# CLIVAR Ocean Model Development Panel (OMDP) Activities (in Support of CLIVAR and WCRP Science)

Gokhan Danabasoglu (NCAR, US; OMDP co-chair)
Simon Marsland (CSIRO, Australia; OMDP co-chair)
Stephen Griffies (NOAA/GFDL, US; CLIVAR SSG member)
Anna Pirani (CLIVAR)

# Key Roles for OMDP in CLIVAR and WCRP

To collaborate with and to advise other CLIVAR panels and Research Foci (RF) Teams on issues related to ocean modeling.

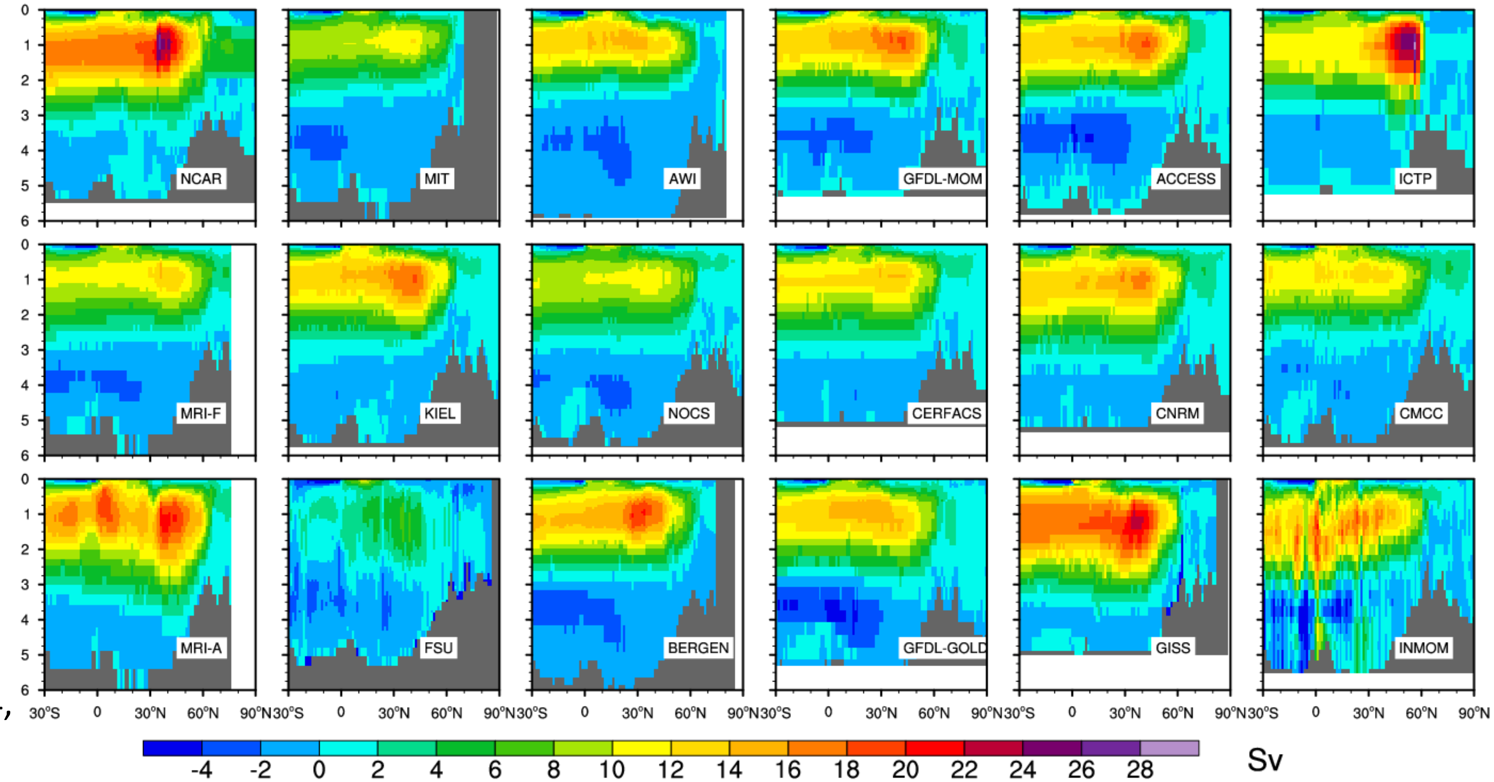
To coordinate activities aimed at addressing:

- Modeling needs (e.g., experimental protocols and analysis methods),
- Model biases (e.g., eastern boundary upwelling; Southern Ocean ventilation; Gulf Stream separation),
- Ocean processes understanding and their representation (parameterizations),
- Issues impeding progress of CLIVAR core activities, RF, and WCRP Grand Challenges.

# Coordinated Ocean-ice Reference Experiments (CORE)

CORE phase II (CORE-II) represents an experimental protocol for coupled ocean – sea-ice simulations forced with inter-annually varying prescribed atmospheric data.

CORE is recognized as the community standard for coordination of global ocean – sea-ice simulations.




