The Variability of Deep Convection and the Subpolar Gyre in the North Atlantic

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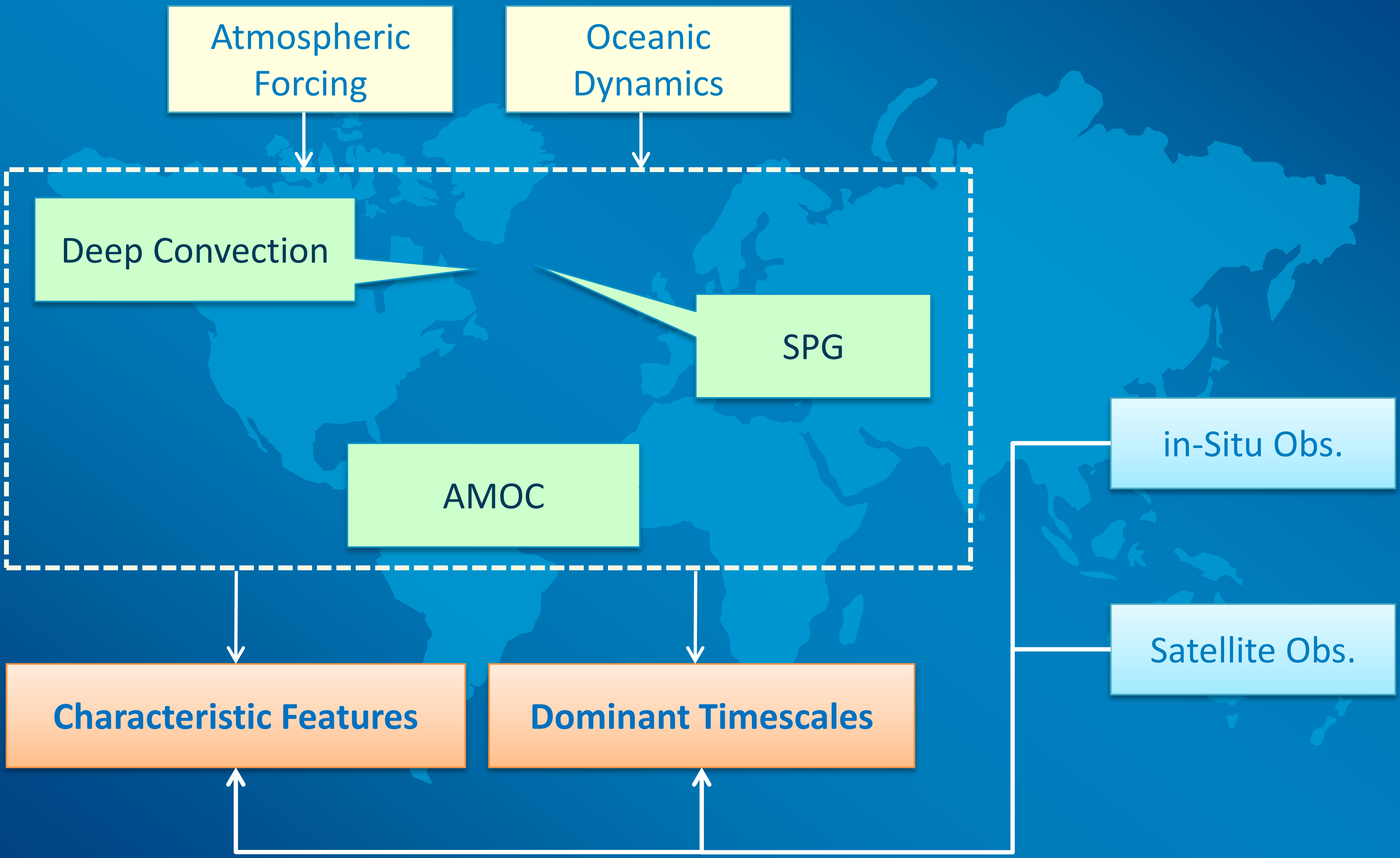
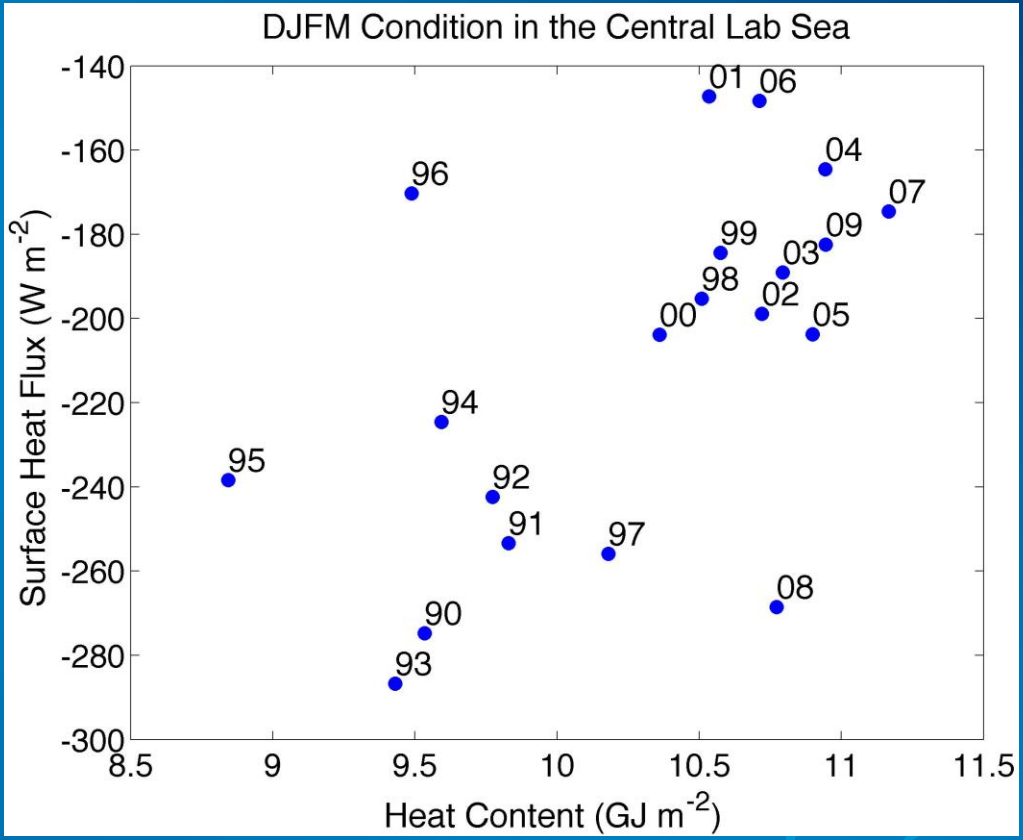
Goal: use observations to examine coherent changes between deep convection, the subpolar gyre and the AMOC



