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PROJECT REPORT

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1. Recommend that Bergen model run a multi-centennial run to analyse overturning (H. Drange, M. Bentsen)

CORE Surface Forcing

2. Recommend that the CORE surface forcing interannual river run off data set should be extended past 2004 by climatology (G. Danabasoglu, S. Yeager)

3. Groups should document how run-off is incorporated to run CORE (All)

4. Recommend that the CORE surface forcing dataset should include leap years in the next release. NCAR will decide when that will happen in the near future. (W. Large, G. Danabasoglu)

5. Recommend a twin experiment with DRAKKAR forcing/winds compared to CORE-IAF (A. -M. Treguier, H. Drange, S. Griffies, G. Danabasoglu)

CORE-II

6. NCAR should establish guidelines for uploading model data from simulations forced with CORE-II interannual atmospheric data sets, including the data volume constraints. These model data will be hosted by NCAR on the ESG for use in model comparison projects.

7. Implement the CMIP5 Griffies *et al.* (2010) recommendations for ocean model output as a basis for CORE-II data output (All).

CORE-II Protocol

8. Recommend a standard salinity restoring comparison experiment (G. Danabasoglu, S. Griffies)

9. Recommend free use of salinity restoring, but that the individual groups are encouraged to test and use the weakest restoring possible. The resulting fresh water restoring field must be stored (All).

10. Update CORE-II protocol release_notesV2 (G. Danabasoglu, H. Drange, S. Griffies), adding also the values used in NCAR CORE-II procedure, including restoring time (see Section 5.4 in CORE-II release_notesV2) (G. Danabasoglu)

11. Provide links to the datasets used for the CORE-II initial conditions (Levitus and PH2, modified according to Doney and Hecht and Fox basin correction) on the CORE-II GFDL webpage (S. Griffies, G. Danabasoglu)

12. Verify that the salinity dataset that is distributed by the CORE-II GFDL website is the recommended one. Make sure it is the same one being used at NCAR (G. Danabasoglu, S. Yeager, S. Griffies)

13. Report on status of merging potential temperature and salinity datasets for providing improved initial conditions for future CORE-II experiments - CARS and PHC3 (S. Marsland)

14. Provide PHC3 data sets at 1-degree horizontal resolution on a spherical grid for analysis (H. Drange, M. Bentsen)

15. Consult AOMIP for their assessment of i) CORE II data sets and ii) Levitus 2009 for Arctic.

16. Recommend that AOMIP participate in a paper looking at CORE-II results (W. Large will represent WGOMD at 2010 AOMIP meeting)

17. Provide guidance and links on how to implement CFC tracers as part of CORE Large and Yeager (2008) surface forcing fields and supply a protocol for using CFC11, CFC12 and ideal age (G. Danabasoglu).

18. Extend ideal age recommendation, starting from guidelines provided in CMIP5 Griffies *et al*. (2010) recommendations (G. Nurser, H. Drange, G. Danabasoglu).

CORE-II Analysis and Benchmark Publication

19. Aim to submit the baseline CORE-II paper by July 2012 for assessment by the IPCC AR5

20. Invite everyone onto CORE-II Wiki to share diagnostics and analysis recommendations (A. Pirani)

21. Compute climate indices such as AMOC, PDO, AMO, and Nino 3 as part of CORE-II assessment (All)

REOS

22. Update transports and references (S. Marsland, H. Drange, G. Danabasoglu to A. Pirani)

Membership

23. Recommend D. Holland, G. Nurser and K. Fennel as new members

1. Introduction

The 9th WGOMD meeting was held on 23-25 September 2010, hosted by W. Large and G. Danabasoglu at NCAR in Boulder, CO, USA. The meeting agenda is given in Appendix A, the list of participants is in Appendix B. The meeting presentations, together with some pre-meeting reports, are available on the webpage (http://www.clivar.org/organization/wgomd/wgomd9/wgomd_ncar.php). The reports are also available at the end of this report in Appendix C. The meeting focused on the Co-ordinated Ocean-ice Reference Experiments (CORE), particularly on the CORE-II protocol and plans for coordinated analysis, as well as the status and developments of the CORE interannual forcing (IAF) dataset and the Repository for Evaluating Ocean Simulations (REOS). The WGOMD meeting was preceded by the WGOMD-GSOP Workshop on Decadal Variability, Predictability and Predictions: Understanding the Role of the Ocean, which was held on 20-23 September 2010 (www.clivar.org/decadal.php).

