On the Evolution of AMOC Fingerprint in the North Atlantic

Jinting Zhang* and Rong Zhang**

* Applied Physics Laboratory/School of Oceanography, University of Washington, Seattle, Washington, USA

** GFDL, NOAA, Princeton, New Jersey, USA

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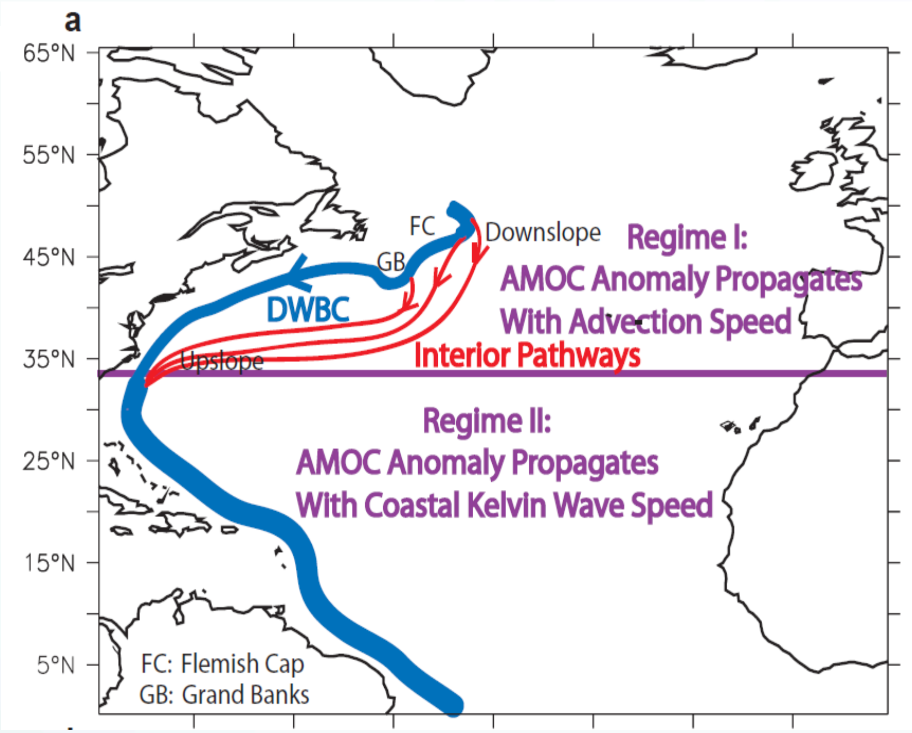
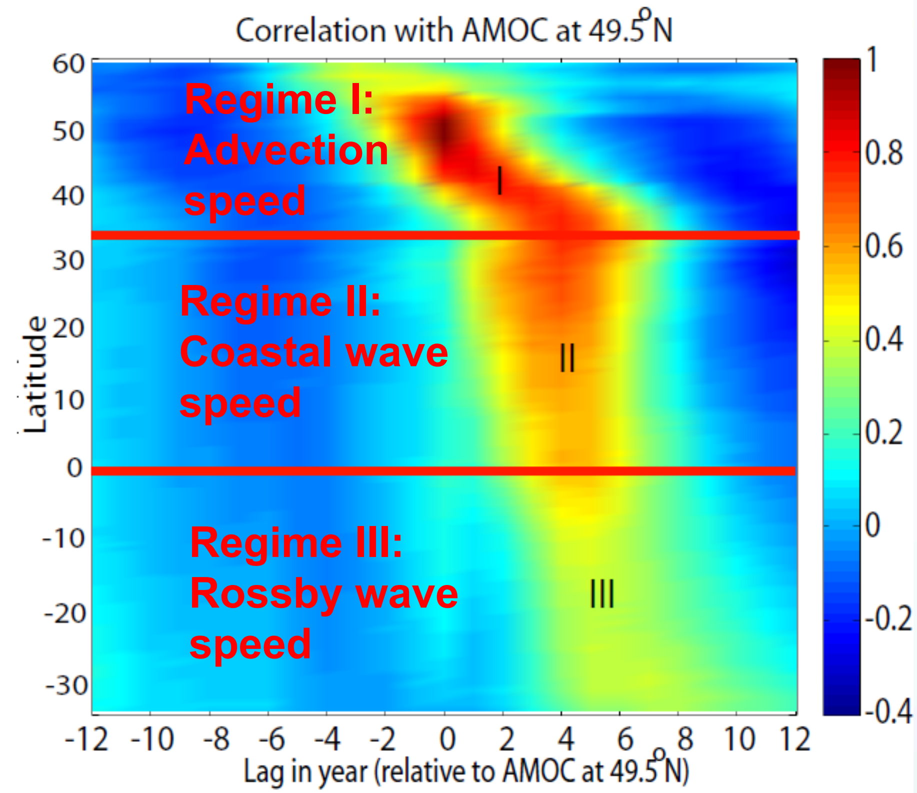
Background: Meridional Coherence of AMOC Variability



