Center for Nonlinear Studies

Compensation between Poleward Atmospheric and Oceanic Heat Transports in CMIP6 Climate Simulations

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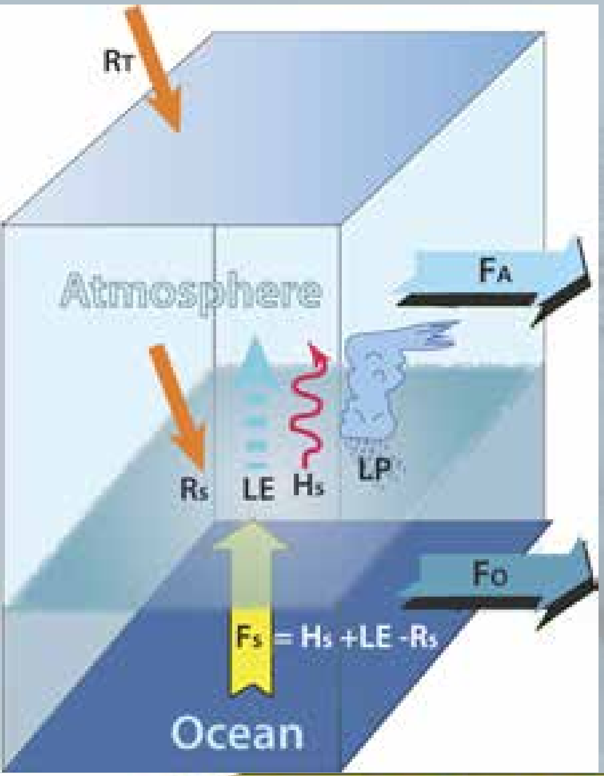
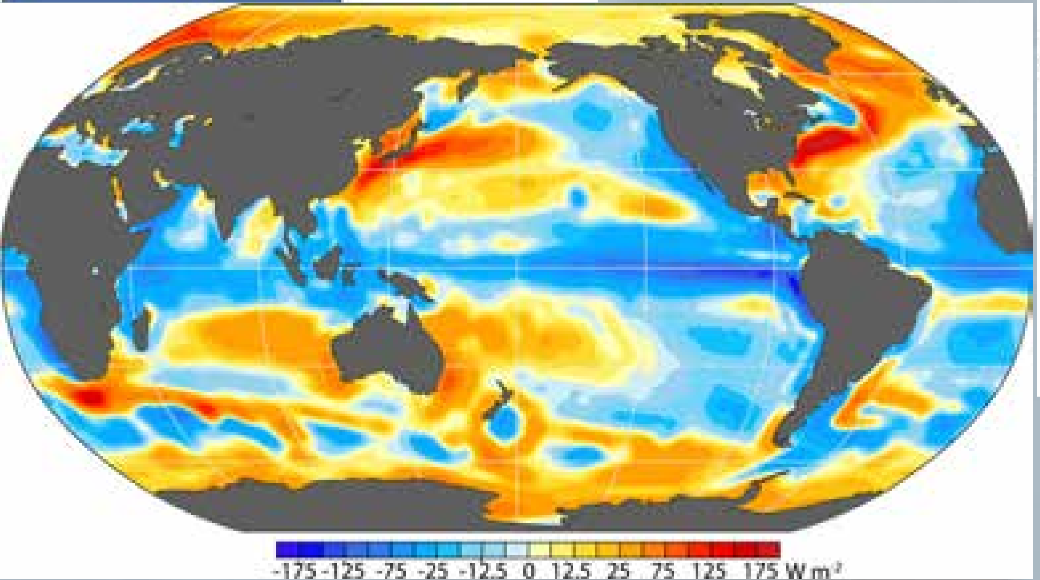
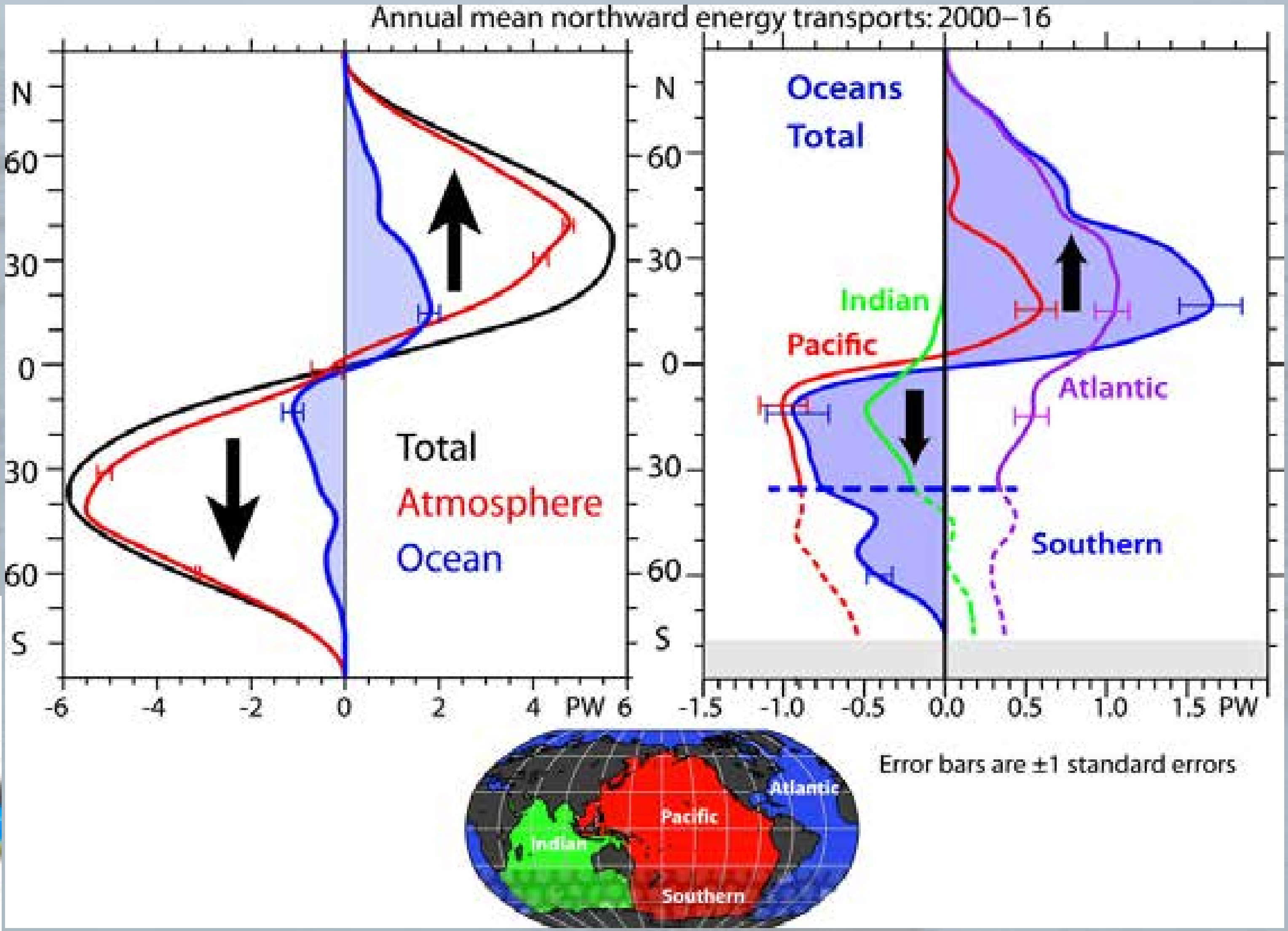
Heat Transport in the Earth System

