U.S. AMOC Science Team

www.usclivar.org/amoc

An U.S. inter-agency program

NASA Earth Science Division
Satellite data analyses, modeling and space-based observations

NOAA Climate Program Office
Observing systems, monitoring, climate modeling

NSF Geosciences Program
Process studies, models, and observations

U.S. Department of Energy
Climate and process modeling, climate impacts

U.S. AMOC Program Scientific Objectives

- Implementation and evaluation of AMOC observing system;
- Assessment of AMOC state, variability, and change;
- Assessment of AMOC variability mechanisms and predictability;
- Assessment of the role of AMOC in global climate and ecosystems

65 funded projects (~125 scientists) supported by 4 agencies

U.S. AMOC Program Organization

Science Team: Comprised of PIs and co-PIs, performing relevant research designated by the funding agencies

Task Teams:

1. AMOC Observing System Implementation and Evaluation
   (Chair: Patrick Heimbach; Vice-chair: Chris Meinen)
2. AMOC State, Variability, and Change
   (Chair: Rong Zhang; Vice-chair: LuAnne Thompson)
3. AMOC Mechanisms and Predictability
   (Chair: Rym Msadek; Vice-chair: Steve Yeager)
4. Climate Sensitivity to AMOC: Climate/Ecosystem Impacts
   (Chair: Yochanan Kushnir; Vice-chair: Ruth Curry)

Executive Committee:

Science Team chair: Gokhan Danabasoglu

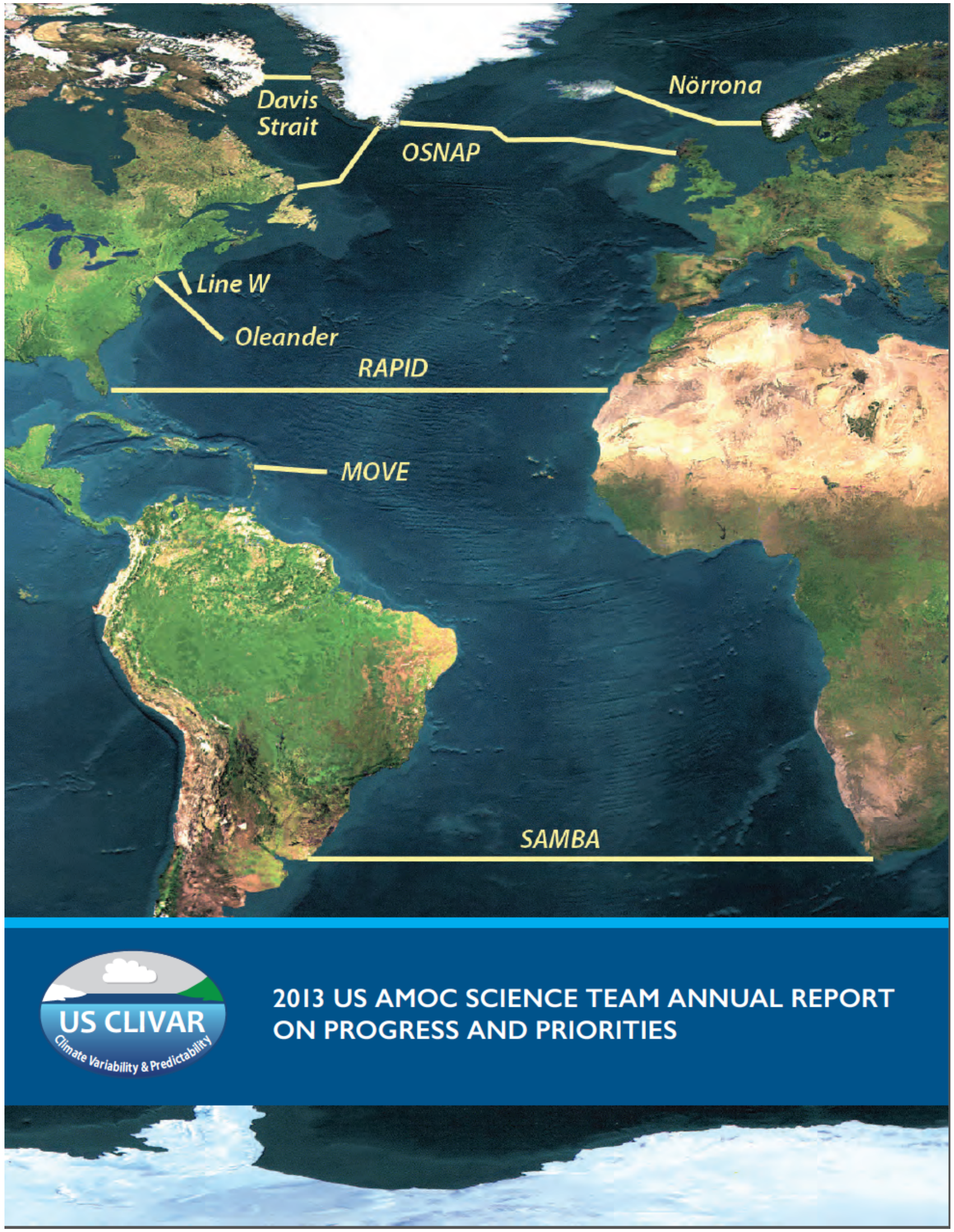
+ Task Team chairs and vice-chairs

The U.S. AMOC Executive Committee is charged with:

- Identifying research needs to achieve the program objectives;
- Encouraging and developing research activities to address these needs;
- Coordinating ongoing U.S., and whenever possible international, research activities to address the program objectives;
- Summarizing the state of the science and program progress;
- Developing input to AMOC program reports as necessary.