Danabasoglu et al. (2014, Ocean Modellling)

CORE-II hindcast simulations provide a framework for

- evaluation, understanding, and improvement of ocean models
- investigation of mechanisms for seasonal, interannual, and decadal variability
- evaluation of robustness of physical mechanisms across models
- complements data assimilation / state estimation
  - bridges observations and modelling
  - ocean initial conditions for climate (decadal) prediction simulations.

# CORE-II Special Issue of Ocean Modelling (2014-2015)
# (20+ participating models)

- North Atlantic and Atlantic meridional overturning circulation (AMOC)
  - Part I: Mean states (Danabasoglu & Yeager et al), PUBLISHED — Highly Cited Paper
  - Part II: Variability (Danabasoglu & Yeager et al)
- Global and regional sea level (Griffies & Yin et al), PUBLISHED
- Southern Ocean water masses, ventilation, and sea-ice (Downes et al)
- Antarctic Circumpolar Current and Southern Ocean overturning circulation (Farneti et al)
- Arctic Ocean and sea-ice (Gerdes, Wang, & Drange et al)
- South Atlantic simulations (Farneti et al)
- Ocean circulation in temperature and salinity space (Nurser & Zika et al)
- Indian Ocean (Ravichandran, Rahaman, Harrison, Swathi, & Griffies et al)
- Pacific Ocean circulation and its variability (Tseng et al)
- Indonesian Throughflow (England & Santoso et al).

# Ocean Model Intercomparison Project (OMIP)

09 March 2015

**Name of MIP:** Ocean Model Inter-comparison Project (OMIP)

**Co-chairs of OMIP**


Gokhan Danabasoglu, NCAR, USA (gokhan@ucar.edu)
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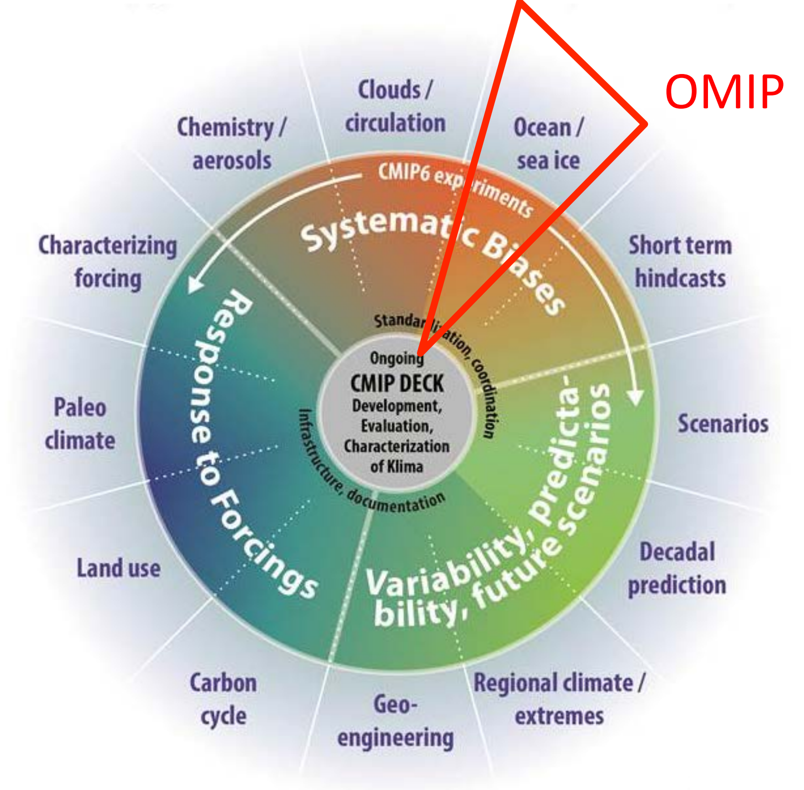
**Scientific Steering Committee**

**Physical processes** (CLIVAR OMDP and collaborators)

1. Claus Boning (Germany)
2. Eric Chassignet (USA)
3. Enrique Curchitser (USA)
4. Gokhan Danabasoglu (USA)
5. Helge Drange (Norway)
6. Stephen Griffies (USA)
7. David Holland (USA)
8. Yoshiki Komuro (Japan)
9. William Large (USA)
10. Simon Marsland (Australia)
11. Simona Masina (Italy)
12. George Nurser (UK)
13. Anna Pirani (CLIVAR ICPO)
14. Anne-Marie Treguier (France)
15. Mike Winton (USA)
16. Stephen Yeager (USA)

