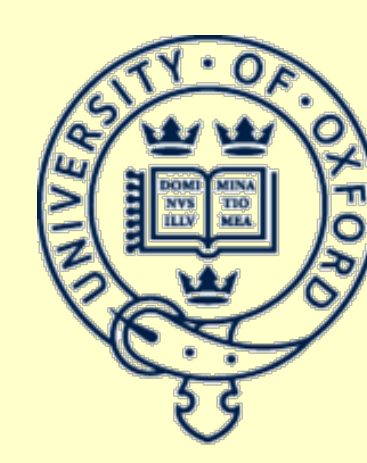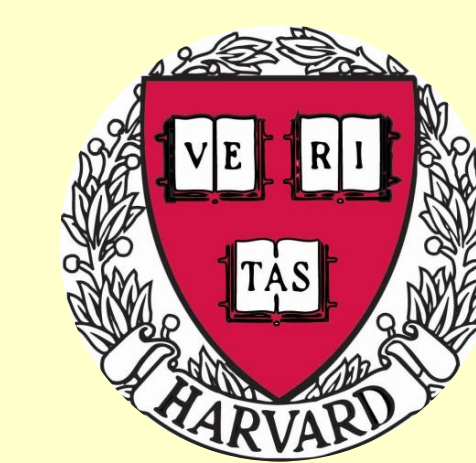# AMOC variability under 4xCO$_2$ conditions

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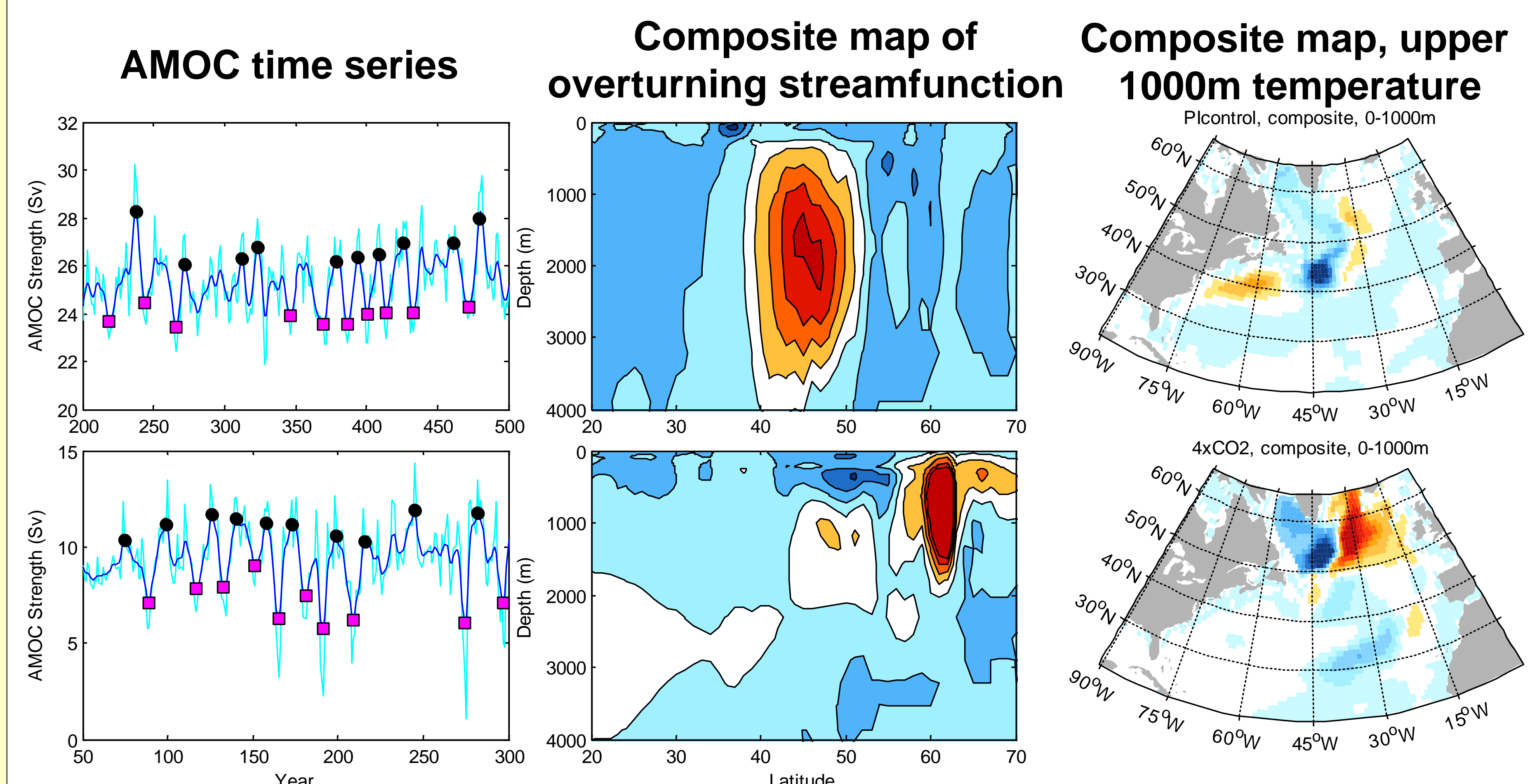Oxford University
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Goals

