Impacts of Ocean Model Parameterizations and Atmospheric Initial Condition Perturbations on AMOC in the Community Earth System Model (CESM)

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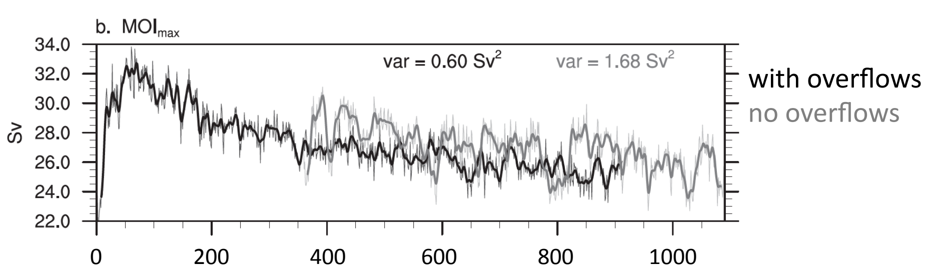
BACKGROUND and MOTIVATION

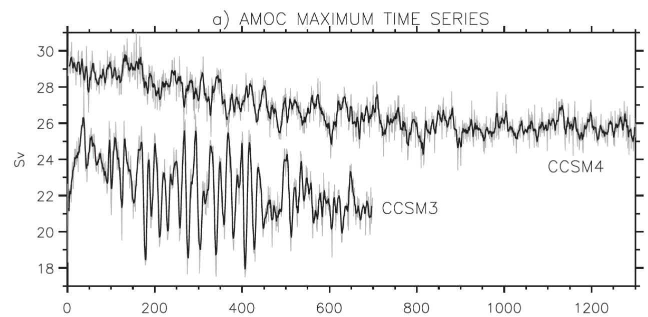
- Coupled model simulations show rich AMOC variability, but time scales of variability and mechanisms differ substantially among them.
- Studies with CESM showed that the ocean model's subgrid scale parameterizations play a role in creation of the Labrador Sea density anomalies that lead to changes in 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.

Pre-industrial control (FV2)



Yeager & Danabasoglu (2012, J. Climate)

pre-industrial vs. present-day control



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:

