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

- 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
• 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
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

\[
\text{IE} = \int_{\omega} H^2(\omega, t) d\omega
\]

\[
\text{MSD} = \int_{0}^{T} H(\omega, t) dt
\]
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)

Li et al. GRL (2012)
Low-frequency Variability

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

Li et al. GRL (2012)
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 \(V = \frac{L}{T} = 1.46\ \text{cm/s}\)
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!