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

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Atlantic Multidecadal Variability

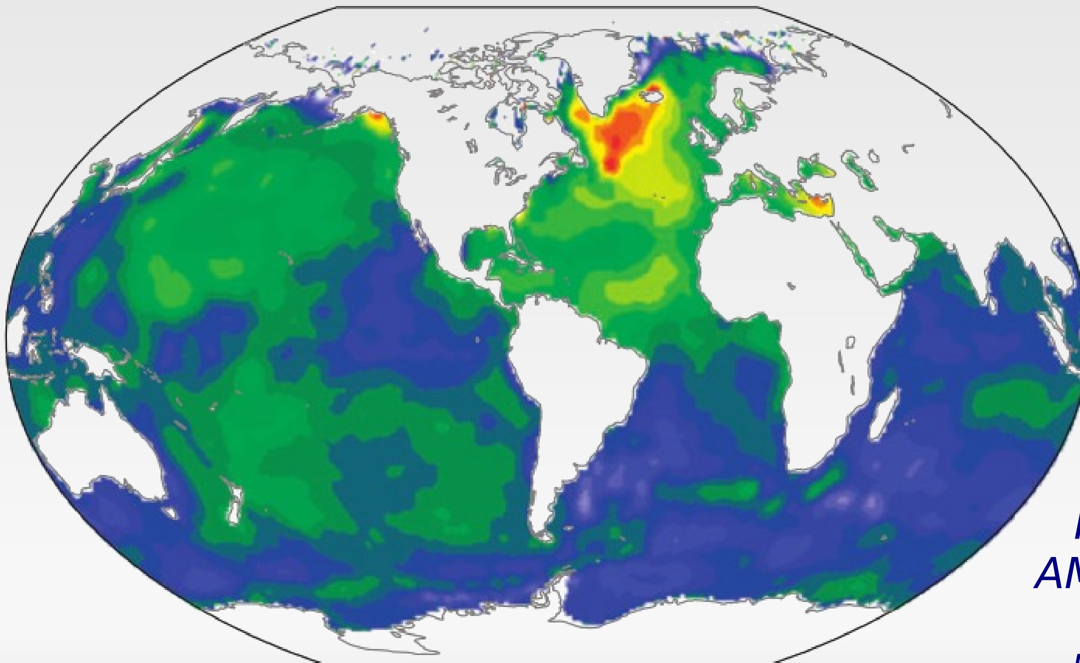
- Sea Surface Temperatures (SST) in the North Atlantic contain a cycle at multidecadal time scales → **AMO**
- Correlated to the Atlantic **MOC** through Ocean Heat Transport [Knight et al., GRL 2005]

AMO (Atlantic Multidecadal Oscillation):

$$\rightarrow \; AMO = \langle SST \rangle_{North\ Atlantic}$$

MOC (Meridional Overturning Circulation):

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



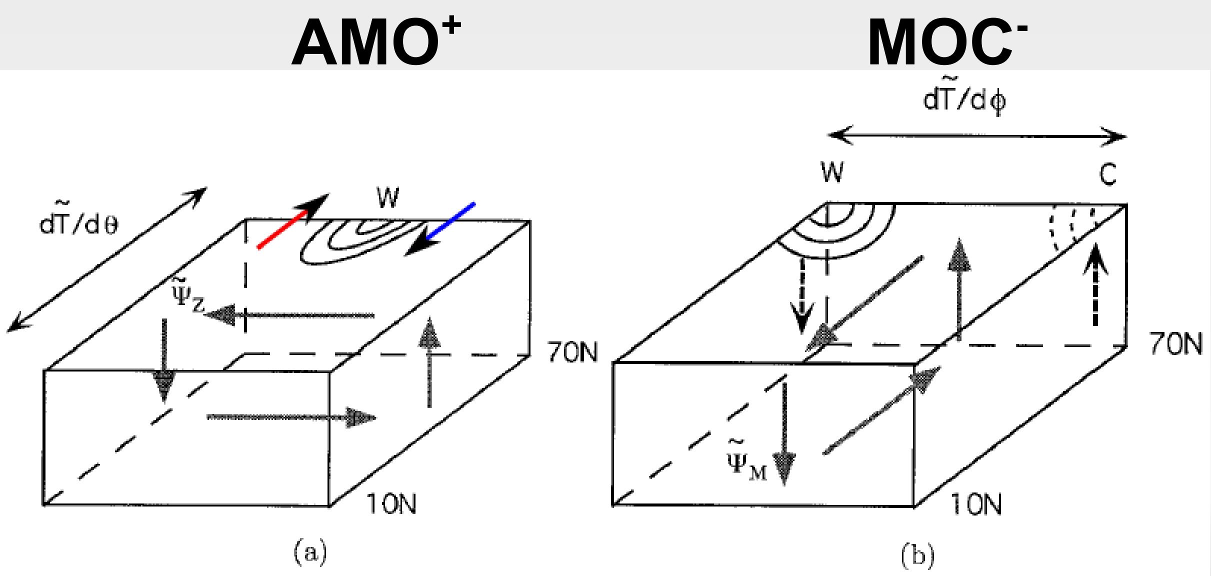
Regressed SST on the AMO index derived from HadISST dataset [Deser et al., ARMS 2010]