- How might interannual AMOC variability change with increased CO$_2$?
  - Focus on GFDL ESM2M which has a peak in power spectrum of AMOC variability at roughly a 15 year period
  - Compare preindustrial and 4xCO$_2$ simulations
- Key difference is a northward shift in the pattern of variability
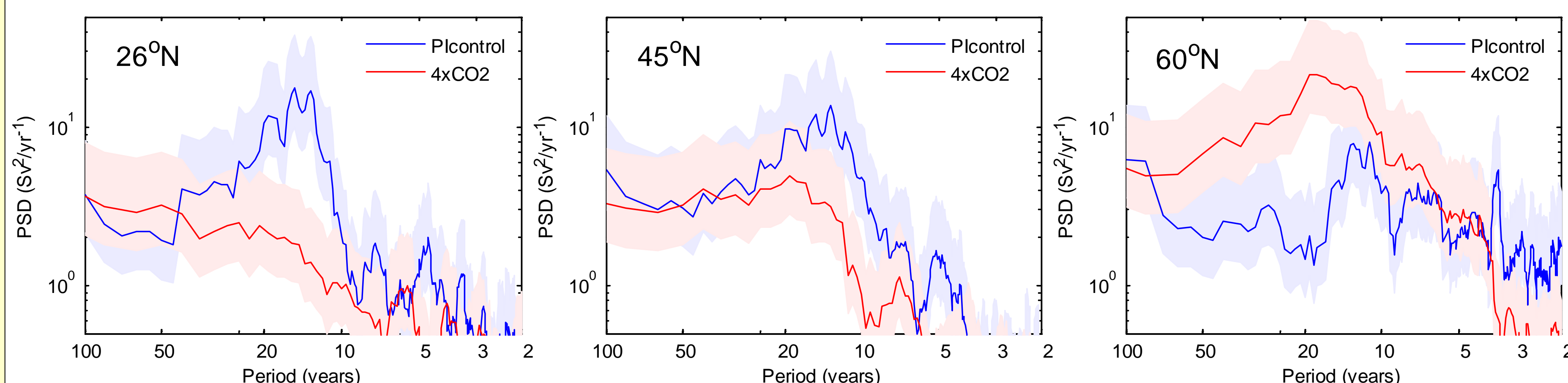
Oscillation Pattern: Composite Maps

- Generate average anomaly pattern from years when AMOC is at a maximum minus years at a minimum
 - See time series at left (45°N for preindustrial, 60°N for 4xCO$_2$)

AMOC time series   **Composite map of overturning streamfunction**   **Composite map, upper 1000m temperature**