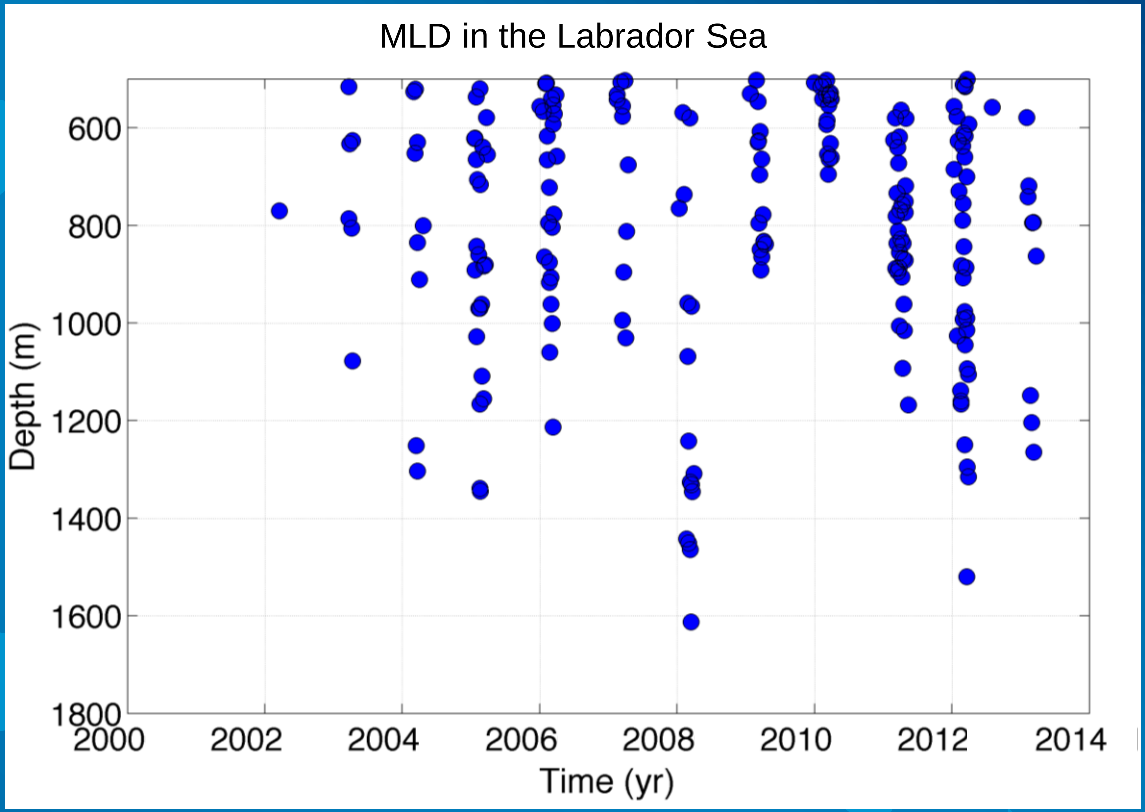
Surface Heat Flux and Heat Content

- Harsh winters: 1992 – 1994
- Mild winters: the mid-1990s to the 2000s
- The winter of 2008 was exceptional in the 2000s