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?**

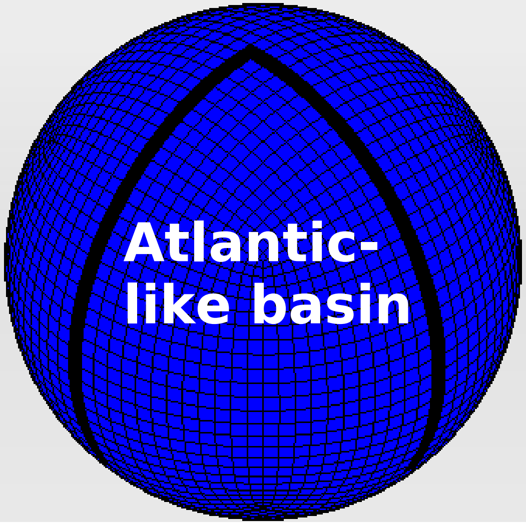


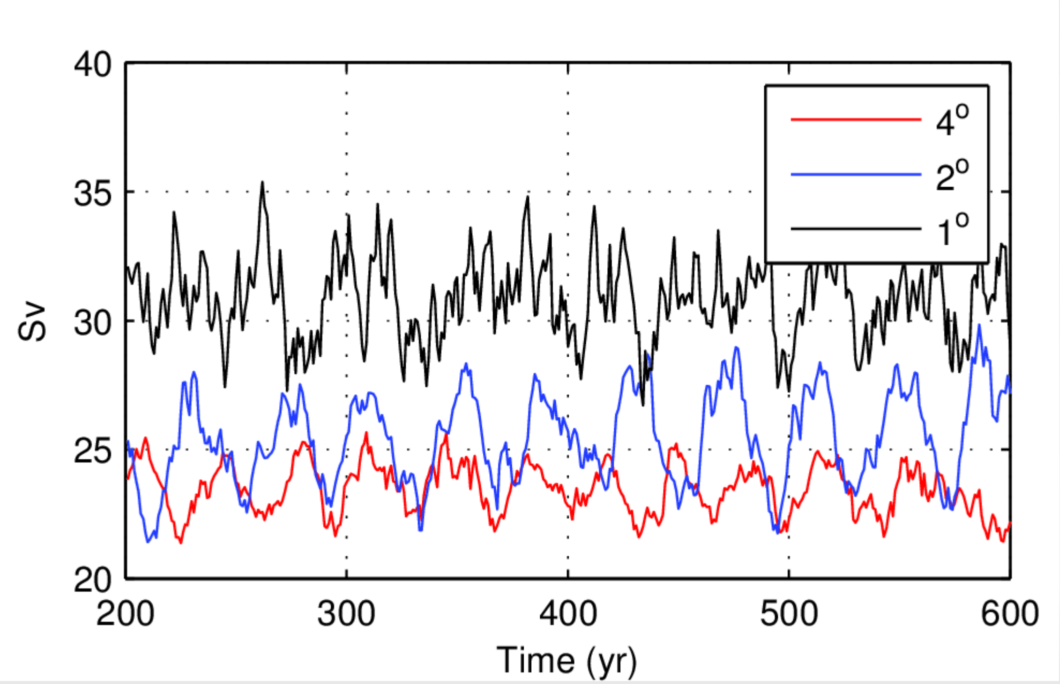
*Schematic diagram of the **baroclinic Rossby waves** mechanism [teRaa and Djkstra, JPO 2002]*

