CLIVAR OCEANS & CLIMATE

variability, predictability and change

Simon Marsland
Gokhan Danabasoglu, Helge Drange, and Anna Pirani

WCRP's project on ocean-atmosphere interactions

To improve understanding and prediction
of ocean-atmosphere interactions
and their influence on climate variability and change,
to the benefit of society and the environment.

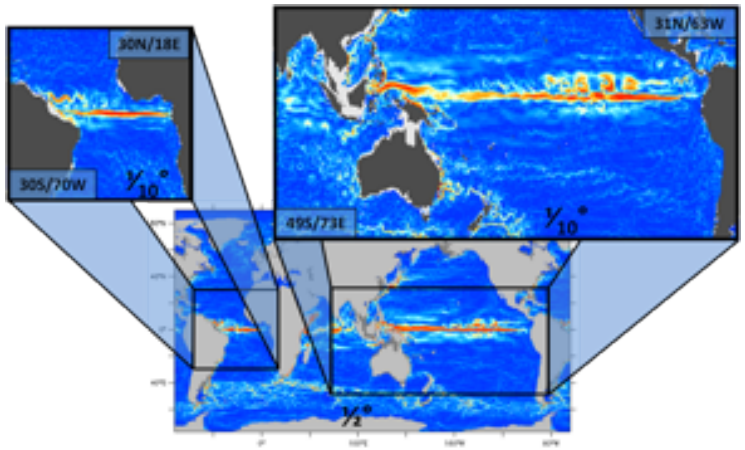
CLIVAR

Core Research Areas

- Anthropogenic Climate Change
- Decadal Variability, Predictability and Prediction
- Intra-to-Seasonal Variability, Predictability and Prediction

Core Capabilities

- Improved Atmosphere and Ocean Components of ESMs
- Data Synthesis and Analysis
- Ocean Observing System
- Knowledge Exchange
- Capacity Building



There is a continued need to address the fidelity of models in their representation of climate variability

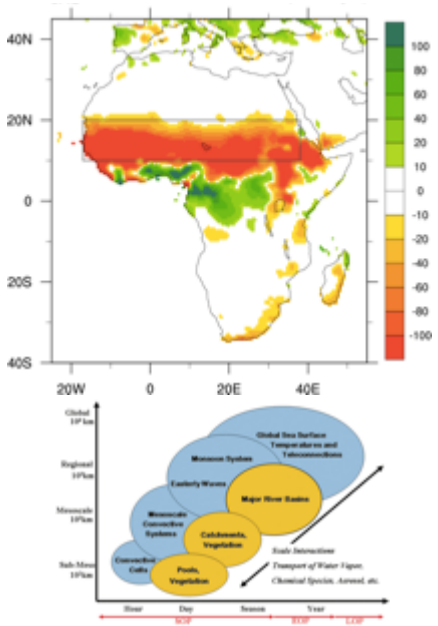
CLIVAR Objectives

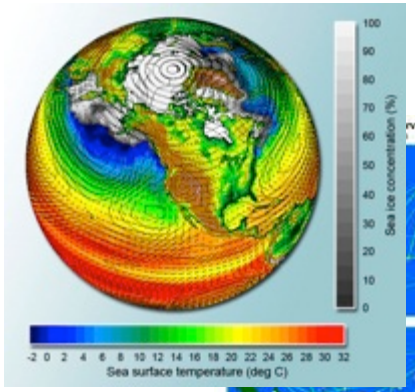
- Understand the causes of climate variability on intra-seasonal to centennial time-scales through observations, analysis, and modeling.

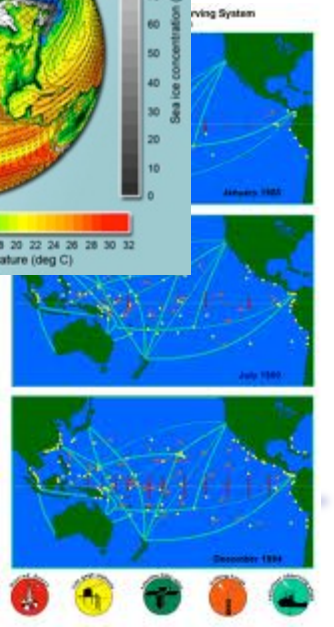
- Improve predictions of climate variability and change associated with both internal and external processes.

- Improve the atmosphere and ocean components of Earth-System Models.

- Extend observational climate record through assembly of quality-controlled data sets.

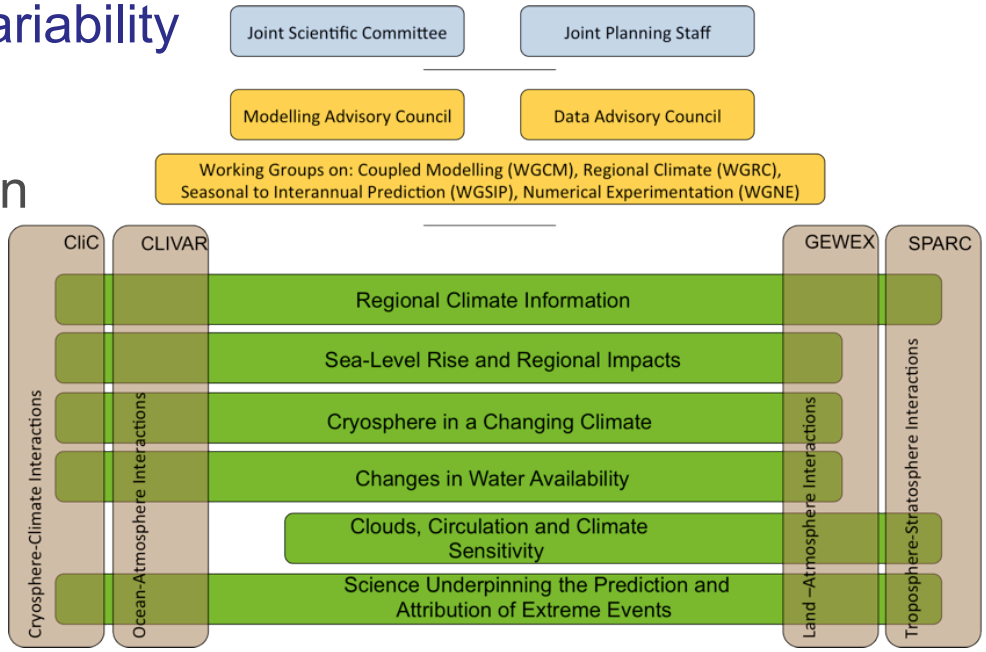






CLIVAR Research Opportunities

- Intraseasonal, seasonal and interannual variability and predictability of monsoon systems
- Decadal variability and predictability of ocean and climate variability
- Trends, nonlinearities and extreme events
- Marine biophysical interactions and dynamics of upwelling systems
- Dynamics of regional sea level variability
- …
- Planetary heat balance and ocean heat storage
- ENSO in a warmer world