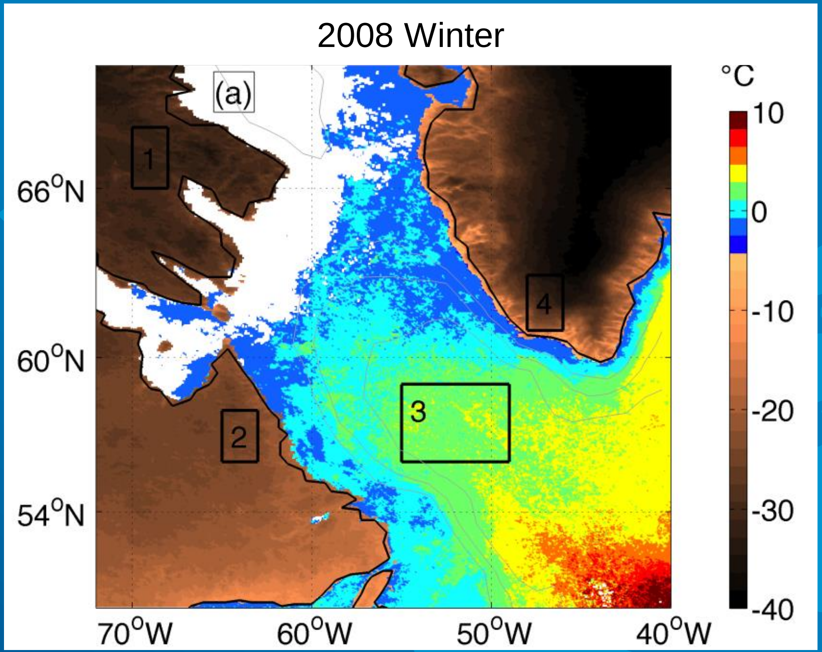


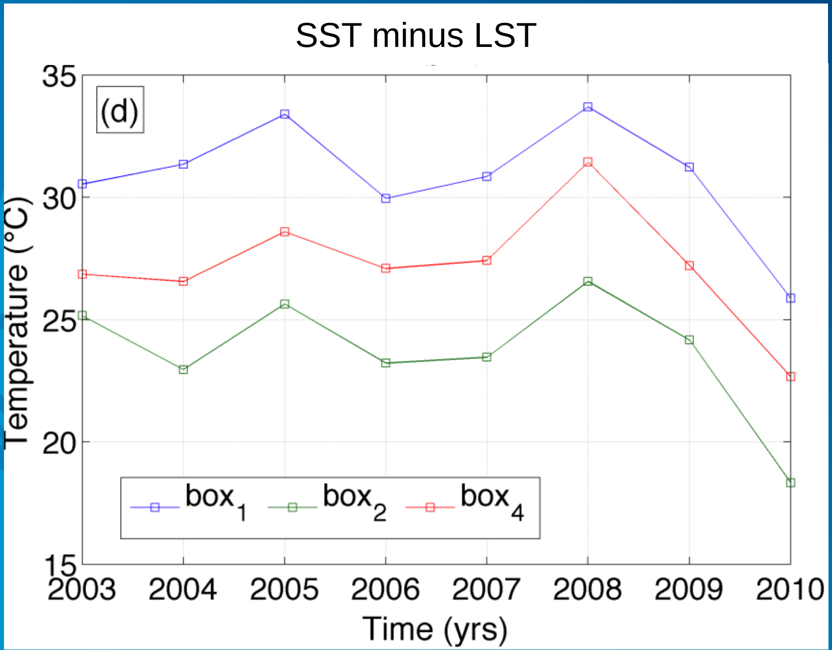
Mixed Layer Depth

- Lack of Argo data before 2003
- 2004-2010: Decreased MLD
- Enhanced deep convection after 2010



