Bering Strait Ocean Heat Transport Drives Decadal Arctic Variability in a High-Resolution Climate Model

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• Bjerknes Compensation (BjC) is the tendency of the atmosphere to respond to ocean heat transport (OHT) anomalies with opposing anomalies in atmospheric heat transport (AHT).
• Kurtakoti et al. (2024) found that the ice-albedo and cloud feedbacks play a critical role in BjC.
• Here we investigate BjC in a high-resolution climate model.
• We find that:
  o OHT through the Bering Strait has an outsized impact on Arctic temperatures compared to Atlantic OHT.
  o Bering Strait OHT is amplified strongly by the ice-albedo feedback, creating a strong atmospheric heat anomaly.
  o This heat anomaly is not transported away but stays in place, balanced by outgoing longwave radiation.
  o BjC takes place in the Atlantic sector only.

Approach: CESM1.3
• We analyze 350 years from a 500-year pre-industrial control simulation of CESM1.3 (Chang et al. 2020)
• Resolution
  0.25° in the atmosphere and land
  0.1° in the ocean and sea-ice
• We infer atmospheric heat transport across 65°N by integrating surface and Top-of-the-Atmosphere fluxes zonally and southward:
  \[ \text{AHT}(\theta) = \int_0^{65^\circ} \text{SW}_{\text{sw}} + \text{SHF}_{\text{sw}} + \text{LW}_{\text{toa}} - (\text{LW}_{\text{sw}} + \text{SW}_{\text{toa}}) \, d\theta \]
• The model has an accurate representation of Bering Strait heat transport (see poster by Gaopeng Xu) and a realistic representation of sea ice cover.

Timeseries Analysis
• Arctic surface temperatures \((r = 0.7)\) and sea ice \((r = -0.7)\) are highly correlated with Bering Strait OHT; correlations with Atlantic OHT are much weaker \((r = 0.3/-0.4)\).
• Atlantic OHT is strongly correlated with AHT \((r = -0.61)\), while Bering Strait OHT is not \((r = -0.18)\).

Atmospheric Response
• Surface air temperature and sea ice concentration show a strong sensitivity to Bering Strait OHT in the Chukchi Sea. The Response to Atlantic OHT is much weaker.
• The atmospheric response to OHT variability is shown below as regressions of OHT on contributions to AHT (red). Negative regressions hence strengthen Bjerknes Compensation.
• Atlantic OHT (dashed) is compensated: ocean heat is transferred to the atmosphere by turbulent fluxes (Heat flux) and carried away (AHT); shortwave (SW) and longwave (LW) contributions are small.
• Pacific OHT (solid) is not compensated: ocean heat and the ice-albedo feedback (SW sfc) generate an atmospheric heat dome that is balanced by outgoing longwave radiation (LW TOA).

References
• Chang et al. (2020): An unprecedented set of high-resolution earth system simulations for understanding multiscale interactions in climate variability and change. Journal of Advances in Modeling Earth Systems, 12, e2020MS002298.
• Kurtakoti et al. (2024): Sea Ice and Cloud Processes Mediating Compensation between Atmospheric and Oceanic Meridional Heat Transports across the CMIP6 Preindustrial Control Experiment. Journal of Climate, 37, 505-525.

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