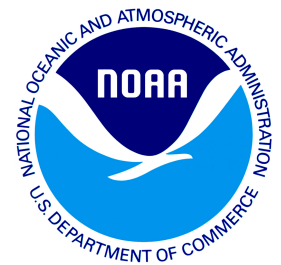# Robust and Nonrobust Aspects of Atlantic Meridional Overturning Circulation Variability and Mechanisms in the Community Earth System Model

Gokhan Danabasoglu, Laura Landrum, and Steve Yeager

National Center for Atmospheric Research
Boulder, CO

BACKGROUND and MOTIVATION

- Coupled model simulations show rich AMOC variability, but time scales of variability and mechanisms differ substantially among them.

- Studies with CESM showed that the ocean model's subgrid scale parameterizations play a role in creation of the Labrador Sea density anomalies that lead to changes in AMOC.

- We present a systematic assessment of the impacts of several ocean model parameter choices as well as atmospheric initial condition perturbations on AMOC characteristics in CESM with the primary goal of identifying both robust and non-robust elements of AMOC variability and mechanisms.

GFDL CM2.1

CCSM
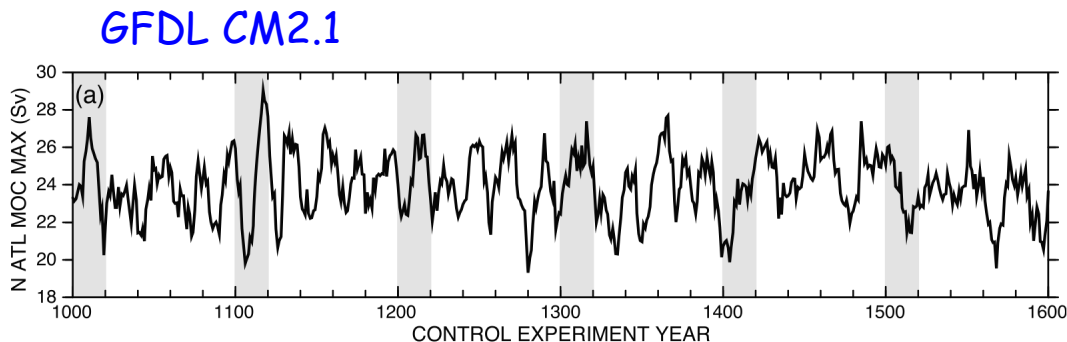
Msadek et al. (2010)
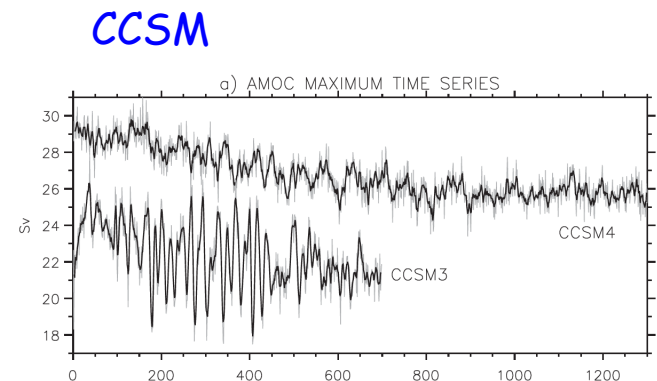
Danabasoglu et al. (2012, J. Climate)

Experiments with CESM

Vertical mixing parameterization:
Reduce internal background mixing from 0.17×10^{-4} to 0.10×10^{-4} m^2 s^{-1}

Submesoscale mixing parameterization:
The circulation is inversely proportional to width of mixed layer fronts, L, but no guidance on L except that $0.2 < L < 5$ km. Reduce L from 5 to 3.33 km.