Temperature Difference

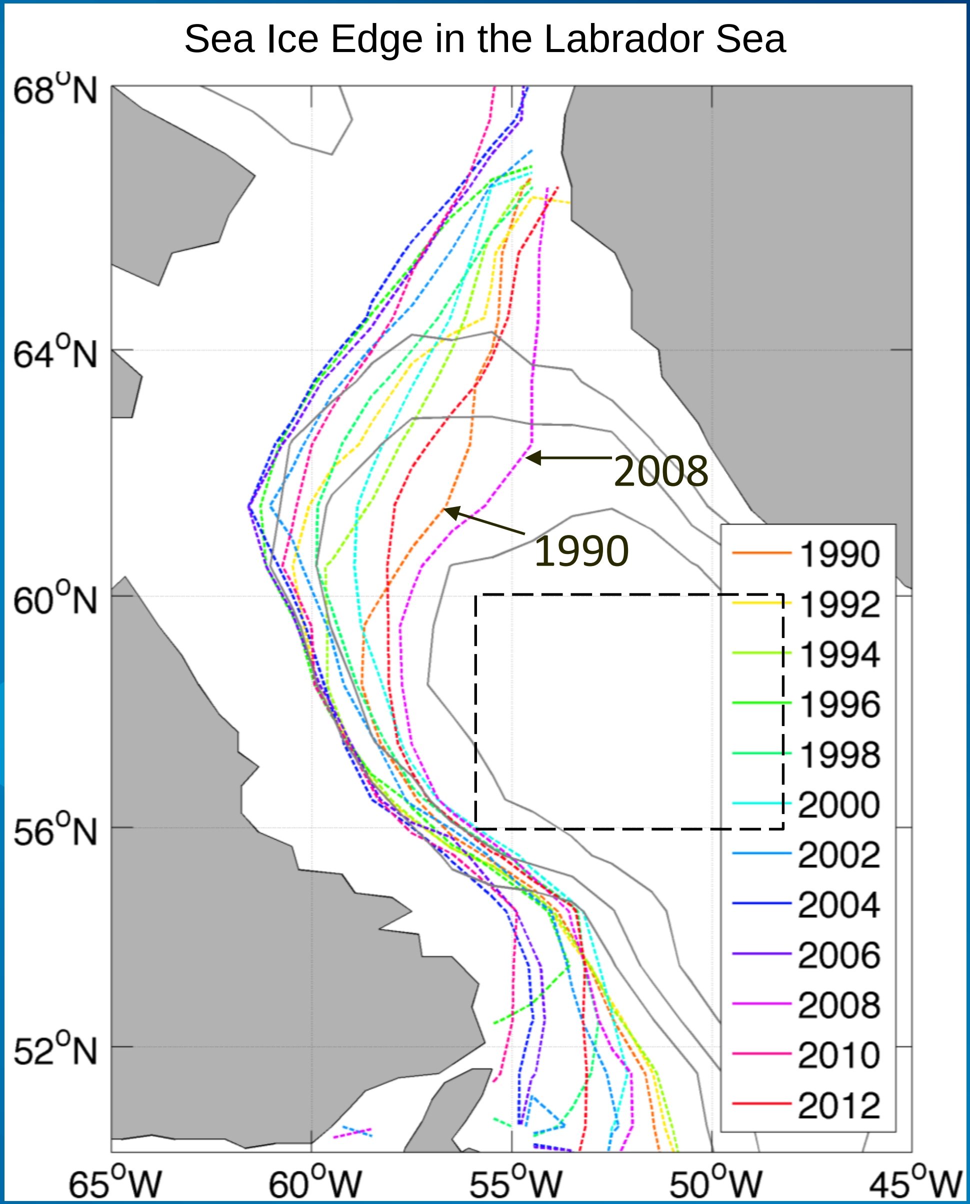




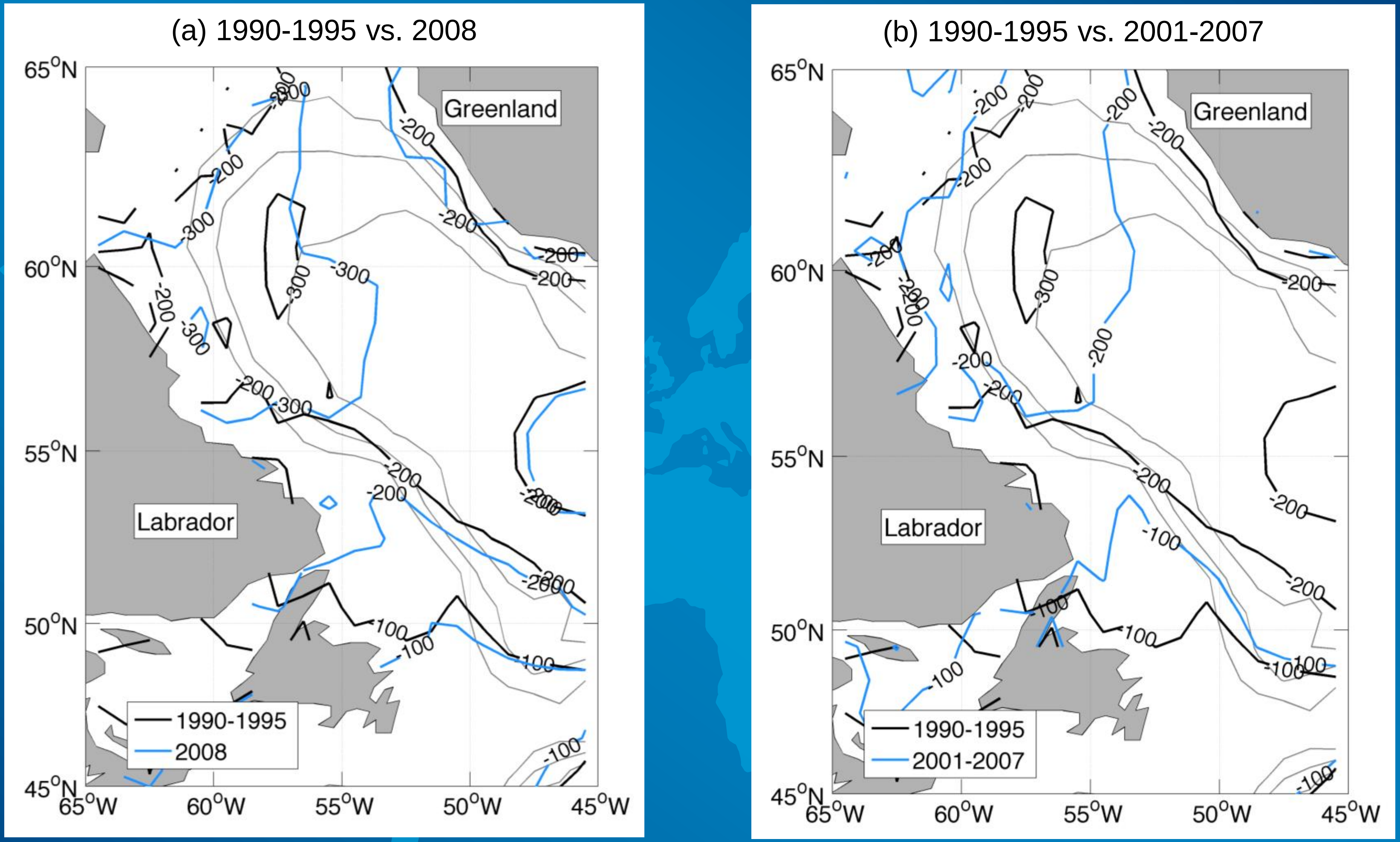
- Large temperature difference corresponds to enhanced deep convection (e.g., 2005 MLD=1400m and 2008 MLD=1700m)

Sea Ice Extent

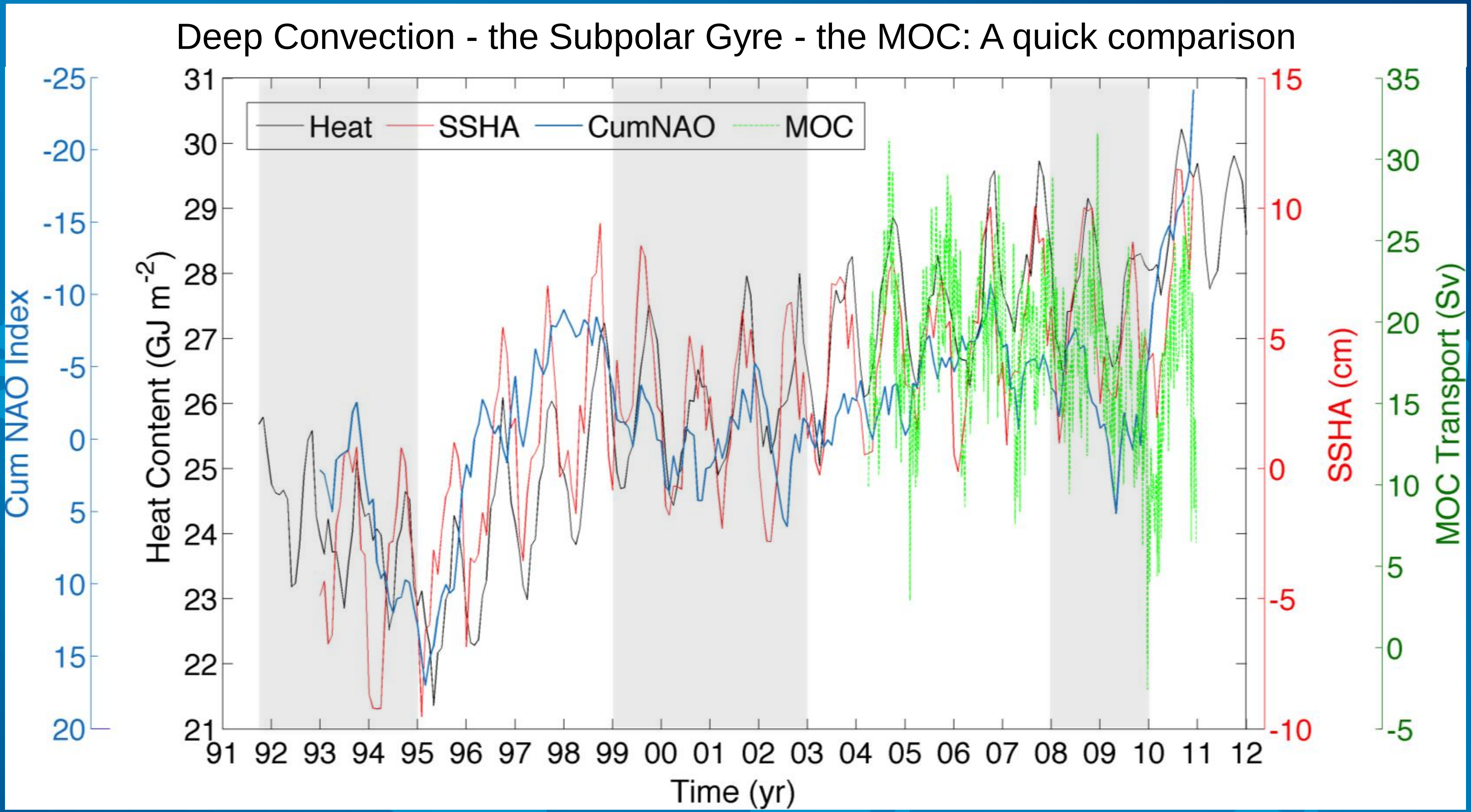
- 1990-2007: Northwestward retreat
- 2008: extended ice coverage exceeds the conditions in the early 1990s



