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# Energetic constraints on the ITCZ position in the observed seasonal cycle

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Energetic arguments have provided useful constraints on the zonally and annually averaged ITCZ position and shifts. However, we have recently shown how in idealized simulations with a seasonal cycle there exists a lag between the energy flux equator (EFE) and the ITCZ on timescales shorted than seasonal. These results imply that the tropical Hadley cell can achieve energy balance not through shifts in its ascending branch but through changes in its efficiency of energy transport (or gross moist stability, GMS), which can in fact become negative as the cell develops a shallow return flow near the moist static energy minimum. Shallow circulations are known to exist in the Eastern Pacific, but their relationship to the ITCZ position and cross-equatorial energy transport has not been previously investigated.

In this work, we explore to what extent similar mechanisms are seen in MERRA-2 reanalysis data both in the zonal mean and different zonal sectors. We find that in the zonal mean, an offset exists between the ITCZ and the EFE near the end of the year as the ITCZ is retreating from the northern to the southern hemisphere. This occurs as the southern Hadley cell develops a bottom-heavy structure, favoring a northward energy transport. In the Eastern Pacific sector, the existence of two nodes in the meridional energy transport during parts of the seasonal cycle suggests the possibility of negative GMS in the associated meridional overturning circulation. While bottom-heavy vertical velocity profiles favoring shallow return flows exist throughout the year, the bottom heaviness becomes much stronger at times with negative GMS, and weak SSTs and large negative SST Laplacian below the ITCZ. These results suggest that EFE and ITCZ are not related in any simple manner in the course of the seasonal cycle.