Role of the Ocean-Atmosphere interactions for the Atlantic Multidecadal Variability in an idealized coupled model

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Atlantic Multidecadal Variability

- Sea Surface Temperatures (SST) in the North Atlantic contain a cycle at multidecadal time scales $\rightarrow$ **AMO**

- Correlated to the Atlantic **MOC** through Ocean Heat Transport [Knight et al., GRL 2005]

**AMO (Atlantic Multidecadal Oscillation):**

$\rightarrow \quad AMO = \left\langle SST \right\rangle_{\text{North Atlantic}}$

**MOC (Meridional Overturning Circulation):**

$\rightarrow \quad MOC = \int_{x_w}^{x_e} \int_{-h}^{z} v \, dz \, dx$

Regressed SST on the AMO index derived from HadISST dataset [Deser et al., ARMS 2010]
Atlantic Multidecadal Variability

- No consensus on the **role of the Atmosphere**
  - Coupled mode [Timmermann et al., JC 1998]
  - forced by NAO [Eden & Willebrand, JC 2001]
  - **Oceanic intrinsic mode** [Colin de Verdière & Huck, JPO 1999]

- **Oceanic intrinsic** MOC variability related to the propagation of large scale baroclinic Rossby waves

> How robust is this mechanism to ocean-atmosphere interactions?

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Schematic diagram of the **baroclinic Rossby waves** mechanism [teRaa and Dijkstra, JPO 2002]
Idealized numerical experiments

- MITgcm Coupled model with idealized flat bottom oceanic geometry
  → **Multidecadal MOC variability**
  [Buckley et al., JC 2012]

- Horizontal resolution of 4°, 2° and 1° (ocean & atmosphere) to better resolve synoptic structures

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**Yearly MOC index at 4°, 2° and 1°**

Idealized oceanic geometry (top) and MOC (in Sv) within the Atlantic-like basin (bottom) [Ferreira et al., JC 2010]
Large scale oceanic Rossby waves

- Westward propagation of large scale temperature anomalies, interacting with the MOC along the western boundary

→ Large scale Rossby waves mechanism seems robust at all resolutions

Subsurface temperature anomalies near 60°N, propagating from east to west; associated MOC anomalies on the left

Atlantic subsurface temperature std (σ), maximum around 60°N (thick black line)
Atmospheric variability

- Increased horizontal resolution
  - Increased atmospheric variability ...

EOF1 of yearly North hemisphere SLPA (hPa)

- ... associated with emergence of higher frequency signal at 1°

Yearly MOC index at 4°, 2° and 1° (top) and respective power spectrum (right)
Correlation between Sea Level Pressure Anomalies (SLPA) and the MOC index most significant when the SLPA leads the MOC by 2 years.

- No significant correlation at 4°: oceanic intrinsic mode [Buckley et al., JC 2012]
- Significant correlation at 1°: Similar to climate models [Gastineau and Frankigoul, CD 2012]

Does the NAO drive oceanic variability at 1°?
Ocean-Atmosphere interactions

- Observed SST variability driven by [Bjerknes, 1964; Gulev et al., Nature 2013]:
  - Atmosphere at interannual time scales
  - Ocean at multidecadal time scales

\[
\langle SST' \cdot Q' \rangle > 0 \rightarrow \text{atmosphere drives}
\]

\[
\langle SST' \cdot Q' \rangle < 0 \rightarrow \text{ocean drives}
\]
Ocean-Atmosphere interactions

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\[ Q \propto (T_a - SST) \]
- Q positive downward

In our simulations, SST variability in the north "Atlantic" is driven by the ocean on multidecadal time scales

\[ \text{Correlation} \langle SST' \cdot Q' \rangle, \text{based on the 10-yr smoothed SST and heat fluxes (Q) anomalies} \]
Ocean-only forced experiment

- Ocean-only experiment at 1°
- Forced with **200yr averaged** atmospheric fluxes from the coupled model (wind, heat, FW)

→ The MOC variability is **more regular**

**Yearly MOC index for the coupled and forced runs (left) and respective power spectrum (top)**
Ocean-only forced experiment

➔ **MOC variability** and propagation of large scale **baroclinic Rossby waves** are more regular

*Subsurface temperature anomalies near 60°N, propagating from east to west; associated MOC anomalies on the left.*
Conclusions

- Increased atmospheric variability with a significant SLPA/MOC correlation when atmosphere leads by 2 years at 1°

**BUT**

- Intrinsic oceanic variability associated with westward propagating large scale baroclinic Rossby waves

Thank you for your attention!


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