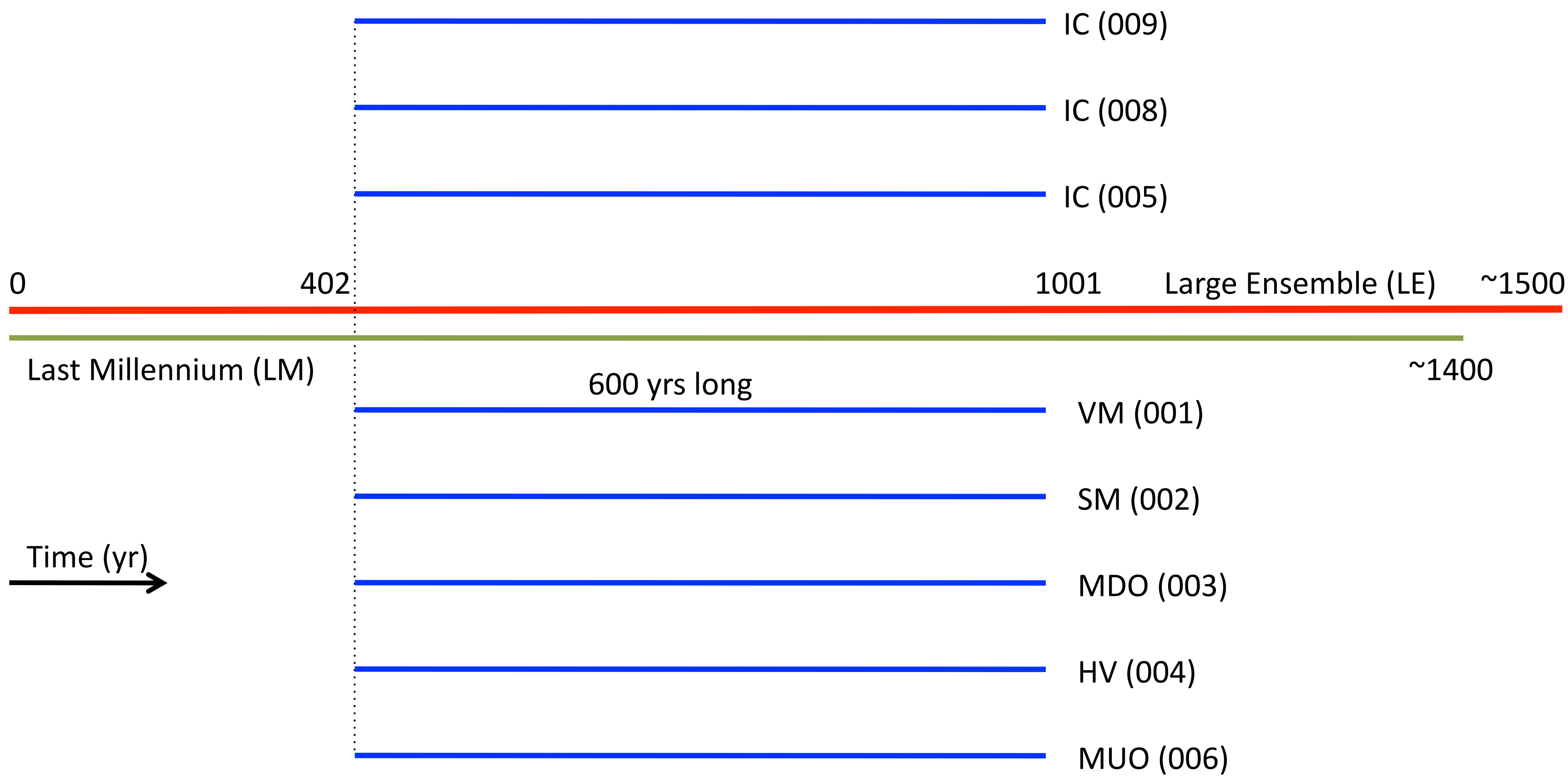
Reduce the interior viscosities from 600 to 300 $m^2\ s^{-1}$

Atmospheric initial condition perturbations:

Round-off level perturbation of initial temperature field

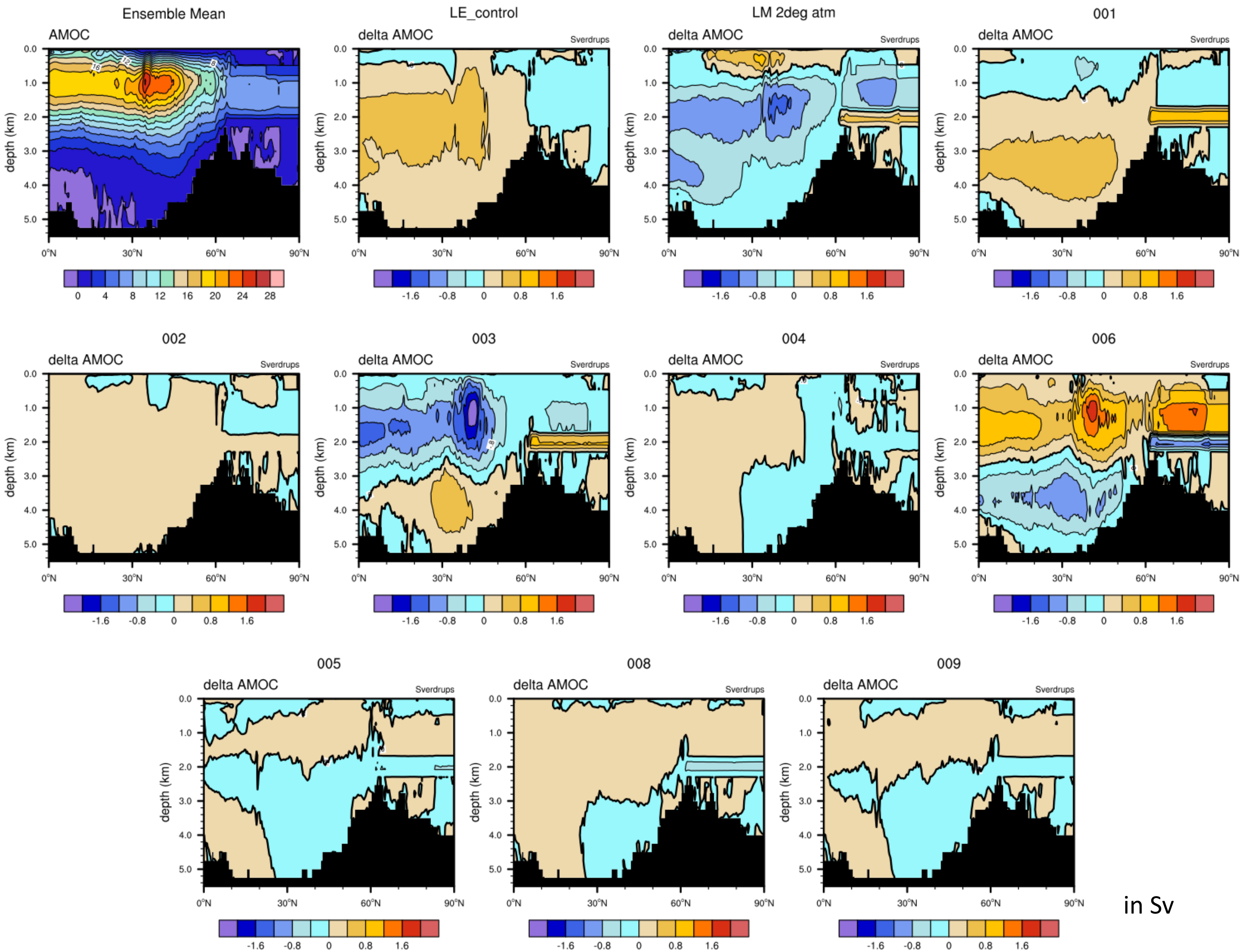
Experiments with CESM

- CAM5 FV; nominal 1° horizontal resolution; pre-industrial,
- Initialized from a 1500-year control, a.k.a., Large Ensemble (LE) control



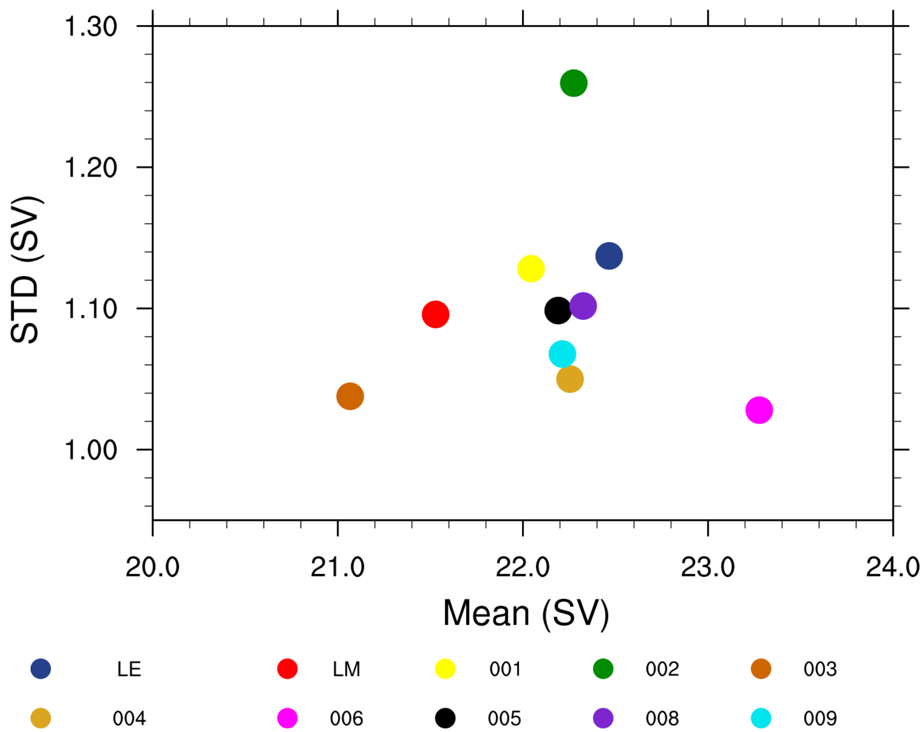
Annual-mean output unless otherwise indicated;
AMOC index: 10-year low-pass filtered maximum transport at 45°N