- Oscillation in overturning streamfunction peaks at 45°N in preindustrial, 60°N in 4xCO$_2$
- Effect on temperature, salinity, density, etc. all occur further north
  - Including Nordic sea (not shown in plot above)
- Variability in vertical velocity @ 1000m depth:
  - Mostly off of Greenland in 4xCO$_2$
  - Near Grand Banks in preindustrial
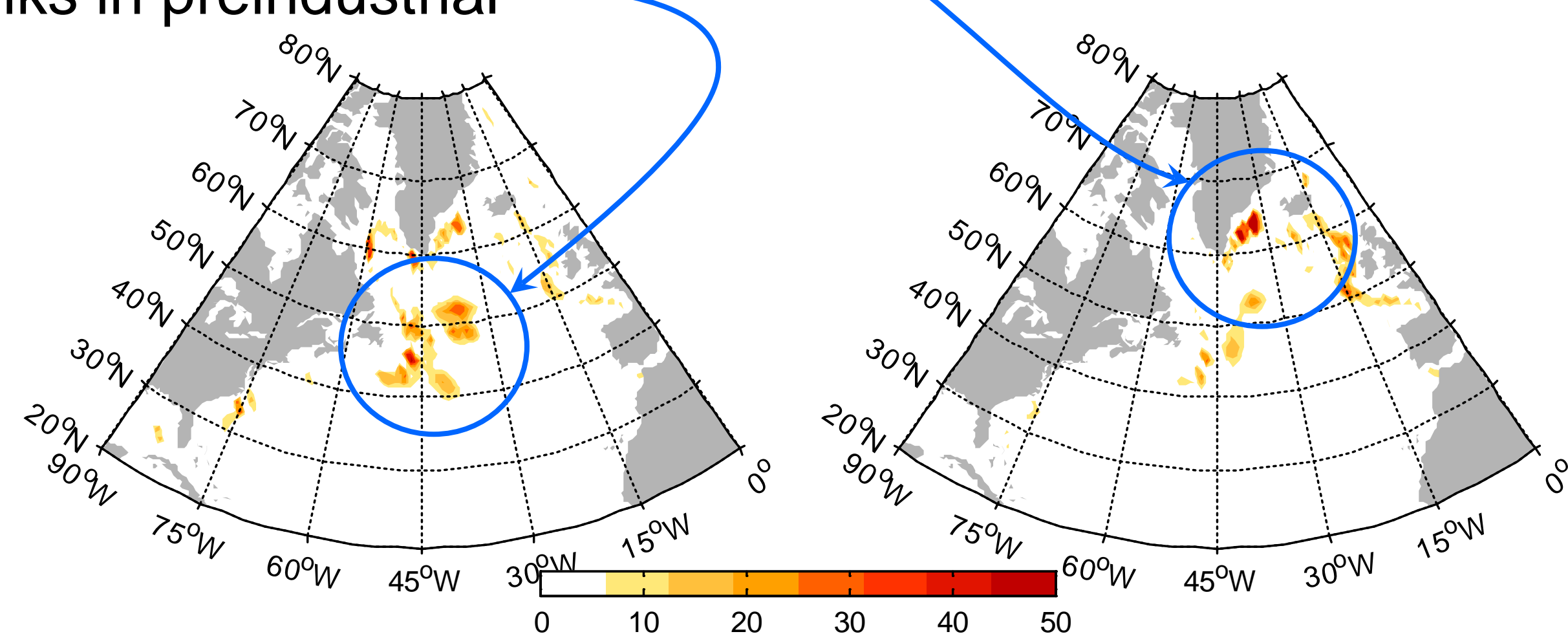
- Oscillation is thermohaline in both PI and 4xCO$_2$ cases (based on phase relationship between temperature, salinity, and AMOC)

Change in forcing or dynamics?

