

Recent subpolar Atlantic climate shift due to wind forcing of midlatitude gyre circulation*

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Martha Buckley³, and Ichiro Fukumori⁴

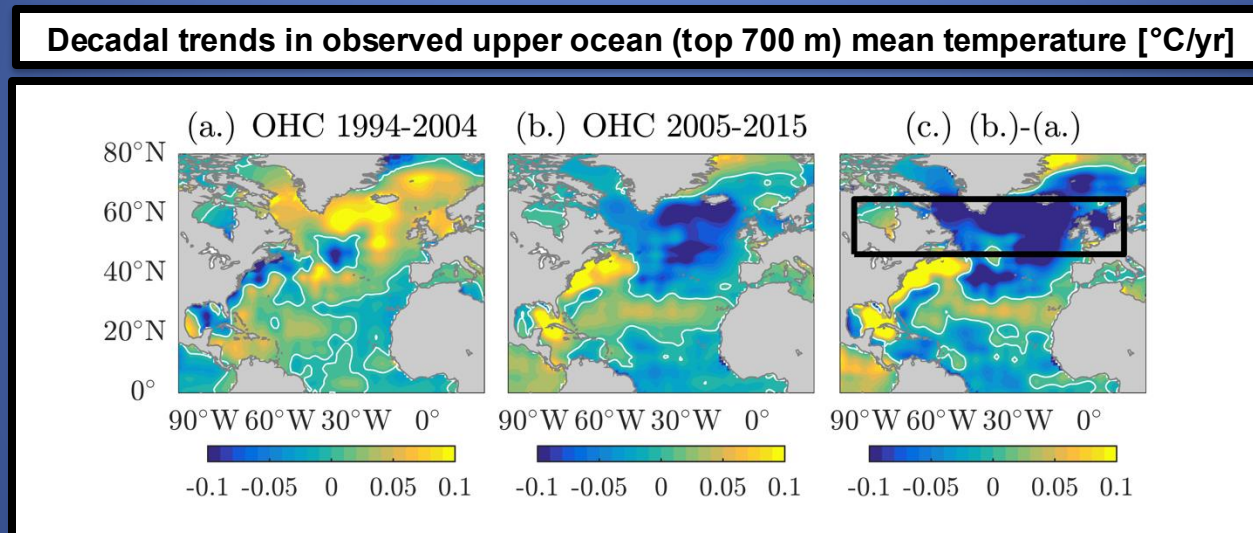
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*Piecuch, Ponte, Little, Buckley, and Fukumori: Mechanisms underlying recent decadal changes in subpolar North Atlantic Ocean heat content, *J. Geophys. Res.-Oceans*, 122(9), doi:10.1002/2017JC012845, 2017.

Recent Subpolar North Atlantic (SPNA) Decadal Climate “Shift”

- *Robson et al.* [2016, *Nat. Geosci.*, 9] show that decadal trends in SPNA SST and OHC reversed sign in ~2005



- Not due to Ekman transports or surface heat fluxes, but related to changing AMOC and Labrador Sea densities