U.S. AMOC Program History

- January 2007: AMOC identified as near-term priority by JSOST
- October 2007: U.S. AMOC Implementation Plan released
- March 2008: U.S. AMOC Science Team formed
- May 2009: 1st Annual PI Meeting (Annapolis, MD)
- June 2010: 2nd Annual PI Meeting (Miami, FL)
- July 2011: Joint U.S./U.K. AMOC Science Conference (Bristol, U.K.)
- August 2012: 3rd U.S. AMOC Meeting (Boulder, CO)
- 2012-2013: External Review of the Program
- July 2013: Joint U.S./U.K. International AMOC Science Meeting (Baltimore, MD)
- **09-11 September 2014: 4th U.S. AMOC Meeting (Seattle, WA)**
- **20-24 July 2015: Joint U.S./U.K. International AMOC Science Meeting (Bristol, U.K.)**



COVER IMAGE: Components of the AMOC observing system; Credit: Jack Cook, Woods Hole Oceanographic Institution

External Review of the U.S. AMOC Program

Lynne Talley (SIO), Galen McKinley (U. Wisconsin-Madison), and Noel Keenlyside (U. Bergen)

The review report is very positive in its assessment of the US AMOC program objectives, structure, and progress. The executive summary of the report summarizes the findings of the committee as such:

"The US CLIVAR AMOC program is successful, impressive, and stimulating. It is producing major innovations and discoveries around a major scientific topic - the mechanisms and variability of the overturning circulation in the Atlantic and its interaction with other climate elements. The science is relevant to a large community of climate scientists and policy makers. The presence of a large cohort of scientists at the US AMOC meeting, and the alternation of the meeting between the US and its international partners, are indications of the viability, strong science, and enthusiasm around this program.

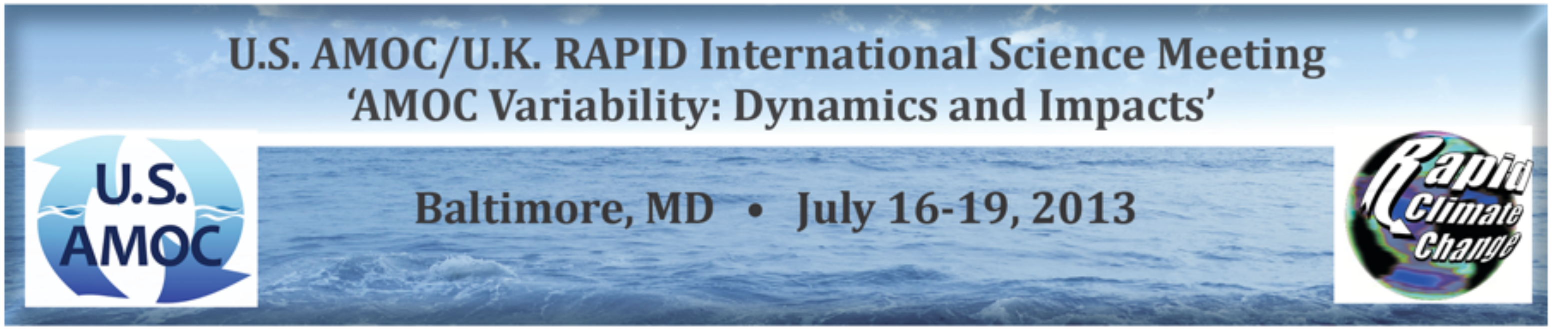
The unique interagency funding structure that supports the US AMOC program is strongly commended, with excellent communication between the funding managers in the several agencies that support US AMOC (NSF, NASA, NOAA, DOE), and with the US CLIVAR Project Office. The creation of this large program from individually funded proposals in the absence of the desired targeted federal funding is commended."

External Review of the U.S. AMOC Program

The external review committee report has also made several recommendations to further improve the US AMOC program. These recommendations include:

- concerns with adequacy of funding;
- improving communication with new PIs, i.e., science team members;
- expanding and updating the web presence; formalizing leadership rotation procedures; and
- setting long-term goals in addition to near-term priorities, by actively seeking input from the science team members and encouraging more discussion.

Several of the committee recommendations have been already adopted, such as formalizing leadership rotation procedures; having task team teleconferences to improve communication; expanding our email list to include co-PIs, etc.; and hosting the 2014 Annual Meeting near a university (University of Washington). Next steps will include a discussion of the external review committee report with the broader Science Team at the 2014 Seattle meeting.



Jointly organized by U.S. AMOC and U.K. RAPID scientists; Attended by 100+

Following set of international collaborative research needs were identified:

- Faster real time availability of RAPID data
- Adoption of new technologies as they mature (for example, autonomous gliders) to sustain the monitoring arrays over many decades
- Development of proxies of AMOC variability using long records of sea level, SST and paleo data
- Development of data assimilation and other estimation techniques to combine available oceanic and meteorological observations in ways consistent with the equations governing the two systems
- Testing of variability mechanisms in models
- Understanding of the impact of ocean model biases in coupled model simulations
- Identification of similarities and differences between the AMV in the historical record, the corresponding variability in coupled climate models, and their relationships to AMOC
- Exploration of the role of aerosol forcing in impacting the climate of the North Atlantic sector
- Investigation of AMOC variability and biogeochemistry/carbon sequestration

A meeting summary is in press in the Bulletin of the American Meteorological Society.