**Chemical and biogeochemical processes**

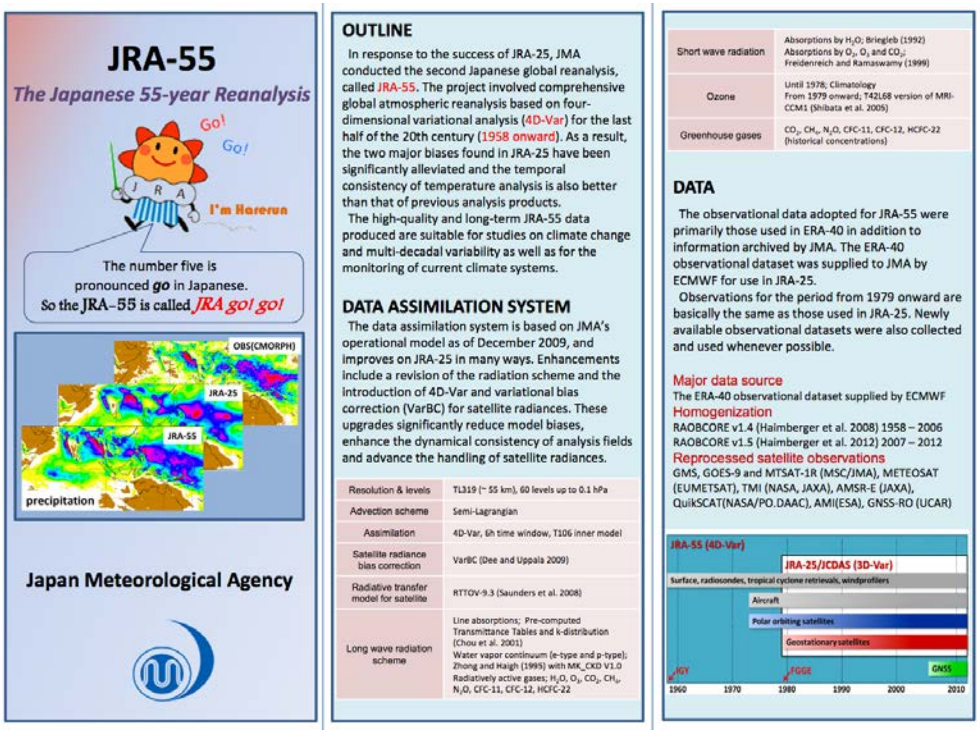
1. James Orr (France)
2. Laurent Bopp (France)
3. Scott Doney (USA)
4. John Dunne (USA)
5. Fortunat Joos (Switzerland)
6. Galen McKinley (USA)
7. Andreas Oschlies (Germany)
8. Toste Tanhua (Germany)
9. Keith Lindsay (USA)




Meehl et al. (2014, EOS)

# CORE-II Plans

- OMDP will continue to coordinate preparation, update, and maintenance of the CORE atmospheric data sets.
- OMDP will continue to coordinate CORE analysis projects and further refinement of existing and new experimental designs.
- OMDP is considering the JRA-55 reanalysis product to replace our existing data sets.





## OUTLINE

In response to the success of JRA-25, JMA conducted the second Japanese global reanalysis, called JRA-55. The project involved comprehensive global atmospheric reanalysis based on four-dimensional variational analysis (4D-Var) for the last half of the 20th century (1958 onward). As a result, the two major biases found in JRA-25 have been significantly alleviated and the temporal consistency of temperature analysis is also better than that of previous analysis products.

The high-quality and long-term JRA-55 data produced are suitable for studies on climate change and multi-decadal variability as well as for the monitoring of current climate systems.

## DATA ASSIMILATION SYSTEM

The data assimilation system is based on JMA's operational model as of December 2009, and improves on JRA-25 in many ways. Enhancements include a revision of the radiation scheme and the introduction of 4D-Var and variational bias correction (VarBC) for satellite radiances. These upgrades significantly reduce model biases, enhance the dynamical consistency of analysis fields and advance the handling of satellite radiances.

| | |
|---|---|
| Resolution & levels | TL319 (~ 55 km), 60 levels up to 0.1 hPa |
| Advection scheme | Semi-Lagrangian |
| Assimilation | 4D-Var, 6h time window, T106 inner model |
| Satellite radiance bias correction | VarBC (Dee and Uppala 2009) |
| Radiative transfer model for satellite | RTTOV-9.3 (Saunders et al. 2008) |
| Long wave radiation scheme | Line absorptions; Pre-computed Transmittance Tables and k-distribution (Chou et al. 2001)<br>Water vapor continuum (e-type and p-type); Zhong and Haigh (1995) with MK_CKD V1.0<br>Radiatively active gases; $H_2O$, $O_3$, $CO_2$, $CH_4$, $N_2O$, CFC-11, CFC-12, HCFC-22 |

| | |
|---|---|
| Short wave radiation | Absorptions by $H_2O$; Briegleb (1992)<br>Absorptions by $O_2$, $O_3$ and $CO_2$; Freidenreich and Ramaswamy (1999) |
| Ozone | Until 1978; Climatology<br>From 1979 onward; T42L68 version of MRI-CCM1 (Shibata et al. 2005) |
| Greenhouse gases | $CO_2$, $CH_4$, $N_2O$, CFC-11, CFC-12, HCFC-22 (historical concentrations) |

## DATA

The observational data adopted for JRA-55 were primarily those used in ERA-40 in addition to information archived by JMA. The ERA-40 observational dataset was supplied to JMA by ECMWF for use in JRA-25.