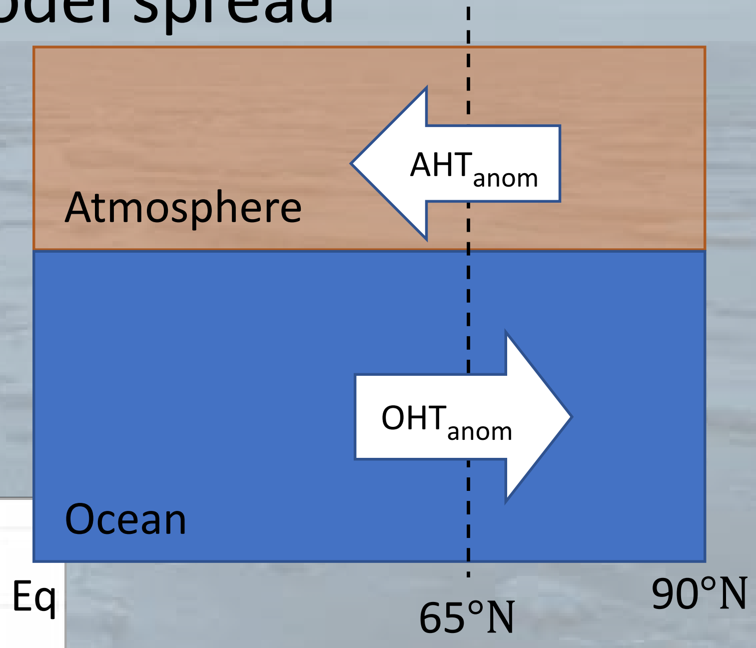






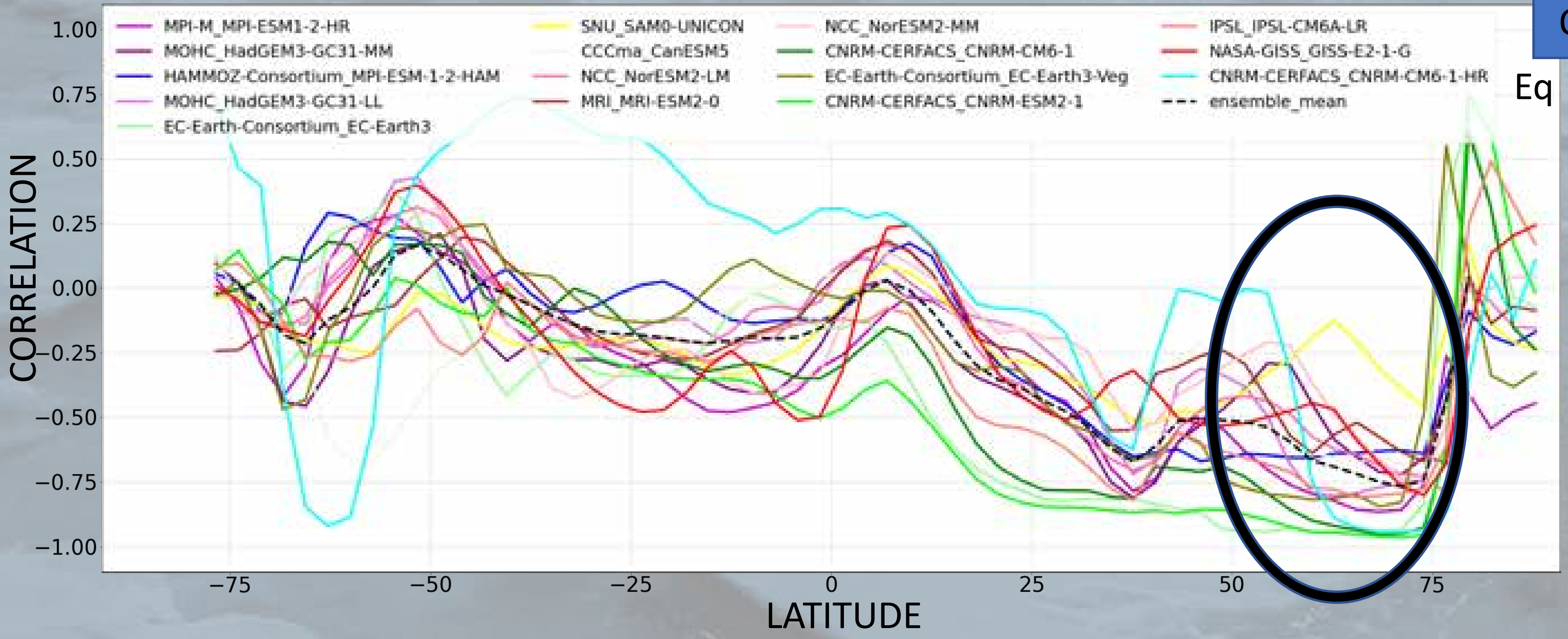
Trenberth, Kevin E., et al. "Observation-based estimates of global and basin ocean meridional heat transport time series." *Journal of Climate* 32.14 (2019): 4567-4583.