- Power spectrum of atmospheric forcing is relatively unchanged, but the transfer function from surface forcing to AMOC changes at peak frequency of AMOC
  - E.g. PSD of high-latitude wind stress
  - Transfer function to AMOC at 26N (left) and at 60N (right); PI (blue) and 4x (red)
- Difference in AMOC variability is mostly due to difference in dynamics
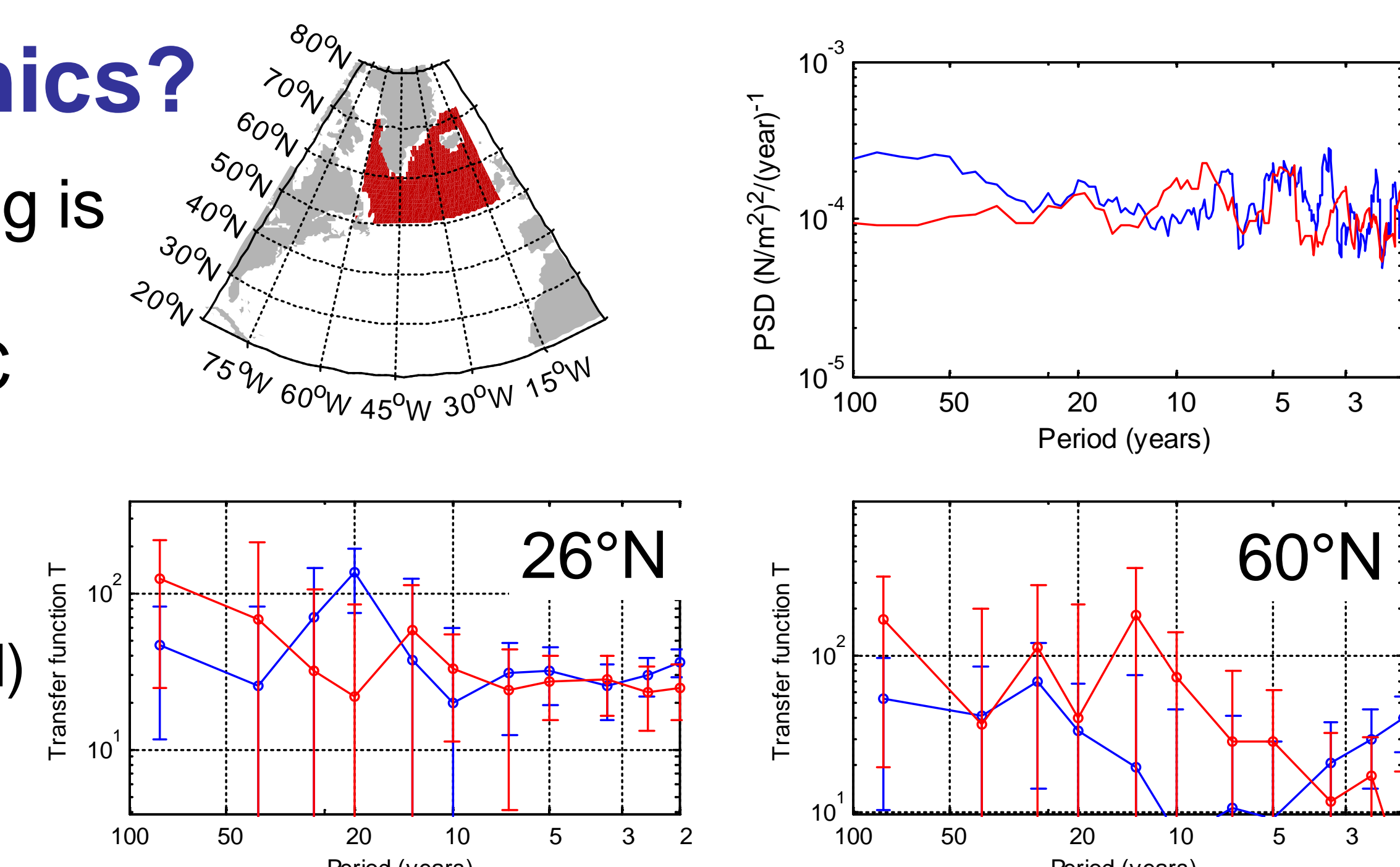
Relevant changes in mean field (in progress)

- Mean field changes due to high-CO$_2$ result in higher stratification *at depth* in the area where the variability in vertical velocity used to be high in preindustrial
  - Results in suppression of overturning variability at 45°N
  - Consistent with the decrease in both the mean strength and mean depth of the overturning circulation
  - No change at depth where variability occurs in 4xCO$_2$.