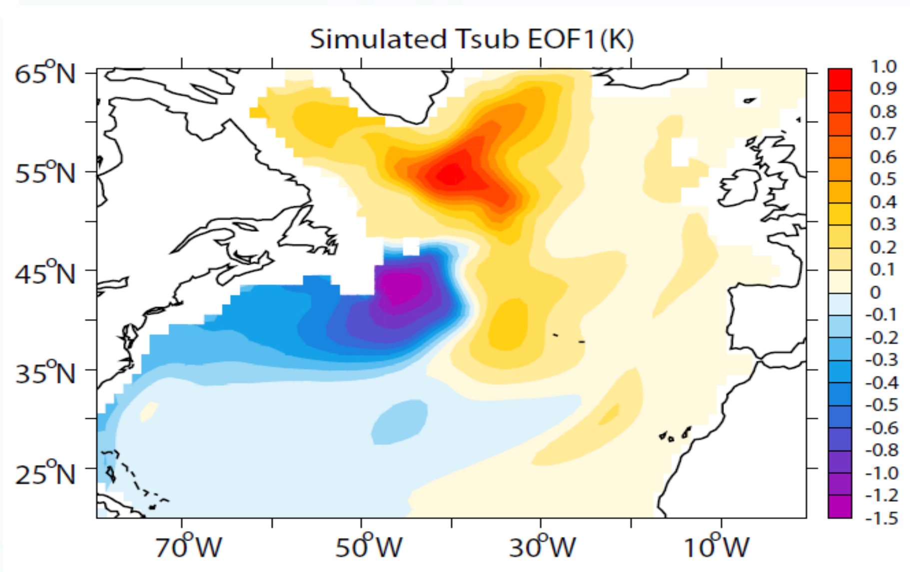
AMOC Correlation



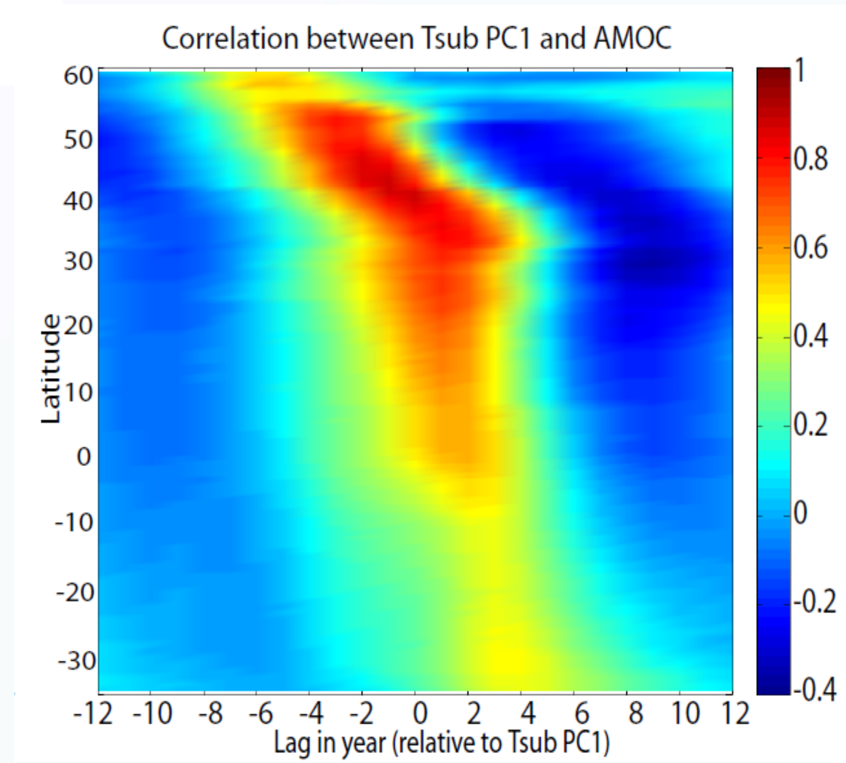
(Zhang, 2010)

- Due to the existence of interior pathways, AMOC variations in Regime I propagate with the slow advection speed
- Subpolar AMOC variations lead subtropical AMOC variations by several years