WCRP Grand Challenges

Proposed CLIVAR Organization

Scientific Steering Group | ICPO

Core Panels

- Ocean Model Development Panel
- Global Synthesis and Observations Panel
- Atlantic Region Panel
- Pacific Region Panel
- Indian Ocean Region Panel
- Southern Ocean Region Panel
- Monsoons Panel
- ETCCDI
- Knowledge Exchange and Capacity Building Panel

GEWEX

Focused& Integrated Res. Opportunities

- predictability of monsoon systems
- Decadal climate variability and predictability
- biophysical interactions and dynamics of upwelling systems
- Dynamics of regional sea level variability
- Prediction and attribution of extreme events
- ENSO in a warmer climate
- ocean heat storage
- NEW

Key areas for progress in the next 5-10 years

Intraseasonal, seasonal and interannual variability and predictability of monsoons

- **Improved model constraint** on monsoon variability and change.
- **Better model representation** of the key processes involved in monsoon variability.
- **Improved prediction** of monsoon variability and change using land surface modelling and incorporation of land surface initialisation.
- **Enhanced understanding** of natural climate variability and anthropogenic change on monsoon systems.

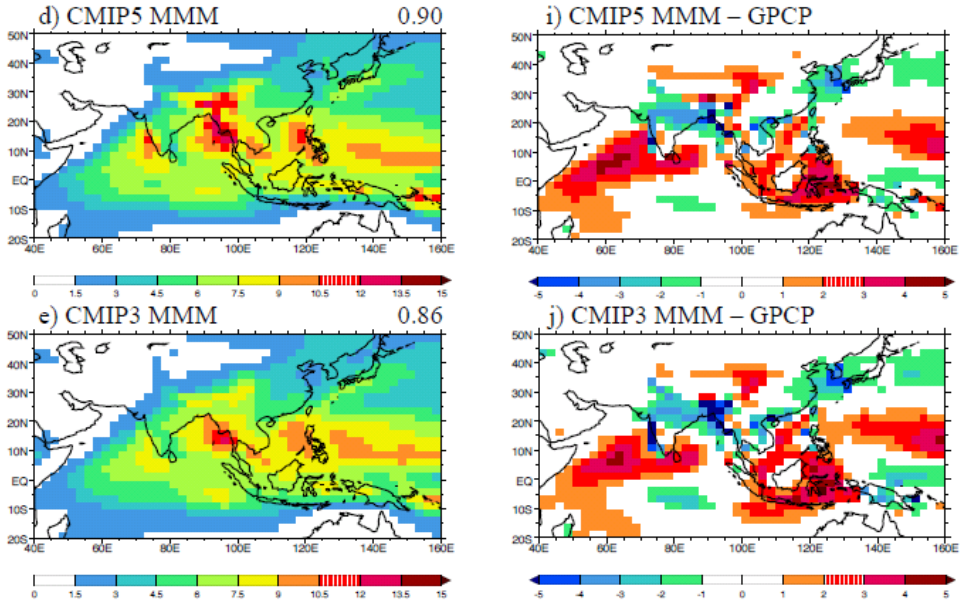
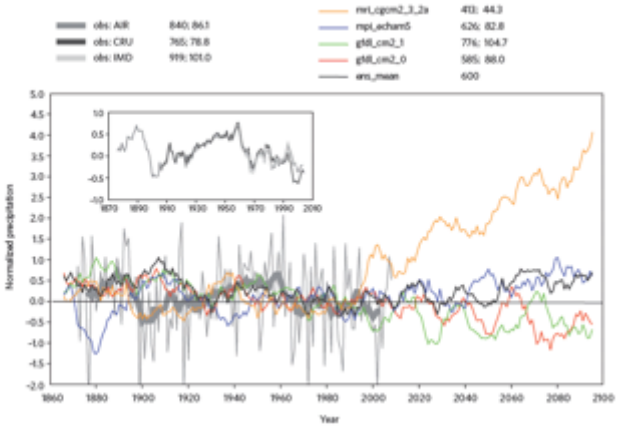


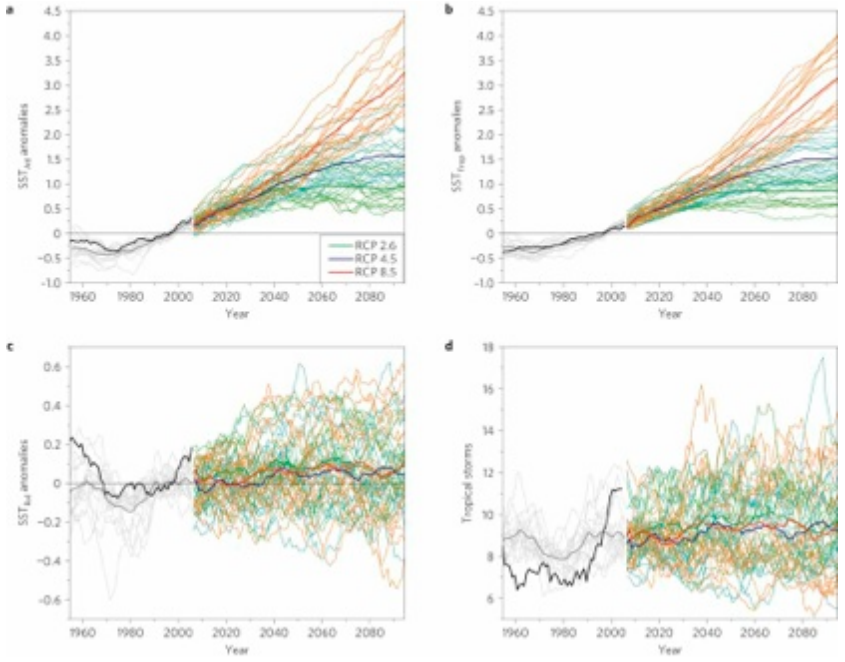
Figure shows large multi-model mean precipitation biases are present for the Asian summer monsoon in CMIP5 (from Sperber *et al*., 2012, *Clim. Dyn.*).

