Multi-decadal Variability of AMOC in Community Climate System Model Version 3

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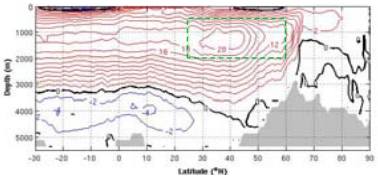
Summary

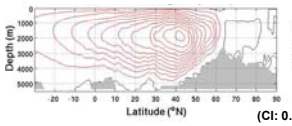
Atlantic meridional overturning circulation (AMOC) in the 700-year long present-day control integration of the CCSM3 T85x1 exhibits two distinct regimes of the decadal variability: (1) strong 20-yr oscillation in yrs 150-399 and (2) red noise-like weak multi-decadal variability in yrs 450-699. In the former regime, the decadal signal is clearly seen also in the atmosphere (Danabasoglu 2008, J. Climate), while the latter is likely to be primarily an ocean-only damped mode driven by stochastic atmospheric forcing associated North Atlantic Oscillation (NAO) and critically involving anomalous density advection by the subpolar gyre. In addition to the differences in NAO forcing, slightly different strengths in the subpolar gyre circulation result in advection of opposite signed density anomalies into the convection site for each regime, which induces very different AMOC variability.

AMOC in CCSM3 T85x1 Present-day Control Integration

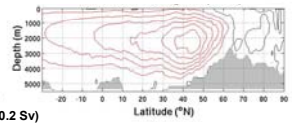
▪ Climatological mean (Yrs: 150-699) (CI: 2 Sv)



▪ EOF1 for Regime I (60.9%)

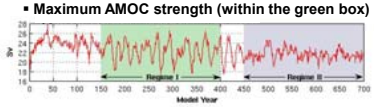


▪ EOF1 for Regime II (45.9%)

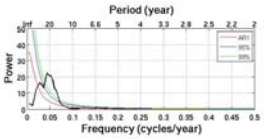


(CI: 0.2 Sv)

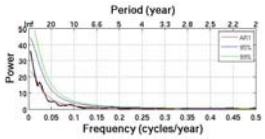
▪ Maximum AMOC strength (within the green box)



▪ PC1 for Regime I



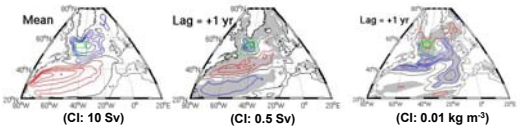
▪ PC1 for Regime II



- Regime I (Yrs 150-399): Strong 20-year oscillation.
- Regime II (Yrs 450-699): Red noise-like multi-decadal variability with persistence longer than10 yrs.

Direct Responses to NAO (Regime II only)

▪ Barotropic Streamfunction



(CI: 10 Sv) (CI: 0.5 Sv)

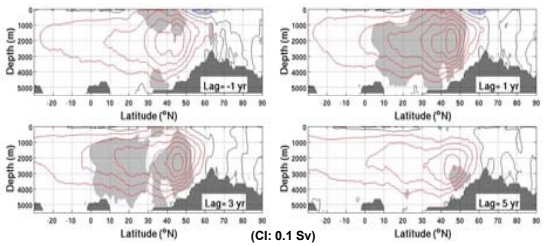
▪ Upper 500m Density

(CI: 0.01 kg m^{-3})

- Convection region (green boxes):
  Denser & anomalous cyclonic gyre
  ⇐ Surface buoyancy Forcing + positive feedback
- Gulf Stream-North Atlantic Current region:
  Northward shift of the currents
  ⇐ Wind stress curl forcing

•Large green box: Maximum mean convection region
•Small green box: Region of maximum winter MLD anomalies correlated with AMOC variability ⇒ Region for the convection index (next section)

▪ AMOC Regression on NAO (: positive lag = AMOC lags NAO)