Mesoscale mixing parameterization:
- Increase deep ocean values of isopycnal and thickness diffusivities from 300 to 600 m^2 s^{-1}
- Reduce the boundary layer / upper ocean isopycnal and thickness diffusivities from 3000 to 2000 m^2 s^{-1}
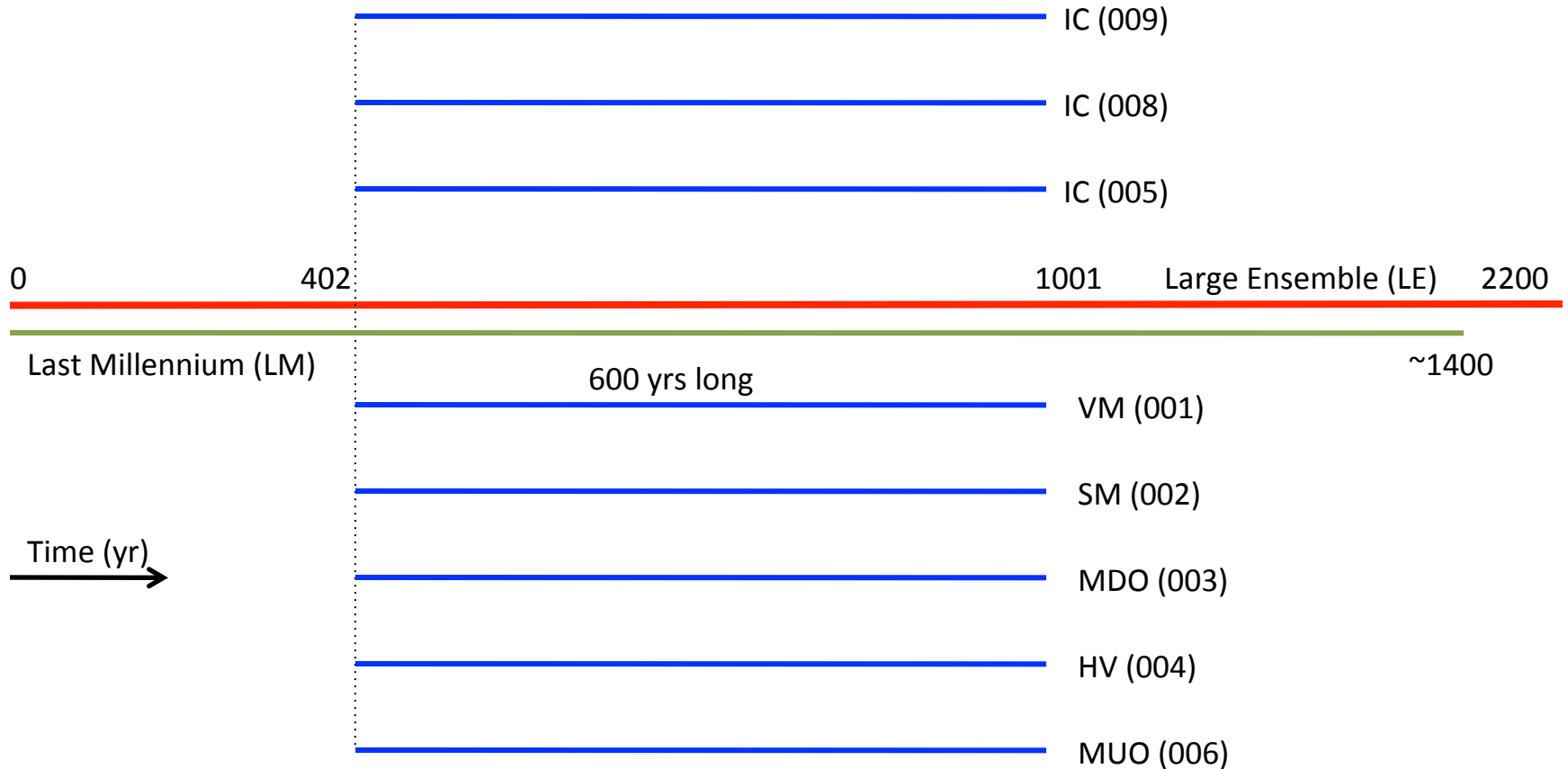
Horizontal viscosity parameterization:
Reduce the interior viscosities from 600 to 300 m^2 s^{-1}

Atmospheric initial condition perturbations:
Round-off level perturbation of initial temperature field