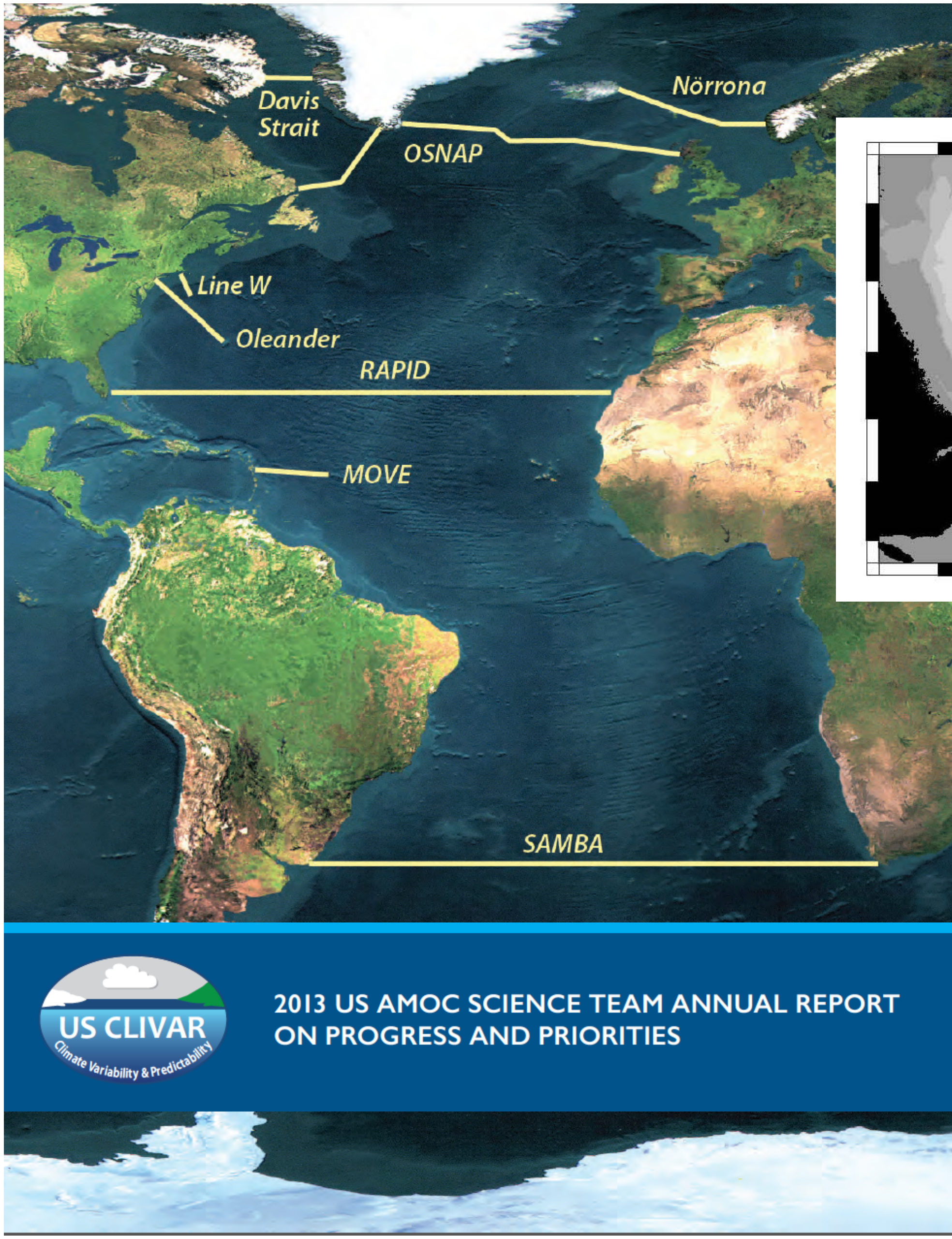
Near-Term Research Priorities

- Expand the existing observing system to better capture the deep ocean and quantify the role of deep temperature and salinity signals in controlling AMOC variability, i.e., deep Argo, full-depth gliders, and enhanced moored observations
- Improve understanding of the meridional coherence (or lack thereof) of AMOC and the mechanisms that control AMOC changes via enhanced observing systems, i.e., OSNAP and SAM, and model simulations
- Develop multivariate fingerprinting techniques for AMOC by combining model simulations with observations, including paleoclimate reconstructions
- Develop a set of metrics for AMOC, e.g., AMOC in both depth and density space; water mass transformation; relationships between surface heat and freshwater fluxes and AMOC; connections to climate signals such as the NAO
- Focus assimilation and hindcast modeling efforts on reaching a consensus on the variability of the AMOC over the past few decades throughout the Atlantic basin, and on placing realistic uncertainty bounds on these estimates
- Investigate AMOC and MHT relationships, in various models (forward, assimilation, non-eddy-resolving, eddy-resolving) in comparison with observational data to understand the reasons for differences, or biases, in the relationship between model AMOC intensity and MHT in models