Net Heat Flux



- Enhanced heat loss in the Labrador Sea interior during the winter of 2008



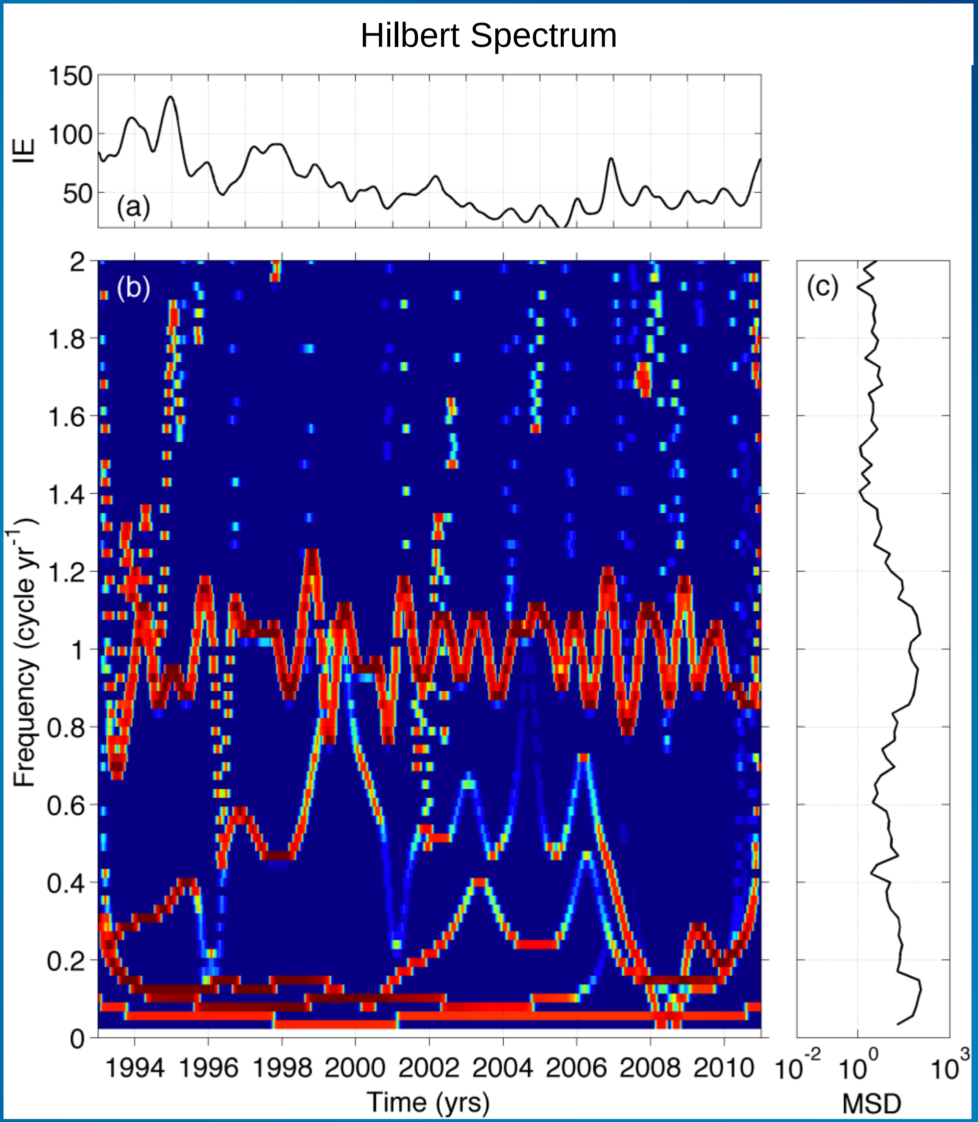
- High correlations at annual and interannual scales
- Cum NAO is indicative of low-frequency variations

The Subpolar Gyre Sea Level Variability

- Two persistent maxima: annual and decadal scales
- IE plot: no significant in the 2000s

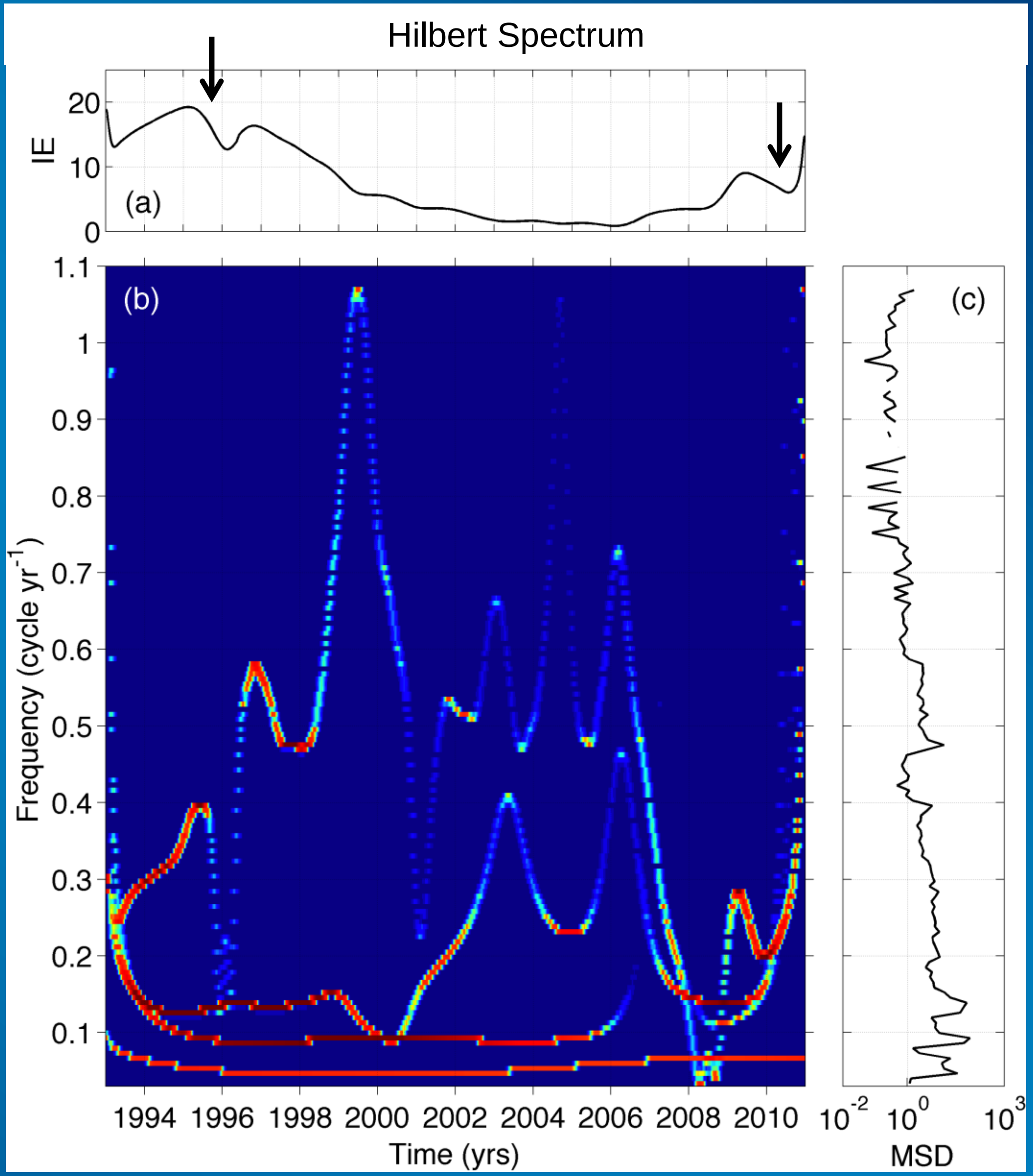
$$\mathrm{IE} = \int_{\omega} H^2(\omega,t)\,d\omega$$