AMOC Mean

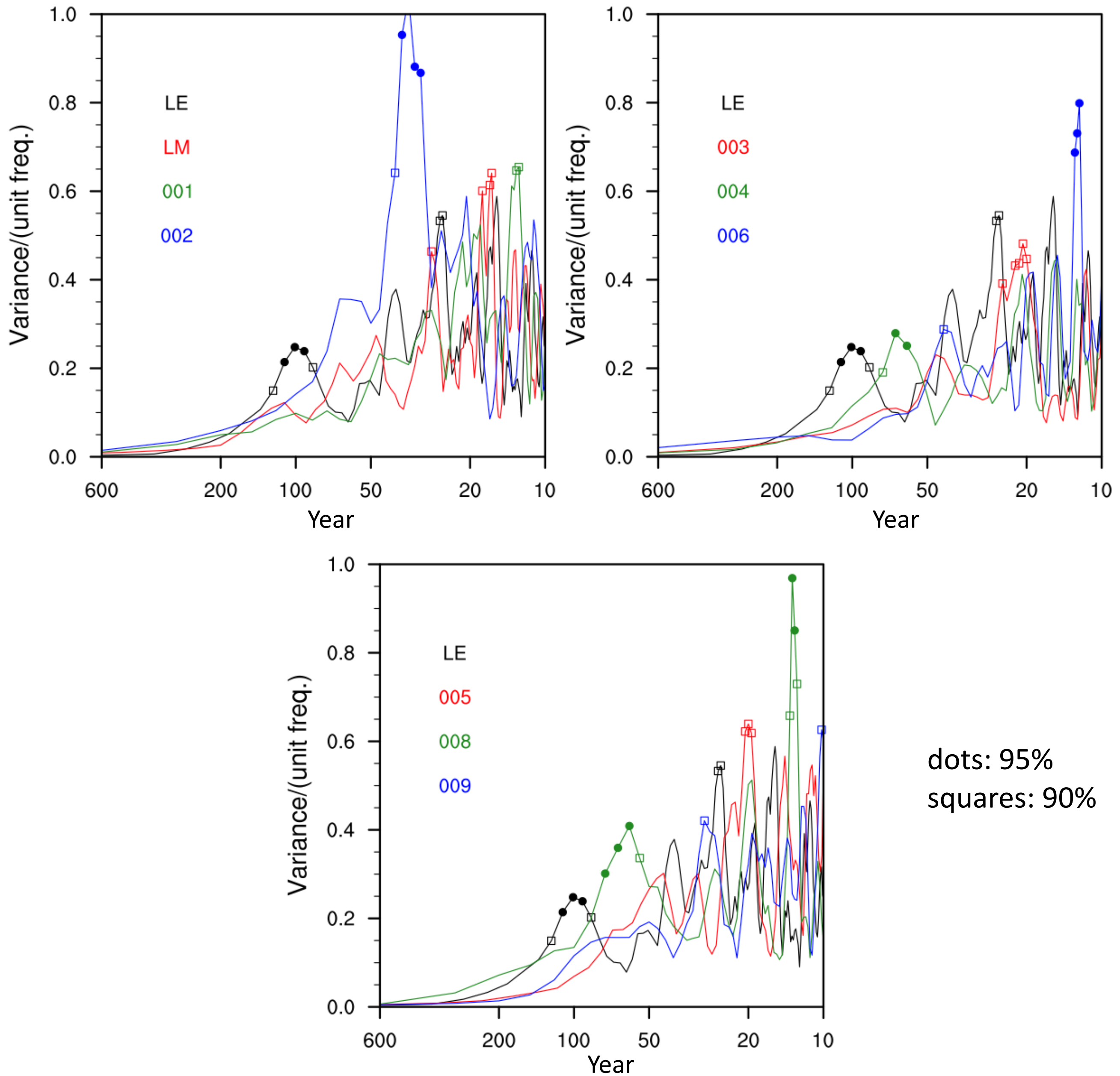


in Sv

AMOC Mean and Standard Deviation