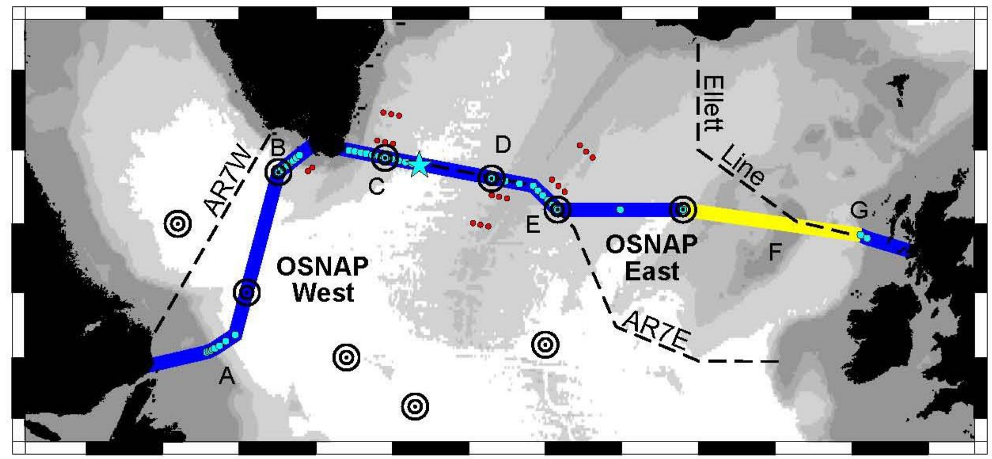
Near-Term Research Priorities (continued)

- Develop a synthesis of existing observations, including synthesis of proxy data, to discriminate various model-based proposed mechanisms and feedbacks against the observational data
- Identify if there is a connection between AMOC and the recent hiatus in global warming and deep ocean heat uptake and, if so, investigate controlling mechanisms
- Understand linkages between the subpolar North Atlantic with accelerating changes in the Arctic, including changes in sea-ice extent and heat and fresh water exchange between the Arctic and the North Atlantic
- Clarify the relative roles of heat, freshwater, and momentum forcing, Nordic Sea overflows, Southern Ocean and Arctic Ocean teleconnections, coupled air-sea feedbacks, and mesoscale processes on AMOC variability and stability
- Assess AMOC impacts on the cryosphere, particularly Arctic sea-ice and the Greenland Ice Sheet
- Improve understanding of how AMOC variability affects ocean-atmosphere exchanges of carbon, biogeochemical cycles, and associated changes in marine ecosystems
- Understand the response of climate to AMOC variability
- Assess AMOC impacts on global and regional sea level change

AMOC Observing System



OSNAP: Overturning in the Subpolar North Atlantic



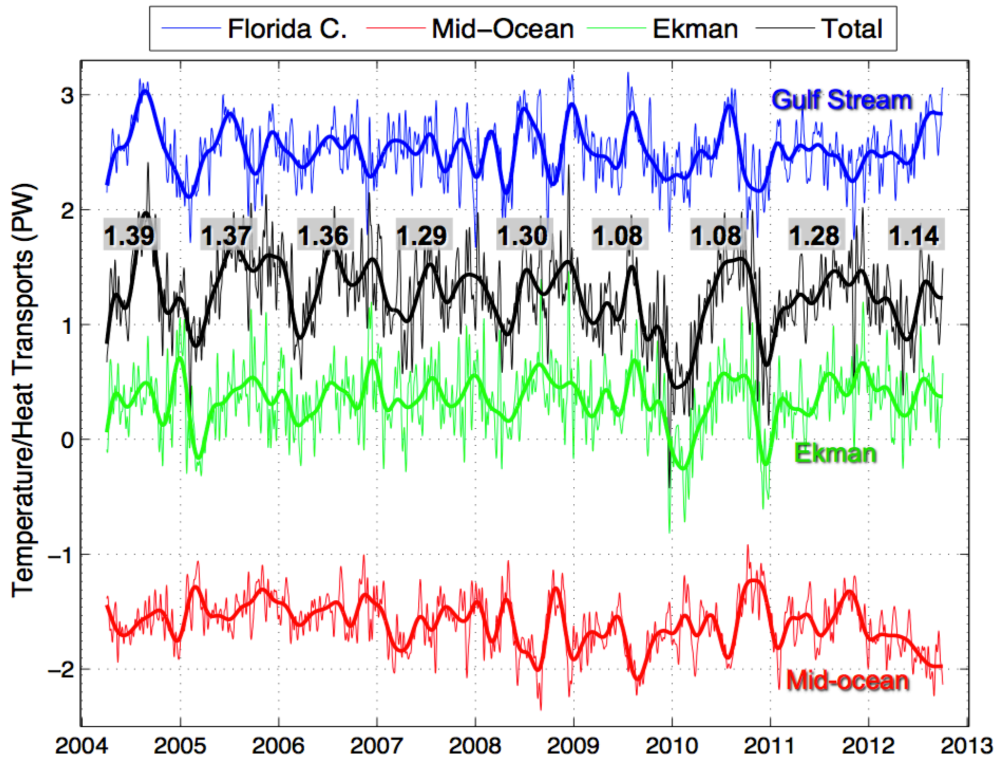
Lozier et al.

The specific OSNAP objectives are:

- Quantify the subpolar AMOC and its intra-seasonal to interannual variability via overturning metrics, including associated fluxes of heat and freshwater.
- Determine the pathways of overflow waters in the NASPG to investigate the connectivity of the deep boundary current system.
- Relate AMOC variability to deepwater mass variability and basin-scale wind forcing.
- Determine the nature and degree of the subpolar-subtropical AMOC connectivity.
- Determine from new OSNAP measurements the configuration of an optimally efficient long-term AMOC monitoring system in the NASPG.