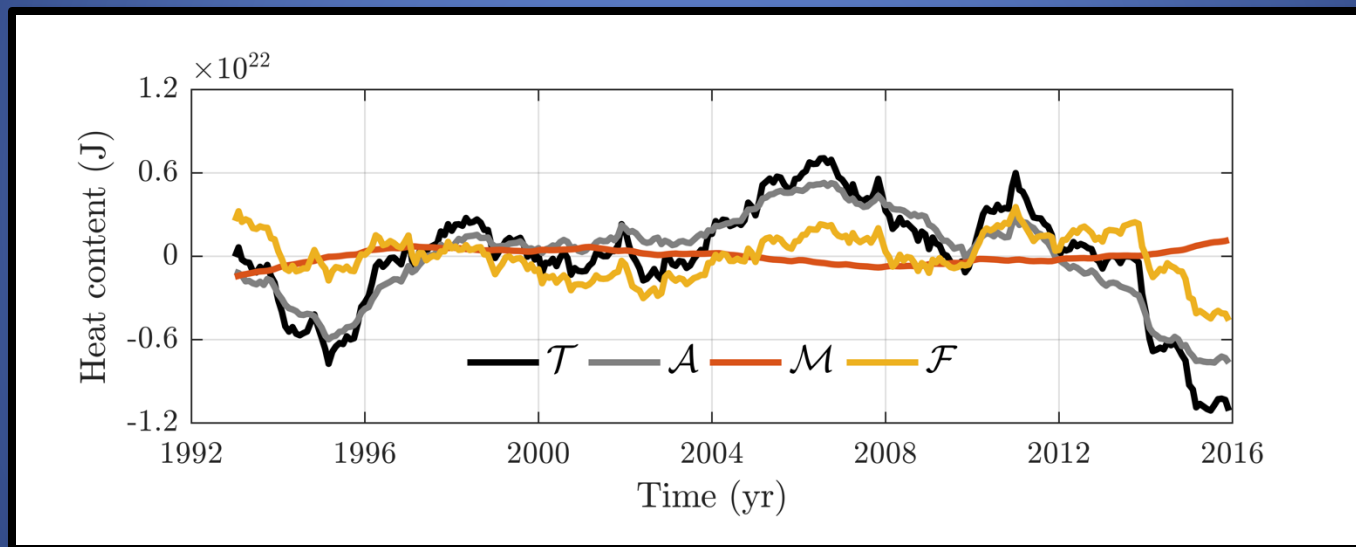
Focus of our Investigation

- What was responsible for the recent decadal trend reversal in the SPNA?
- Use ECCOv4 [*Forget et al.*, 2015, *Geosci. Model Dev.*, 8]
 - Release 3 global ocean and ice state estimate over 1992-2015
 - Constrained to most available ocean observations (altimetry, GRACE, Argo and other *in situ* hydrography data, etc.)
 - Agreement with data achieved through adjustments to control vector (i.e., initial and boundary conditions, mixing coefficients)
 - Physically consistent general circulation model solution

ECCOv4 SPNA heat budget

- Diagnose OHC budget for SPNA (46-65°N) in ECCOv4:

$$T = A + M + F$$

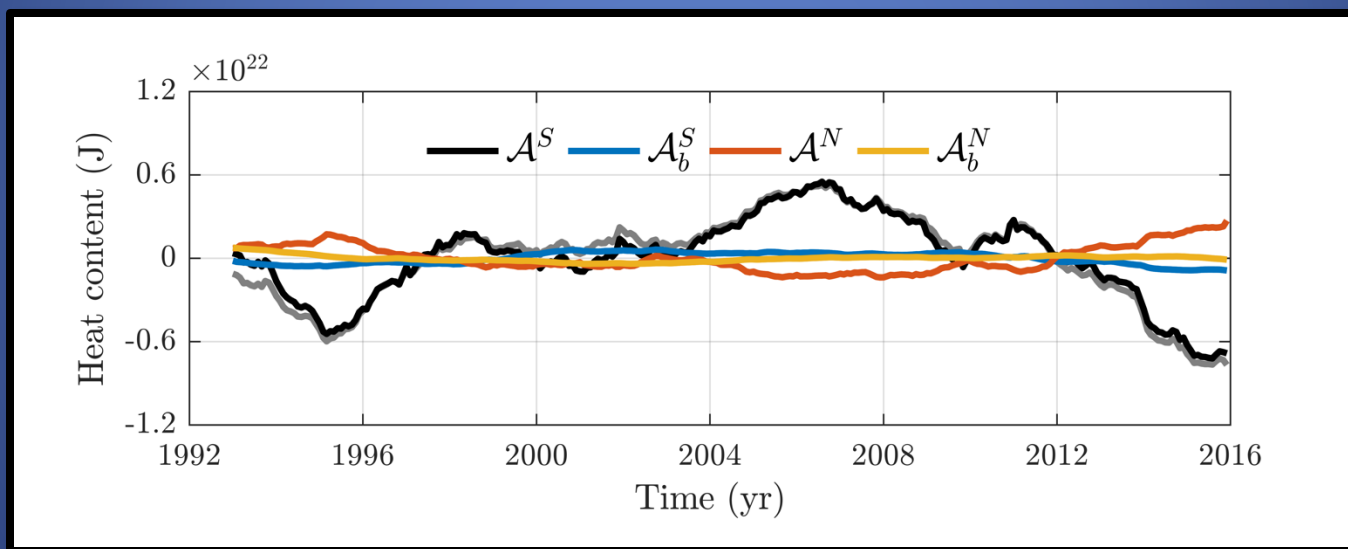


- Decadal SPNA OHC changes T are mostly related to changes in advection A

Partitioning the advection

- Separate resolved and parameterized, southern- and northern-boundary components of advection [$\mathbf{A}$]:

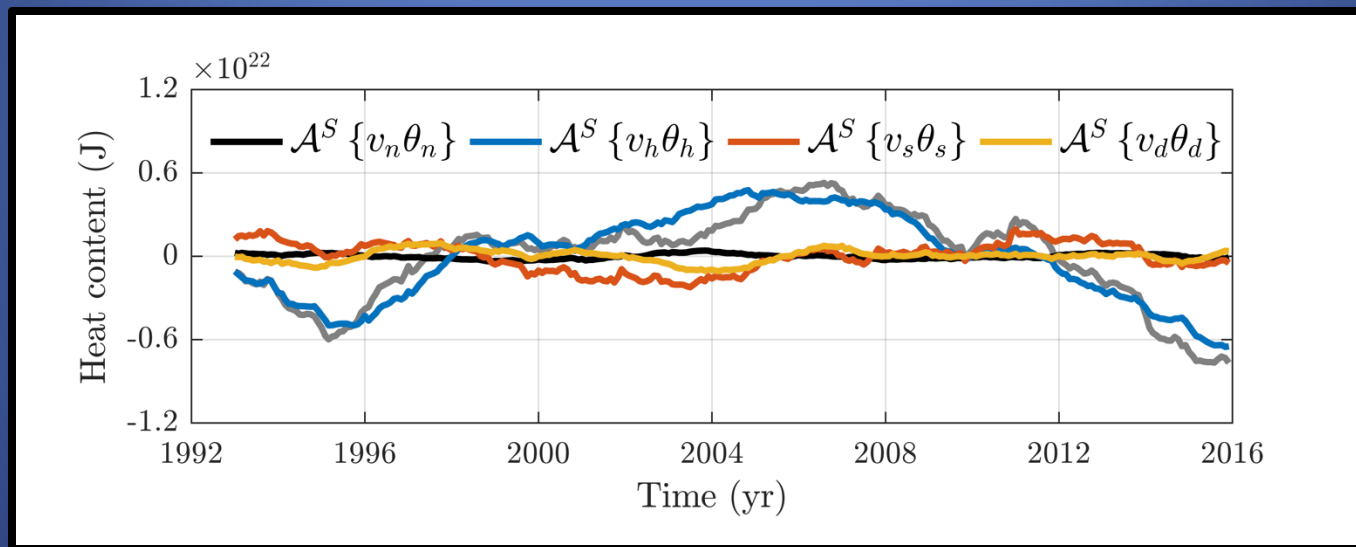
$$\mathbf{A} = \mathbf{A}^S + \mathbf{A}_b^S + \mathbf{A}^N + \mathbf{A}_b^N$$



- $\mathbf{A}$ mostly due to resolved advection across the SPNA southern boundary $\mathbf{A}^S$ (along 46°N)

Circulation decomposition

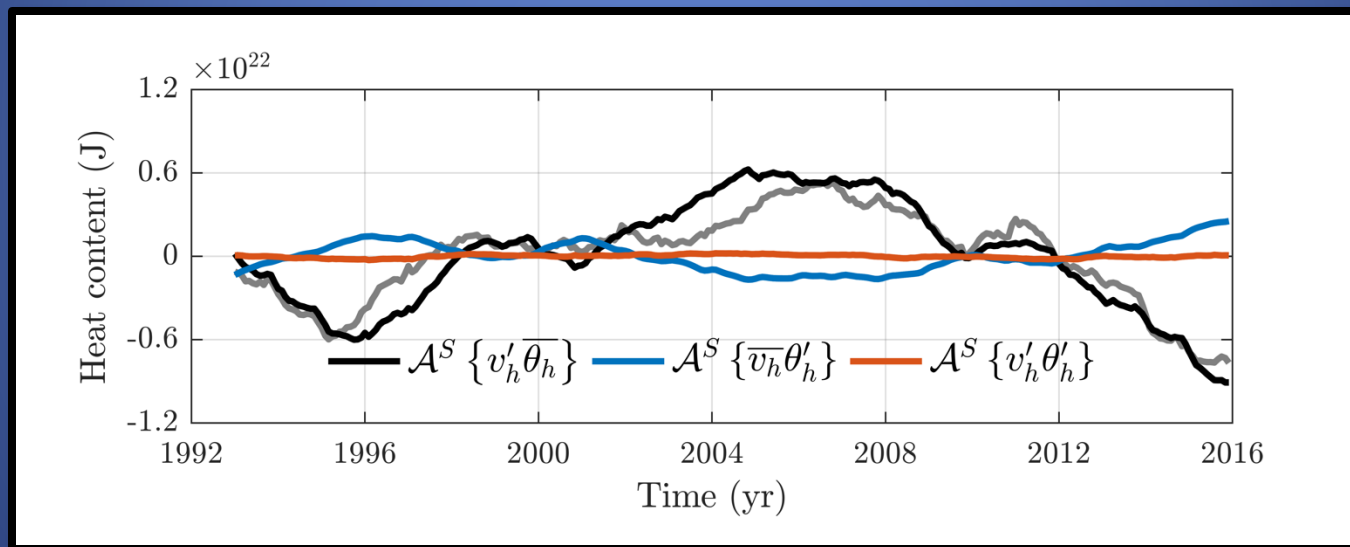
- Identify $\mathcal{A}^S$ changes due to net mass ($\mathcal{A}^S\{v_n\theta_n\}$), horizontal gyre ($\mathcal{A}^S\{v_h\theta_h\}$), shallow Ekman overturning ($\mathcal{A}^S\{v_s\theta_s\}$), and deep geostrophic overturning ($\mathcal{A}^S\{v_d\theta_d\}$)