Experiments with CESM

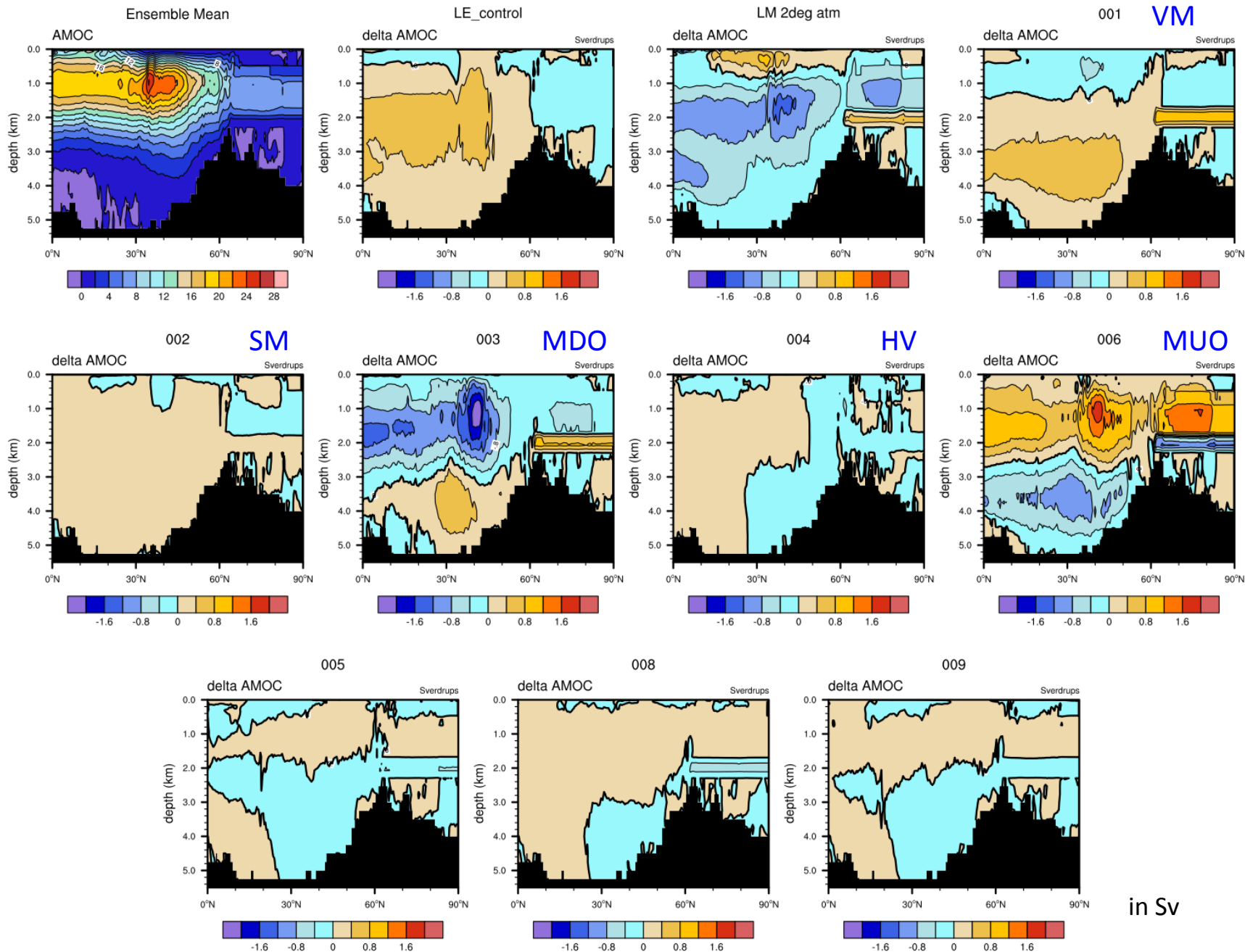- Nominal $1°$ horizontal resolution component models,
- Based on a 2200-year pre-industrial control simulation (LE)

IC (009)

IC (008)

IC (005)

| 0 | 402 | 1001 | Large Ensemble (LE) | 2200 |

Last Millennium (LM)

~1400

600 yrs long

VM (001)
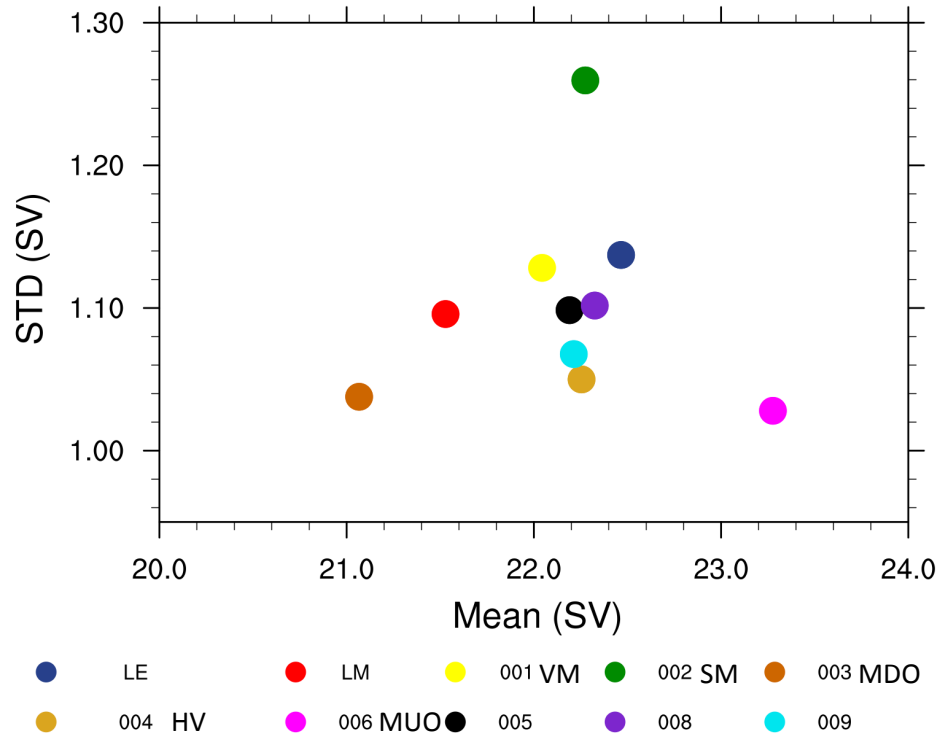
SM (002)