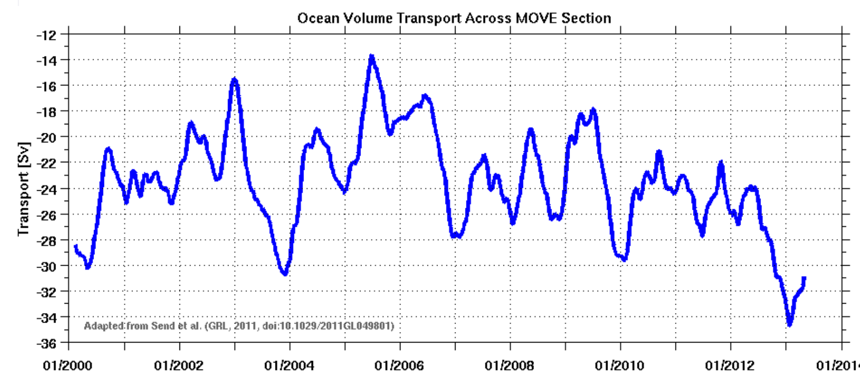
Heat and Volume Transport Variability from Observations

RAPID-MOCHA Array 26.5°N



Johns et al.

MOVE: Meridional Overturning Variability Experiment (16°N)

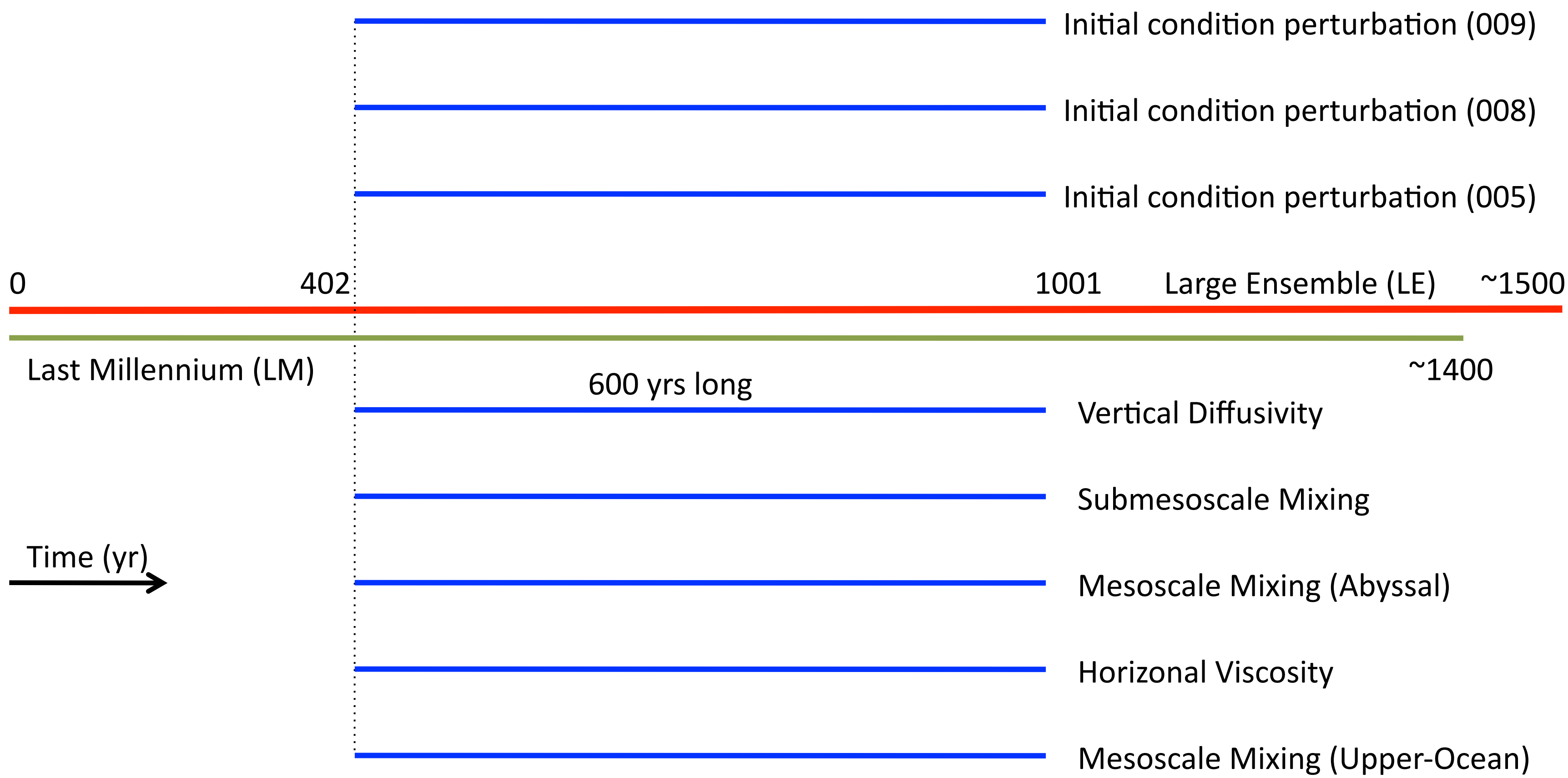


Send et al.