Idealized numerical experiments

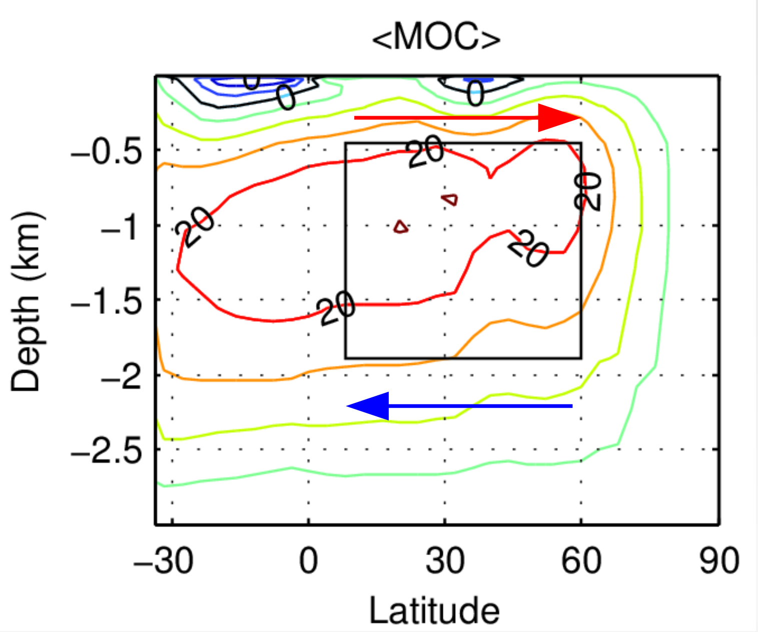
- MITgcm Coupled model with idealized flat bottom oceanic geometry
  → **Multidecadal MOC variability**
  [Buckley et al., JC 2012]

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





Yearly MOC index at 4°, 2° and 1°

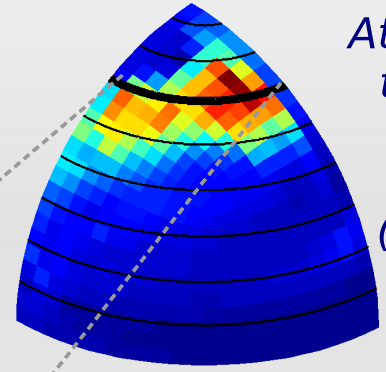


Idealized oceanic geometry (top) and MOC (in Sv) within the Atlantic-like basin (bottom) [Ferreira et al., JC 2010]