- Horizontal gyre transports $\mathcal{A}^S\{v_h\theta_h\}$ contribute most importantly to decadal changes in advection $\mathcal{A}^S$

Variable decomposition

- Quantify roles of variable gyre velocity v_h ($\mathcal{A}^S\{v_h' [\theta_h]\}$), variable potential temperature θ_h ($\mathcal{A}^S\{[v_h] \theta_h'\}$), and covariance between v_h and θ_h ($\mathcal{A}^S\{v_h' \theta_h'\}$)



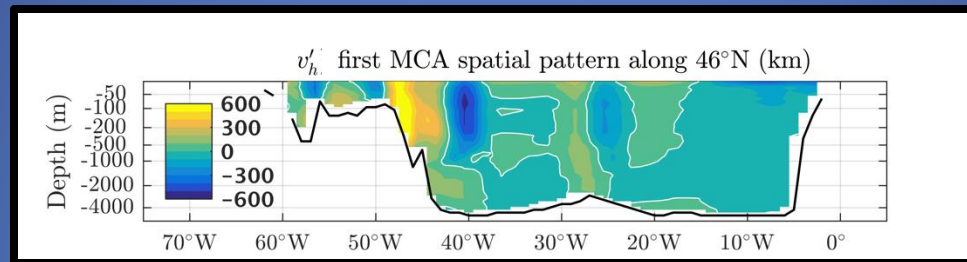
- Dominant decadal $\mathcal{A}^S\{v_h \theta_h\}$ contributions are rendered by horizontal gyre velocity anomalies $\mathcal{A}^S\{v_h' [\theta_h]\}$

Conclusions so far ...

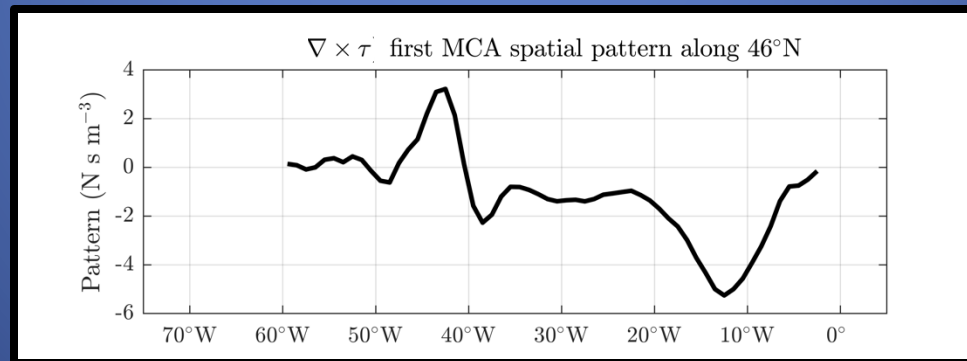
- Anomalous horizontal gyre circulations (v_h') along the SPNA southern boundary are the foremost contributor to a recent decadal SPNA OHC trend reversal in ECCOv4
- What drives these horizontal gyre circulation anomalies?
- Previous studies suggest that wind stress curl ($\nabla \times \tau$) is important forcing mechanism of gyre circulation changes
 - Häkkinen and Rhines [2009], Häkkinen et al. [2011, 2013], et al.
- Maximum Covariance Analysis of v_h' and $\nabla \times \tau$ along 46°N