AMOC Mechanisms and Variability

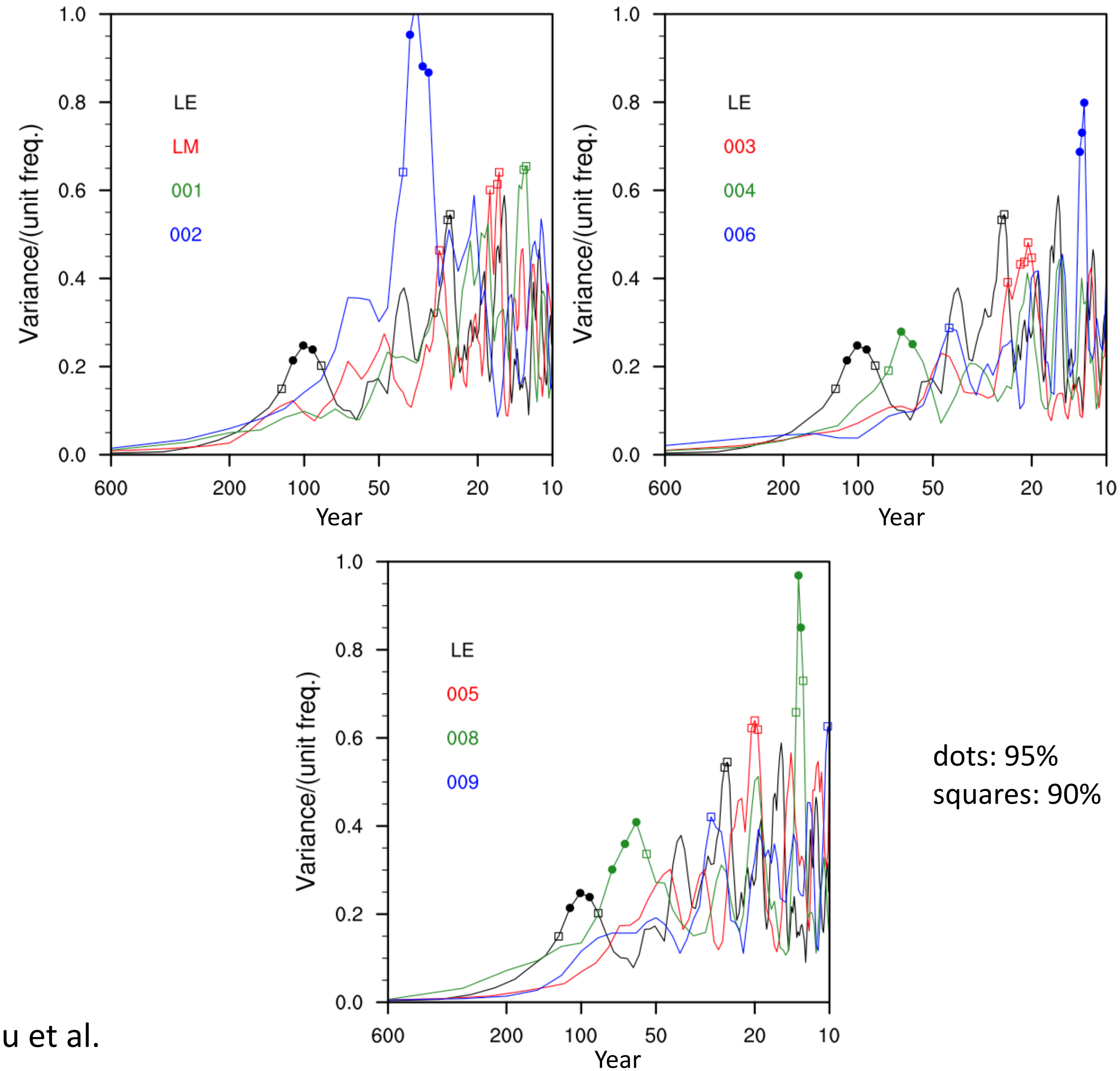
Experiments with Community Earth System Model (CESM)

CESM w/ CAM5 FV; nominal 1° horizontal resolution; pre-industrial control



Danabasoglu et al.