WGOMD also had joint sessions with the DIMES Project and the US CLIVAR Working Group on Decadal Predictability (WGDP), who met in parallel at NCAR. The former brought together modelers and observationalists and stimulated an exchange of information about how current models treat isopycnal and diapycnal mixing and what the state of observations is in the Southern Ocean. The joint session with WGDP gave an overview of some proposed decadal variability diagnostics and a discussion possible uses of CORE-II forced experiments.

2. Coordinated Ocean-ice Reference Experiments (CORE)

The CORE framework continues to be used by ocean modelling groups to benchmark progress as they develop their ocean modelling systems. In light of recent non-stationary (not reaching equilibrium) results of a multi-centennial run by the GFDL GOLD isopycnic model, it is recommended that the Bergen isopycnic model also run a multi-centennial run to analyse its overturning circulation. The results from the CORE-I intercomparison (Griffies *et al*., 2009) showed that isopycnic models generally have more drift.

ACTION: Recommend that Bergen model run a multi-centennial run to analyse overturning (H. Drange, M. Bentsen)

2.1 CORE Surface Forcing

The CORE interannually varying forcing (IAF) air-sea flux dataset (Large and Yeager, 2009) has been extended and version 2 now covers the period 1948-2007, with all fields varying interannually from 1984. Table 1 shows the incorporated datasets, including their sources and frequencies. The release of the CORE IAF dataset has contained some unfortunate mistakes, many of which were identified by users of CORE, thus supporting the utility of a public release. Some of these mistakes could have been identified earlier with more quality control crosschecking between GFDL and NCAR. For future releases, the GFDL and NCAR will increase data cross checking.

Table 1: Characteristics of primary datasets (red box) used for computing the CORE.v2 fluxes and for determining objective adjustments to forcing data (Large and Yeager, 2009).
Note that in the 'Variables' column, 'All' refers to a data source that has all the necessary variables for computing the full set of air-sea fluxes, as listed in the first paragraph of section 3 of Large and Yeager (2009). 'Most' means that the associated data source does not quite have a complete set of variables for computing air-sea fluxes.

Variables	Source	Frequency	Duration	Resolution	Coverage	Basis
SST	Hadley-OI	Monthly	1871–2007[a]	1°	Global	Satellite
Atmospheric State	NCEP	6 hourly	1948–2006[a]	T62	Global	NWP
Radiation	ISCCP-FD	Daily	1984–2006[a]	2.5°	Global	Satellite
Precipitation	GPCP	Monthly	1979–2006[a]	2.5°	Global	Satellite
Precipitation	CMAP	Monthly	1979–2006[a]	2.5°	Global	Blend
Precipitation	S-H-Y	Monthly	Climatology	0.5°	50°N–90°N	In situ
Ice fraction	NSIDC	Daily	10/79–2006[a]	25 km	Global	Satellite
All	NOC	Monthly	1980–1995	1°	Global	Ships
All	TAO	Daily	1995–2004[a]	2°–20°	Pacific	Buoys
Most	PIRATA	Daily	1998–2004[a]	2°–20°	Atlantic	Buoys
Vector winds	QSCAT	6 hourly	1999–2004[a]	0.5°	Global	Satellite
Air temperature	POLES	12 hourly	1979–2003	100 km	60°N–90°N	In situ
Precipitation	MSU	Monthly	1979–1993	2.5°	55°S–55°N	Satellite

[a] Ongoing production of the dataset is expected beyond these durations

River run off in version 1 of the CORE surface forcing dataset was based on the 19 continental drainage basin approach described in Large and Yeager (2004). Monthly-mean climatological runoff data based on the 1948-2004 average have been made available since August 2010. The data are based on Dai et al. (2009), but 0.07 Sv has been added as the continental discharge from Antarctica. Interannually varying runoff data for the period 1948-2004 are available and the authors will update this to 2009. WGOMD has recommended that the interannually varying run off be extended past 2004 based on this updated data set.

ACTION: Recommend that the CORE surface forcing interannual river run off data set should be extended past 2004 (S. Yeager and G. Danabasoglu)

ACTION: Groups should document how run-off is incorporated to run CORE-II (All)

The CORE IAF forcing dataset currently does not include leap years. WGOMD recommends that the whole system should evolve to include leap years. This would, for example, expedite inclusion of tidal forcing in the CORE-II runs.

ACTION: Recommend that the CORE surface forcing dataset should include leap years in the next release. NCAR will decide when that will happen in the near future. (W. Large, G. Danabasoglu)

The DRAKKAR consortium has developed a different surface forcing product for running ocean-ice experiments. While the CORE IAV forcing is based on NCEP, the DRAKKAR forcing is based on ERA40. It uses the same bulk formula as CORE but has different air temperature, humidity and winds. The global fluxes are calculated and then a correction, which is different than in CORE, is calculated. A comparison is recommended to test the ocean-ice sensitivity to the choice of forcing product.