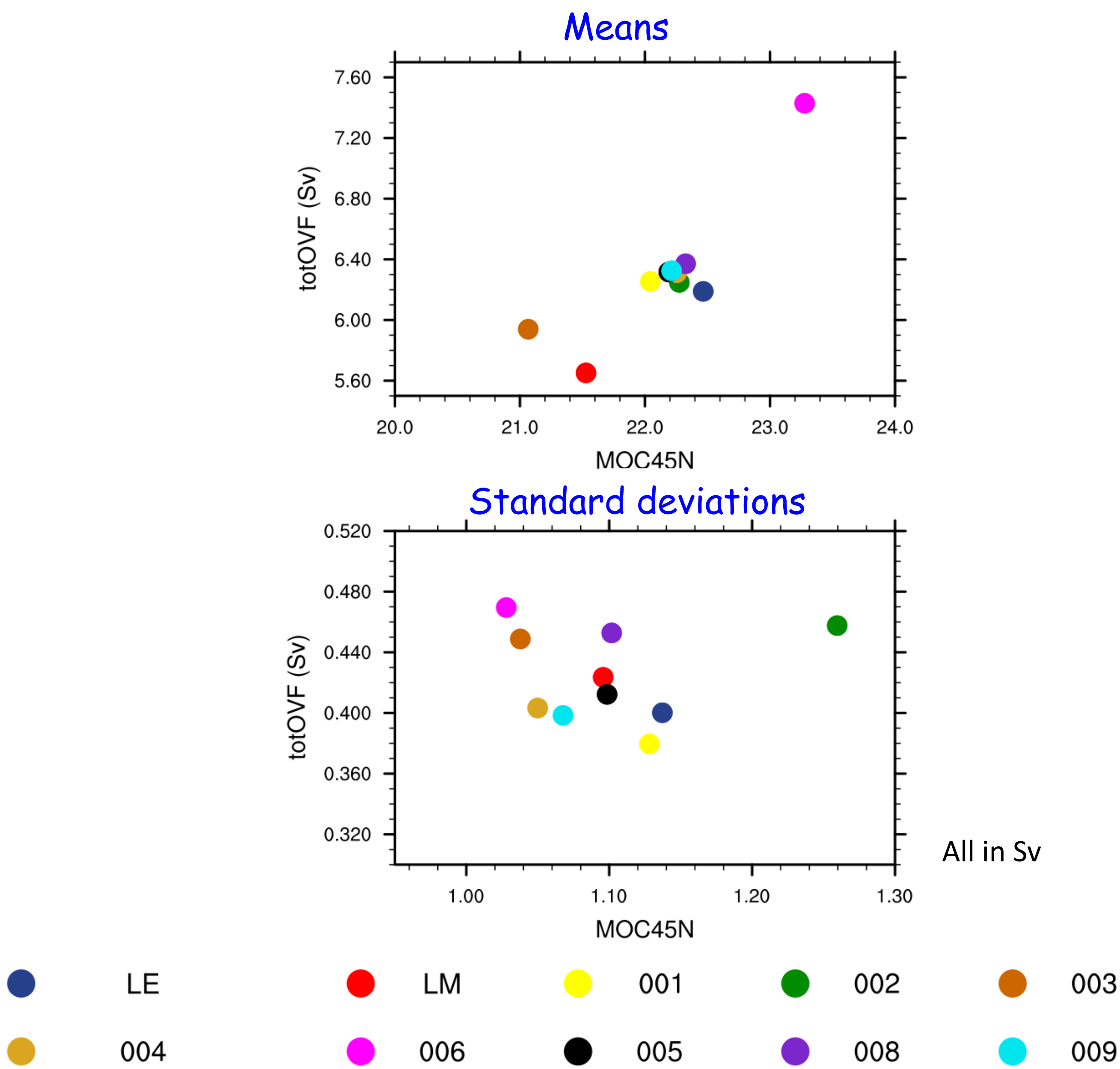


AMOC Index Power Spectra



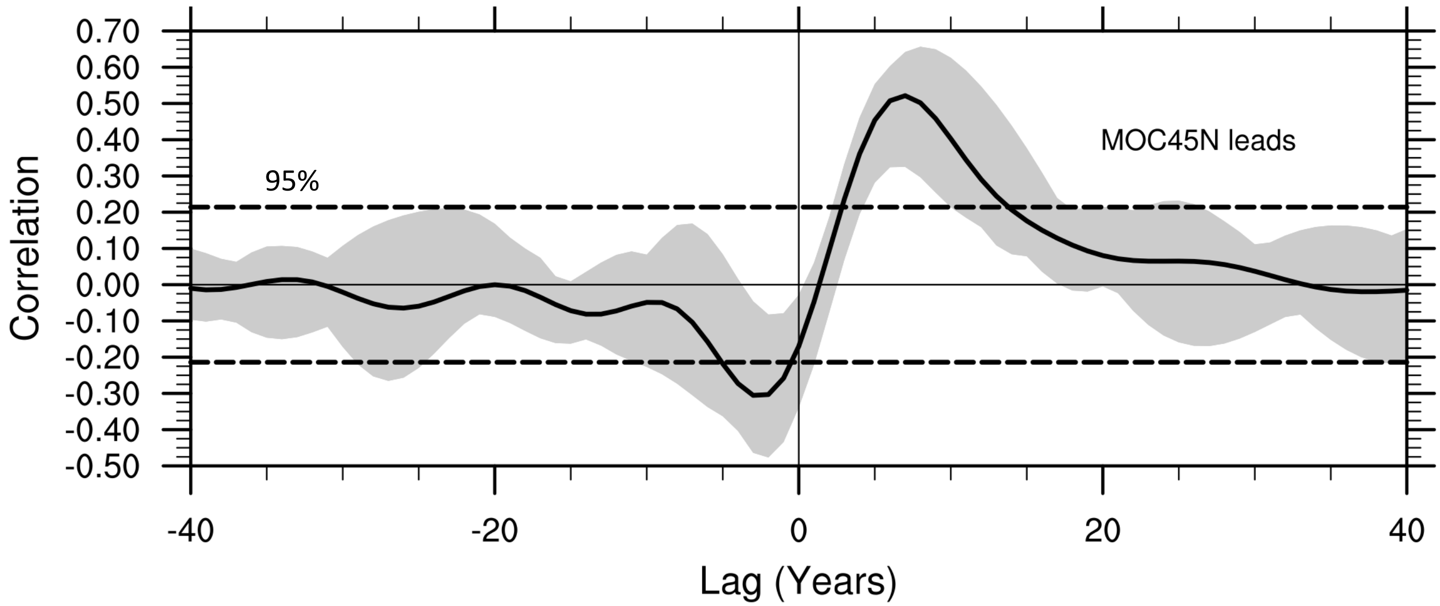
dots: 95%
squares: 90%