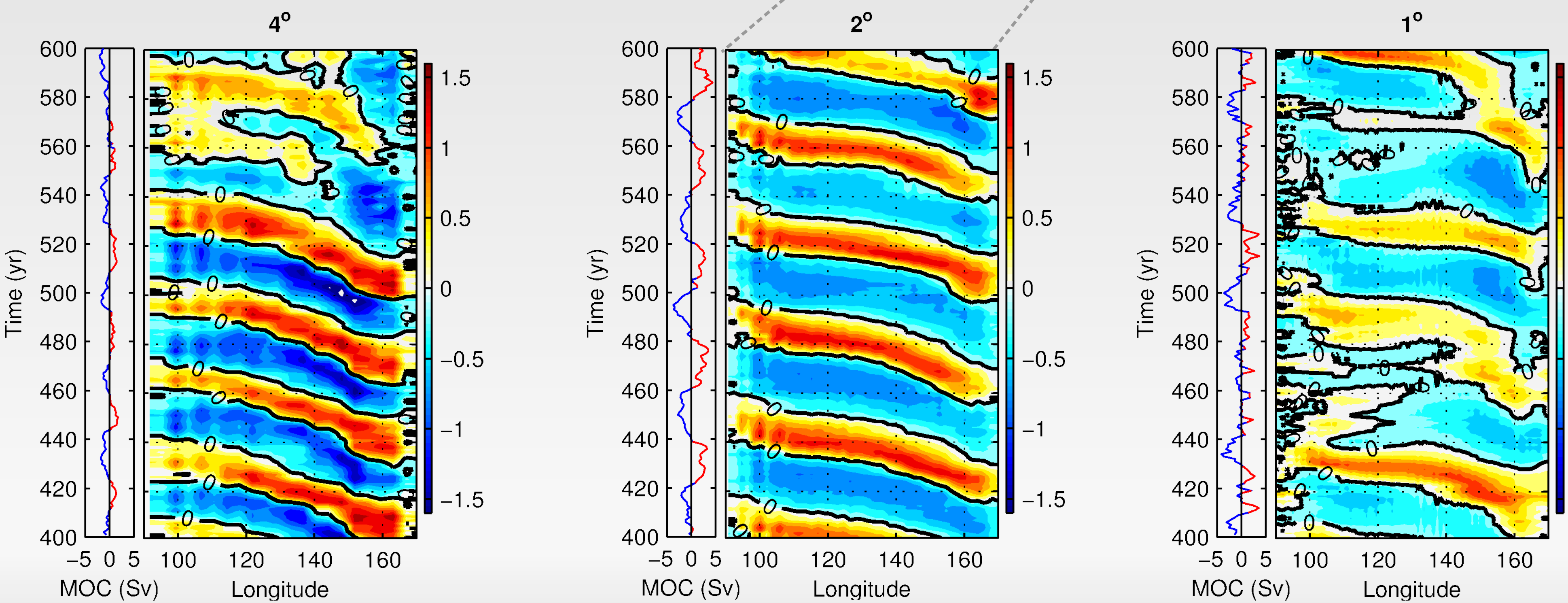
Large scale oceanic Rossby waves

- 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***



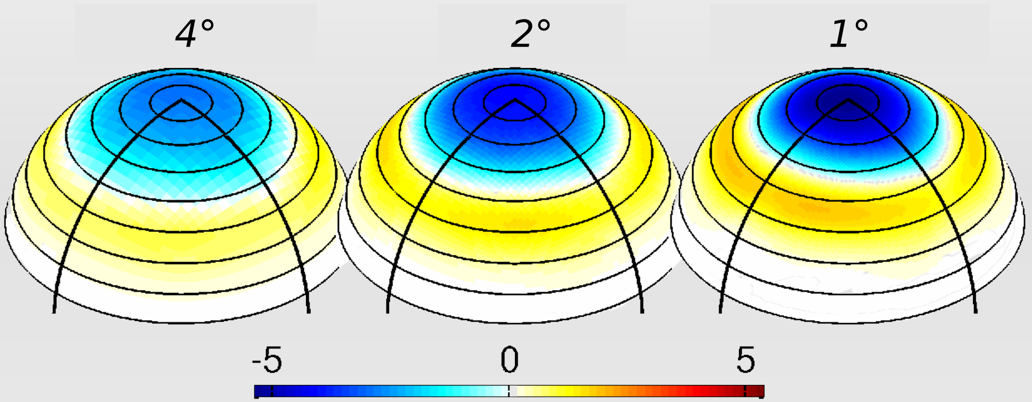
Atlantic subsurface temperature std (σ), maximum around 60°N (thick black line)



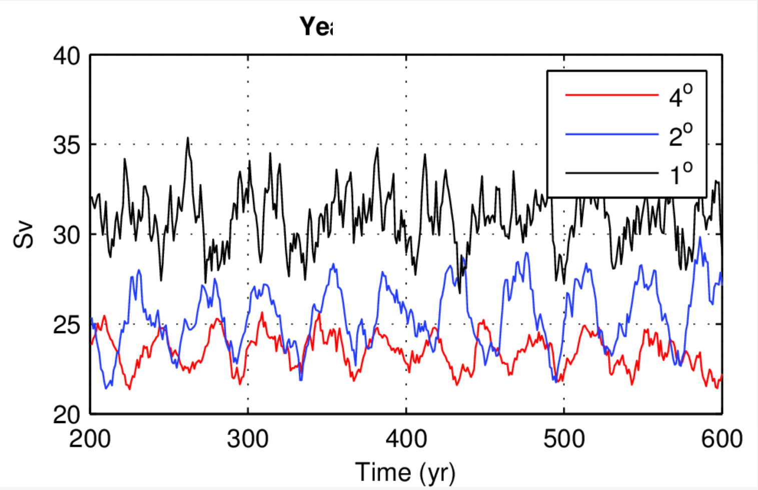
Subsurface temperature anomalies near 60°N, propagating from east to west; associated MOC anomalies on the left