Observations for the period from 1979 onward are basically the same as those used in JRA-25. Newly available observational datasets were also collected and used whenever possible.

**Major data source**
The ERA-40 observational dataset supplied by ECMWF

**Homogenization**
RAOBCORE v1.4 (Haimberger et al. 2008) 1958 – 2006
RAOBCORE v1.5 (Haimberger et al. 2012) 2007 – 2012

**Reprocessed satellite observations**
GMS, GOES-9 and MTSAT-1R (MSC/JMA), METEOSAT (EUMETSAT), TMI (NASA, JAXA), AMSR-E (JAXA), QuikSCAT(NASA/PO.DAAC), AMI(ESA), GNSS-RO (UCAR)

# Guidance for CMIP6 physical ocean diagnostics

## Sampling the Physical Ocean in CMIP6 Simulations

CLIVAR Ocean Model Development Panel (OMDP)
Committee on CMIP6 Ocean Model Output

Stephen M. Griffies (NOAA Geophysical Fluid Dynamics Laboratory, USA)
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V. Balaji (NOAA/GFDL and Princeton University, USA)
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Trevor J. McDougall (University of New South Wales, AUS)
Ronald J. Stouffer (NOAA Geophysical Fluid Dynamics Laboratory, USA)
Karl E. Taylor (LLNL/Program for Climate Model Diagnosis and Intercomparison, USA)

Version 1.0
March 6, 2015

### Abstract

We present recommendations for sampling physical ocean fields for the World Climate Research Program (WCRP) Coupled Model Intercomparison Project #6 (CMIP6), including its DECK experiment suite, the historical simulation (1850-2014), as well as any CMIP6 satellite MIPs that include a physical ocean model component. Such MIPs in particular include the Ocean Model Intercomparison Project (OMIP), Coupled Climate Carbon Cycle Model Intercomparison Project (C4MIP), Decadal Climate Prediction Project (DCPP), High Resolution Model Intercomparison Project (HighResMIP), and the Flux Anomoly Forcing Model Intercomparison Project (FAFMIP). We motivate the diagnostics by presenting salient scientific reasons for their relevance, and present a practical framework for meaningful comparisons across climate models and observational based measurements. We focus on diagnostics related to physical properties and processes within the simulated ocean, along with associated ocean boundary fluxes. The audience for this document includes the WCRP Working Group for Coupled Modeling (WGCM), the CMIP panel, CLIVAR Scientific Steering Group (SSG), CLIVAR Ocean Model Development Panel (OMDP), scientists contributing model results to CMIP, and scientists analyzing ocean climate simulations.

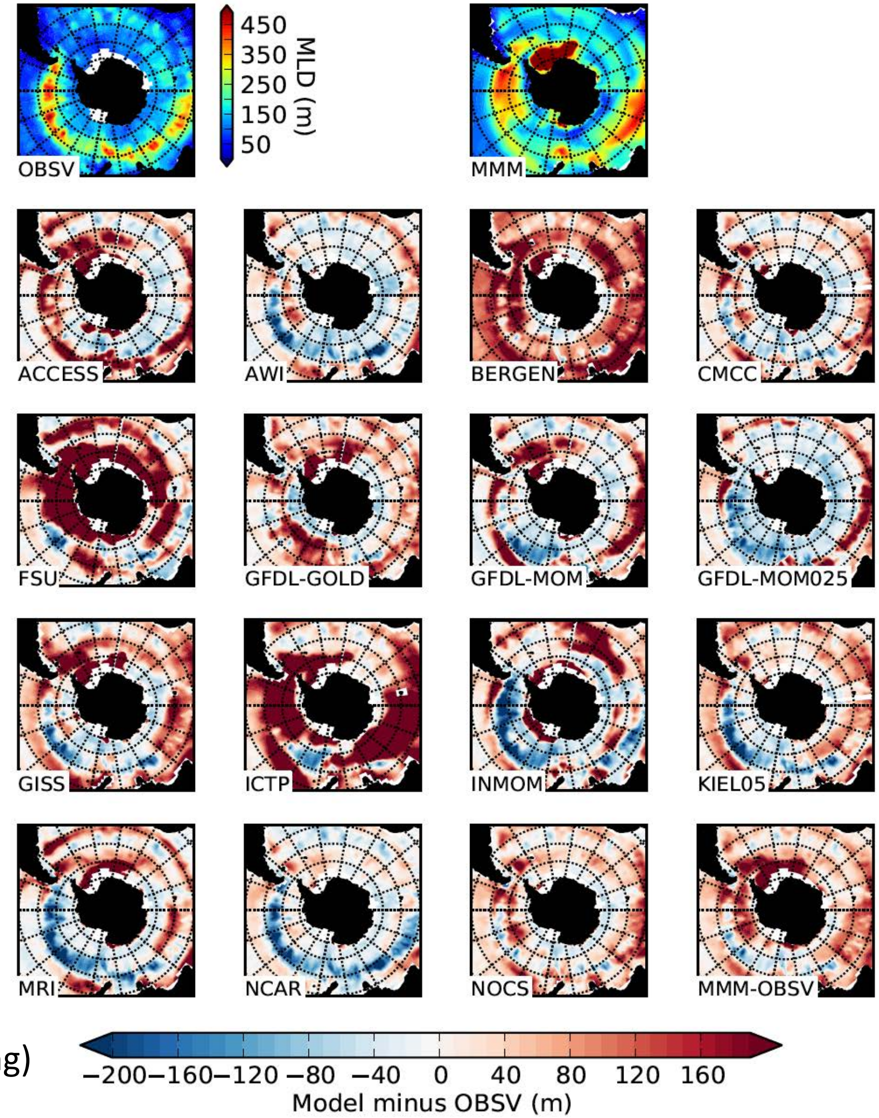
# OMDP Engagement in CLIVAR RF and Links to WCRP Grand Challenges