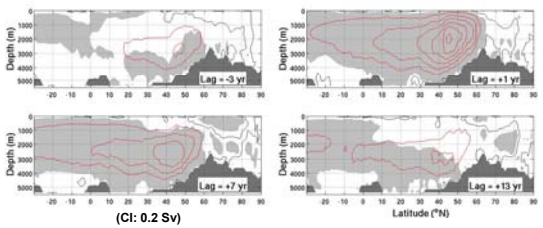
(CI: 0.1 Sv)

- Low-pass filtered (> 10 yr) regression.
- Pattern highly correlated to the AMOC EOF-1 pattern.
- Persistence shorter than 5 yrs.
  ⇒ **Need additional mechanism to explain long (> 10 yrs) persistence of AMOC variability.**

•Red/blue contour: positive/negative anomalies
•Shadings: significant at 95%

Delayed Ocean Circulation Feedback (Regime II only)

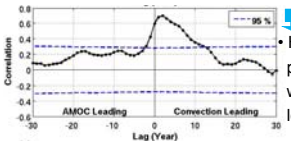
▪ AMOC Regression on the Convection Index (: positive lag = convection leads)



(CI: 0.2 Sv)

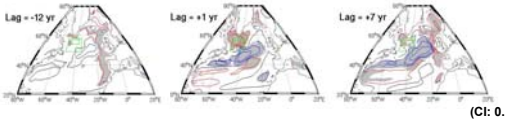
- Convection Index: Upper 500m density averaged over the convection index region (small green box)
- Persistence longer than 10 years!

▪ AMOC PC1 vs. Convection



- Hint of weak positive feedback when AMOC leads.

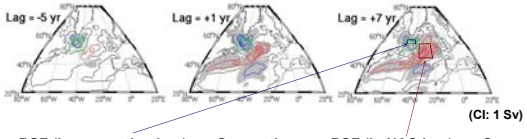
▪ Upper 500m Density Correlation with Convection



(CI: 0.2)

- Positive density anomalies from eastern boundary due to vertical mixing over continental slope associated with anomalous southward flow
  ⇒ **Positive feedback on the convection and thus AMOC**

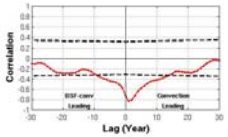
▪ Barotropic Streamfunction Regressed on Convection



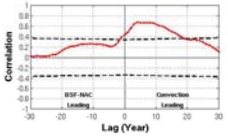
(CI: 1 Sv)

- **Positive feedback between convection/AMOC and horizontal circulation:**
  Greater convection
  ⇒ Intensified cyclonic gyre
  ⇒ Northward shift and anti-cyclonic anomalies in Gulf Stream-North Atlantic Current
  ⇒ Dense water anomalies along the eastern boundary
  ⇒ Greater convection

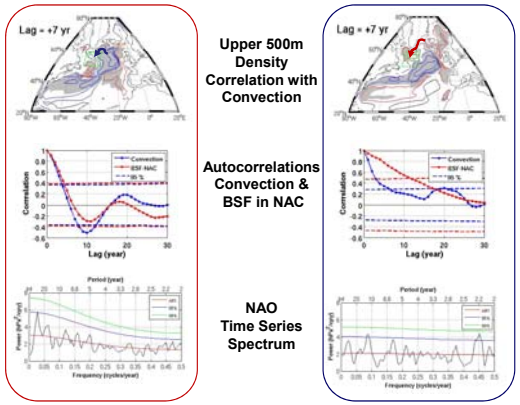
▪ BSF (in convection box) vs. Convection



▪ BSF (in NAC box) vs. Convection



Regime I vs. Regime II



Upper 500m Density Correlation with Convection

Autocorrelations Convection & BSF in NAC

NAO Time Series Spectrum

- **Possibility I: Subpolar Gyre Strength**
  Regime I: Slightly stronger gyre circulation advects negative density anomalies from interior of the gyre to the convection site. ⇒ Negative feedback & Oscillation

  Regime II: Weaker gyre circulation advects positive density anomalies from the eastern boundary.
  ⇒ Positive feedback & Persistence.

- **Possibility II: Atmosphere-Ocean Coupling**
  Regime I: Red noise-like NAO ⇒ Active coupling

  Regime II: White noise-like NAO ⇒ Passive ocean