Mean Brunt-Väisälä frequency at 1000m depth
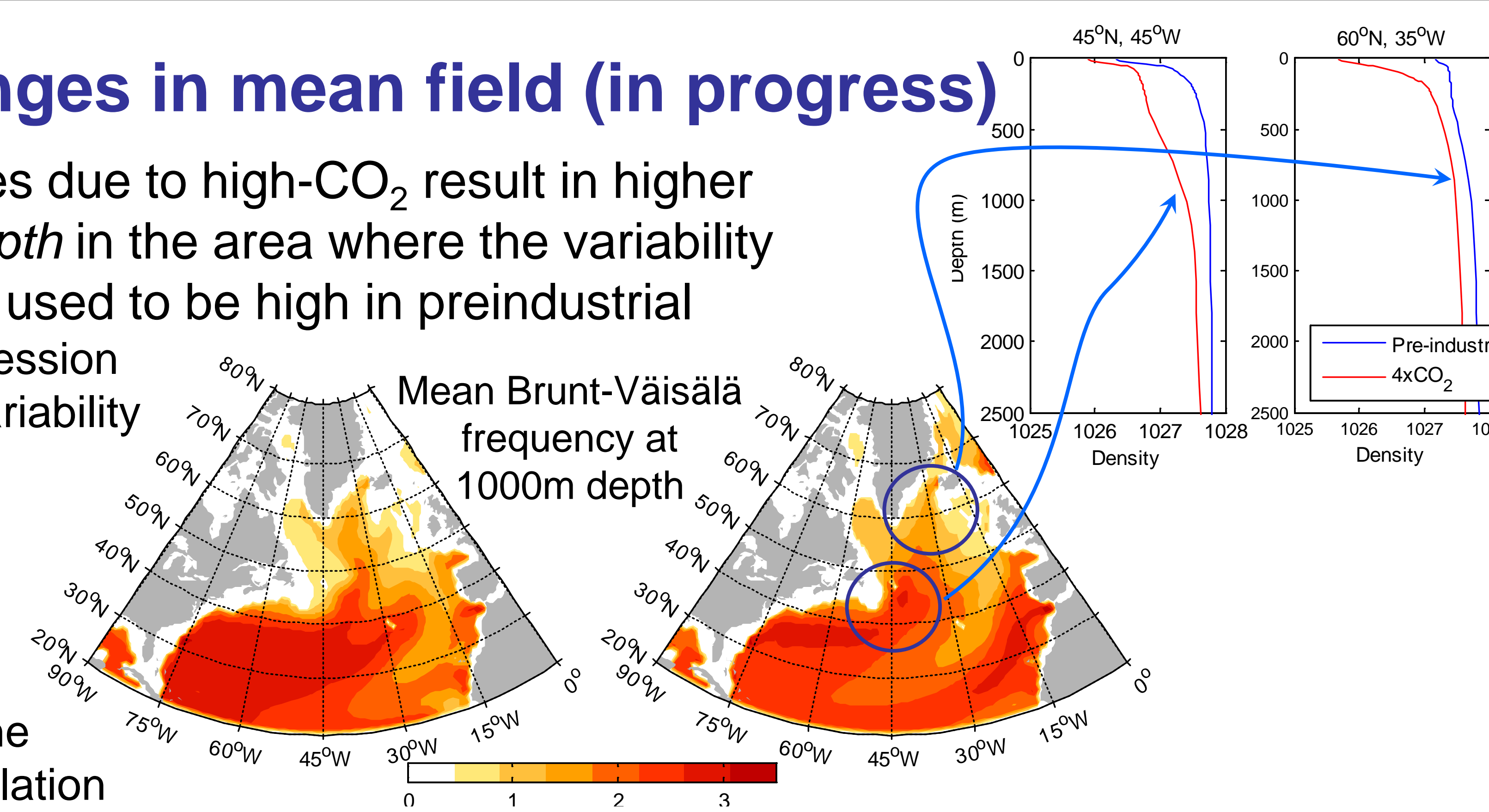
- Decreased surface density north of 45°N is primarily due to decreased salinity
- Further analysis is in progress…