Time (yr)

MDO (003)

HV (004)

MUO (006)

Annual-mean output unless otherwise indicated;
AMOC index: 10-year low-pass filtered maximum transport at 45°N

AMOC Mean

Ensemble Mean — AMOC

LE_control — delta AMOC — Sverdrups

LM 2deg atm — delta AMOC — Sverdrups

001 VM — delta AMOC — Sverdrups

002 SM — delta AMOC — Sverdrups

003 MDO — delta AMOC — Sverdrups

004 HV — delta AMOC — Sverdrups

006 MUO — delta AMOC — Sverdrups

005 — delta AMOC — Sverdrups
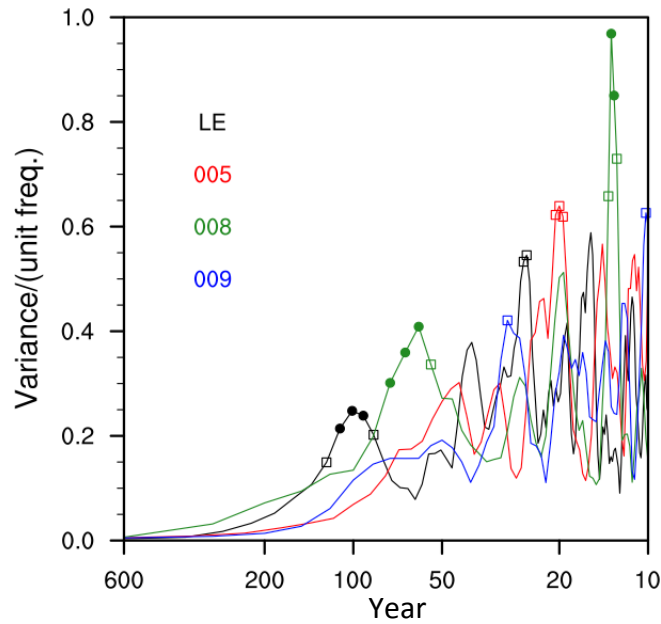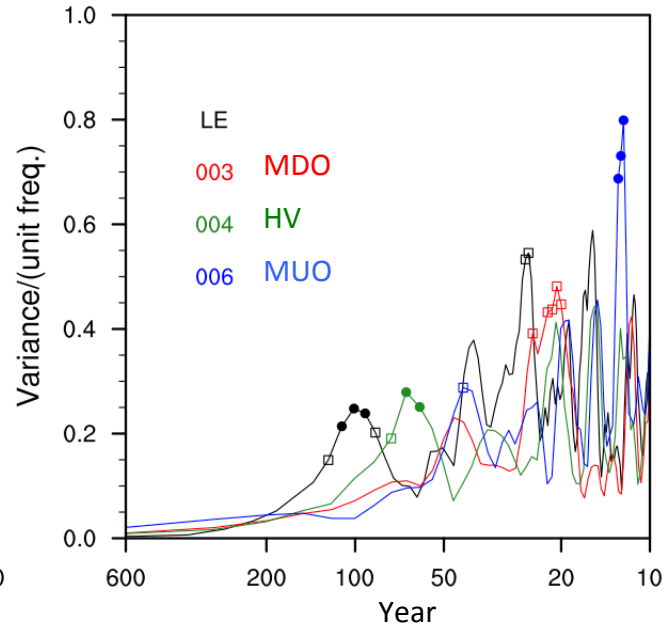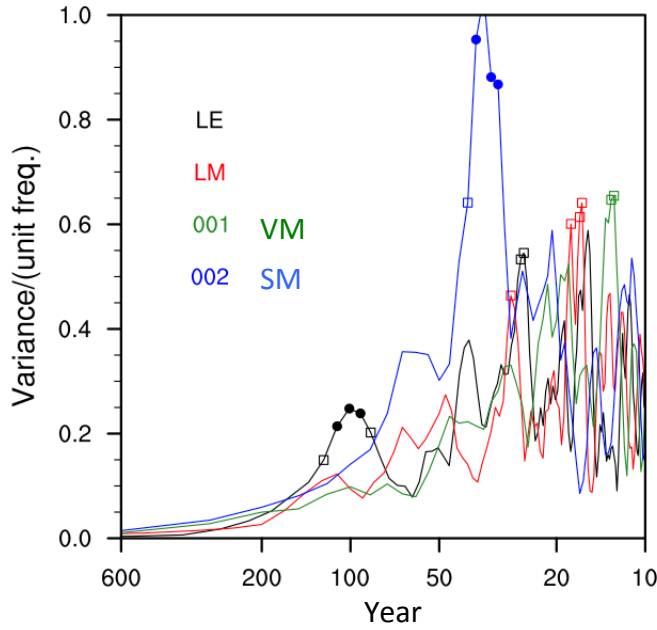
008 — delta AMOC — Sverdrups