Objectives: Identify processes in the ocean, atmosphere, sea ice important for Bjerknes compensation and its inter-model spread



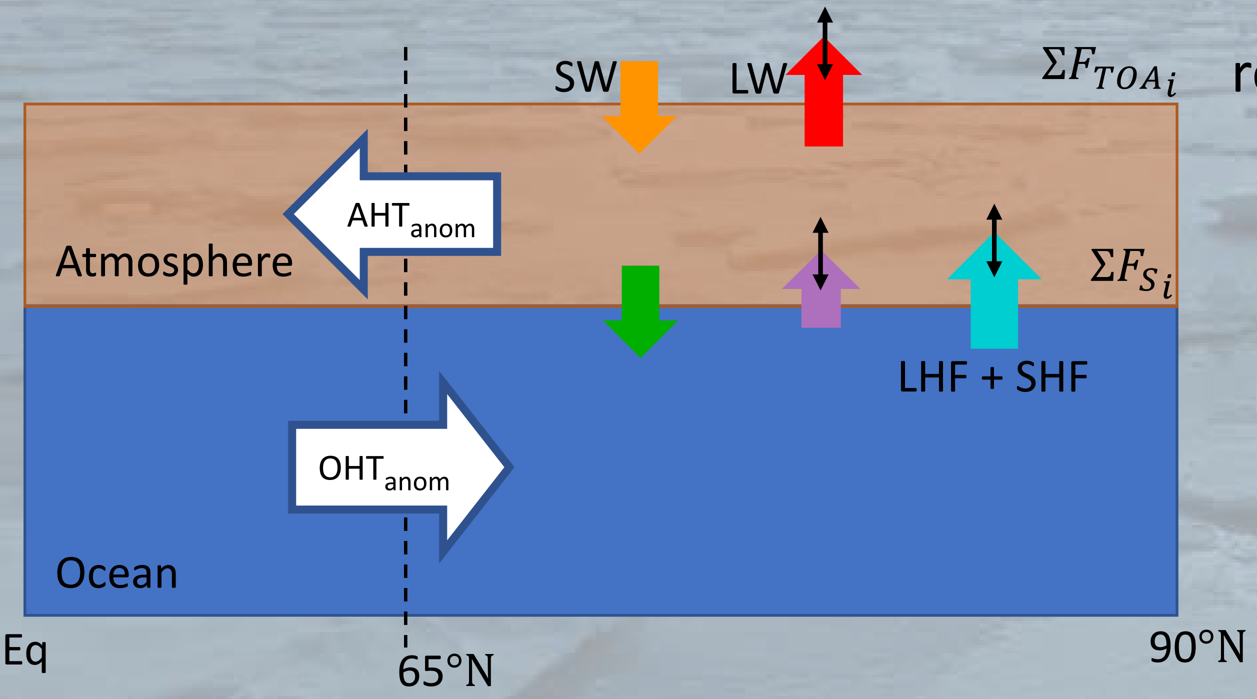
Bjerknes compensation (BJC) : Tendency for changes in the **atmosphere heat transport (AHT)** and **ocean heat transport (OHT)** to compensate each other on decadal to multidecadal timescales. BJC is important for the Arctic energy budget.

