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Meridional energy transport in the coupled atmosphere-ocean system: Compensation and partitioning

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The variability and compensation of the energy transport in the atmosphere and ocean are discussed with a hierarchy of coupled models. A state-of-the-art Coupled Model (GFDL CM2.1), an Intermediate Complexity Climate Model (GFDL ICCM) and a simple Energy Balance Model (EBM) are used in this study.
For decadal time scales, a high degree of compensation is found for the transport in the Northern Hemisphere in the Atlantic sector. The variability of the total, or planetary, heat transport (PHT) is much smaller than the variability in either the atmosphere (AHT) or ocean (OHT) alone, a feature sometimes referred to as 'Bjerknes compensation'. In the coupled models used, natural decadal variability stems from the Atlantic meridional overturning circulation (AMOC), and variations in the strength of the AMOC tend to lead the variability in the OHT. Furthermore, the PHT is positively correlated with the OHT, implying that the atmosphere is compensating, but imperfectly, for variations in the ocean transport. In the Southern Hemisphere no significant anticorrelation is found between OHT and AHT, consistent with the absence of decadal scale variability in the ocean. For both coupled models, the strongest anticorrelation between transports is found at the period of AMOC variability and decreases as the time scale decreases. Unlike the AHT and AMOC, the AHT and the transport in the oceanic gyres are positively correlated, suggesting that coupling between the wind-driven ocean circulation and the atmosphere militates against long-term variability involving the wind-driven flow. Moisture and sensible heat transports in the atmosphere are also positively correlated at decadal time scales. In the Northern Hemisphere compensation is weaker at low latitudes than at high. This is consistent with the notion that at low latitudes a larger fraction of the oceanic transport is due to the wind-driven warm cell, and the atmospheric and wind-driven oceanic energy transports vary in unison, preventing compensation. With the help of a two-layer EBM, we finally argue that compensation can best be interpreted as arising from the highly efficient, super-diffusive nature of the energy transport in the atmosphere, which effectively constrains the meridional temperature distribution determining the outgoing infra-red radiation.