009 — delta AMOC — Sverdrups

in Sv

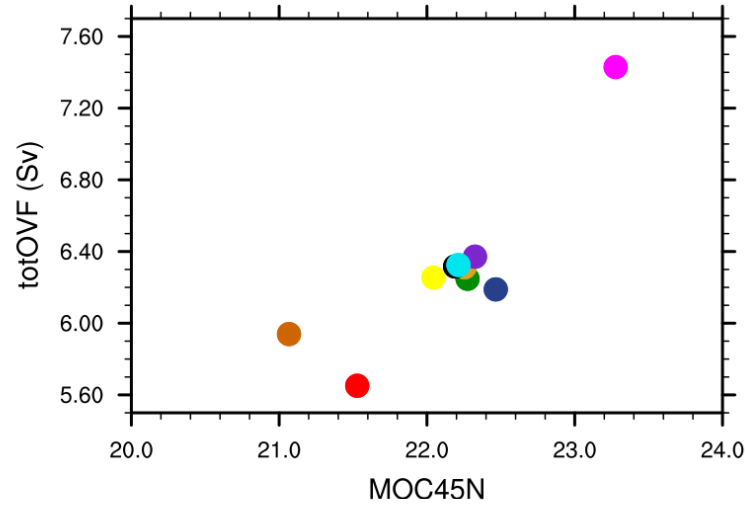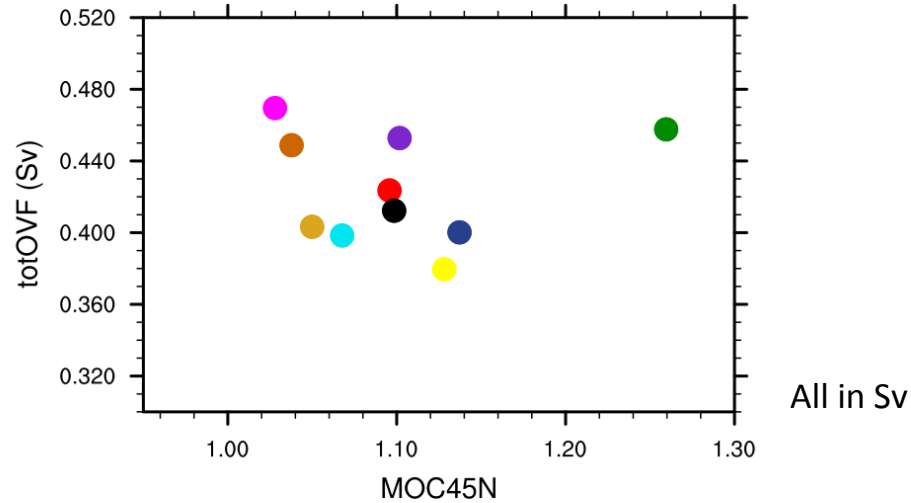AMOC Mean and Standard Deviation

