOMD has organized four earlier scientific workshops. The workshops are part of the WGOMD terms of reference to educate and communicate topical ocean science issues to the science community. Each workshop provided pedogogical lectures introducing state-of-the-science ideas and results; offered opportunities for discussions and candid debates; and facilitated networking and collaboration. These earlier WGOMD workshops are the following:

_ "State of the Art in Ocean Climate Modelling": June 2004, Princeton/GFDL USA. Roughly 120 scientists attended this 3-day workshop to discuss the status of ocean climate modelling, based largely on development of the AR4 coupled models. The workshop consisted of four sessions, each introduced by an overview lecture, followed by a selection of shorter specialized presentations. Presentations are available at http://www.clivar.org/organization/wgomd/wgomd5/gfdl04.php.

_ "Modelling the Southern Ocean": November 2005, Hobart Australia. Roughly 100 scientists attended a 2-day workshop consisting of 10 lectures and discussion, each of 90 minutes duration. The lecturers provided insights regarding key elements of Southern Ocean physics, biogeochemistry, and modelling. Presentations are at http://www.clivar.org/organization/wgomd/wgomd6/so model.html.

_ "Numerical Methods in Ocean Models": August 2007, Bergen Norway. Roughly 100 scientists attended this 2-day workshop consisting of seven sessions, each introduced by an overview lecture and then followed by a selection of specialized presentations. This workshop focused on uncovering the latest ideas in numerical and physical methods for simulating the ocean. Presentations are at http://www.clivar.org/organization/wgomd/nmw/nmw programme.php.

_ "Ocean Mesoscale Eddies: Representations, Parameterizations, and Observations". April 2009, UK Met Office Hadley Centre, Exeter, UK. Roughly 140 participants attended this 3-day workshop to discuss different views on the state-of-the-science in ocean mesoscale eddies as seen through observations, simulations, and theory. The workshop consisted of six speakers per day with 70 minutes each to delve in-depth into the chosen subject, and for questions and discussion. Additionally, there were more than 40 posters from students, post-docs, and senior scientists. The presentations and most of the posters are available at http://www.clivar.org/organization/wgomd/meso/meso.php.

GSOP has since 2006 promoted and organized annual workshops on the evaluation and intercomparison of ocean synthesis products, with large participation of the community. Individual ocean synthesis efforts were invited to take part in this activity by making their results available to the project for further evaluation. As part of the project, a CLIVAR Ocean Synthesis Directory was developed (http://www.clivar.org/data/synthesis/directory.php).

7 References

Balmaseda, M.A. & Co-authors (2010). "Initialization for seasonal and decadal forecasts" in Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2), Venice, Italy, 21-25

September 2009, Hall, J., Harrison D.E. & Stammer, D., Eds., ESA Publication WPP-306.

Heimbach, P. & Co-Authors (2010). "Observational Requirements for Global-Scale Ocean Climate Analysis: Lessons from Ocean State Estimation" in Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2), Venice, Italy, 21-25 September 2009, Hall, J., Harrison D.E. & Stammer, D., Eds., ESA Publication WPP-306.

Hurrell, J. & Co-Authors (2010). "Decadal Climate Prediction: Opportunities and Challenges" in *Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2),* Venice, Italy, 21-25 September 2009, Hall, J., Harrison D.E. & Stammer, D., Eds., ESA Publication WPP-306.

Large, W.G., and S.G. Yeager, 2008: The global climatology of an interannually varying air sea flux data set. *Climate Dynamics*, doi:10.1007/s00382-008-0441-3, 24pp.

Latif, M. & Co-Authors (2010). "Dynamics of Decadal Climate Variability and Implications for its Prediction" in *Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2),* Venice, Italy, 21-25 September 2009, Hall, J., Harrison D.E. & Stammer, D., Eds., ESA Publication WPP-306.

Lee, T. & Co-Authors (2010). "Ocean State Estimation for Climate Research" in Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2), Venice, Italy, 21-25 September 2009, Hall, J., Harrison D.E. & Stammer, D., Eds., ESA Publication WPP-306.

Meehl, G.A., and Co-authors, 2009: Decadal prediction. Can it be skillful? *BAMS*, **90**, 1467-1485.

Stammer, D. & Co-Authors (2010). "Ocean Information Provided through Ensemble Ocean Syntheses" in Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2), Venice, Italy, 21-25 September 2009, Hall, J., Harrison D.E. & Stammer, D., Eds., ESA Publication WPP-306.