Figure demonstrates (for South Asian monsoon):
• Discrepancies between observed datasets.
• Apparent recent downward trend in monsoon rainfall
• Large decadal variability
• Uncertainty in future projections in SRES-A1B
(from Turner & Annamalai, 2012, *Nature Climate Change*).



Decadal variability and predictability of ocean and climate variability

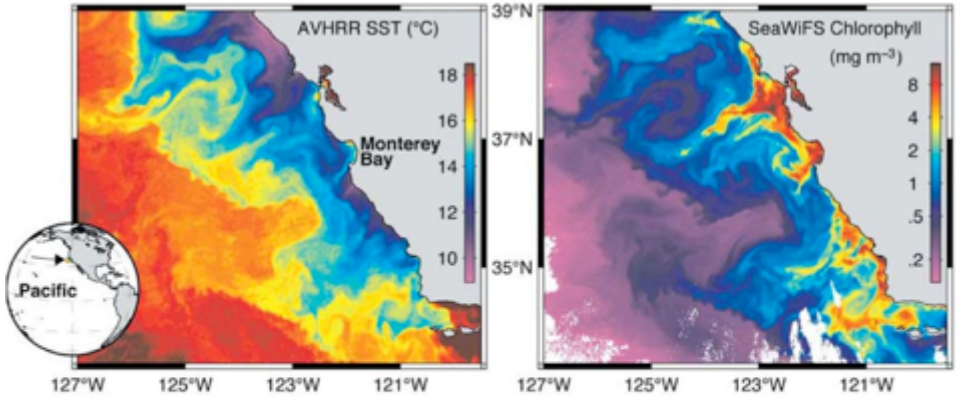
- **Improving understanding** of decadal variability and predictability.
- **Improving models** to better represent key processes associated with decadal variability.
- **Analysis and development** of current prediction potential of CMIP5 hindcasts.
- **Application of past data** sets including instrumental and proxy data.
- **Developing critical evaluations** of proposed climate/geo engineering methods.



Twenty-first-century projections of SST (top) and North Atlantic Tropical Storm frequency (bottom) using CMIP5 (Villarini and Vecchi 2012)

Marine biophysical interactions and dynamics of upwelling systems

- **Improving model representation** of upwelling processes.
- **Examining the cause of tropical bias** in climate models.
- **Examining interactions** between the physical, biogeochemical and marine ecological systems.
- **Understanding future variability** of upwelling systems, including changes in the biology and biogeochemistry associated with upwelling.



Satellite remote sensing imagery of the central California Current upwelling system. (a) Sea surface temperature (SST) from the Advanced Very High Resolution Radiometer (AVHRR) on August 14, 2000, and (b) surface chlorophyll from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) on August 16, 2000. Source: Ryan et al. (2005). Marine Ecology Process Series. 287:23-32.

ENSO in the climate system and how it may change in a warmer world

1. To better understand the role of different physical processes that influence ENSO characteristics.

2. To provide a synthesis of existing ENSO evaluation methods in GCMs.

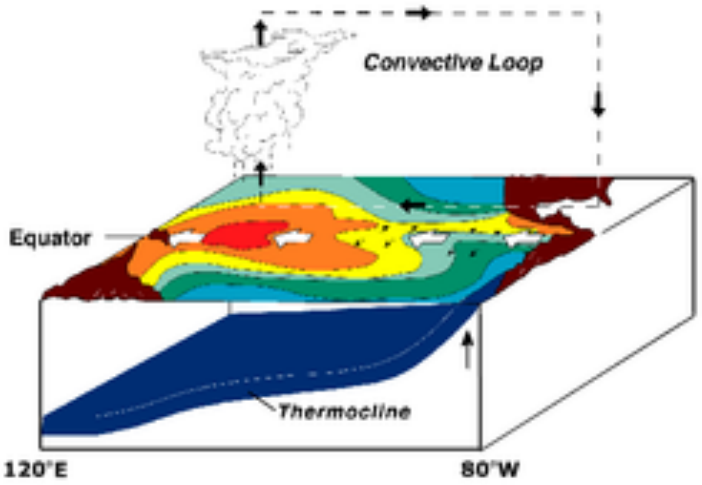
3. To propose ENSO evaluation protocols and develop a strategy for coordinated ENSO analysis of CMIP models, including development and maintenance of an interactive website, in coordination with the WGCM Metrics Panel.

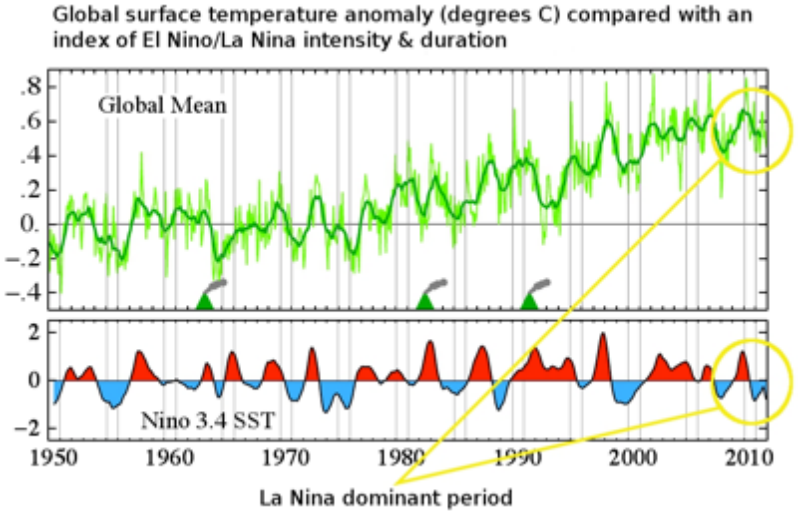
4. To identify new observations needed to better constrain ENSO processes, both for the current climate and for past climates (via paleo proxies).

5. To provide a better understanding of how ENSO might change in the future.

6. To promote and coordinate international collaboration between observationalists and modelers for studies of ENSO

7. To build research capacity by contributing to the development of the next generation of talent dealing with ENSO science.