Background: Meridional Coherence of AMOC Variability and AMOC Fingerprint



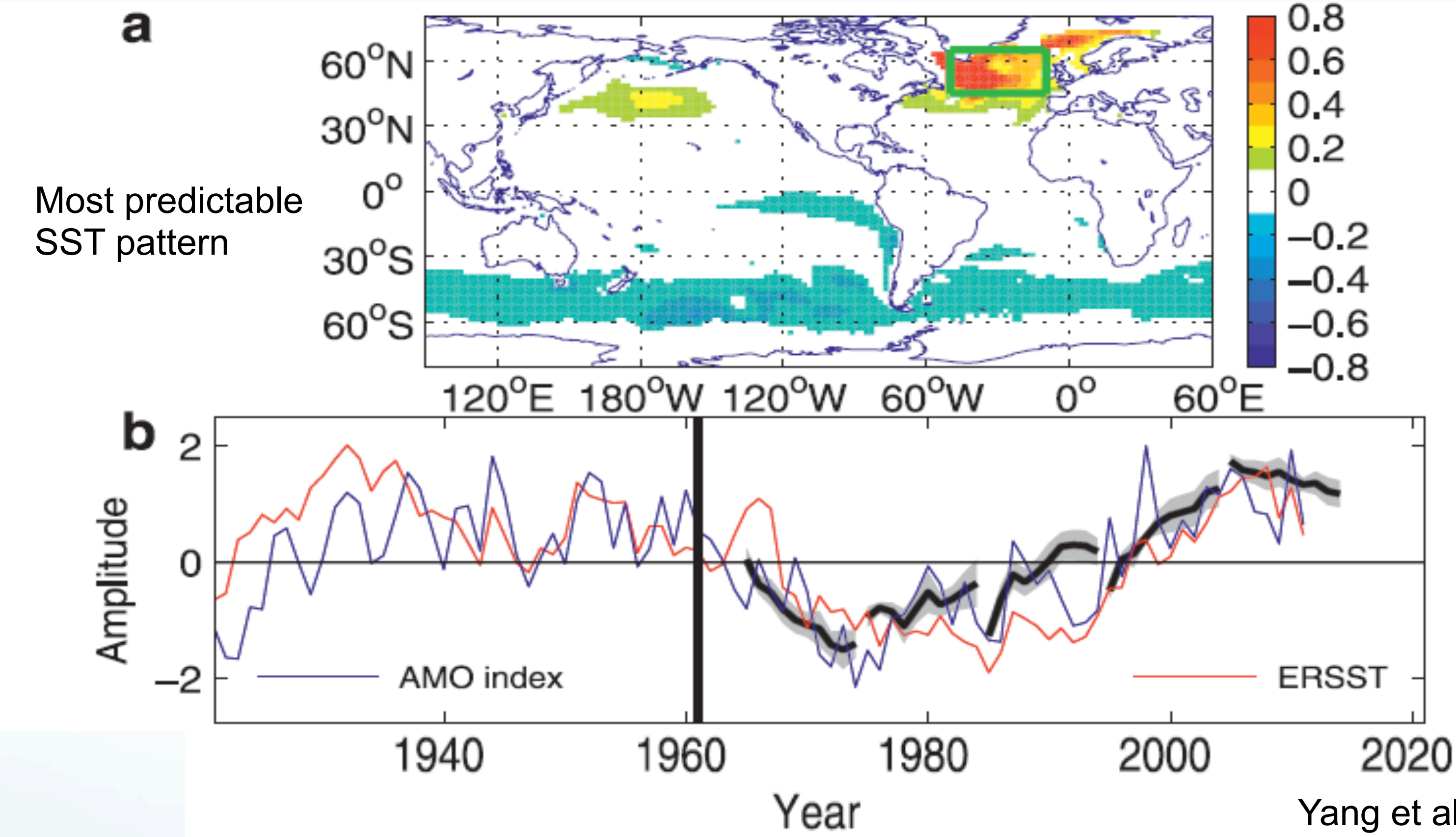
AMOC Fingerprint - leading mode of subsurface temperature in extra-tropical North Atlantic (Zhang, 2008)



(Zhang, 2010)

Zhang (2010) shows that a strengthening AMOC at high latitude leads the AMOC fingerprint thus warming in subpolar gyre (SPG) and cooling in the Gulf Stream (GS) region by several years. The several year time lead may provide a more useful predictability.

Background: The Role of AMOC in Decadal Prediction



Yang et al., 2013

Recent decadal prediction studies from NCAR, University of Reading, and GFDL all successfully predicted the decadal warming shift in the mid 90's in the NA SPG with initialized ocean state and initializing a strong AMOC at northern high latitudes is key for successful predictions (Yeager et al. 2012; Robson et al. 2012; Yang et al., 2013; Msadek et al. 2014) .

Questions

- Why does a positive AMOC anomaly at northern high latitudes induce the warming in SPG and cooling in GS region? Why is this dipole pattern of AMOC fingerprint confined to north of 34N?

- What is the physical mechanism linking the meridional coherence of AMOC variability with the evolution of AMOC fingerprint?

- Why is there an enhanced decadal prediction skill in the North Atlantic (especially in the SPG) in recent decadal prediction experiments?

Description of Experiments

To investigate the mechanism for the evolution of the AMOC fingerprint, we conducted two sets of experiments using GFDL CM2.1.

Each set of experiments includes:

- An ensemble of 10-member control experiments, each member has a different initial condition taken from 50 years apart in CM2.1 control simulation.

- An ensemble of 10-member perturbed experiments, each member has the same initial condition as the corresponding control ensemble member, except that all ensemble members here are perturbed initially with the positive salinity anomaly (0.5PSU) in the upper northern North Atlantic and Nordic Sea.

- The anomaly is defined as the ensemble mean difference between the perturbed and the control experiments.

