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Bjerknes Compensation in Meridional Heat Transport under Freshwater Forcing and the Role of Climate Feedback

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Using a coupled Earth climate model, freshwater experiments are performed to study the Bjerknes compensation (BJC) between meridional atmosphere heat transport (AHT) and meridional ocean heat transport (OHT). Freshwater hosing in the North Atlantic weakens the Atlantic meridional overturning circulation (AMOC) and thus reduces the northward OHT in the Atlantic significantly, leading to a cooling (warming) in surface layer in the Northern (Southern) Hemisphere. This results in an enhanced Hadley Cell and northward AHT. Meanwhile, the OHT in the Indo-Pacific is increased in response to the Hadley Cell change, partially offsetting the reduced OHT in the Atlantic. Two compensations occur here: compensation between the AHT and the Atlantic OHT, and that between the Indo-Pacific OHT and the Atlantic OHT. The AHT change compensates the OHT change very well in the extratropics, while the former overcompensates the latter in the tropics due to the Indo-Pacific change. The BJC can be understood from the viewpoint of large-scale circulation change. However, the intrinsic mechanism of BJC is related to the climate feedback of Earth system. Our coupled model experiments confirm that the occurrence of BJC is an intrinsic requirement of local energy balance, and local climate feedback determines the extent of BJC, consistent with previous theoretical results. Even during the transient period of climate change in the model, the BJC is well established when the ocean heat storage is slowly varying and its change is weaker than the net heat flux changes at the ocean surface and the top of the atmosphere. The BJC can be deduced from the local climate feedback. Under the freshwater forcing, the overcompensation in the tropics (undercompensation in the extratropics) is mainly caused by the positive longwave feedback related to cloud (negative longwave feedback related to surface temperature change). Different dominant feedbacks determine different BJC scenarios in different regions, which are in essence constrained by local energy balance.