- Upwelling - E. Curchitser, A. Oschlies, G. Danabasoglu
- Decadal - G. Danabasoglu
  - Linked to regional climate information WCRP Grand Challenge
- Sea level - S. Griffies, S. Marsland, Y. Komuro
  - Linked to sea level WCRP Grand Challenge
- Heat uptake - A. M. Treguier, M. Winton, G. Nurser
  - Linked to sea level WCRP Grand Challenge

# OMDP Model Process Understanding and Development Efforts

- Improved representations of unresolved physics, e.g, mesoscale and submesoscale eddies,
- Southern Ocean biases (e.g., heat and carbon uptake),
- Western boundary current separation,
- Warm biases off the west coasts of continents (upwelling),
- Ocean physics and BGC interactions, e.g., Oxygen minimum zones,
- Land-ice – ocean interaction
- …

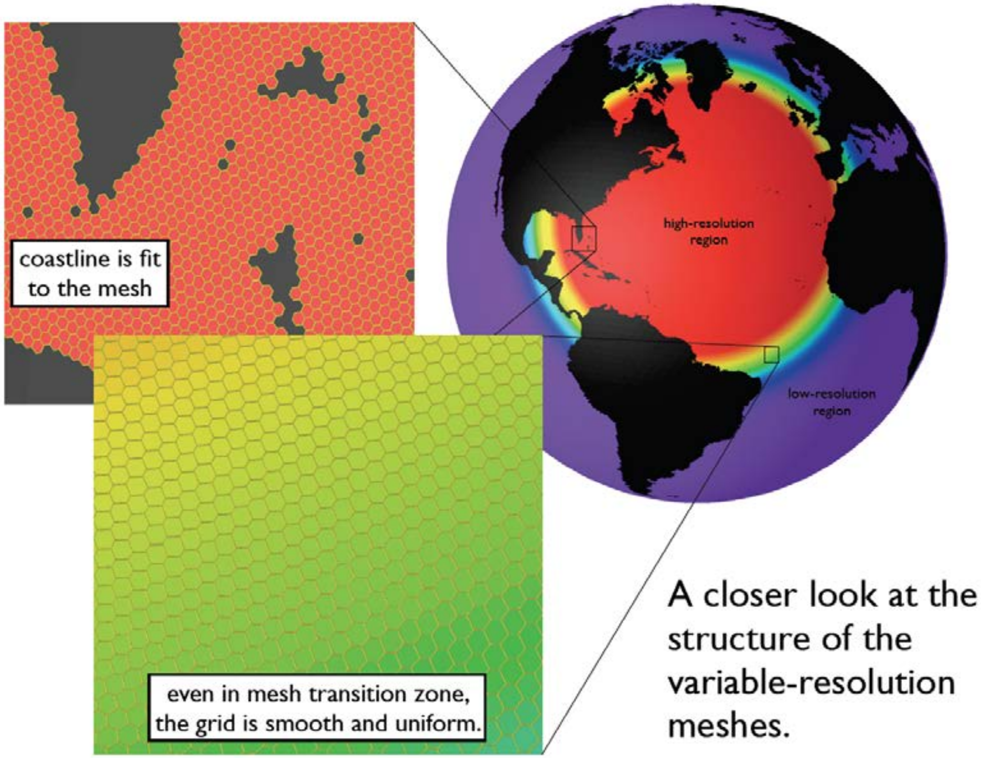
## Mixed Layer Depth (MLD)




Downes et al. (2015, Ocean Modelling)

# High Resolution Ocean Modeling and Challenges

- Model spin up and initialization: with costly high resolution ocean models, this becomes a major issue
- Parameterizations: scale selective / adaptive
- Forcing the ocean and coupling to atmosphere
- Technical issues - data, computing challenges
- Strategies regarding resolution and regionalisation
- Model verification




Model for Prediction Across Scales (MPAS-Ocean) (from Todd Ringler, LANL)

# Community Ocean Vertical Mixing (CVMix) Project

Michael Levy, Gokhan Danabasoglu, and Bill Large (NCAR)
Stephen Griffies, Alistair Adcroft, and Robert Hallberg (NOAA/GFDL)
Todd Ringler and Doug Jacobsen (LANL)

Community supported open source Fortran source code for parameterizing vertical mixing processes in numerical ocean models.