AMOC Index Power Spectra

dots: 95%
squares: 90%

Overflows and AMOC

Means

Standard deviations

All in Sv

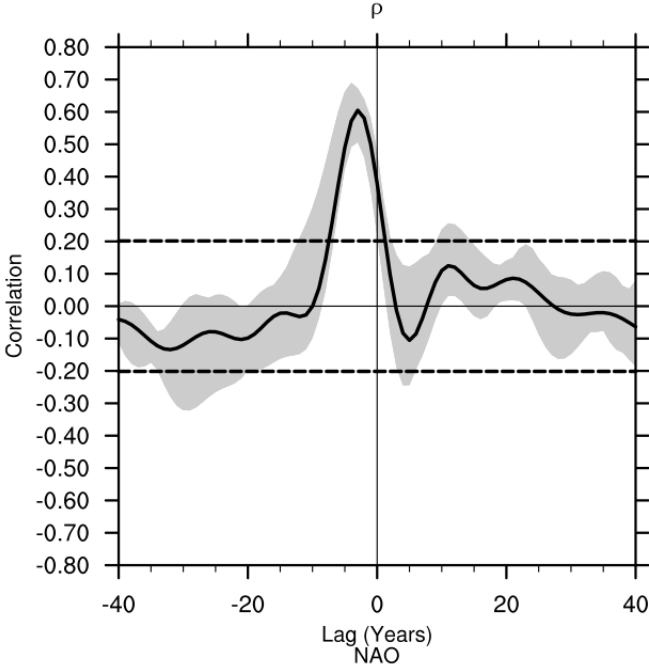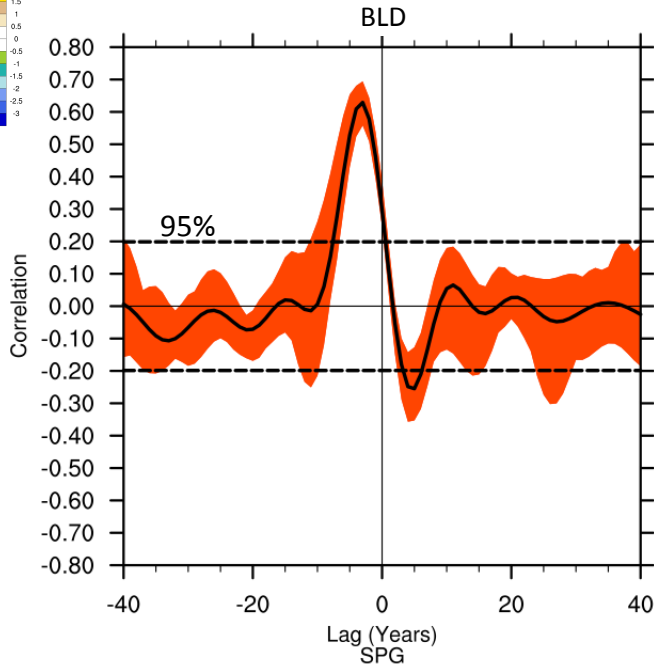|				
● LE	● LM	● 001 VM	● 002 SM	● 003 MDO
● 004 HV	● 006 MUO	● 005	● 008	● 009