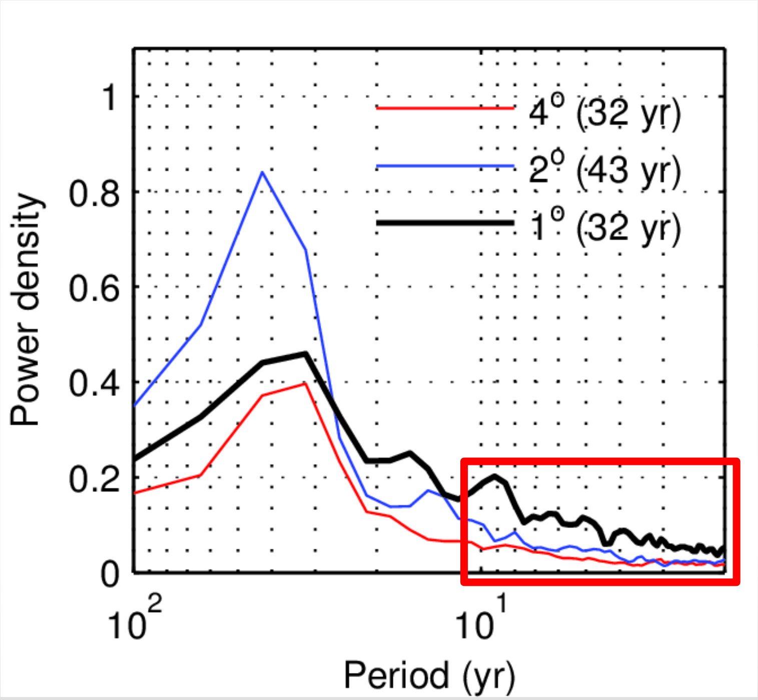
Atmospheric variability

- Increased horizontal resolution
  - ➔ Increased atmospheric variability ...



EOF1 of yearly North hemisphere SLPA (hPa)



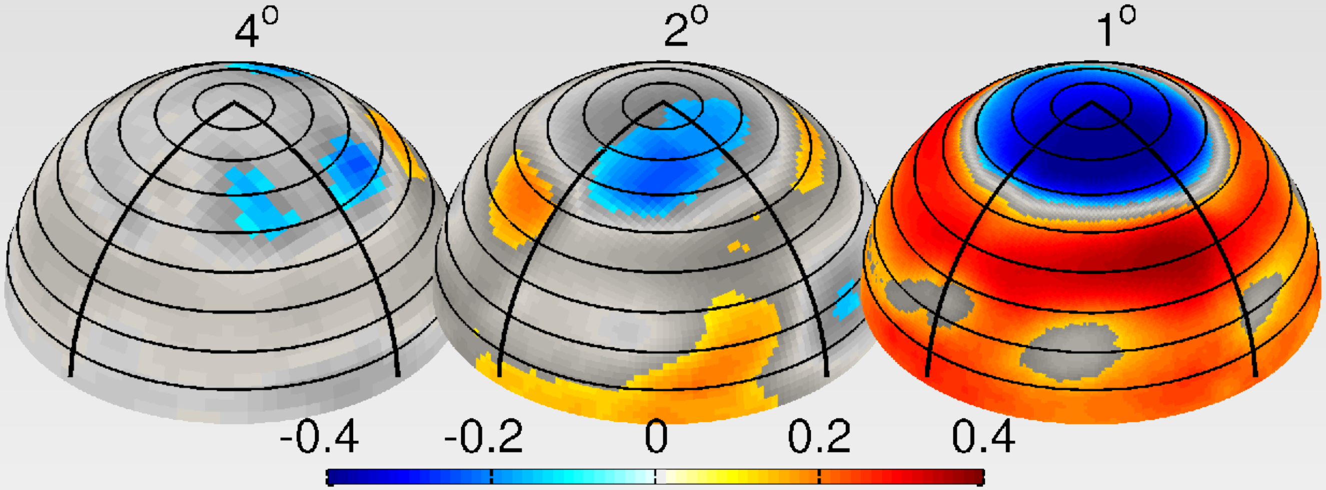


Yearly MOC index at 4°, 2° and 1° (top) and respective power spectrum (right)