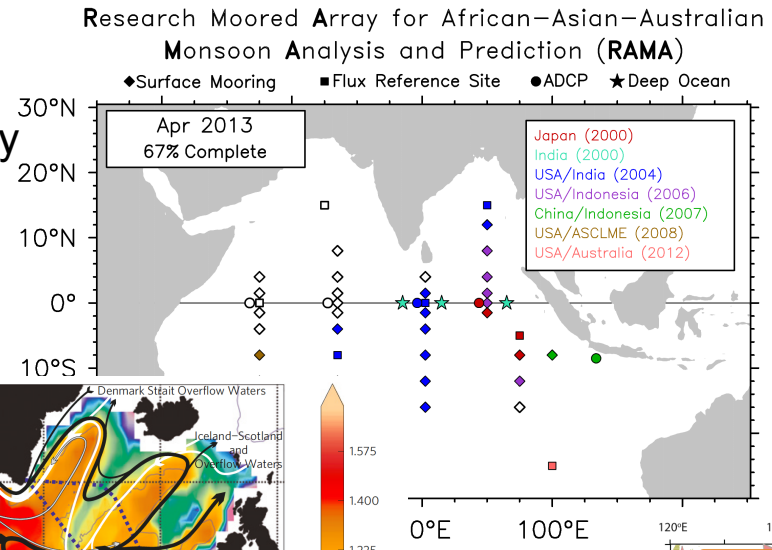




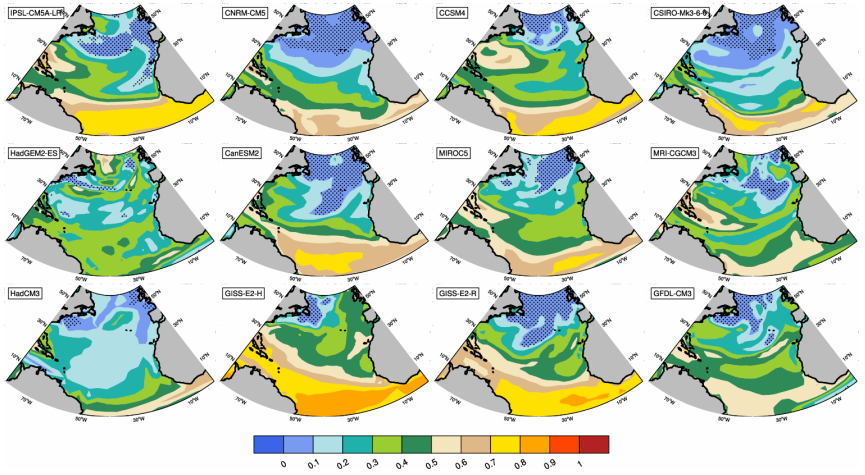
CLIVAR - WCRP Modeling

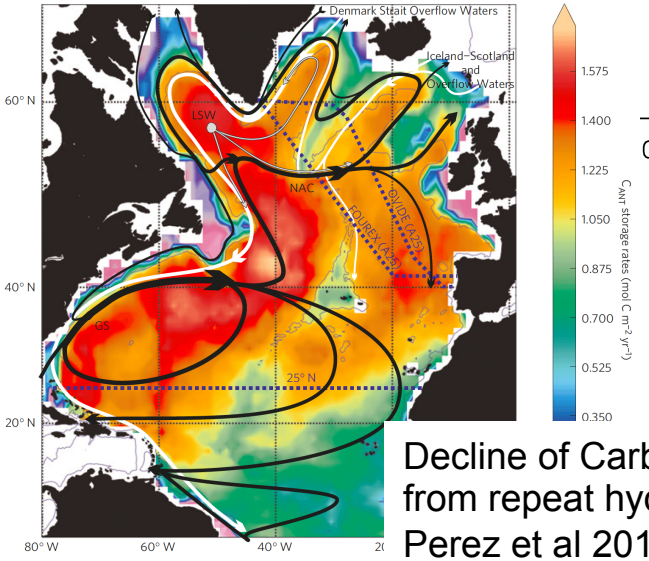
CLIVAR coordinates regional and global observational-process-modeling studies of the variability and predictability of the climate system.

RAMA Array

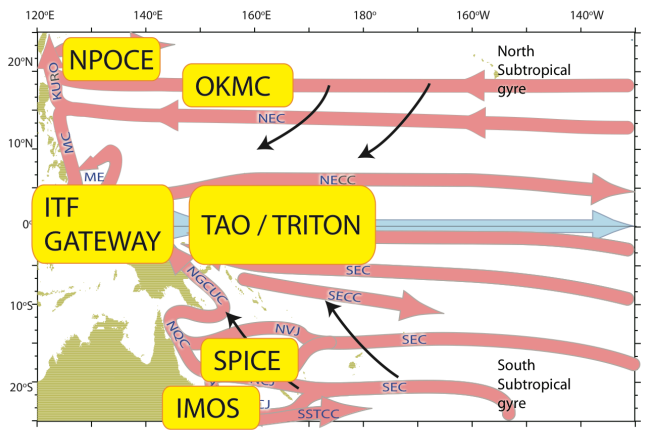


Forced variance versus internal variability, Terray 2012





Decline of Carbon uptake from repeat hydrography, Perez et al 2013



Multi-national, -institutional, and -investor process study programs

CLIVAR - WCRP Modeling

Need an integrated approach for progress on modeling issues

As an example - Global scale modeling issues impacting American monsoon predictability and climate change impacts:

• Fundamental issues exist in properly representing the large scale dynamics responsible for the seasonal evolution of the monsoons in the Americas

• Model biases in the tropical Atlantic may be influencing monsoon dynamics, also potentially affecting tropical storm formation and evolution, an important component of N. American monsoon rainfall

• Such issues affect the seasonal prediction of American monsoon behavior and the pervasive model biases and related lack of fidelity in the representation of the monsoon system are likely impeding our progress in understanding or projecting likely climate change impacts in the region

CLIVAR - WCRP Modeling

Opportunities exist

- Connecting CLIVAR activities to global model development
- Entraining CLIVAR in exploiting the multi-model data sets
- Developing a framework for CLIVAR input to coordinated modeling activities eg CMIP6 design
- Designing focused coordinated activities under the WCRP Grand Challenges/CLIVAR Research Opportunities

Hazards arise

- Availability of observational data and continued and sustained observations are crucial for success of CLIVAR modeling activities.
- A major concern of the CLIVAR ocean modeling community is the reductions in the TAO array.