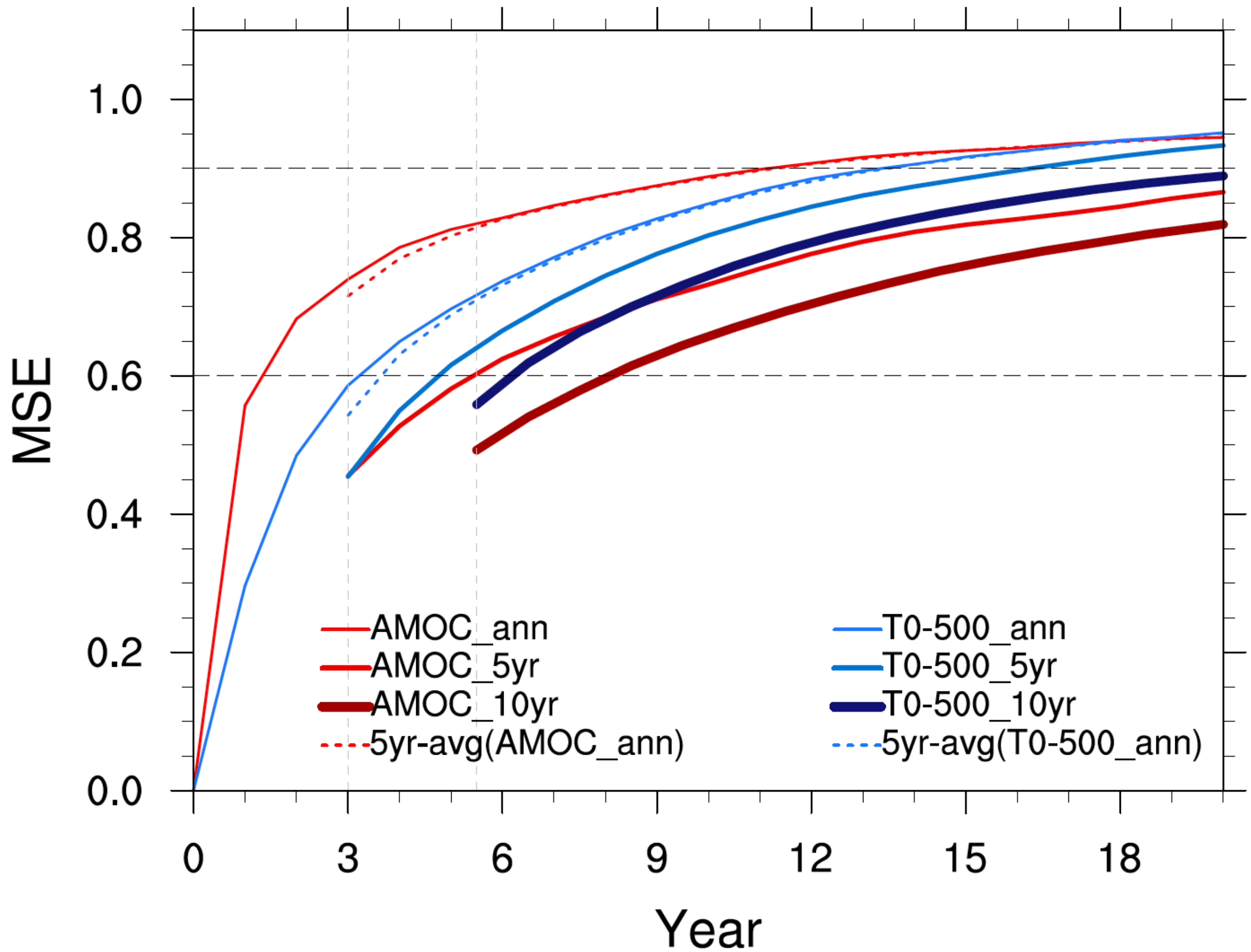
AMOC Index Power Spectra



dots: 95%
squares: 90%

Danabasoglu et al.

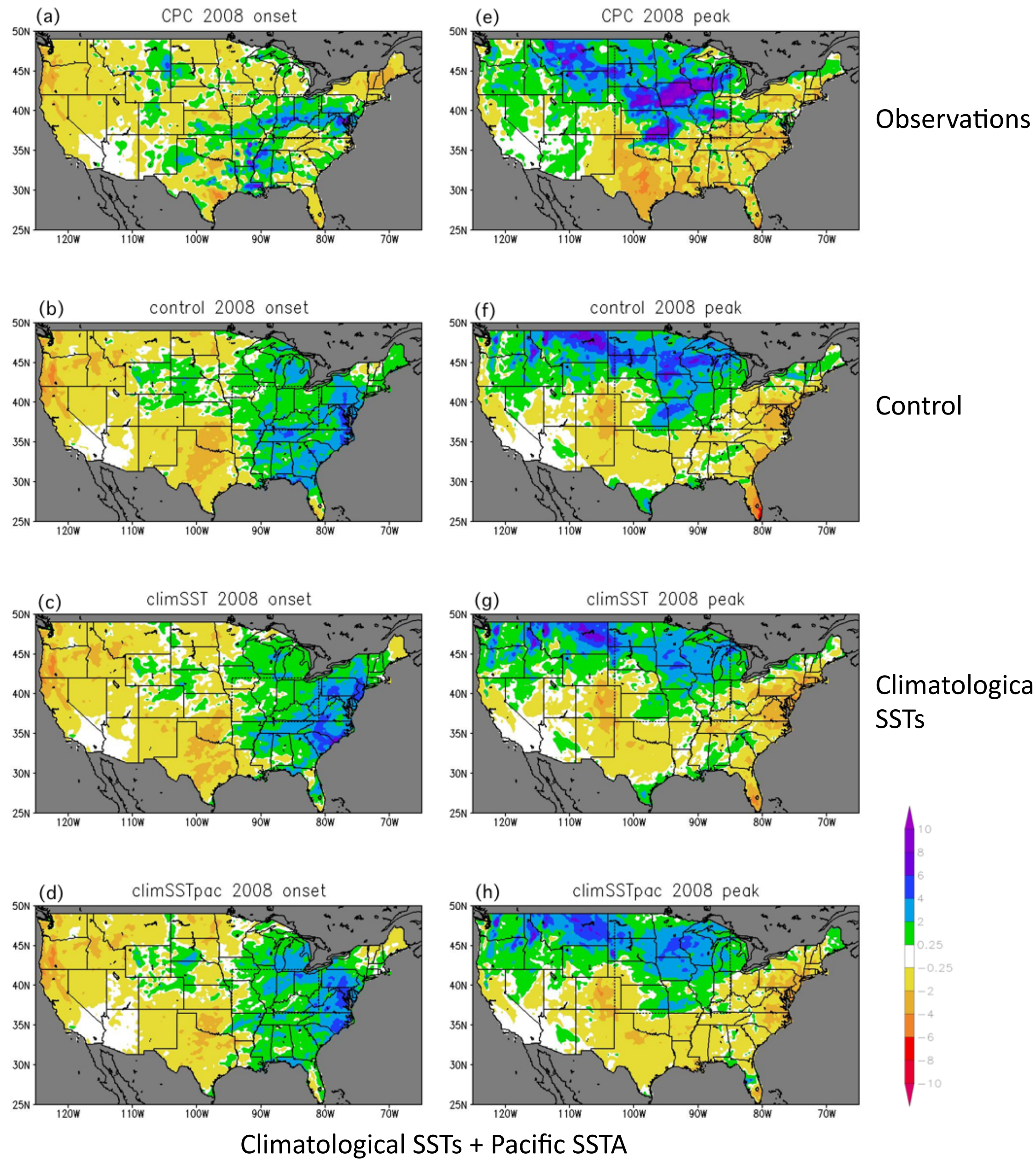
AMOC Predictability



Branstator & Teng (2014, J. Climate)

AMOC Climate Impacts

Simulation of the 2008 Midwest floods using WRF: Precipitation anomaly (mm/day) relative to the corresponding 1981-2000 base period during the 2008 onset (early May) and peak (late May to mid-June) periods, respectively.