ACTION: Recommend a twin experiment with DRAKKAR forcing/winds compared to CORE-IAF (A. -M. Treguier, H. Drange, S. Griffies, G. Danabasoglu)

2.2 CORE-II

The second phase of CORE (CORE-II) is underway forced by interannually varying CORE IAF.v2 forcing (Large and Yeager, 2009) that covers the period 1948-2007. The participating groups will make their simulations available to the wider community, particularly the CLIVAR ocean basin panels, for analysis over the next year. Two sets of experiments have already been archived by NCAR on the Earth System Grid (ESG) for anyone interested to look at and analyze. These experiments have been conducted using the nominal 1-degree horizontal resolution version of the CCSM4 ocean model. One is with an active sea-ice model and the other has a data ice model. Currently, the model output on the ESG is from the fourth (last) forcing cycle, but if there is any interest, the other cycles can be provided as well.

ACTION: NCAR should establish guidelines for uploading CORE-II data, including the volume constraints.

ACTION: Implement the CMIP5 Griffies *et al.* (2010) recommendations for ocean model output as a basis for CORE-II data output.

2.3 CORE-II Protocol

Various groups have been running CORE-II experiments, testing the experimental design, in particular the choice of salinity restoring and the impact this has on the stability of the overturning circulation.

The experimental protocol recommended by the Bergen group consists of an initial spin-up with strong salinity restoring for multiple realizations of CORE-IAF (at least four realizations), with a cap on the maximum ΔSSS used for computing salinity restoring to reduce over-freshening in the subpolar North Atlantic due to large restoring fluxes in the Gulf Stream region. The final realization used for analysis uses a diagnosed salt flux from the previous realization that is applied as a "flux correction" and a very weak SSS restoring is added.

NCAR has tested various salinity restoring timescales: 1 month, 1 year, 4 years, and infinity, i.e., no restoring. The restoring is applied the same everywhere and the global mean of the salinity restoring fluxes is subtracted at every time step from each grid point, so that the total impact of restoring to the global salinity budget is zero at every time step. No limits are set to the ΔSSS used. AMOC metrics of the different runs show the sensitivity of the ocean simulation to the choice of restoring. In ocean-only (ice is prescribed) mode, the no-restoring case leads to a collapse of the AMOC. However, in ocean-ice mode, the no-restoring case gives the strongest AMOC transport. There is a robust, monotonic increase in AMOC strength as the restoring timescale is increased. In general, a stronger AMOC is associated with less ice. The response to different salinity restoring approaches is also sensitive to the changes in the sea ice model. The salinity restoring approach selected by NCAR uses a relaxation of 4 years over 50 meter length scale, with the global mean subtracted as stated above.

The sensitivity to the choice of salinity restoring is model dependent so the CORE-II protocol cannot impose a common restoring. Individual groups are nonetheless encourage to test and use the weakest possible restoring and the resulting restoring terms should be saved for comparison purposes. A standard restoring comparison experiment is recommended, where groups run a standard restoring protocol in addition to their preferred method. GFDL has implemented the Bergen approach with MOM, with some minor modifications, but the transition to the final "analysis" segment was unsatisfactory, resulting in an exceptionally large drift in this particular model. GFDL will also be implementing the 4 year/50m NCAR restoring approach.

ACTION: Recommend a standard restoring comparison experiment (G. Danabasoglu, S. Griffies)

ACTION: Recommend free use of salinity restoring, but that the individual groups are encouraged to test and use the weakest restoring possible. The resulting restoring field must be stored.

ACTION: Update CORE-II protocol release_notesV2 (G. Danabasoglu, H. Drange, S. Griffies), adding also the values used in NCAR CORE-II procedure, including restoring time (see Section 5.4 in CORE-II release_notesV2) (G. Danabasoglu)

The dataset for the CORE-II initial conditions is Levitus temperature and salinity, merged with the Polar science center Hydrographic Climatology version 2 (PHC2). This may be revisited in the future as improved initialization states are developed via merging PHC3 and the CSIRO Atlas of Regional Seas (CARS). PHC3 improves the representation of the Arctic. Levitus (2009) may include the Arctic conditions from PHC3. The salinity restoring used by groups may need to be revisited if these new data sets are also used for surface salinity restoring.