Description of Experiments

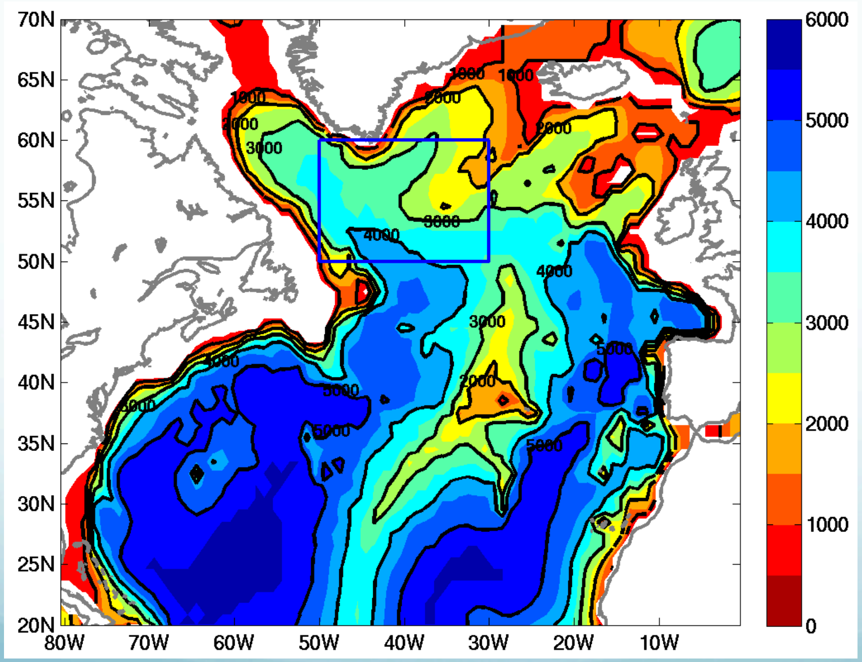
- **First set (CM2.1):**

- Anomaly = Perturbed - Control

- **Second set (CM2.1 with fixing deep subpolar ocean):**

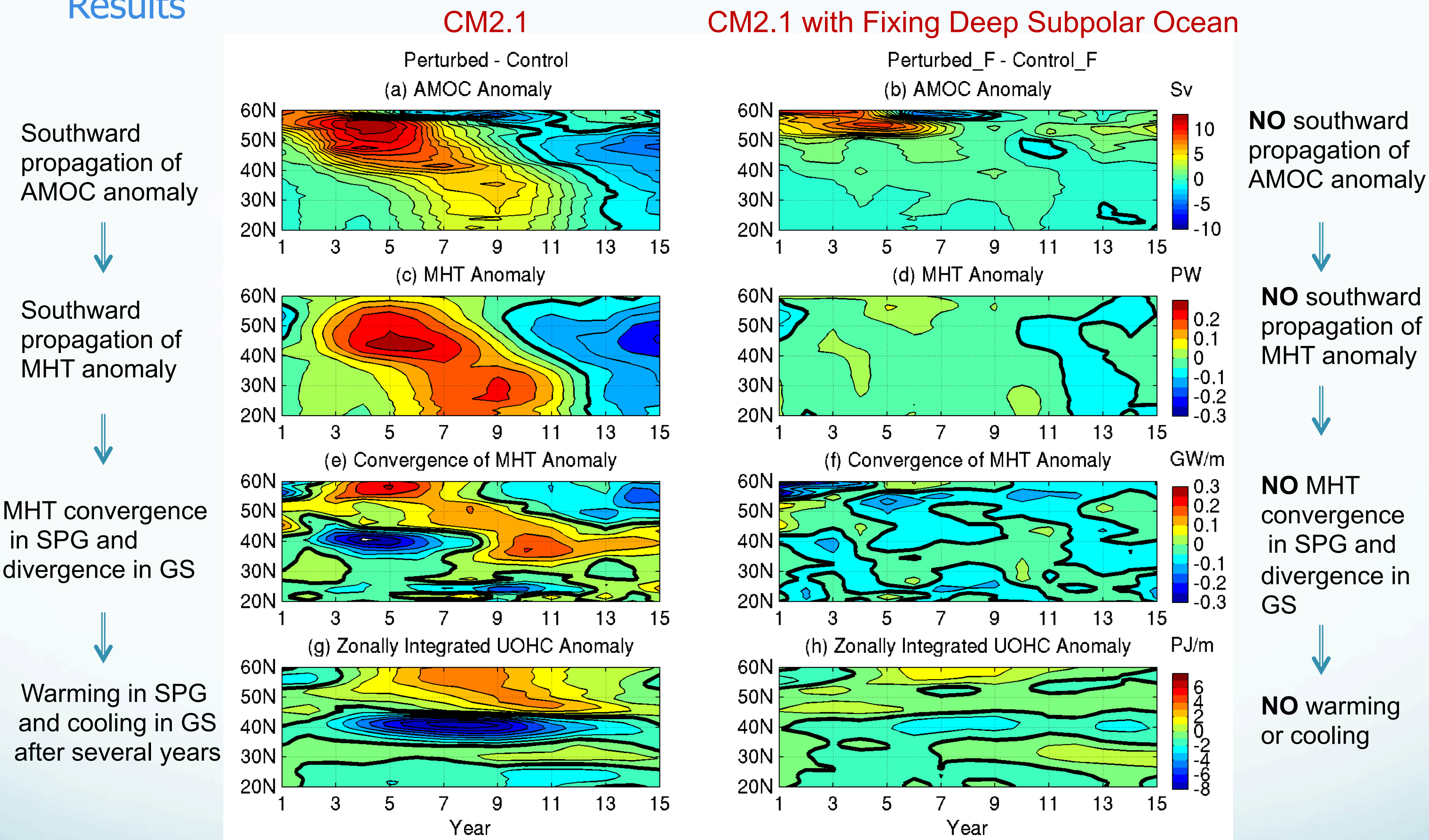
- Both control experiments and perturbed experiments are with fixed Temperature and Salinity below 2200m in the NA SPG (50°N - 60°N, 30°W – 50°W, blue box)

- Anomaly = Perturbed_F – Control_F



Topography in GFDL CM2.1

Results



- The positive AMOC/MHT anomaly at high latitudes induced by the initial positive salinity perturbation propagates.