$$\mathrm{MSD} = \int_{0}^{T} H(\omega,t)\,dt$$



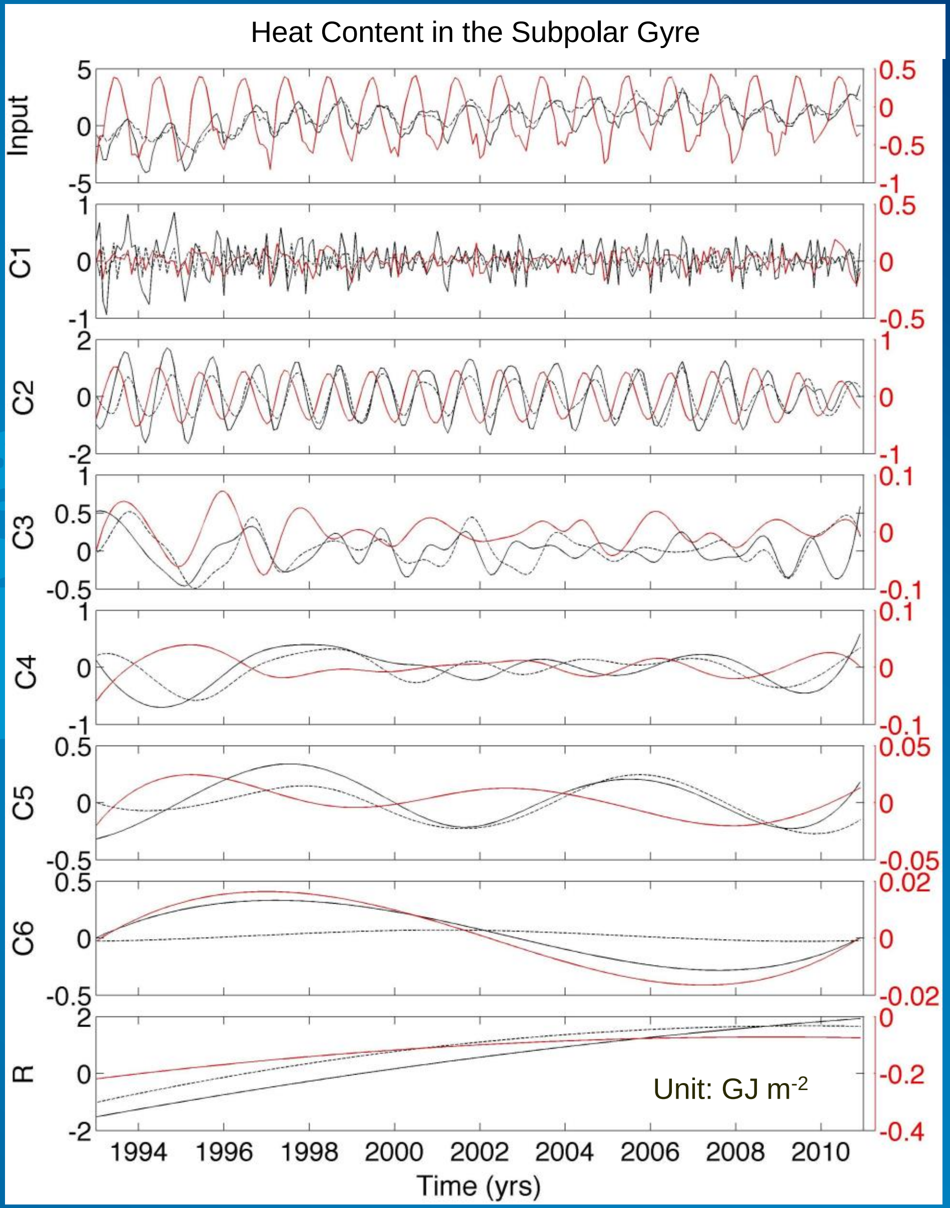
The Subpolar Gyre Sea Level Variability

- The intra-annual and annual signals removed
- Maximum amplitudes are shifted toward low frequency bands
- Reversal of IE around mid-2000s
- Sudden IE drops in 1995-1996 and 2009-2010