CLIVAR Working Group on Ocean Model Development (WGOMD)

G. Danabasoglu (co-chair)	National Center for Atmospheric Research, USA
H. Drange (co-chair)	University of Bergen, Norway
E. Curchitser	Rutgers University, USA
M. Winton	Geophysical Fluid Dynamics Lab., NOAA, USA
S. Marsland	CSIRO, CAWCR, Australia
H. Johnson	Dept of Earth Science, University of Oxford, UK
H. Tsujin	Meteorological Research Institute, Japan Meteorological Agency, Japan
D. Holland	Courant Institute of Mathematical Sciences, New York University, USA
K. Fennel	Dalhousie University, Canada
G. Nurser	National Oceanography Center, UK

Emeritus

C. Böning	Institut für Meereskunde, Kiel, Germany
A. M. Treguier	Laboratoire de Physique de Océans, IFREMER, France
R. Gerdes	Alfred Wegener Institut für Polar- und Meeresforschung, Germany
E. Chassignet	Florida State University, USA

Working Group on Ocean Model Development (WGOMD)

- Workshops

WGOMD/SOP Workshop on Sea Level Rise, Ocean-Ice shelf Interactions and Ice Sheets (Hobart, Feb 2013)

4th WGNE Workshop on Systematic Errors in Weather and Climate Models (Exeter, April 2013)

WGOMD Workshop on High Resolution Ocean Modeling (Kiel, Spring 2014)

- Coordinated Ocean – ice Reference Experiments phase II (CORE-II)

The key goals of CORE are to provide a workable and agreeable experimental design for global ocean-ice models to be run for long-term climate studies and to establish a framework where the experimental design is flexible and subject to refinement as the community gains experience and provides feedback.

- Future WGOMD foci and activities

WGOMD/SOP Workshop on Sea Level Rise, Ocean/Ice Shelf Interactions and Ice Sheets

18-20 February 2013
CSIRO, Hobart, Australia

The workshop aims to bring together leading international scientists and early career scientists from the ocean, ice-sheet, ice-shelf, and sea level rise modeling and observational communities to:

- ***Identify priorities for reducing uncertainties in the projections of global and regional sea-level rise.***
- ***Evaluate the state-of-science of ocean and land-ice interactions.***
- ***Investigate pathways for the development of the next generation of climate models incorporating interactive land-ice components***

The workshop sessions will cover sea level rise, ocean - ice-shelf interactions, ice-sheet observation and modeling, ice-sheet - ice-shelf interactions, and related ocean modeling. In addition to the invited overview talks, the sessions will include more specialized, invited talks by early career scientists as well as contributed oral and poster presentations by the attendees.

Plenary Speakers:
John Church, CSIRO, Australia
Jonathan Gregory, Uni. Reading, UK
Stephen Griffies, NOAA/GFDL, USA
Patrick Heimbach, MIT, USA
Hartmut Hellmer, AWI, Germany
David Holland, Courant Institute, USA
Robert Kopp, Rutgers Uni., USA
Eric Larour, JPL, USA
Bill Lipscomb, LANL, USA
Eric Rignot, University of California, USA
Bernadette Sloyan, CSIRO, Australia
Detlef Stammer, Uni. Hamburg, Germany
Mark Tamisiea, NOC, UK

Organizing Committee:
Gokhan Danabasoglu, NCAR, USA
Helge Drange, Uni. Bergen, Norway
Matthew England, UNSW, Australia
Kevin Speer, FSU, USA
Simon Marsland, CSIRO, Australia
John Church, CSIRO, Australia
Catia Domingues, ACE CRC, Australia
Stephen Griffies, NOAA/GFDL, USA
David Holland, Courant Institute, USA
Patrick Heimbach, MIT, USA
Anna Pirani, CLIVAR, UK

For more information, to register, submit abstracts, and apply for early career scientist travel support, see:
http://www.clivar.org/organization/wgomd/sealevel

Registration is open until 15 November 2012

CLIVAR Exchanges Special Issue (summer 2013)

WGOMD High Resolution Ocean Modeling Workshop
Kiel, Germany - Spring 2014

Motivation: With the recent increases in computational power, more and more modeling groups are conducting high-resolution ocean-only and / or coupled simulations. Most of these activities appear to be quite independent despite encountering similar challenges and trying similar solutions. It is important to foster collaboration between these groups to expedite progress.

Relevance: High resolution modeling is needed for many scientific and societal applications, including regional climate information regarding sea level and extremes as well as decadal prediction efforts.

Target participants: Key high resolution ocean modelling communities. The idea is to keep the meeting relatively small for useful information exchange. About 50 participants.

Outcomes: Improved high resolution ocean modeling; expedited progress; improved communication; addressing common problems; progress towards scale-aware parameterizations.

The 12th Session of the WGOMD panel will follow this workshop.

CORE II Experiments

Coupled Ocean-ice Reference Experiments Phase II - *CORE-II*

An experimental protocol for ocean – sea-ice coupled simulations forced with inter-annually varying atmospheric data sets for the 1948-2007 period (Large and Yeager 2009).

These hindcast simulations provide a framework for

- evaluating, understanding, and improving ocean models
- investigating mechanisms for seasonal, inter-annual, and decadal variability
- evaluating the robustness of mechanisms across models,
- complementing data assimilation in bridging observations and modeling and in providing ocean initial conditions for climate prediction simulations.

Overarching hypothesis: Global ocean – sea-ice models integrated using the same inter-annually varying atmospheric forcing data sets produce qualitatively very similar mean and variability in their simulations.

CORE-II PROTOCOL

- The models are integrated for a minimum of 300 years, corresponding to 5 cycles of the 60-year forcing period.
- After an assessment of degree of equilibrium achieved, the solutions from the last cycle are analyzed.
- The participating groups are free in their choices of sea-ice models and surface salinity restoring in their ocean components.

Project Report

Datasets and protocol for the CLIVAR WGOMD Coordinated Ocean-sea ice Reference Experiments (COREs)

October 2012

ICPO Publication Series No. 184
WCRP Informal Report No: 21/2012

The CORE datasets are periodically updated (currently through 2009) and collaboratively supported by NCAR and GFDL.

CORE II PARTICIPATING GROUPS - 18 models:

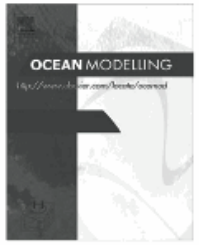
- Australia: CSIRO (ACCESS)
- France: CERFACS, CNRM
- Germany: AWI, IfM-GEOMAR (KIEL)
- Italy: CMCC, ICTP
- Japan: MRI (free, DA)
- Norway: U. Bergen
- Russia: RAS (INMOM)
- UK: NOCS
- USA: FSU, GFDL-GOLD, GFDL-MOM, MIT, NASA GISS, NCAR

Level, isopycnal, hybrid, mass, and sigma coordinates; unstructured finite element ocean model; mostly nominal 1^{o} resolution

Contents lists available at SciVerse ScienceDirect

Ocean Modelling

journal homepage: www.elsevier.com/locate/ocemod



CORE II Special Issue

Papers submitted or in preparation:

- North Atlantic simulations with a focus on the Atlantic meridional overturning circulation, Part I: Mean states; Part II: Variability (Danabasoglu, Yeager, & Bailey, et al.),
- Global and regional sea level (Griffies & Yin, et al.),
- Arctic Ocean and sea-ice (Gerdes, Wang, & Drange, et al.),
- The Antarctic Circumpolar Current and Southern Ocean overturning circulation with a focus on eddy compensation (Farneti & Downes, et al.),
- Evolution of Southern Ocean water masses and ventilation (Downes & Farneti, et al.),
- South Atlantic simulations (Treguier & Weiner, et al.),
- Ocean circulation in temperature and salinity space (Nurser & Zika, et al.).