CM2.1 — Perturbed – Control

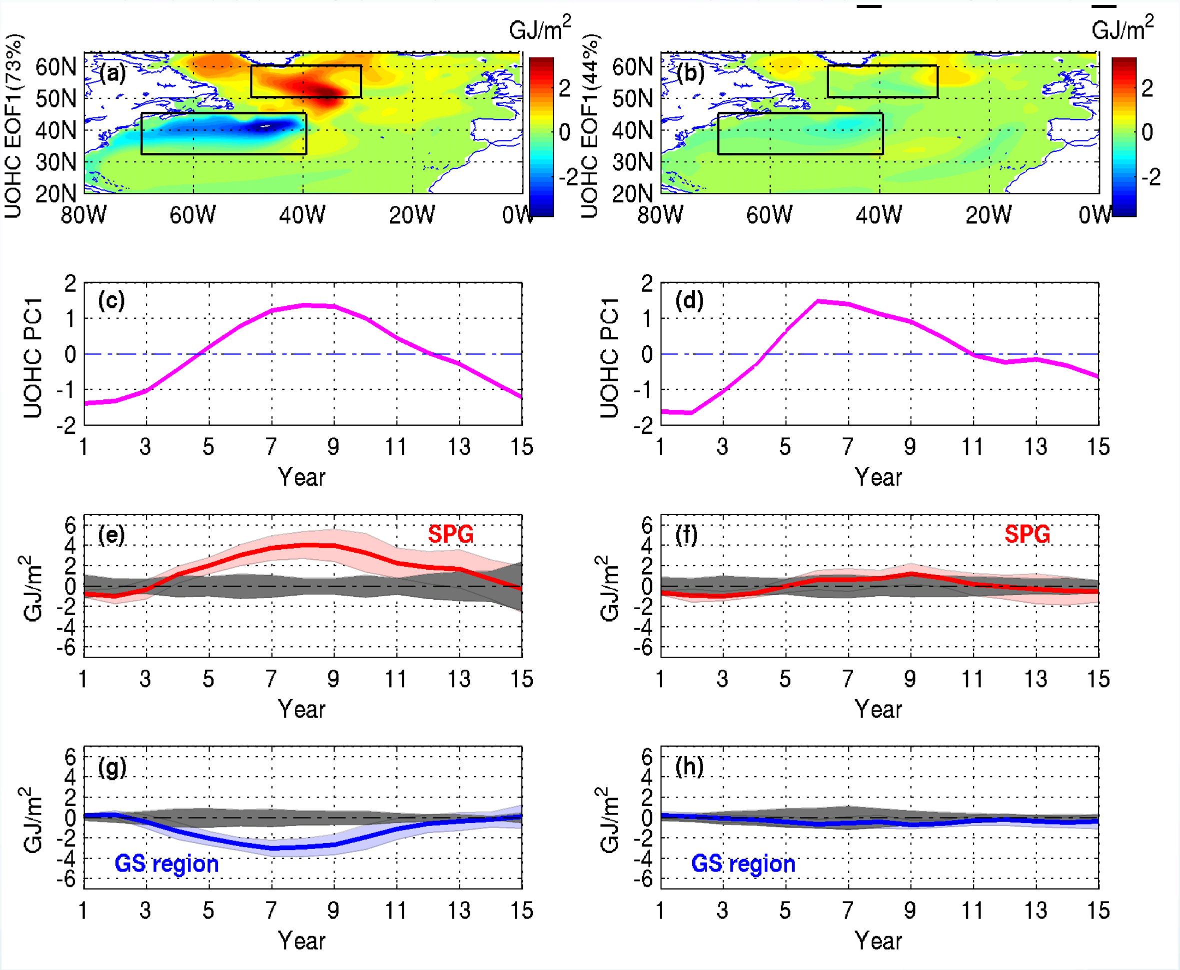
CM2.1 with Fixing Deep Subpolar Ocean — Perturbed_F – Control_F