CORRELATION(AHT,OHT) ON DECADAL TO LONGER TIMESCALES IN THE PICONTROL EXPERIMENT



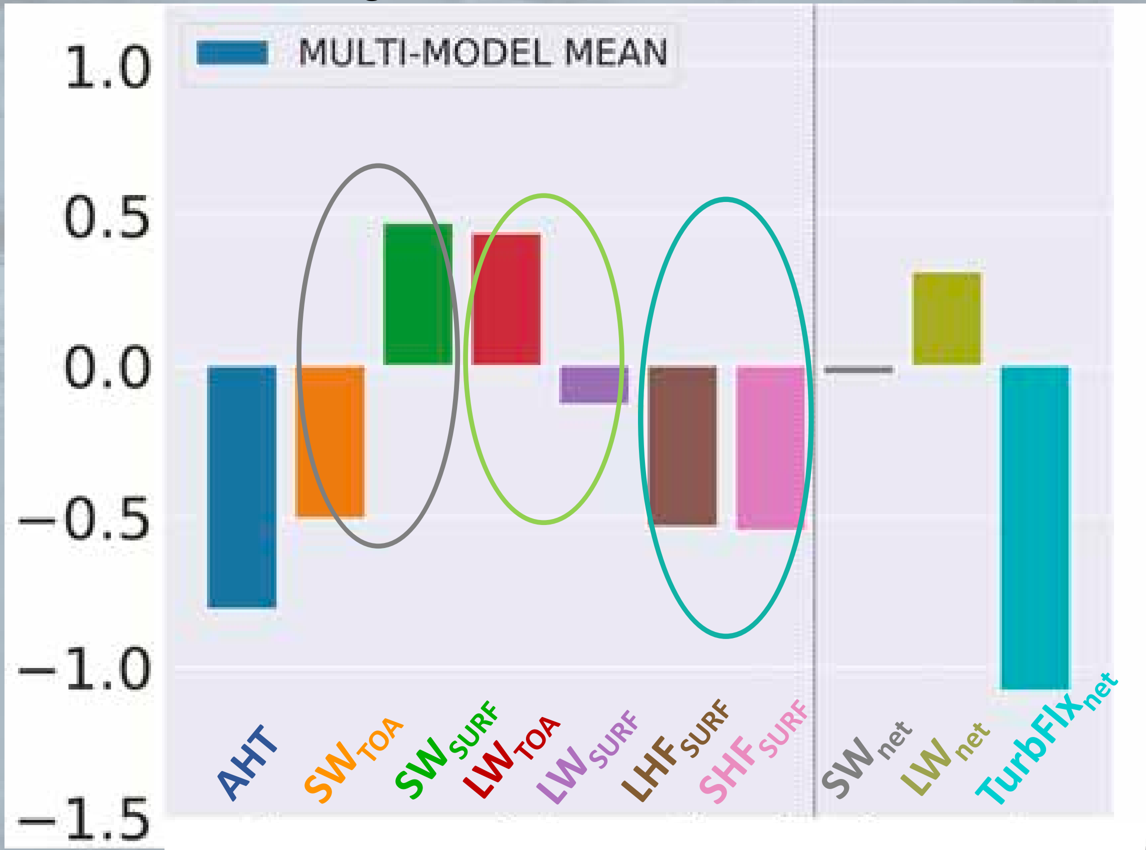
Approach : Characterize OHT and its CORRELATION with AHT Components

Key Result: The longwave and turbulent fluxes response explain the anti-correlation and the inter-model spread at northern high latitudes.