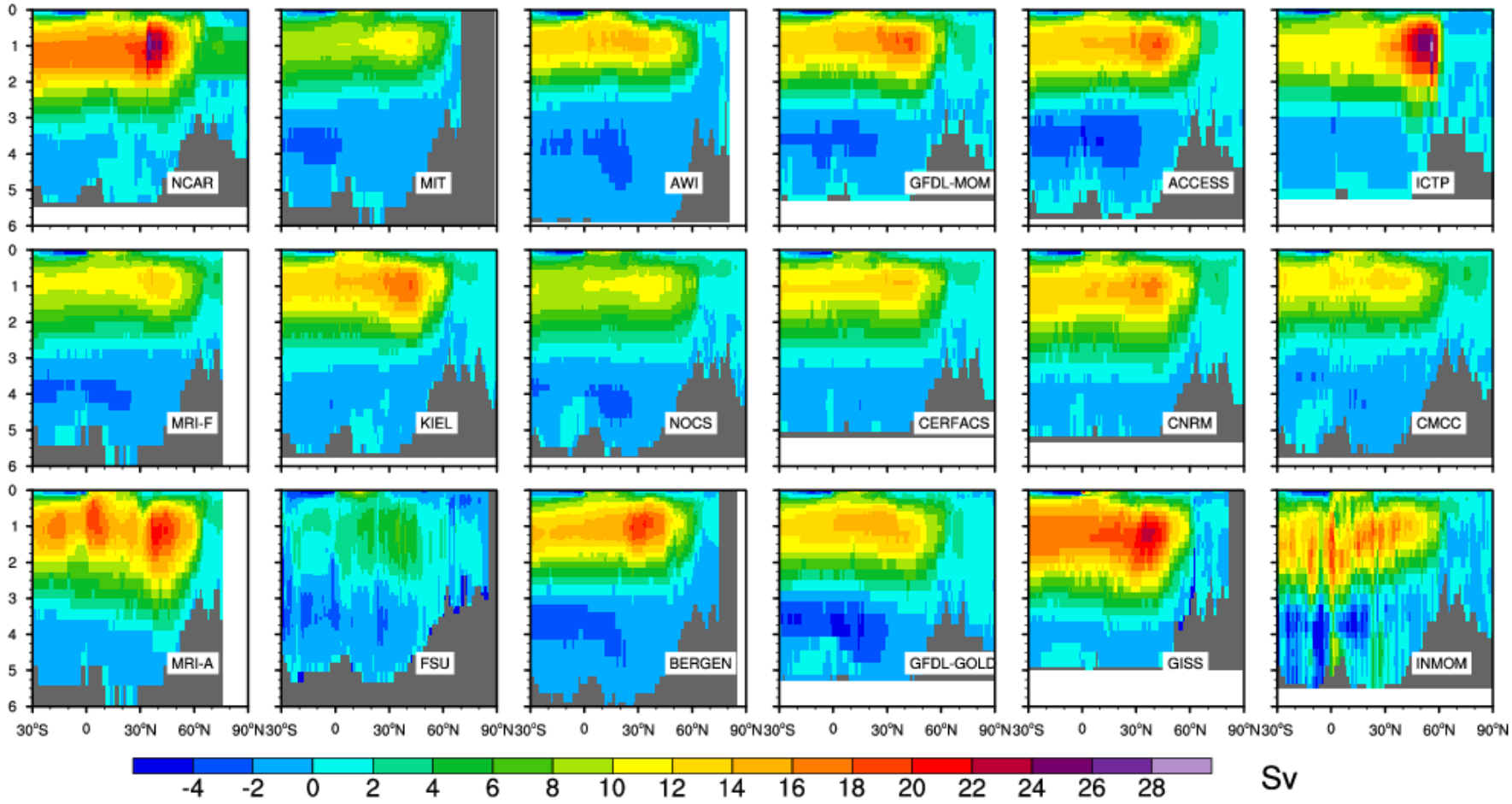
- We plan to actively promote the use and analysis of the CORE-II solutions.
- Other coordinated analysis efforts are encouraged from the CLIVAR community, particularly with a focus on the Pacific and Indian Ocean basins.
- The data are freely available. NCAR has agreed to host and curate the datasets on its ESGF node and is currently testing the service with the NCAR datasets. Information will be available soon on how to access the centralized dataset via the CORE-II website. In the meantime, people can contact the individual modeling groups to obtain the data.

North Atlantic Simulations in Coordinated Ocean-ice Reference Experiments phase-II (CORE-II) (Mean States)