UOHC EOF1

UOHC PC1

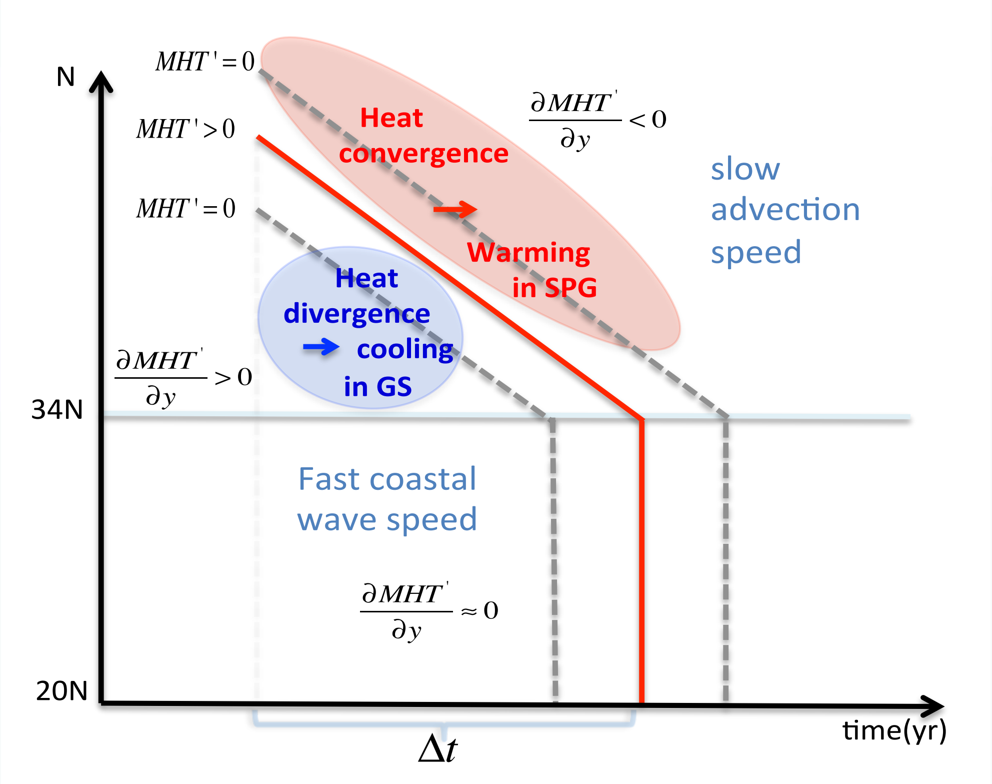
SPG UOHC

GS UOHC



This distinctive dipole pattern of UOHC is predictable on decadal time scale, with the southward propagation of AMOC anomaly, but not predictable for the case with Fixing Deep Subpolar Ocean.

Schematic Diagram of Mechanism



- Southward propagation of a positive AMOC/MHT anomaly with the slow advection speed north of 34N leads to heat convergence (Warming) in SPG and divergence (cooling) in GS region.
- This slow advection time scale north of 34N assures that the distinctive UOHC dipole is predictable on decadal timescale.
- **NO** significant warming/cooling south of 34N induced directly by MHT convergence/divergence due to the fast coastal wave speed.

