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Dynamic and energetic constraints on the modality and position of the intertropical convergence zone in an aquaplanet

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The tropical zonal-mean precipitation distribution can vary between single and double peaks, which are associated with intertropical convergence zones (ITCZs). Here, the meridional modality and the sensitivity to hemispherically-asymmetric heating of tropical precipitation is studied in an idealized GCM with parameterized wind-driven ocean energy transport (OET). In the idealized model, transitions from unimodal to bimodal distributions are driven by equatorial ocean upwelling and cooling which inhibits equatorial precipitation. For sufficiently strong cooling, the circulation bifurcates to anti-Hadley circulation (AHC) in the deep tropics, with a descending branch near the equator and off-equatorial double ITCZs. The intensity of the AHC is limited by a negative feedback: the AHC drives westerly surface winds which balance the easterly stress (and hence equatorial upwelling) required for its maintenance. The modality of the precipitation affects the response to asymmetric heating: For weak ocean stratification, OET damps shifts of the tropical precipitation centroid but amplifies shifts of precipitation peaks. For strong ocean stratification, which leads to double ITCZs, asymmetric heating leads to relative intensification of the ITCZ in the warming hemisphere, but the positions of the double ITCZs are insensitive to changes in the asymmetric heating and ocean stratification. The dynamic feedbacks of the coupled system damp the slope of the atmospheric energy transport (AET) near the equator. This justifies a cubic root relation between the cross-equatorial AET and the position of the ITCZ, which captures migrations of the ITCZ significantly better than the commonly-used linear relation.