MCA*—Spatial Structure

- v_h' MCA pattern suggestive of anomalous gyre circulation



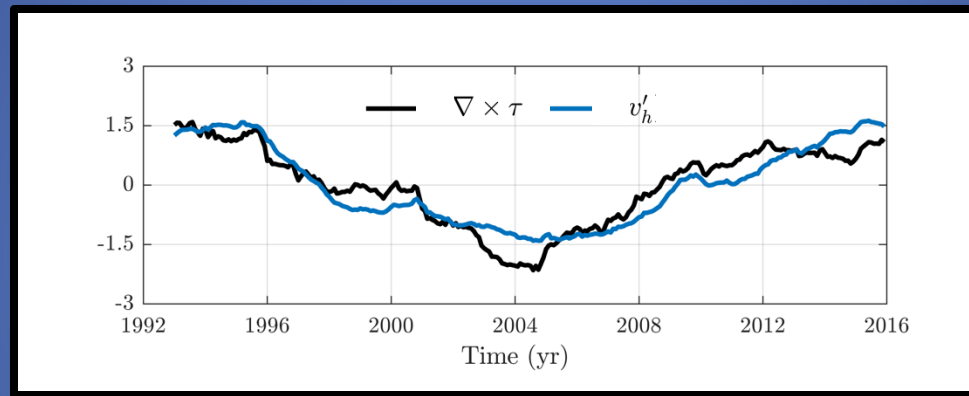
- $\nabla \times \tau$ MCA pattern is a modulation of mean $\nabla \times \tau$ pattern



- The two MCA patterns roughly share the same sign

MCA*—Temporal Structure

- MCA time series are tightly correlated ($r=0.92$, $p=0.05$)



- Similar space and time structures suggest interpretation
 - Sverdrup balance: $V_{Sv} = (\rho\beta)^{-1}(\nabla \times T)$

Conclusions

- Decadal trends in SPNA OHC and SST reversed in 2005 and the ECCOv4 estimate captures the trend reversals
- Budget diagnostics reveal that the SPNA OHC trend reversal was mainly due to horizontal gyre circulation
- Statistical analysis suggests that gyre circulation anomalies were tied to changes in overlying wind curl

Conclusions (continued)

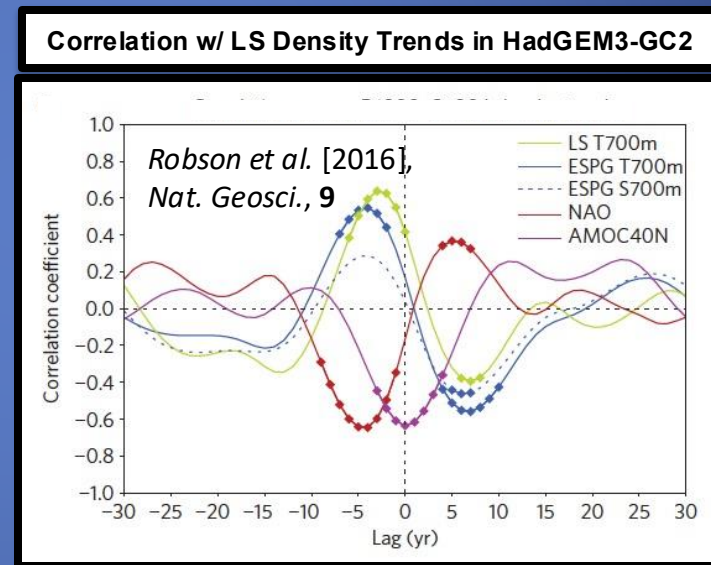
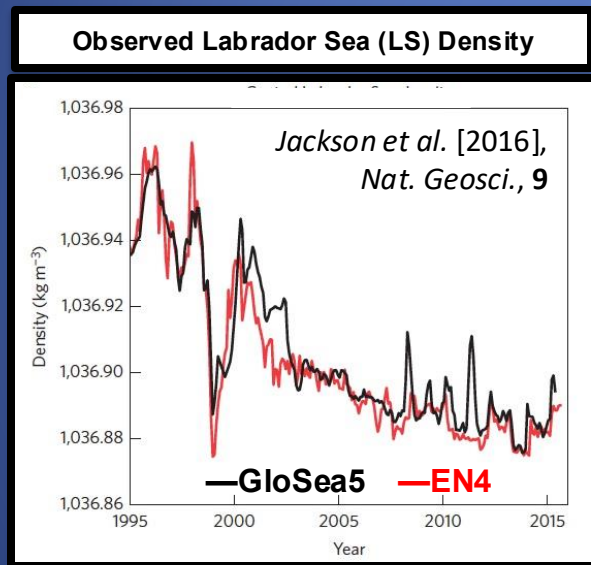
- Results do not support the hypothesis that the recent trend reversals were primarily linked to AMOC changes and declining Labrador Sea density [*Robson et al. 2016*]
- Future efforts will focus on quantifying uncertainties in the nature of SPNA heat budget over decadal periods [e.g., CMIP6, *Griffies et al. 2016, Geosci. Model Dev., 9*]

Thank you!