ACTION: Provide links to the datasets used for the CORE-II initial conditions (Levitus and PH2, modified according to Doney and Hecht and Fox basin correction) on the CORE-II GFDL webpage (S. Griffies, G. Danabasoglu)

ACTION: Verify that the salinity dataset that is distributed by the CORE-II GFDL website is the recommended one. Make sure it is the same one being used at NCAR (G. Danabasoglu, S. Griffies)

ACTION: Report on status of merging datasets for improved initialization state - CARS and PHC3 (S. Marsland)

ACTION: Provide 1-degree spherical coordinated PHC3 dataset for analysis (H. Drange, M. Bentsen)

ACTION: Consult AOMIP for their assessment of Levitus 2009 for Arctic.

ACTION: Recommend that AOMIP commit to a paper looking at CORE-II results (W. Large will represent WGOMD at 2010 AOMIP meeting)

The use of CFCs is a good way to test parameterizations and to identify model physics shortcomings. The ideal age protocol will depend on how many spin up cycles are run. The inclusion of ideal age (Thiele and Sarmiento 1990) as a passive tracer helps to study changes in ocean ventilation. How the ideal age is implemented needs to be considered as it can introduce a non-trivial sensitivity to the time step and surface layer thickness.

ACTION: Provide guidance and links on how to implement CFC tracers as part of CORE Large and Yeager (2008) surface forcing fields and supply a protocol for using CFC11, CFC12 and ideal age (G. Danabasoglu).

ACTION: Extend ideal age recommendation, starting from guidelines provided in CMIP5 Griffies *et al*. (2010) recommendations (G. Nurser, H. Drange, G. Danabasoglu).

2.4 CORE-II Analysis and Benchmark Publication

Between now and the next WGOMD meeting in a year's time, groups participating in CORE-II will start work on a coordinated analysis and documentation. The baseline reference publication should be published by July 2012 to be assessed as part of the IPCC AR5 and the next year's WGOMD meeting will be a working meeting to finalize this publication. The publication aims to be as short as possible, introducing the CORE-II framework but without revisiting the justifications for running ocean-ice simulations that have already been covered in the Griffies *et al*. (2009) CORE-I paper. The CORE-II paper will focus on the robust results in the period of interannual variability from 1984 onwards as compared to ocean state estimates and observations. The CORE-II documentation will include a discussion on salinity restoring and spin up, either in extended appendices or as a supplementary technical note. The likely numerous figures may also be exhaustively collected as a visual database or atlas. It is expected that there will be numerous follow on publications addressing particular regions and processes or additional sensitivity experiments and analyses.

ACTION: Aim to submit the baseline CORE-II paper by July 2012 for assessment by the IPCC AR5

ACTION: Invite everyone onto CORE-II Wiki to share diagnostics and analysis recommendations (A. Pirani)

ACTION: Compute climate indices such as AMOC, PDO, AMO, and Nino 3 as part of CORE-II assessment

3. Repository for Evaluating Ocean Simulations (REOS)

The REOS website continues to be developed to provide the wider community with information useful for evaluating ocean model simulations, including descriptions and links to observational datasets commonly used for evaluation as well as guidelines on metrics and a growing bibliography. The steps taken in Griffies *et al.* (2009) to evaluate the CORE-I simulations are listed and the plan is to provide scripts for computing the figures from the paper so that groups can easily compare their model performance to other groups in a common framework. It is anticipated that the guidelines on metrics will be substantially improved as WGOMD goes through the initial systematic evaluation of the CORE-II simulations by comparing to observations.

ACTION: Update transports and references (S. Marsland, H. Drange, G. Danabasoglu to A. Pirani)

4. WGOMD Business

4.1 Membership

WGOMD seeks to replace H. Hewitt (Banks) from the UK Met Office, who has stepped down, with G. Nurser from the National Oceanography Centre, UK, who will represent UK activities in ocean model development. The CLIVAR SSG approved this year WGOMD's request to expand its list of members to bring new areas of expertise into the group, specifically in the areas of ocean biogeochemical modelling and ocean-ice shelf interactions. K. Fennel, of Dalhousie University Canada, and D. Holland, of the Courant Institute USA, have been nominated. K. Fennell would also represent ocean modelling activities in Canada, since R. Greatbatch is now based at IFM-GEOMAR in Germany. The WGOMD members unanimously endorsed these three nominations.

ACTION: Recommend D. Holland, G. Nurser and K. Fennel as new members

4.2 Next Meeting

The 10th Session of WGOMD will be held on the 21-23 September and will be hosted by G. Umgiesser of the Institute of Marine Sciences in Venice, Italy. In a break from tradition, WGOMD will not organize a scientific workshop to coincide with the meeting. The main focus of this meeting will be to finalize the reference documentation for CORE-II, both a peer-reviewed publication and a more extensive technical note and atlas. A half-day will also be allocated for a chance to interact with local scientists.