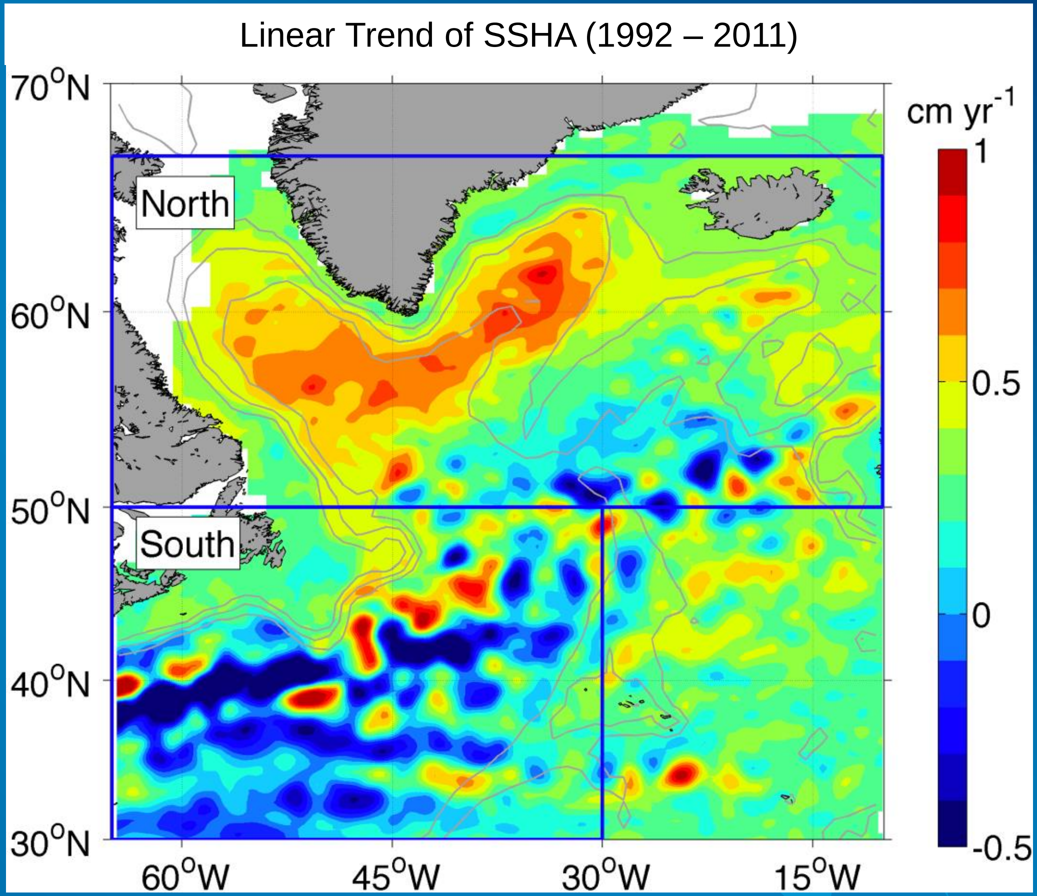
Causes of the SSHA Variations

- Air-sea heat flux (red line) is important at annual scales (2-3 month time lead of heat content changes)
- OHC changes estimated from SSHA (solid black) and from temperature (dashed black) agree well (phase and amplitude)



Mid- to High-Latitude North Atlantic

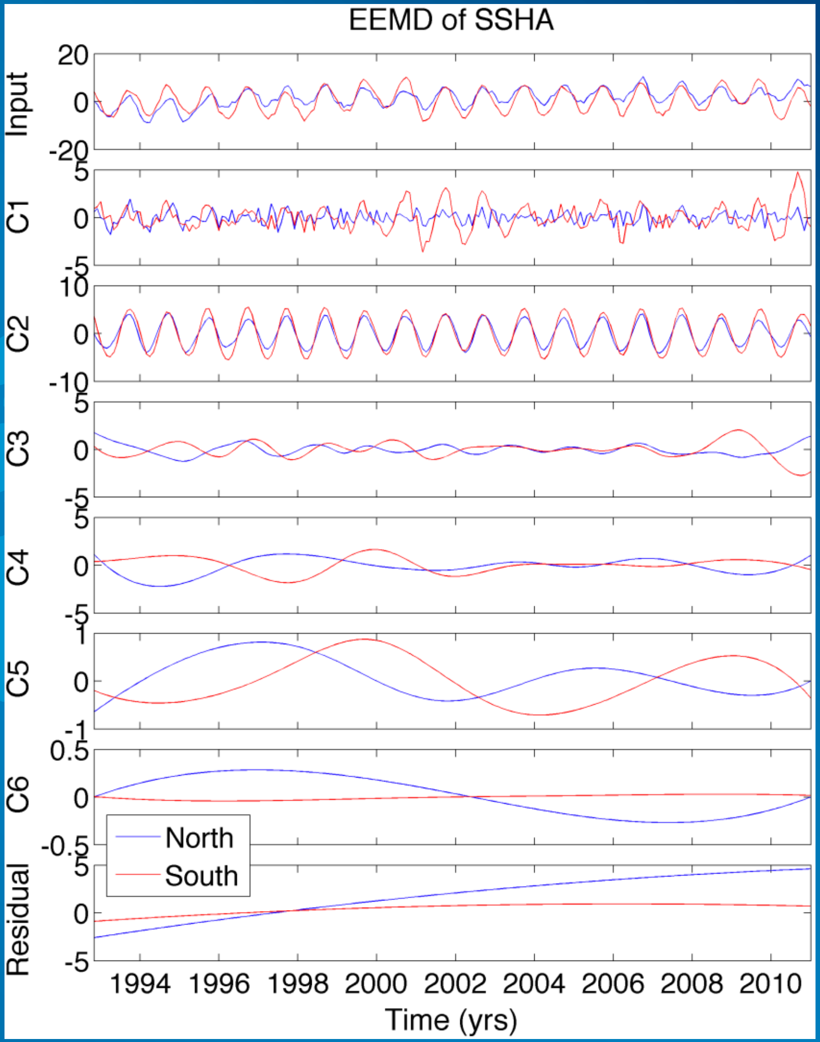
- Increasing in the subpolar region (maximum 8 mm yr^{-1})
- Decreasing in the Gulf Stream region (minimum -10 mm yr^{-1})



Li et al. GRL (2012)

Dipole Pattern

- Simultaneous change at the annual timescale
- Out-of-phase at the interannual timescales
- Residuals: 3.6 mm yr^{-1} (North); 0.8 mm yr^{-1} (South)