Overflows and AMOC

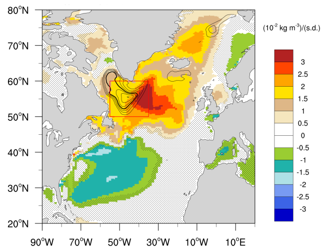


Overflows and AMOC

AMOC index and overflow product water transport correlations

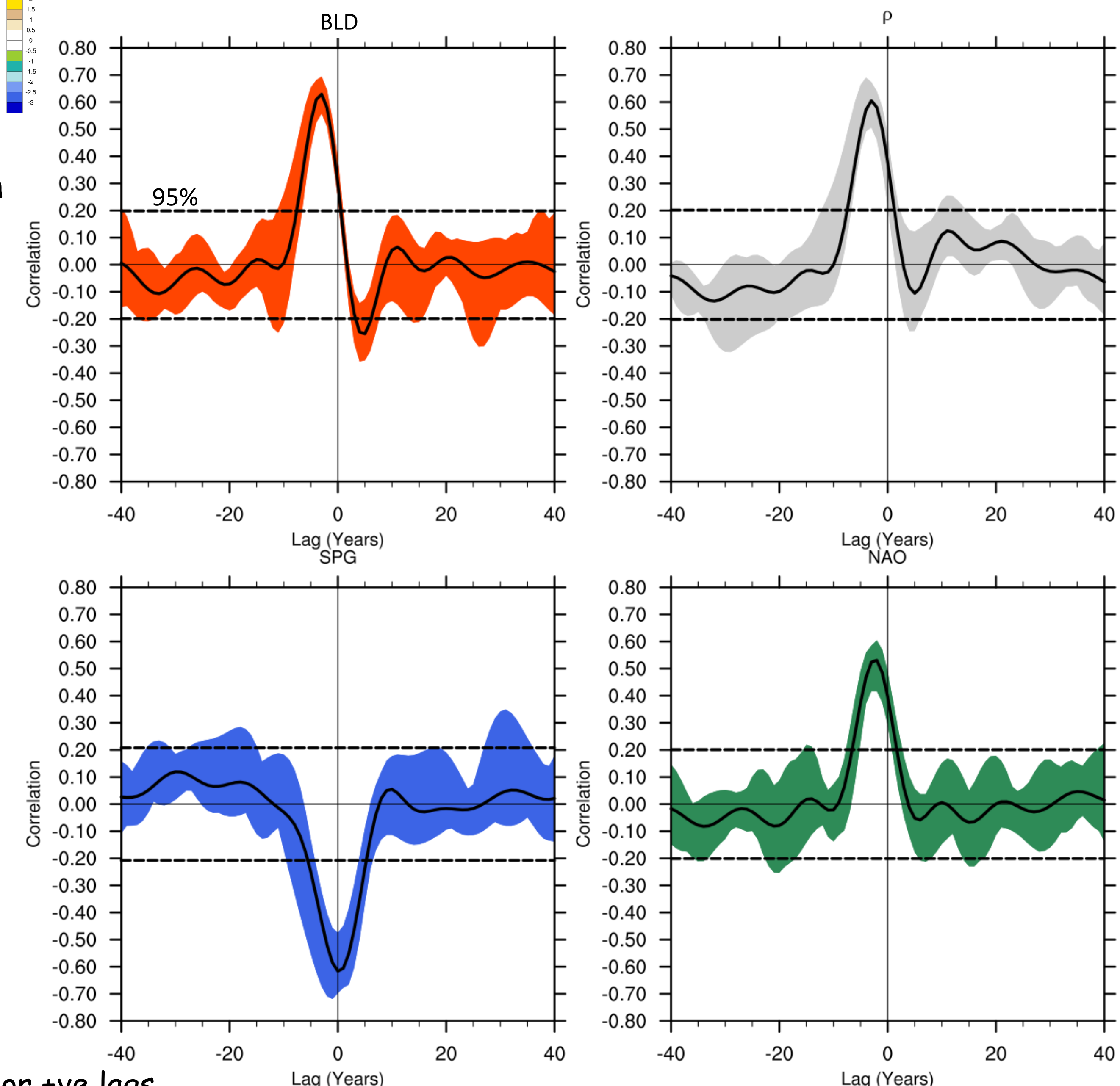


AMOC Index Correlations with ….