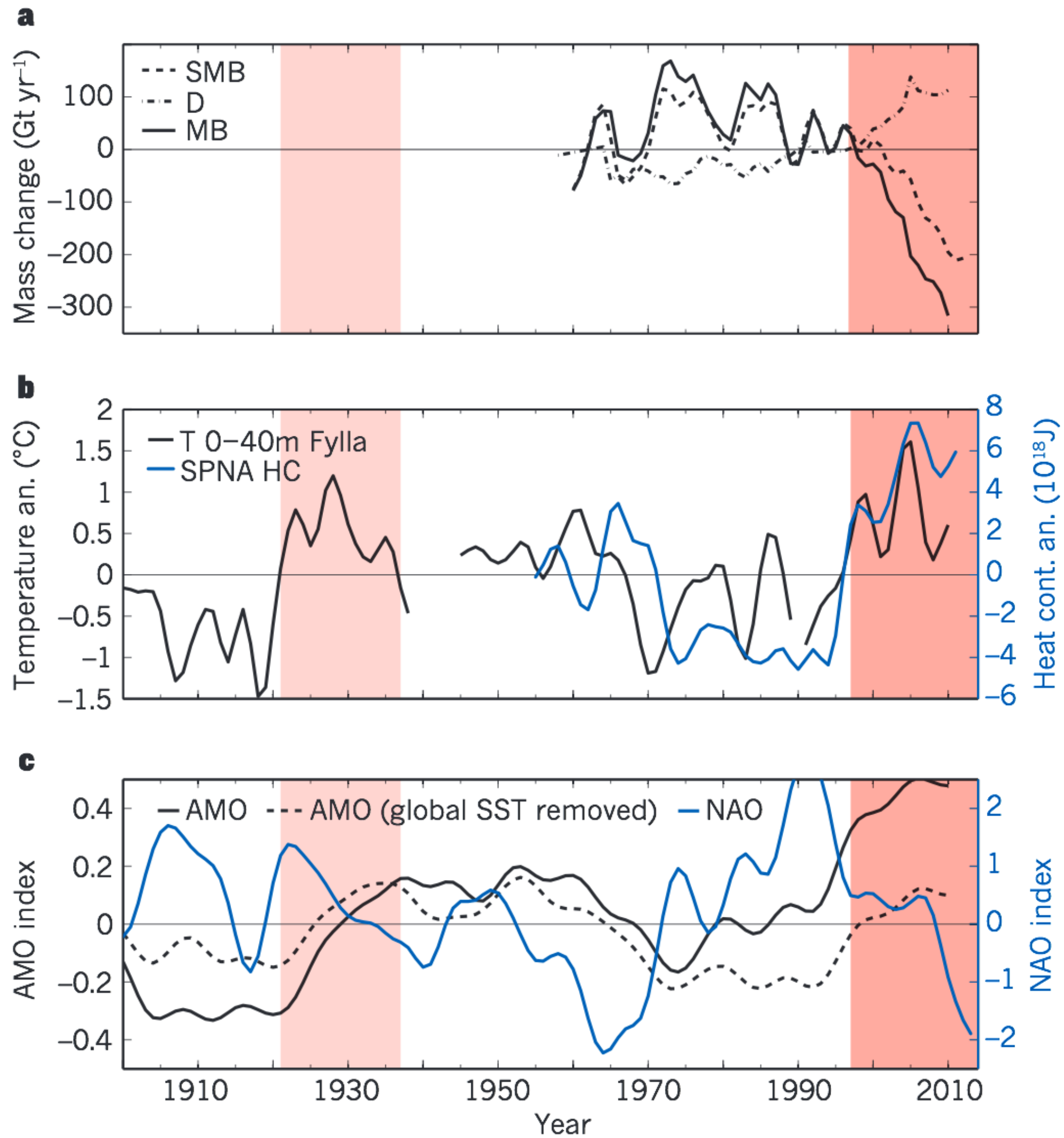


Saravanan & Chang

Glacier – Ocean Coupling in the northern North Atlantic

Retreat of Greenland's outlet glaciers is occurring at a time when the waters of the subpolar North Atlantic are the warmest on record

Anomalies of:
MB: Mass balance
SMB: Surface mass balance
D: ice discharge
T 0-40: Mean temperature of the upper 40 m at Fylla Bank, west Greenland
SPNA: Subpolar North Atlantic heat content (0-700m)
AMO: Atlantic Multidecadal Oscillation with and without the global SST trend
NAO: North Atlantic oscillation (NAO) winter index



Straneo & Heimbach (2013, Nature)

(Photo courtesy Daniel Schwen, Wikimedia Commons)

The meeting is intended to provide an opportunity to:

- *facilitate dissemination of recent research results;*
- *to identify gaps in our understanding and measurement of AMOC;*
- *aid in coordination of efforts or in starting new collaborations among the Science Team members;*
- *discuss the program's emerging near-term priorities as well as its long-term goals.*

A special session of the meeting will highlight research and focus discussion on AMOC linkages with climate variability and change.

78 abstracts submitted; 20-25 oral and 50+ poster presentations;
Break-out and discussion sessions