Results from 1000-yr Control Simulation of GFDL CM2.1

Southward propagation of AMOC anomaly

↓

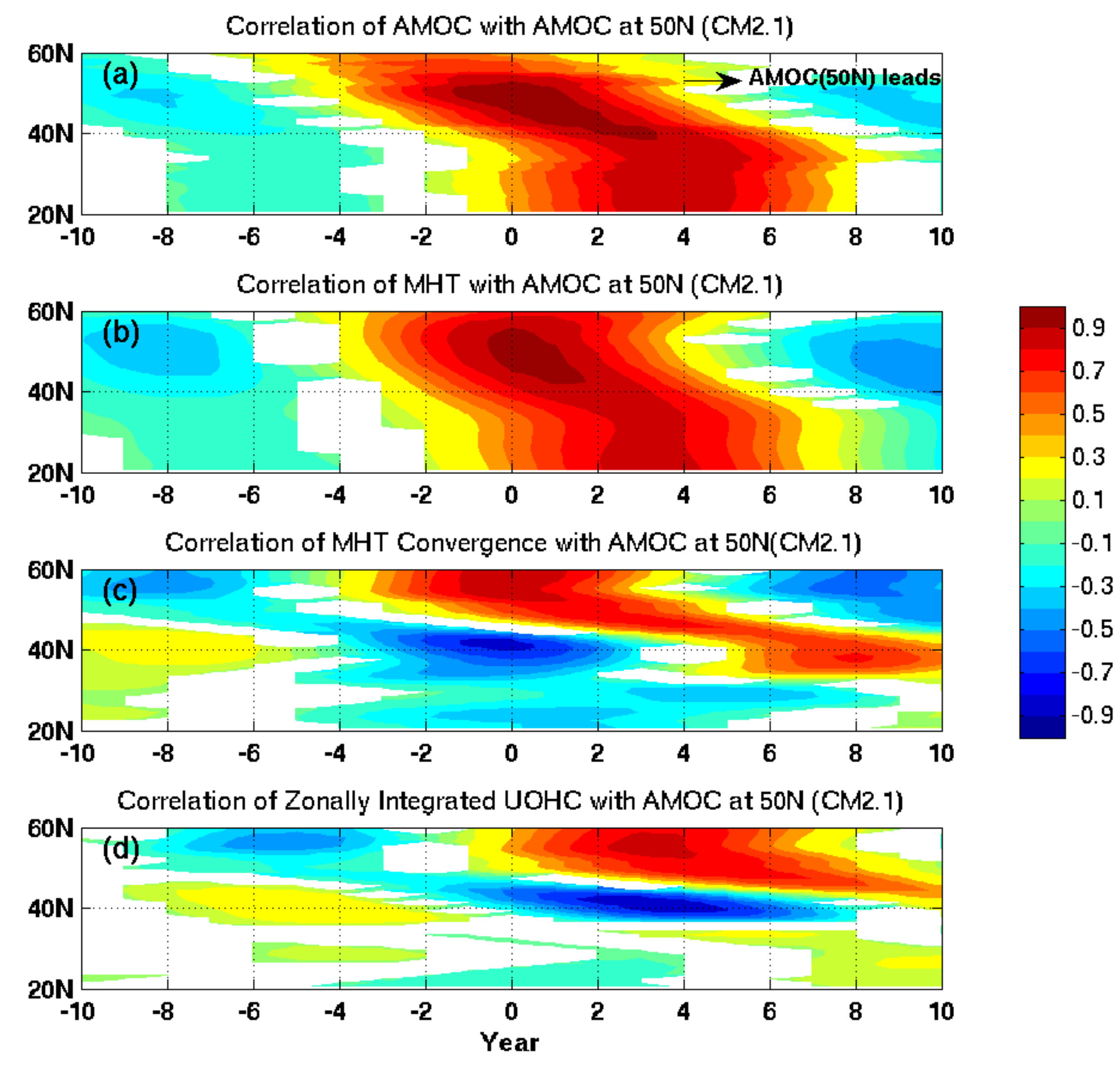
Southward propagation of MHT anomaly

↓

MHT convergence in SPG and divergence in GS

↓

Warming in SPG and cooling in GS



The analysis of the GFDL CM2.1 1000-yr control simulation exhibits the same mechanism for the evolution of the AMOC fingerprint, consistent with experiments and schematic mechanism.

Summary

- Southward propagation of a positive AMOC/MHT anomaly with the slow advection speed north of 34N leads to heat convergence (Warming) in SPG and divergence (cooling) in GS region.

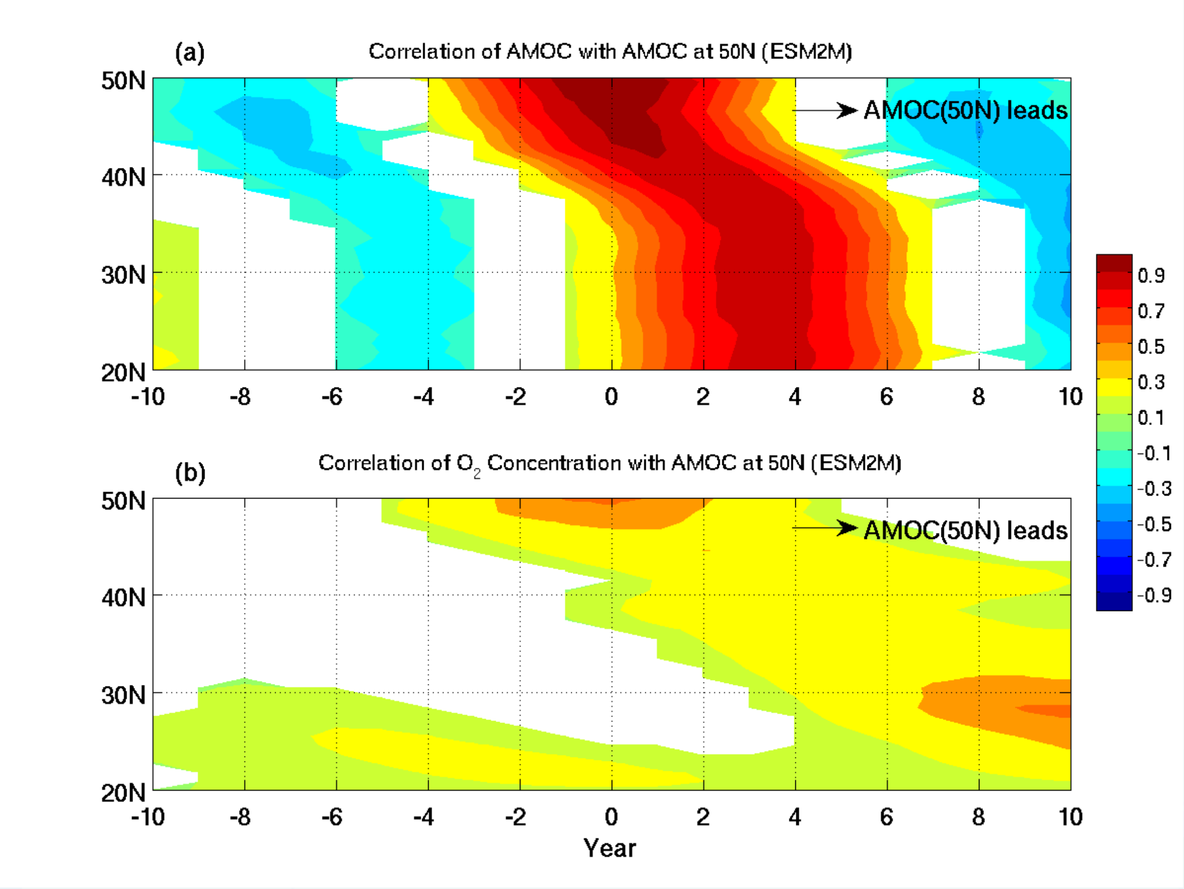
- The dipole AMOC fingerprint is confined to north of 34N, due to the fast coastal wave speed of AMOC/MHT propagation south of 34N.