CVMix contributions being coordinated from various US and European process physics research groups. Examples include KPP boundary layer, surface wave mixing, Langmuir turbulence, internal gravity wave mixing.

It is anticipated that CVMix will become a community standard vertical mixing package for ocean climate models.

Beta release: Summer 2014
Version 1.0 release: Late Spring 2015

## Modeling challenges:

- Improved representations of unresolved physics, e.g, mesoscale and submesoscale eddies,
- Southern Ocean biases (e.g., heat and carbon uptake),
- Western boundary current separation,
- Warm biases off the west coasts of continents (upwelling),
- Ocean physics and BGC interactions, e.g., Oxygen minimum zones,
- …

## Observational needs:

- Deep observations (e.g., deep-Argo),
- Continuous observations,
- Full depth, basin-wide, AMOC and associated transports, including the Arctic Ocean,
- Carefully-derived error estimates for observational data,
- Expanded and improved paleo-climate data,
- …

# Representing Ocean-Related Activities within CLIVAR and WCRP

## Needed Communication Improvements

- OMDP representation at JSC meetings
  - To inform WCRP about ocean modeling activities
  - To be informed about ocean modeling needs of WCRP Grand Challenges
  - Note: WMAC is not a reporting mechanism – rather it serves an advisory role.
- CLIVAR SSG meetings need representation from WGCM, WGSIP, DCPP
- Support for activities that enhance interactions between process physicists, observationalists, and large-scale modelers
  - Organize/sponsor workshops where such activities are nurtured.
  - Integrated approach to improve models and understanding
  - Encourage international Climate Process Teams (CPTs) with clearly defined funding sources

# An example decadal-prediction study using CORE-II initial conditions



SPECIAL
Community Climate System Model CCSM4
COLLECTION

## A Decadal Prediction Case Study: Late Twentieth-Century North Atlantic Ocean Heat Content

Stephen Yeager, Alicia Karspeck, Gokhan Danabasoglu, Joe Tribbia, and Haiyan Teng

*National Center for Atmospheric Research, Boulder, Colorado*

(Manuscript received 12 October 2011, in final form 25 January 2012)

ABSTRACT

An ensemble of initialized decadal prediction (DP) experiments using the Community Climate System Model, version 4 (CCSM4) shows considerable skill at forecasting changes in North Atlantic upper-ocean heat content and surface temperature up to a decade in advance. Coupled model ensembles were integrated forward from each of 10 different start dates spanning from 1961 to 2006 with ocean and sea ice initial conditions obtained from a forced historical experiment, a Coordinated Ocean-Ice Reference Experiment with Interannual forcing (CORE-IA), which exhibits good correspondence with late twentieth-century ocean observations from the North Atlantic subpolar gyre (SPG) region. North Atlantic heat content anomalies from the DP ensemble correlate highly with those from the CORE-IA simulation after correcting for a drift bias. In particular, the observed large, rapid rise in SPG heat content in the mid-1990s is successfully predicted in the ensemble initialized in January of 1991. A budget of SPG heat content from the CORE-IA experiment sheds light on the origins of the 1990s regime shift, and it demonstrates the extent to which low-frequency changes in ocean heat advection related to the Atlantic meridional overturning circulation dominate temperature tendencies in this region. Similar budgets from the DP ensembles reveal varying degrees of predictive skill in the individual heat budget terms, with large advective heat flux anomalies from the south exhibiting the highest correlation with CORE-IA. The skill of the DP in this region is thus tied to correct initialization of ocean circulation anomalies, while external forcing is found to contribute negligibly (and for incorrect reasons) to predictive skill in this region over this time period.