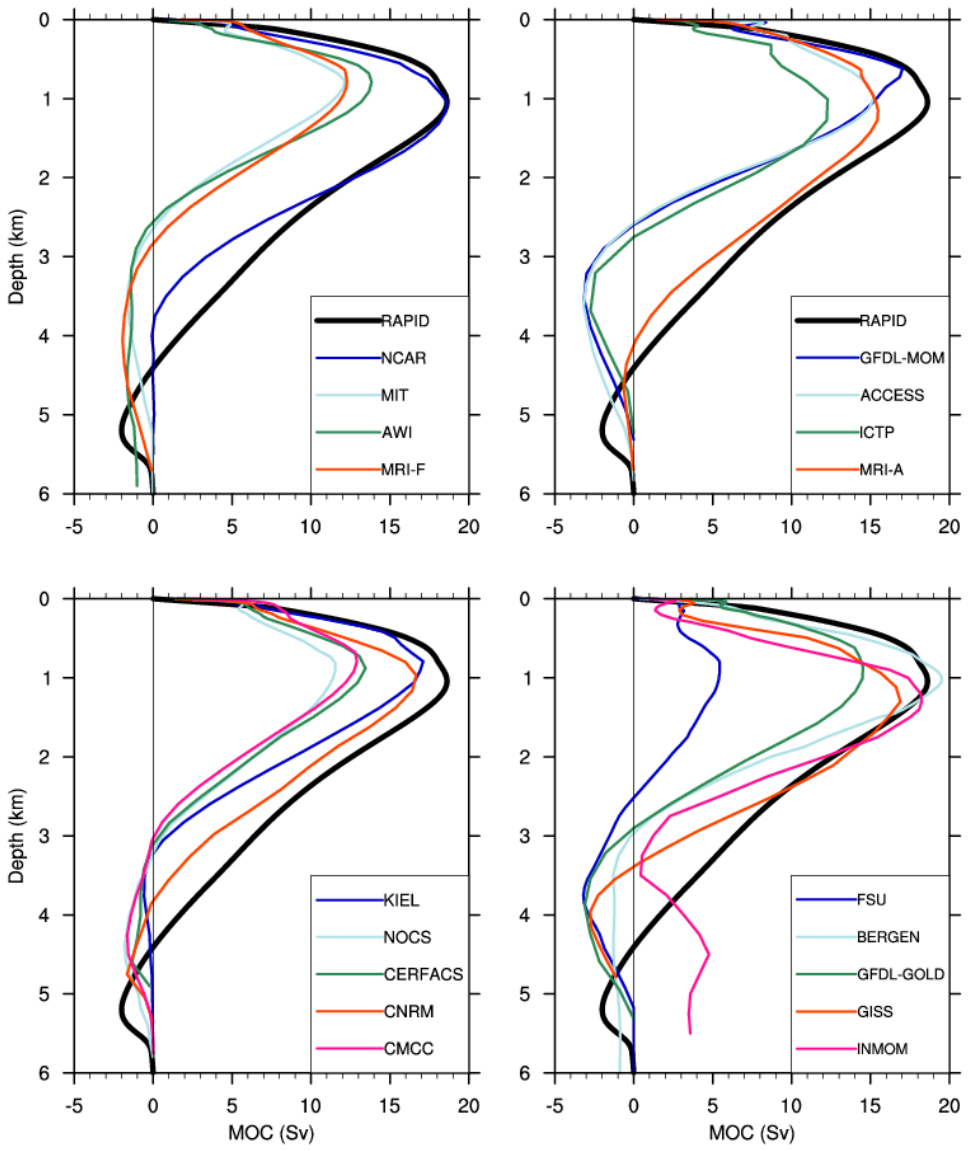
G. Danabasoglu, S. G. Yeager, D. Bailey,
E. Behrens, M. Bentsen, D. Bi, A. Biastoch, C. Boening,
A. Bozec, V. M. Canuto, C. Cassou, E. Chassignet, A. C.
Coward, S. Danilov, N. Diansky, H. Drange, R. Farneti, E.
Fernandez,
P. G. Fogli, G. Forget, Y. Fujii, S. M. Griffies, A. Gusev,
P. Heimbach, A. Howard, T. Jung, M. Kelly, W. G. Large,
A. Leboissetier, J. Lu, G. Madec, S. J. Marsland, S. Masina,
A. Navarra, A. J. G. Nurser, A. Pirani, D. Salas y Melia,
B. L. Samuels, M. Scheinert, D. Sidorenko, A.-M. Treguier,
H. Tsujino, P. Uotila, S. Valcke, A. Voldoire, Q. Wang

Submitted

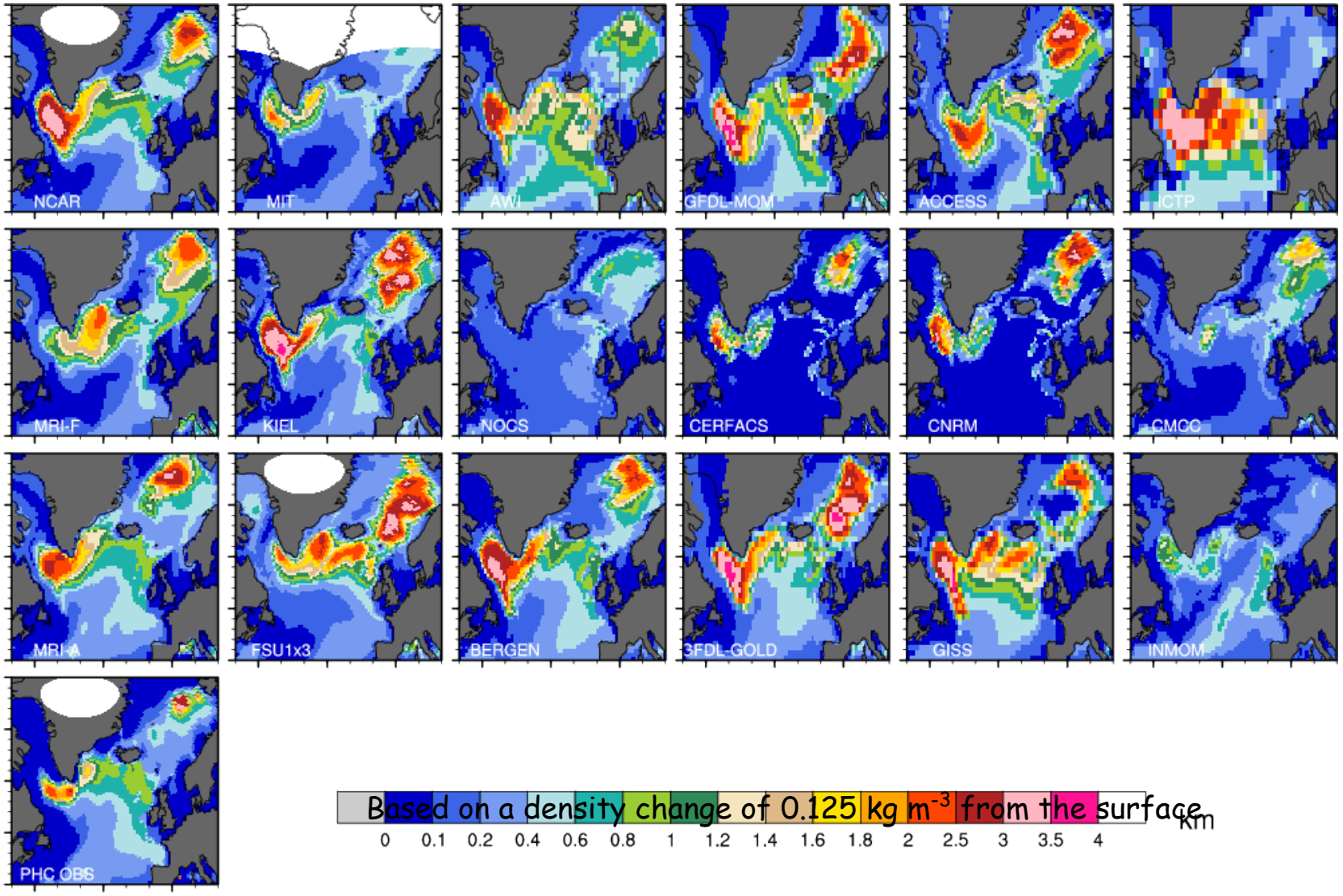
AMOC Mean (1988-2007) in Depth Space



AMOC at 26.5ºN (2004-2007)