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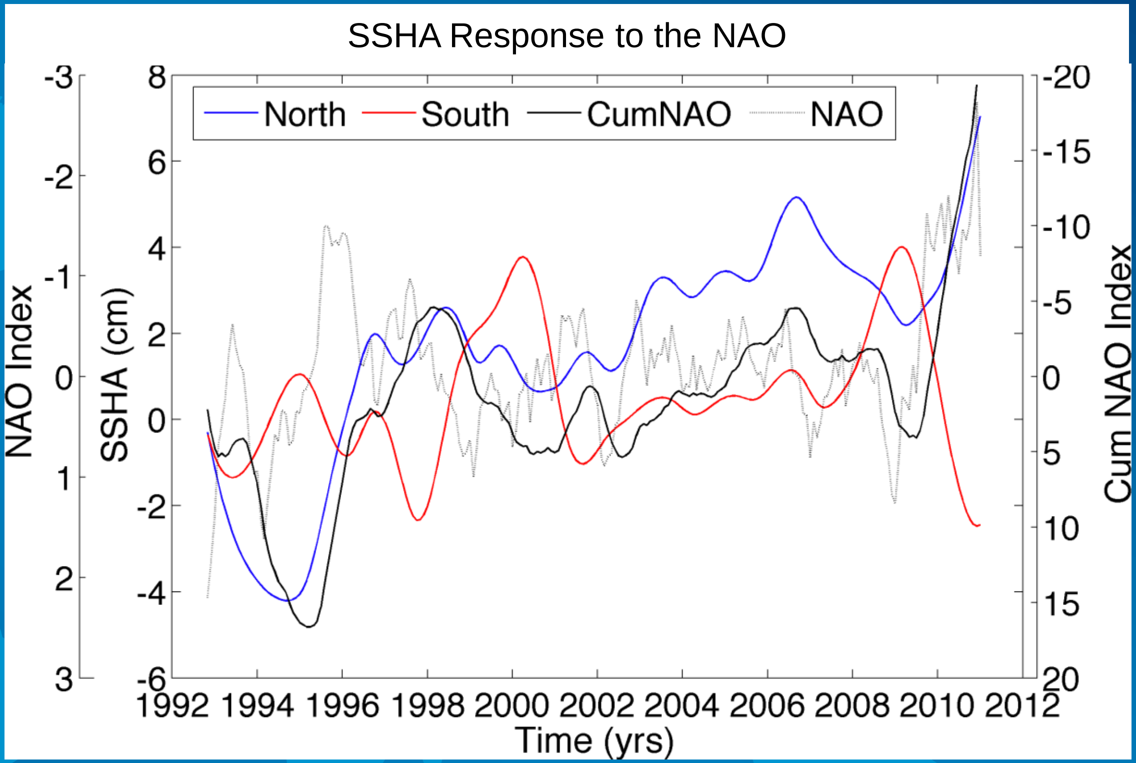
Low-frequency Variability

- SSHA at longer than annual timescales
- 'North' responds to CumNAO more effectively (r=-0.84)



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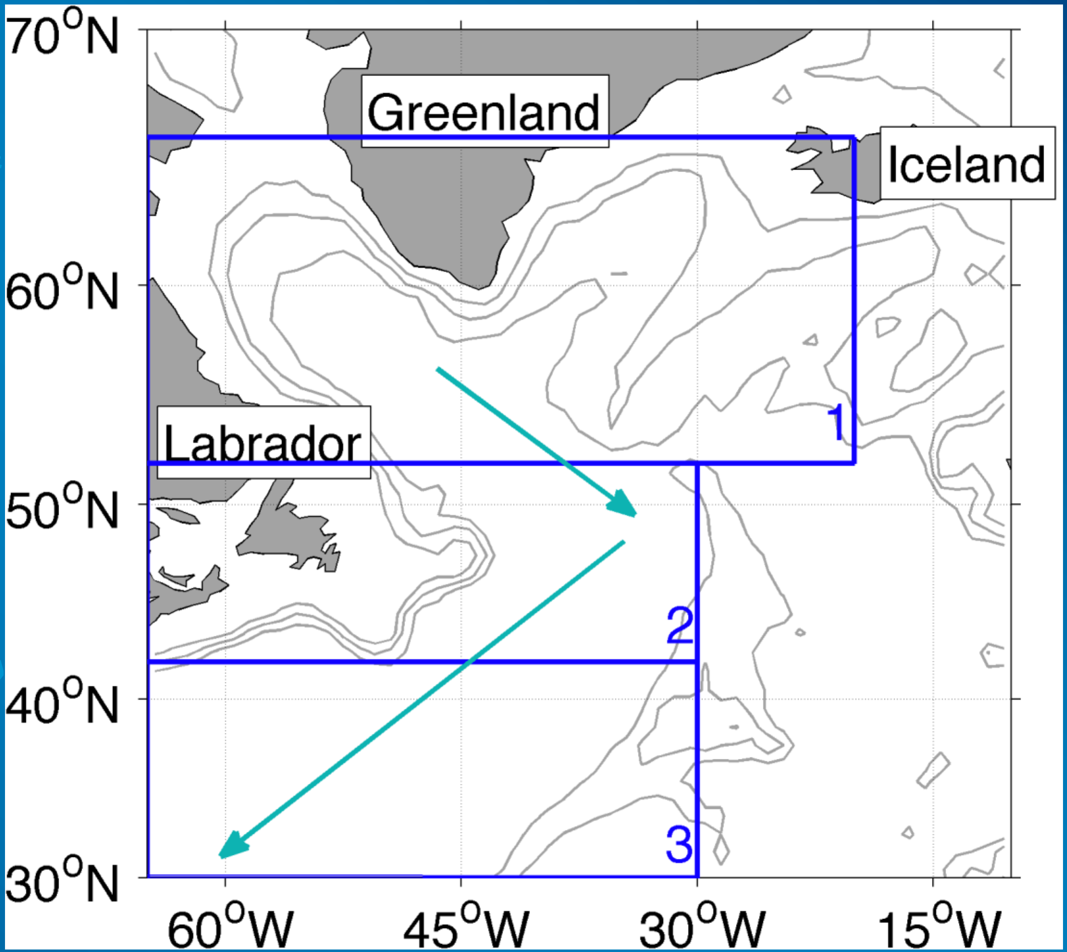
Lagged Sea Level Variations

- Meridional coherence of low-frequency SSHA variations
- Region 1 leads Region 2 by ~ 2 years
- Region 2 leads Region 3 by ~ 5 years
- Propagation velocity V = L/T = 1.46 cm/s



Conclusions

- Observations show significant changes in the subpolar North Atlantic at different temporal and spatial scales.
- Meridional coherence in the SSHA represents propagation of the AMOC variations from high to low-latitudes.
- Remote sensing is a key component in the AMOC observing system.

Thank you!