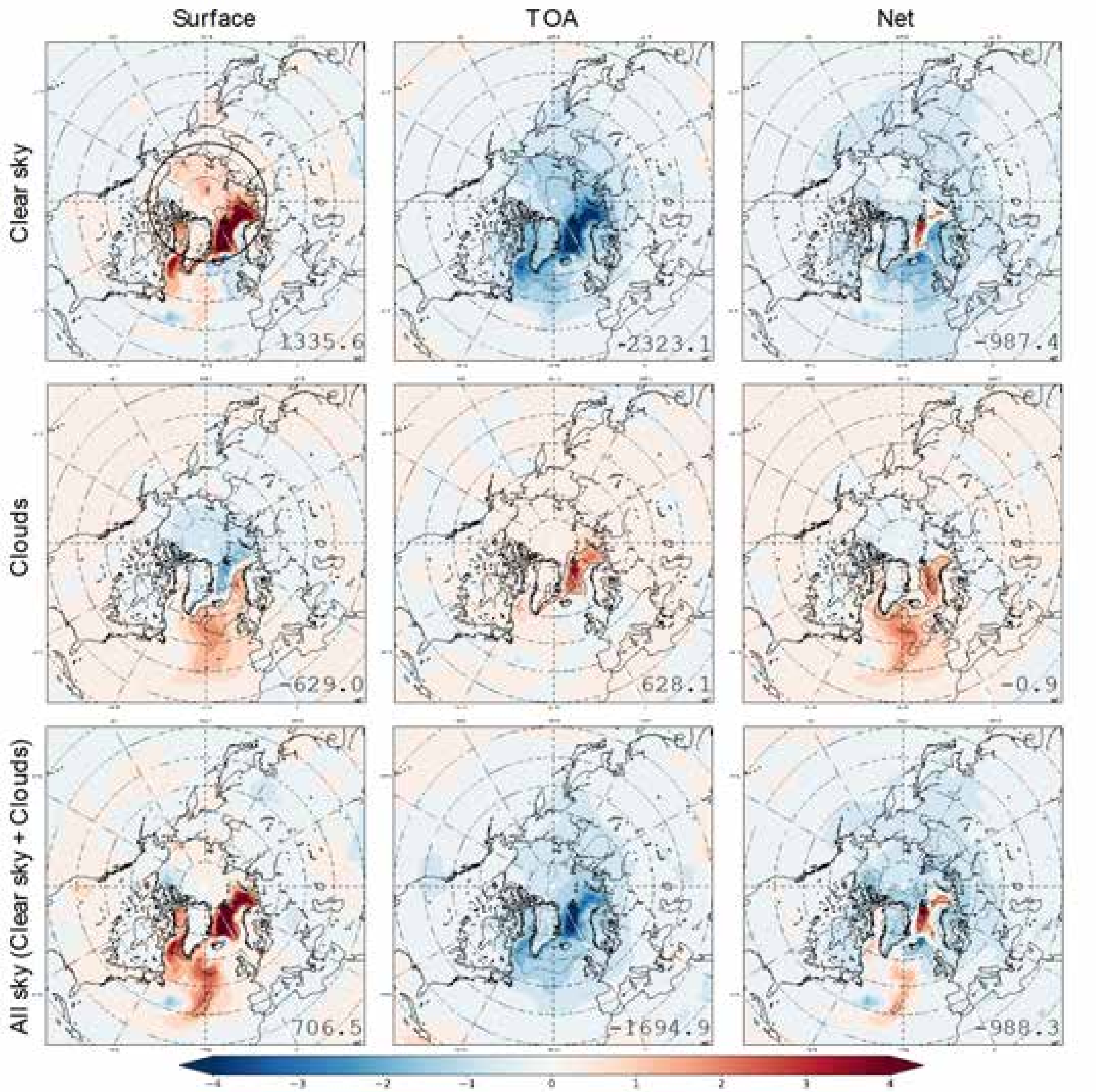


- ✓ OHT anomalies have longest memory
- ✓ AHT anomalies must approximately balance flux divergence of TOA and Surface fluxes

Area/Variance Weighted Correlations of Surface and TOA fluxes