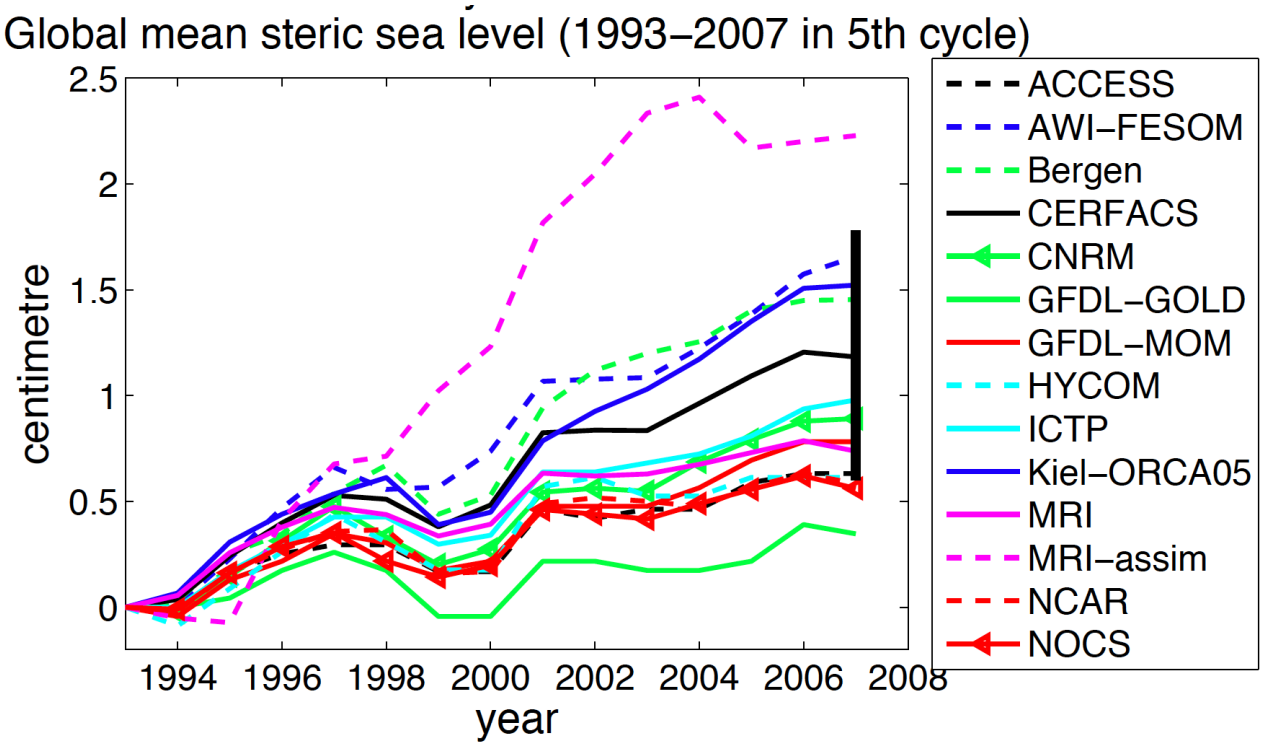


March-Mean Mixed Layer Depth (1988-2007)



Global and regional sea level in a suite of interannual CORE-II hindcast simulations

Stephen M. Griffies[1,*], Jianjun Yin[b], Susan C. Bates[c], Erik Behrens[d], Mats Bentsen[e], Daohua Bi[f], Arne Biastoch[d], Claus Böning[d], Alexandra Bozec[g], Christophe Cassou[h], Eric Chassignet[g], Gokhan Danabasoglu[c], Sergey Danilov[i], Catia Domingues[j], Helge Drange[e], Paul J. Durack[k], Riccardo Farneti[l], Paul Goddard[b], Richard J. Greatbatch[d], Jianhua Lu[g], Eric Maisonnave[h], Simon J. Marsland[f], Katja Lorbacher[f], A. J. George Nurser[m], Davis Salas y Mélia[n], Jaime B. Palter[o], Bonita L. Samuels[a], Markus Scheinert[d], Dmitry Sidorenko[i], Laurent Terray[h], Anne-Marie Treguier[h], Yu-heng Tseng[c], Hiroyuki Tsujino[p], Petteri Uotila[f], Sophie Valcke[h], Aurore Voldoire[n], Qiang Wang[i], Steve Yeager[c], Xuebin Zhang[q]



WGOMD Near Term Plans (1-3 years)

- Complete CORE-II related projects (until early next year).
- Explore forcing ocean models with partial coupling, i.e., with an interactive atmosphere, but controlled forcing, e.g.,
  - wind stress perturbations in the Southern Ocean (SOP),
  - Katabatic wind perturbations off Antarctica (SOP)
- Explore role of ocean physics / dynamics in setting the character of climate response functions with the CORE framework

WGOMD Key Activities over next 1-10 years

- Model biases and improve model physics, considering biogeochemistry and ecosystems,
- High resolution modeling and regional/coastal modeling (scale aware parameterizations),
- Sea level and interactions with ice sheets,
- Role of ocean in decadal variability (e.g., AMOC),
- Operational oceanography and data assimilation.

Pan CLIVAR meeting: July 16-18 2014 in The Hague, Netherlands, joint with GEWEX

(all panels and WGs members meet at the same time)

Opportunities exist

- Connecting CLIVAR activities to global model development
- Entraining CLIVAR in exploiting the multi-model data sets
- Developing a framework for CLIVAR input to coordinated modeling activities eg CMIP6 design
- Designing focused coordinated activities under the WCRP Grand Challenges/CLIVAR Research Opportunities

Thank You!

Simon Marsland (CSIRO)
Gokhan Danabasoglu (NCAR)
Helge Drange (Geophysical Inst., Uni of Bergen)
Anna Pirani (CLIVAR Project Office)