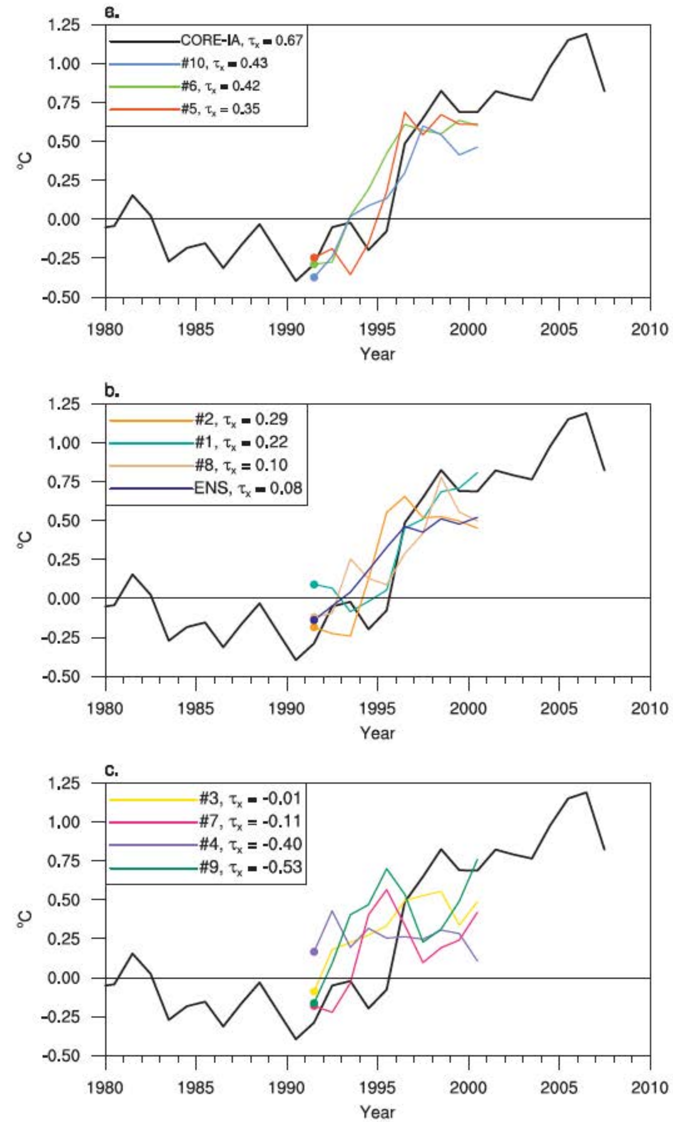
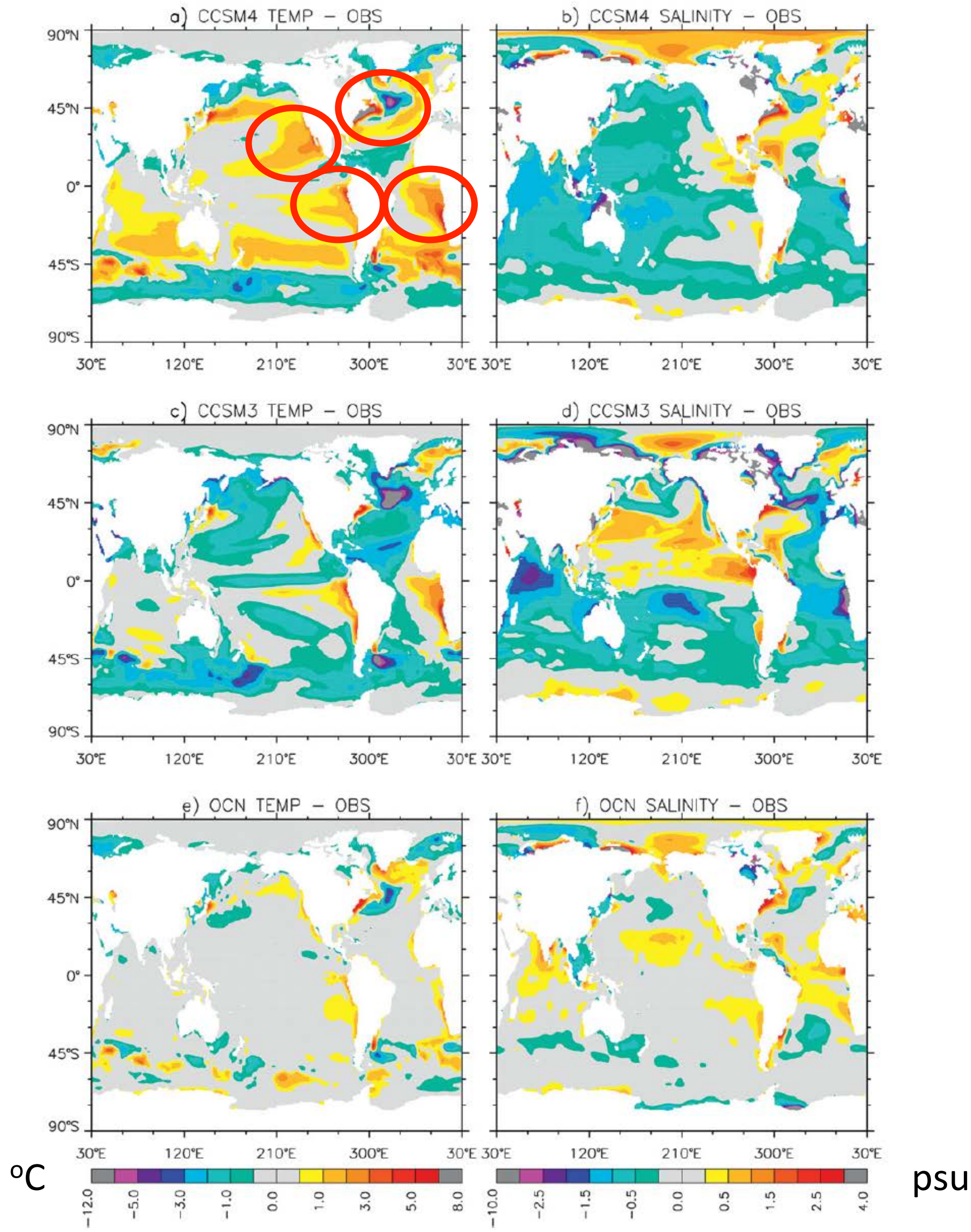



FIG. 9. Annual mean time series of 275-m heat content anomaly in the SPG box from CORE-IA as well as from the ensemble of 1991-initialized DP simulations. The experiments are grouped according to the magnitude of the mean JFM zonal wind stress anomaly ($\tau_x$, N m$^{-2}$) between 1991 and 1995, regionally averaged over the SPG box and computed relative to the CORE-IA 1961–2007 climatology. The panels are thus meant to correspond to (a) strong, (b) medium, and (c) weak winter NAO conditions in the pentad leading up to the observed regime shift. The ensemble mean is included in (b).