References

Dai, A., T. Qian, K. E. Trenberth, and J. D Milliman, 2009: Changes in continental freshwater discharge from 1948-2004. J. Climate, 22, 2773-2791

Large, W. and S. Yeager, 2004: Diurnal to decadal global forcing for ocean and sea-ice models: the datasets and flux climatologies. NCAR Technical Note: NCAR/TN-460+STR, CGD Division of the National Centre for Atmospheric Research.

Large, W.G. and S.G. Yeager. 2009: The global climatology of an interannually varying air-sea flux data set. Climate Dynamics, 33, 341-364, doi:10.1007/s00382-008-0441-3.

Thiele, G., and J.L. Sarmiento, 1990: Tracer dating and ocean ventilation. *J. Geophys. Res*., **95** (C6), 9377-9391.

Appendix B – List of Participants

WGOMD:

Gokhan Danabasoglu (co-Chair) - NCAR, USA
Helge Drange (co-Chair) - University of Bergen, Norway
Stephen Griffies - GFDL/NOAA, USA
Enrique Curchitser - Rutgers University, USA
Simon Marsland - CSIRO, Australia
Gurvan Madec - LODYC, Institute Pierre Simon Laplace, France
Hiroki Tsujino - Meteorological Research Institute, Japan Meteorological Agency, Japan

CLIVAR

Anna Pirani - International CLIVAR Project Office and ICTP, Italy

Invited Participants:

Bill Large - NCAR, USA
Laurent Terray - CERFACS, France
Steve Yeager - NCAR, USA
George Nurser - NOC, UK
Mats Bentsen - University of Bergen, Norway
Eric Chassignet - Florida State University, USA
Claus Boening - Institut für Meereskunde, Kiel, Germany
Anne-Marie Treguier - Laboratoire de Physique de Océans, IFREMER, France

Appendix B – Meeting Agenda

CLIVAR SSG-17 Action Items And Membership Issues - G. Danabasoglu
CLIVAR SSG, Imperatives and WCRP Modeling - A. Pirani
WCRP Modeling Coordination Meeting, Paris 15-17 Nov 2010 - G. Danabasoglu

CORE presentations and discussions

CORE IAF Dataset Update and CORE-II NCAR Simulations - G. Danabasoglu
Summary Of NCAR Modeling Activities - G. Danabasoglu
Update On CORE-II at GFDL - S. Griffies
Developments In The NorESM Ocean Component - M. Bentsen
ACCESS Ocean And Sea Ice Model CORE Simulations - S. Marsland
Experience with CORE II IAF In JMA/MRI - H. Tsujino
CORE-II Related Activities AT IFM-GEOMAR - C. Boening
Forcing Ocean Models With The Compo et al. (2009) 20th Century Reanalyses Project And Exploring Partial Coupling Of Ocean-Ice Models (R. Gerdes)
Mean State And Variability In A Suite Of Forced Global Ocean-Ice Simulations: The Interannual Coordinated Ocean-ice Reference Experiments (CORE-II) - Atlas/Paper Outline (S. Griffies, All)

Joint meeting with the US CLIVAR Working Group on Decadal Predictability

Summary of the DPWG charge and activities (Solomon)
Summary of CORE interannual forcing data and experiments (Danabasoglu)
Ocean model related or other relevant metric details pertaining to decadal prediction (Goddard)
Goal: explore and discuss common interests and projects, e.g., decadal variability diagnostics, including in eddy-permitting models; role of CORE II IAF experiments.

Joint meeting with the Diapycnal and Isopycnal Mixing Experiment in the Southern Ocean (DIMES)

Current practices in ocean diapycnal modeling (including model sensitivities) (M. Jochum)
Comparing methods for computing K (R. Ferrari)
Modeling tracer transport in the DIMES region (E. Shuckburgh)
Current practices for (sub)mesoscale mixing at NCAR (G. Danabasoglu)
Current practices for (sub)mesoscale mixing at GFDL (S. Griffies)
Diagnosing eddy diffusivities from eddy-permitting models (B. Fox-Kemper or F. Bryan)

Discussion:

How can DIMES results contribute to model development?
In what form are DIMES findings needed to help modelers?
How can modeling efforts contribute to DIMES data analysis?
Is DIMES a candidate for a CPT effort?
Are existing parameterizations of isopycnal mixing pertinent?
What happens when interior diapycnal mixing is at the noise floor of the measurement systems---can models cope with such low mixing levels?
If diapycnal mixing varies spatially, at the moment is it more useful to work towards mapping a climatology of these variations or identifying the mechanisms that make it vary?

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