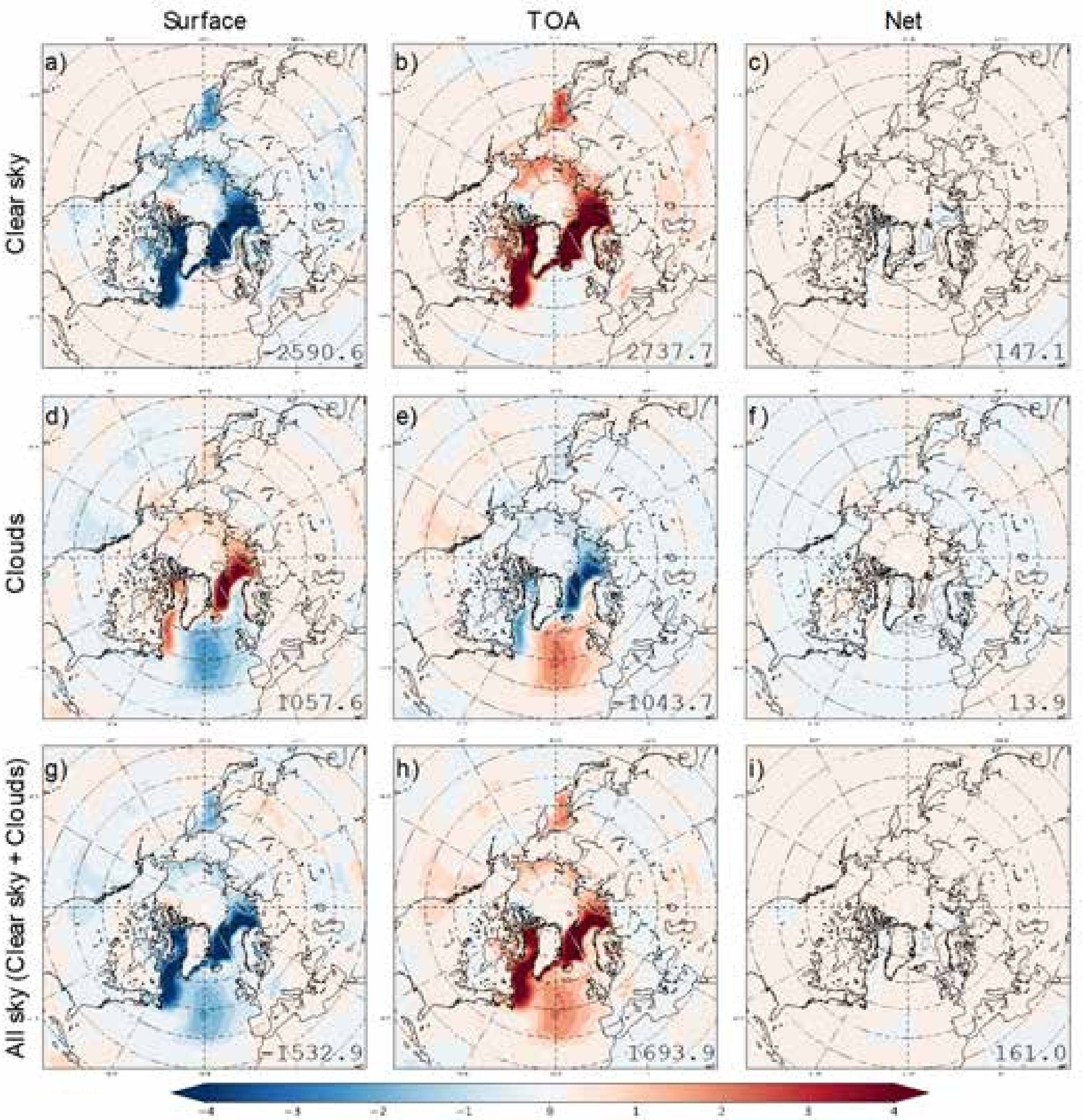
Kurtakoti, P., Weijer, W., Veneziani, A., Verma, T., and Rasch, P. (2022) Compensation between Poleward Atmospheric and Oceanic Heat Transports in CMIP6 Climate Simulations *(in prep)*



