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Bjerknes Compensation and the Multi-decadal Variability of Heat Transport in the Arctic

Stephen Outten and Igor Esau
Nansen Environmental and Remote Sensing Centre and Bjerknes Centre for Climate Research, Bergen, Norway (stephen.outten@nersc.no)

The meridional transport of heat through both the atmosphere and ocean is a fundamental component in maintaining the Earth's climate. Understanding the decadal to multi-decadal changes of these transports provides an insight into the natural variability of the climate system and into the flow of heat into the Arctic. Jacob Bjerknes proposed that the total energy transported by the climate system should remain approximately constant if the ocean heat storage and fluxes at the top-of-the-atmosphere were unchanging [Bjerknes, 1964]. Since it is the atmosphere and ocean that transport heat in the climate system, any large anomalies in the ocean heat transport should be balanced by opposing variations in the atmospheric heat transport, and vice versa; a process that has since been named Bjerknes Compensation.

Bjerknes compensation has been identified in the 600-year control run of the Bergen Climate Model by examining the anomalies of the implied meridional heat transports in both the ocean and atmosphere. These anomalies show strong anti-correlation ($r=-0.72$, $p \leq 0.05$), and a multi-decadal variability with a period of approximately 60 years. Spatial patterns associated with this multi-decadal variability highlight part of the underlying mechanism which occurs through changes in the sea-ice cover in the North Atlantic sector of the Arctic, which lead to strong ocean-atmosphere fluxes and the formation of a thermal low that changes the large scale flow over the Northern Hemisphere. The anomalies in atmospheric heat transport are not only found to be well correlated to the anomalies in Arctic sea-ice, but also to the strength of the sub-polar gyre, suggesting a possible feedback of the atmosphere to the ocean on multi-decadal timescales. Bjerknes Compensation is further identified in a number of CMIP5 models, though several show key differences from the findings of existing literature that have examined Bjerknes Compensation in previous models.