Density change due to temperature   Density change due to salinity   Density change, 4xCO$_2$ - PI
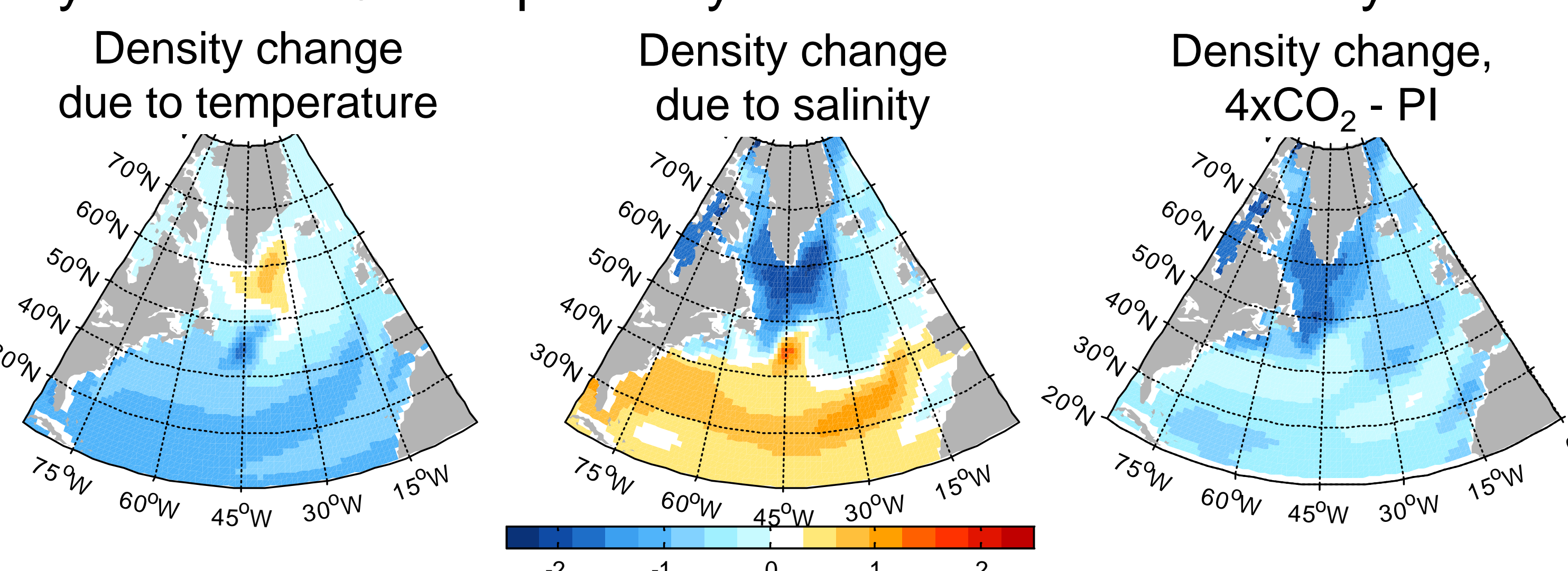
Summary

- Increased atmospheric CO$_2$ can lead to changes in AMOC variability
  - Variability in GFDL ESM2M shifts further north (from largest variability at 45°N to largest variability at 60°N, with no signal at 26°N)
  - Caused by a shift in internal ocean dynamics, rather than any change in "external" forcing
- Changes in mean field are (presumably) responsible for changes in dynamics, however, linkages are still unclear.
  - Potential pathway:
    - Decreased surface density due to decreased salinity
    - Decreased and shallower mean overturning circulation leads to greater stratification at depth (~1000m) in the region where variability in overturning circulation used to occur.
    - Further north where variability occurs in 4xCO$_2$ simulation, surface density changes do not propagate very deep at all; stratification is comparable to pre-industrial.