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

Ocean-Atmosphere interactions

- Correlation between Sea Level Pressure Anomalies (SLPA) and the MOC index most significant when the SLPA leads the MOC by 2 years



Significant correlation (coloured) between SLPA and the MOC 2 yrs later (SLPA leads)

- 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

$\langle SST'.Q'\rangle > 0$ → atmosphere drives

$\langle SST'.Q'\rangle < 0$ → ocean drives

$$Q \propto (T_a - SST)$$

Q positive downward

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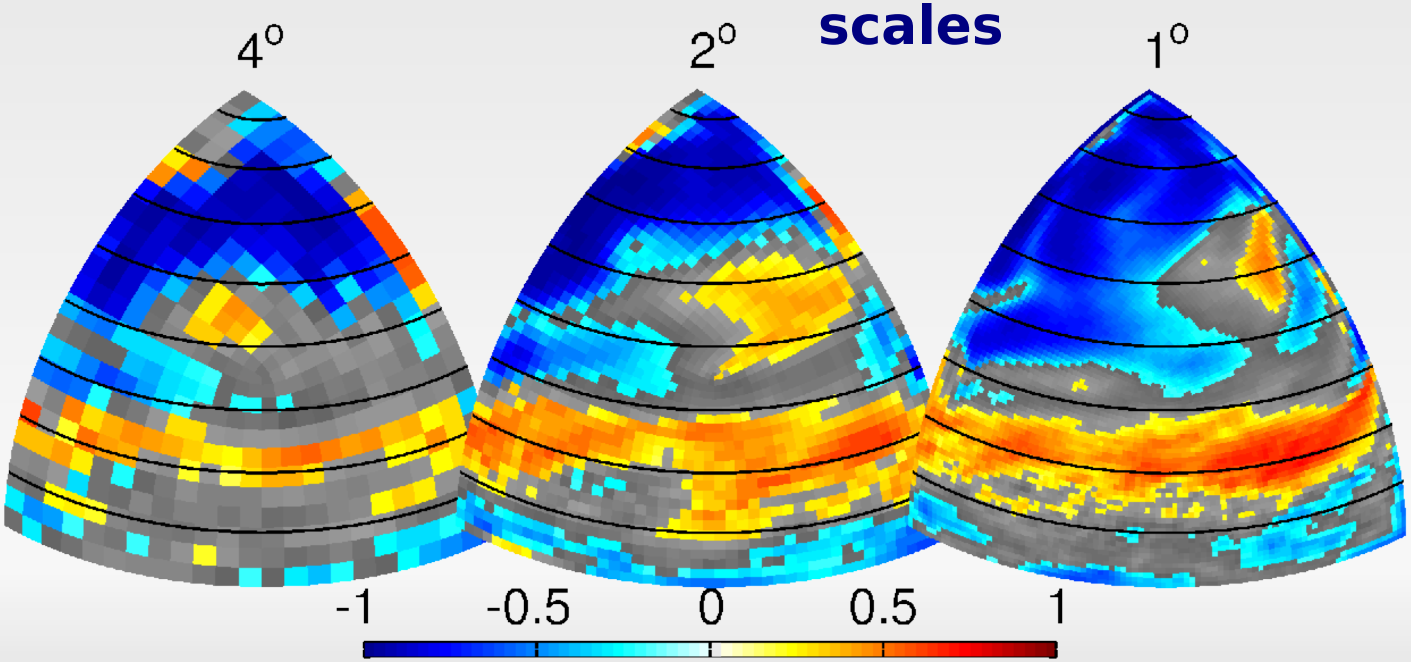
Q positive downward