- Initialized subpolar salinity anomaly is important for triggering the AMOC anomaly at northern high latitudes, but itself cannot directly lead to predictable temperature signals without the southward propagation of the AMOC anomaly with the slow advection speed.

- This slow advection time scale north of 34N assures that the distinctive UOHC dipole (AMOC fingerprint) is predictable on decadal timescale. Our results here provide the physical mechanism for the enhanced decadal prediction skills in SPG temperature.

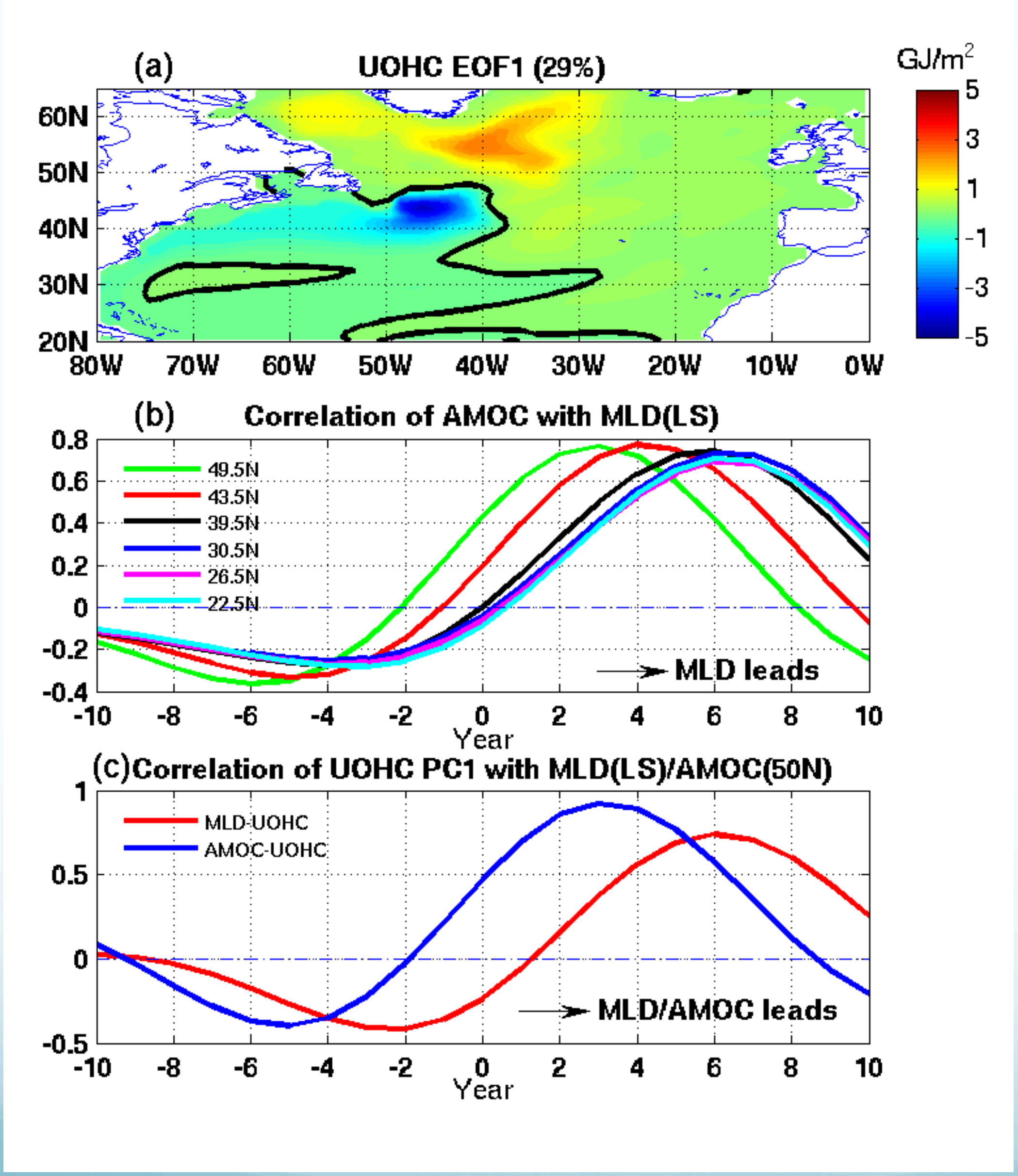
Results: confirmation for slow advection

ESM2M O_2 (500 years)



- O_2 propagation confirms that it takes about 4-5 years of tracer advection time scale for the AMOC to propagate from subpolar region to subtropical area.

Results from 1000-yr control simulation of GFDL CM2.1



- Warming in SPG & cooling in the GS region

- MLD in Labrador Sea leads AMOC at 50°N for 2-3 years.
- It takes 3-4 years for AMOC anomaly to propagate from SPG to subtropical gyre and then quickly moves southward.
- MLD in Labrador Sea leads warming/cooling for 5-6 years, while AMOC leads warming/cooling for about 3 years