# Surface Temperature and Salinity Biases




Danabasoglu et al. (2012, J. Climate)

# U.S. CLIVAR Climate Process Teams (CPTs)

CPTs are highly collaborative projects involving teams of theoreticians, observationalists, process modelers, and coupled climate modelers formed around specific issues or key uncertainties in ocean and climate models.

Their primary goals are to expedite the incorporation of new parameterizations into models and to assess their climate impacts.

# Ocean-Related CPTs

- Mesoscale eddy – mixed layer interactions (completed)
- Gravity current overflows (completed)
- Ocean Mixing Processes Associated with High Spatial Heterogeneity in Sea-Ice (completed)
- Internal-Wave Driven Ocean Mixing (completion 2015)

The US CPT approach has proven successful at leveraging broad expertise to make tangible progress on the parameterization of processes key for ocean climate simulations.

# OMDP Role in Ongoing Parameterization Studies

Coordinated parameterization efforts are on-going at various modeling centers, in communication and sometimes in collaboration with other centers.

- OMDP and collaborators are leading many of these efforts.
- OMDP has supported various parameterization studies through panel meetings and workshops.
- Given the breath of OMDP membership and sponsored workshops, OMDP is keeping abreast of numerous such efforts.
- OMDP does not see a need to gather the ongoing community parameterization research under a working group umbrella.

# OMDP and Global Synthesis and Observations Panel (GSOP)

## Evaluation of forward model and reanalysis products

- An initial focus on AMOC and North Atlantic
- A paper has been submitted to a special issue of Climate Dynamics:

  Karspeck, Stammer, Kohl, Danabasoglu, Balmaseda, Smith, Fujii, Zhang, Giese, Tsujino, and Rosati: Comparison of the Atlantic meridional overturning circulation between 1960 and 2007 in six ocean reanalysis products.

- Use forward model & reanalysis products to improve both.

# OMDP and Southern Ocean Panel (SOP)

- Southern Ocean wind perturbation experiments
  - heat and carbon uptake
  - representation/parameterization of mesocale processes
- Antarctic freshwater perturbation experiments
  - better runoff prescription around Antarctica in CORE-II
  - freshwater perturbation sensitivity experiments
  - Ocean response to increased melt of land-ice (e.g., sea level)
- Development of standard Southern Ocean metrics, including AABW
- SOCCOM (Southern Ocean Carbon and Climate Observations and Modeling)
  - US-NSF funded observation and modeling initiative
  - Princeton (lead), Scripps, Arizona, Un of Washington, GFDL
  - SOP, OMDP, and SSG members are part of SOCCOM leadership (Talley, Russell, Winton, Griffies)

# Repository for Evaluating Ocean Simulations (REOS)

Ocean modelers worry about how to determine sanctioned datasets for use in evaluating simulations. To assist in resolving this limitation, OMDP developed a Repository for Evaluating Ocean Simulations (REOS). This web site aims to facilitate the research community's access to

- basic datasets and analyses/syntheses products,
- metrics for evaluating variability and processes including input by ocean basin proposed by the CLIVAR basin panels,
- guidance on ocean model validation,
- tools available for the community for ocean model data analysis,
- a comprehensive bibliography of papers, linked to the online articles where possible.

# OMDP Activities and Their Connections to CLIVAR Panels, CLIVAR RF, and WCRP

# Community Based Recommendations for CORE

Based on input and discussions from

- CLIVAR OMDP Workshop on High Resolution Ocean Climate Modeling (Kiel, April 2014)
- Pan-CLIVAR meeting (The Hague, July 2014)
- WGCM (Grainau, October 2014)
- Ocean modeling community, in general

Consensus that global ocean – sea-ice COREs are central to CLIVAR and WCRP science

With these encouragements, including from WGCM, OMDP has submitted an Ocean Model Intercomparison Project (OMIP) proposal to the CMIP panel

OMIP is based on CORE-II and it is merged with OCMIP

Example of CORE's recognition as the community standard for ocean – sea-ice simulations.

# Atlantic Panel – OMDP

- Collaborations on upwelling (CLIVAR RF)
  - sensitivity to ocean resolution and wind forcing
  - eastern boundary regions

- Studies related to Gulf Stream separation mechanisms/biases
  - Persistent North Atlantic biases related to the Gulf Stream separation and North Atlantic Current path