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

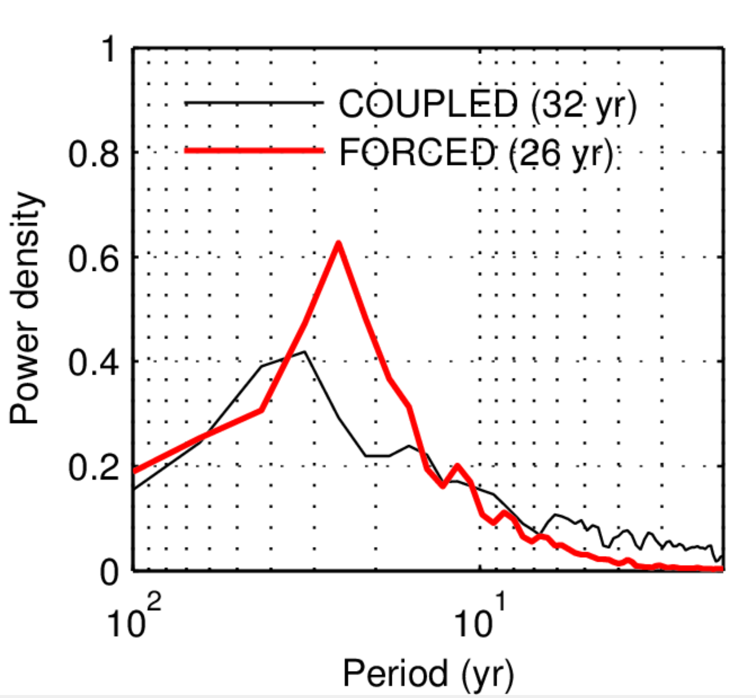


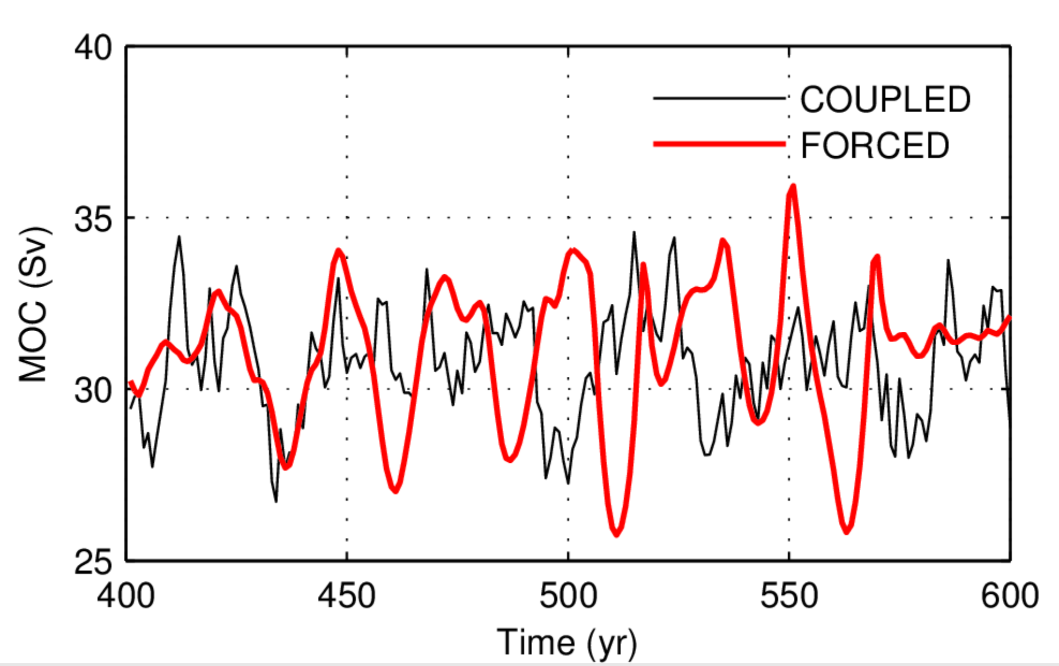
Correlation $\langle SST'.Q' \rangle$, based on the 10-yr smoothed SST and heat fluxes (Q) anomalies