March-mean boundary layer depth (BLD)

Upper-ocean density



Subpolar gyre transport (SPG)

North Atlantic Oscillation (NAO)

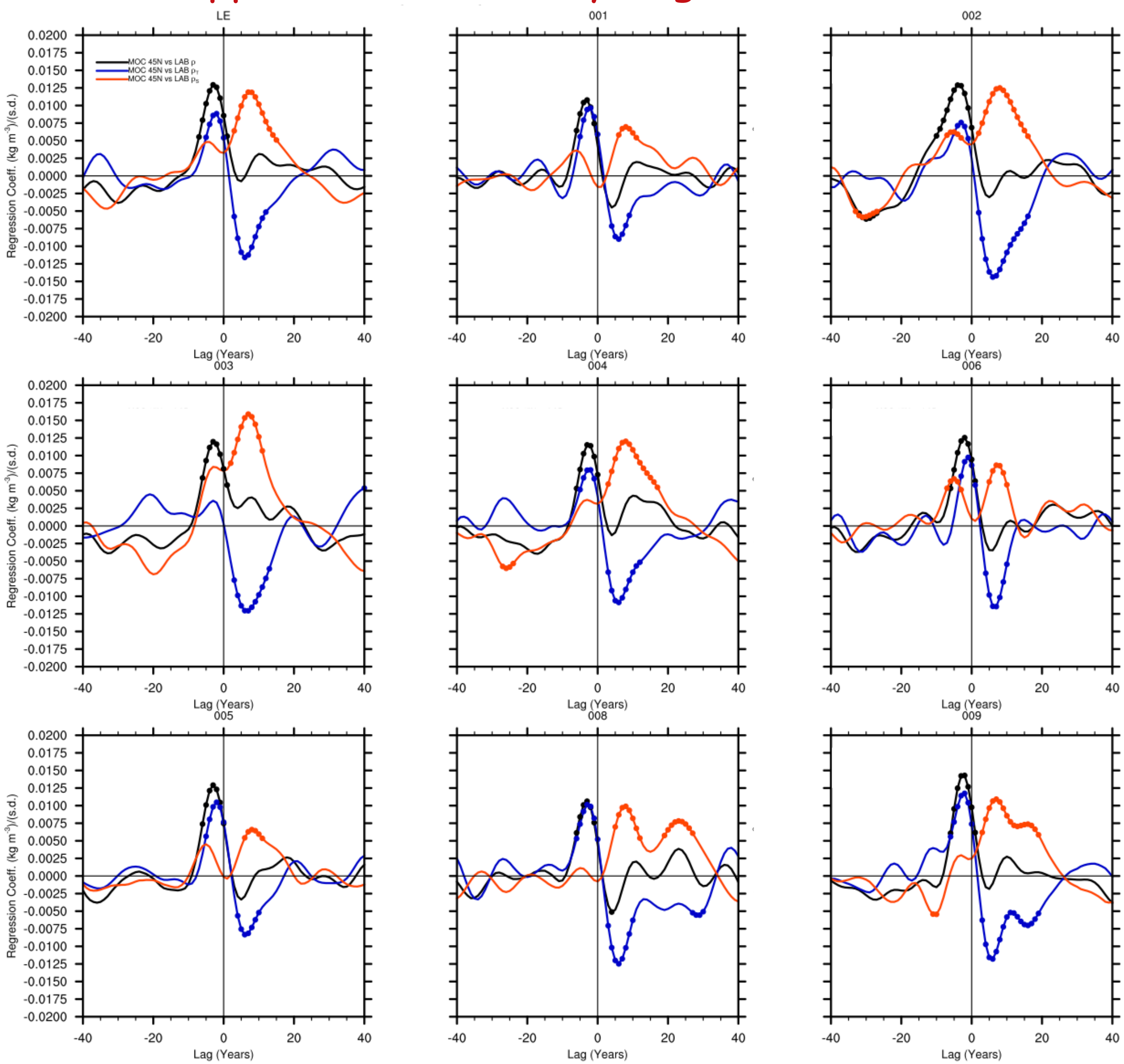
AMOC leads for +ve lags

Labrador Sea Upper-Ocean Density Regressions on to AMOC Index

Full density

Temperature contribution

Salinity contribution



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.