Overflows and AMOC

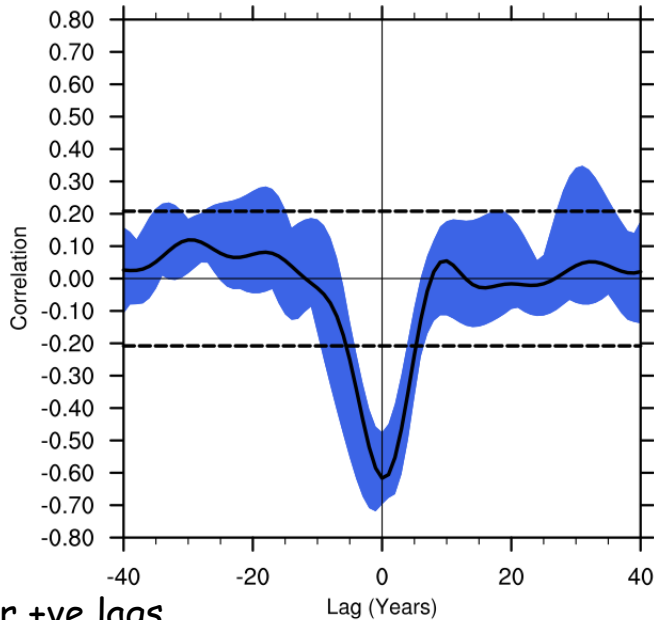## AMOC index and overflow product water transport correlations
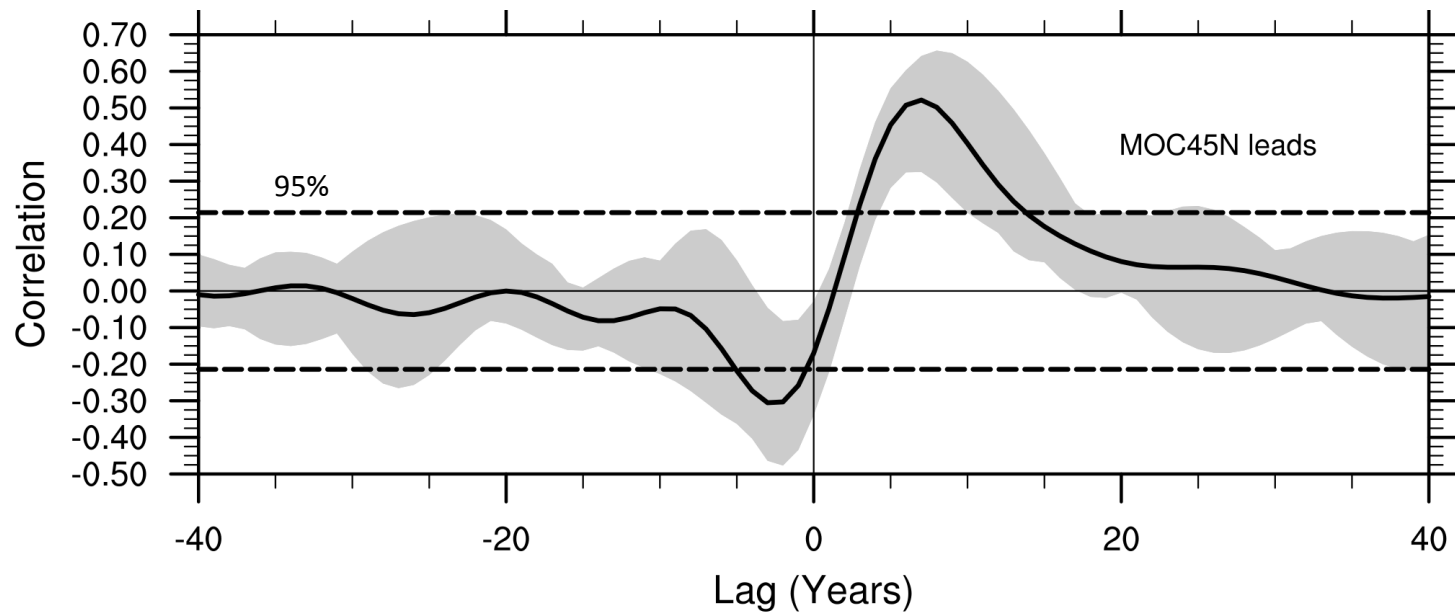
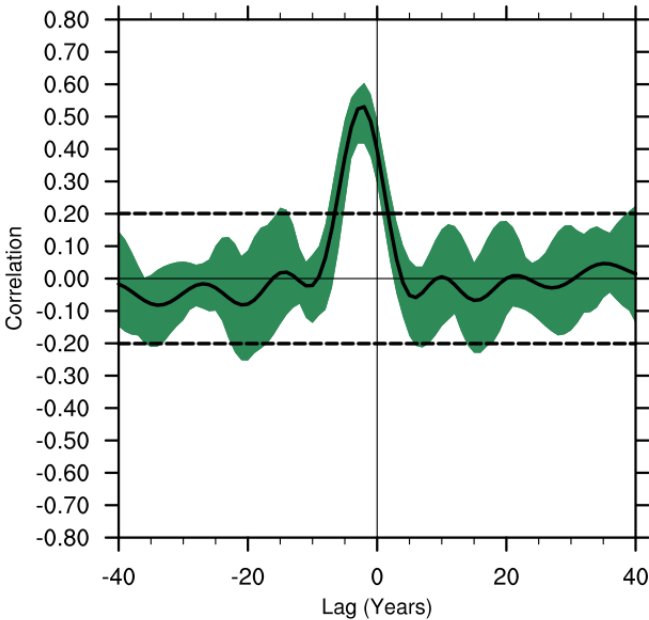# AMOC Index Correlations with ....
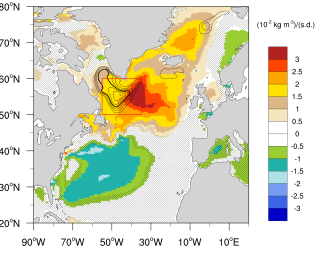
March-mean boundary layer depth (BLD)
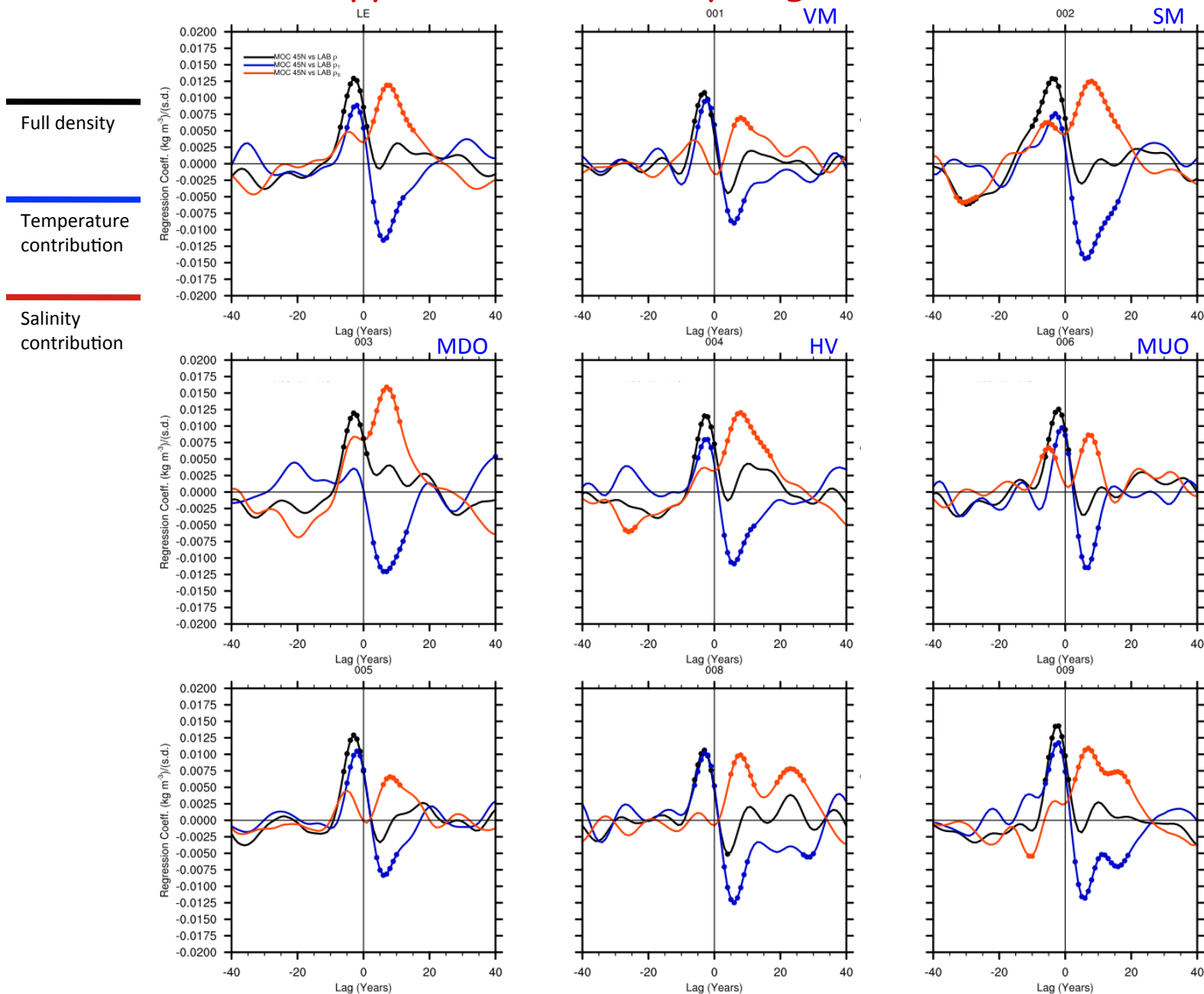
Upper-ocean density

Subpolar gyre transport (SPG)

North Atlantic Oscillation (NAO)

AMOC leads for +ve lags

Labrador Sea Upper-Ocean Density Regressions on to AMOC Index

AMOC leads for +ve lags

Summary and Conclusions

- Both the amplitude and time scale of AMOC variability differ considerably among the experiments with dominant time scales of variability ranging from decadal to centennial.

- There are also differences in details of how the density anomalies leading to AMOC changes come about, but it is more useful to focus on the bigger picture, identifying some robust elements ...

- Some robust elements of AMOC variability mechanisms include:

    i) The Labrador Sea is the key region with upper-ocean density and boundary layer anomalies preceding AMOC anomalies;

    ii) Enhanced Nordic Sea overflow transports do not lead to an increase in AMOC maximum transports;

    iii) After AMOC intensification, subsequent weakening is due to advection of positive temperature anomalies into the model's deep water formation region;

    iv) Persistent NAO$^+$ plays a significant role in setting up the density anomalies that lead to AMOC intensification via surface buoyancy fluxes.