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**

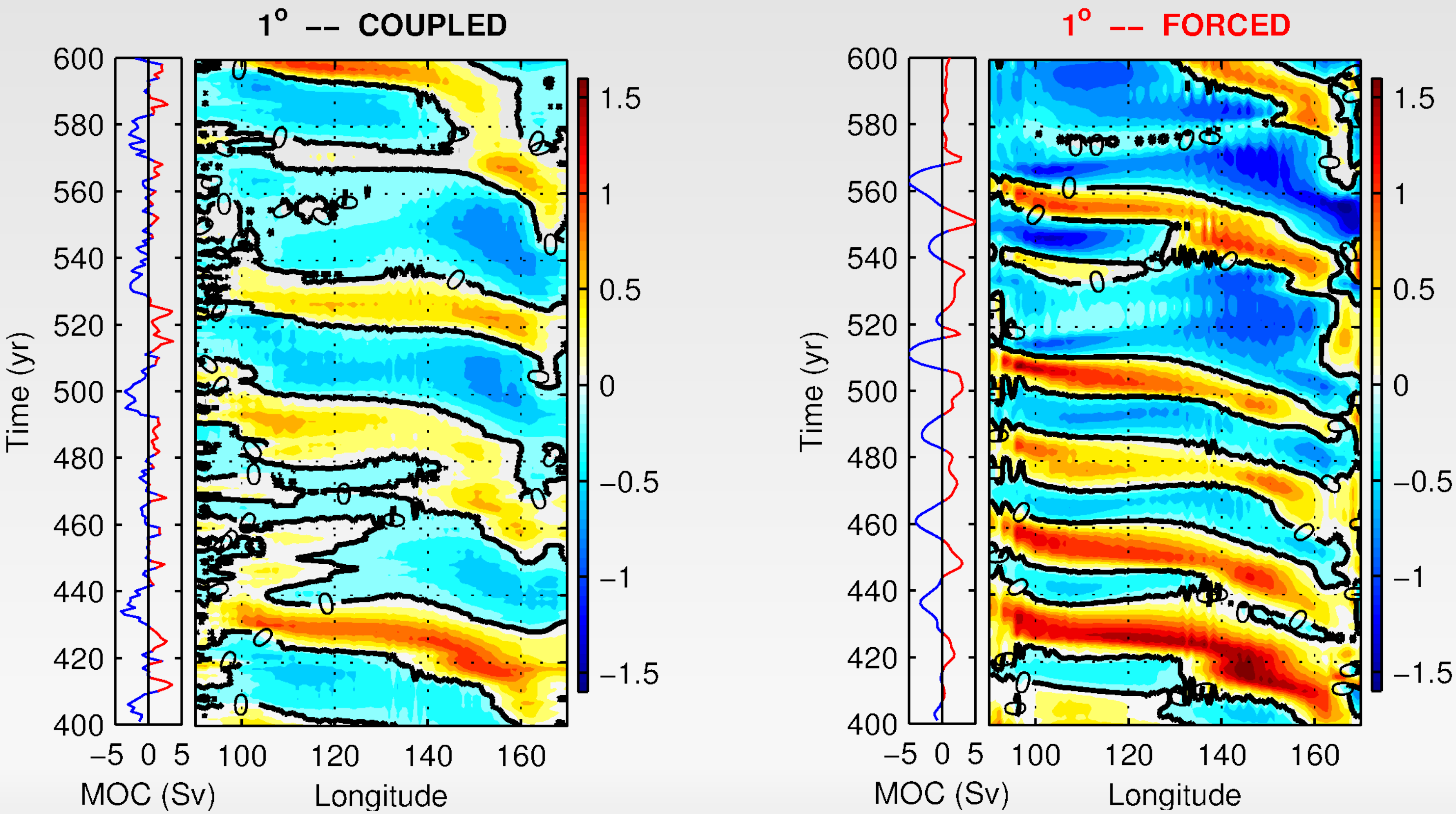




*Yearly MOC index for the **coupled** and **forced** runs (left) and respective power spectrum (top)*

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!

- Q. Jamet, T. Huck, A. Colin de Verdière, O. Arzel and J.-M. Campin: *Oceanic control of multidecadal variability in an idealized coupled GCM*; Clim. Dyn. (in revision)

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