Key Result: Sea ice loss drives the longwave cooling

1. During increased $OHT_{65^\circ N}$ events, the warmer ocean becomes a major source of longwave radiation to the atmosphere over clear sky regions (first row).
2. The atmosphere gains longwave radiation from the oceans in response to increased $OHT_{65^\circ N}$ particularly in the marginal ice seas. Net heat loss at TOA exceeds surface gain under clear sky conditions.
3. Heat gained and lost in regions occupied by clouds is a factor of 2-4 times lower than the clear sky regions (second row).
4. The dipole behavior (second row) at the surface where the atmosphere loses longwave radiation in the Greenland Sea and gains longwave radiation in the Norwegian Sea can be attributed to changes in clouds.
5. The clear sky long wave cooling is the dominant feature associated with increased $OHT_{65^\circ N}$ events (third row).

Sea Ice and Cloud Radiative Contribution Breakdown at the surface and TOA of Longwave Fluxes.



Key Result: Clear sky dominates the shortwave response of the atmosphere.

1. A warmer ocean during enhanced $OHT_{65°N}$ causes sea ice to melt and exposes the ocean, which has a much lower albedo than sea ice.
2. The top row of the regression map shows that the energy entering that atmosphere at TOA in the clear sky (b) is passed to the ocean (a) during anomalous poleward $OHT_{65°N}$, primarily in sea ice melt regions in the Sea of Okhotsk, Labrador, Greenland, and Barents Seas, with little impact on the atmosphere (c).
3. Clouds tend to counter the clear sky impacts over marginal ice seas, reducing the incoming energy at the TOA (e) and passing less energy to the ocean in those regions (d), with little impact on the atmosphere itself (f).
4. The clear sky radiative flux dominate the all-sky flux anomalies poleward of 65°N over ice (panels g-i).

Sea Ice and Cloud Radiative Contribution Breakdown at the surface and TOA of Shortwave Fluxes.

Conclusions

1. Enhanced northward OHT into northern high latitudes is associated with large amount of latent and sensible heat gained by atmosphere from the ocean over marginal ice seas which is the primary driver of BJC.
2. Detailed analysis has revealed that the inter-model spread of BJC across the piControl experiment is primarily driven by the sensitivity of sea ice to $\mathrm{OHT}_{65°N}$
3. During increased $\mathrm{OHT}_{65°N}$ events, the sea ice and cloud response both act to modify the radiative budget. The sea ice response drives the net atmospheric response both in the shortwave and longwave radiation.