(questions?)

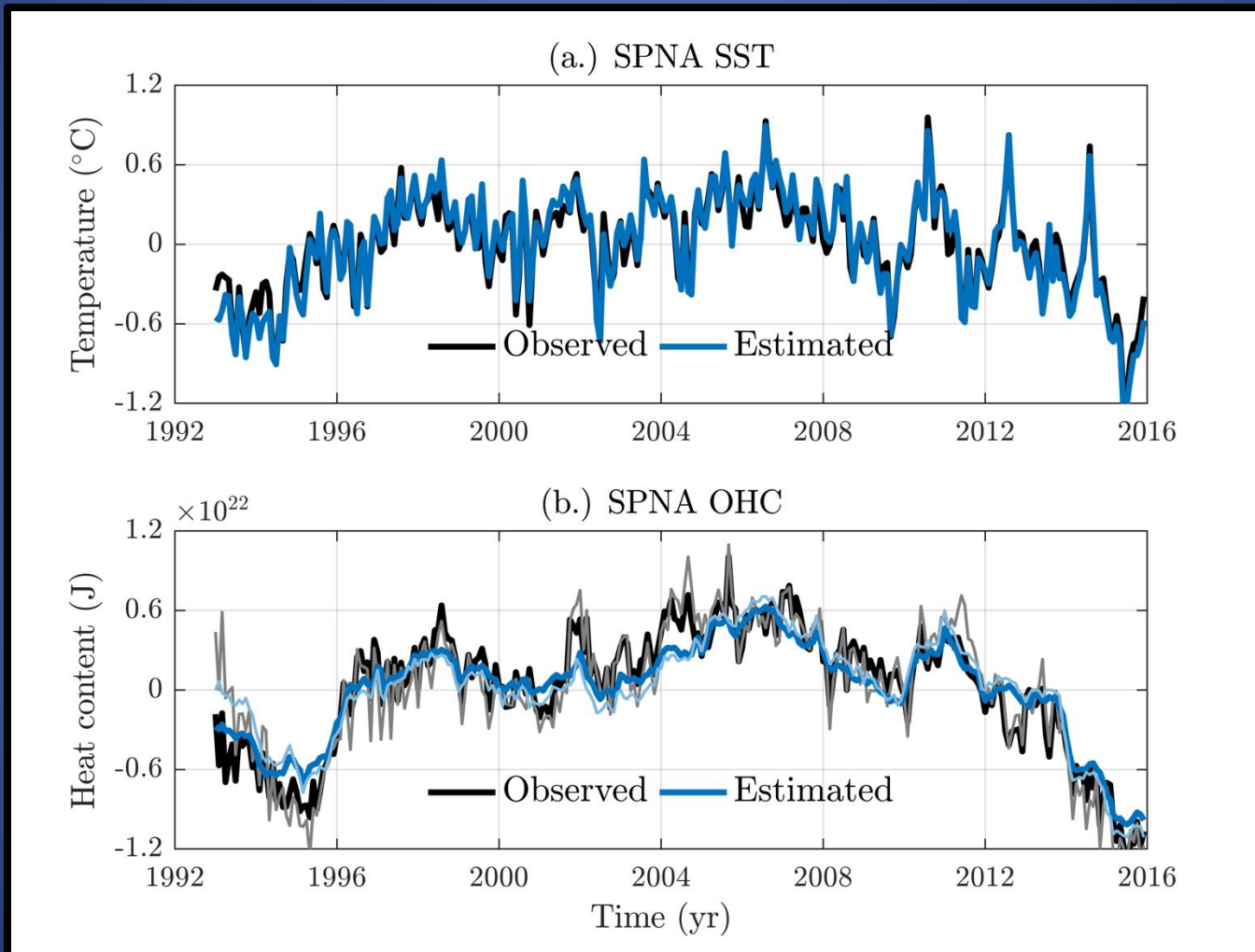
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Comparing ECCOv4 to Data in the SPNA



In (b), thick dark lines are 0-700 m values, while thin light lines are full-depth values