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Energetic constraints on the ITCZ in idealized simulations with a seasonal cycle

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The most intense rainfall over the Earth's surface occurs within the ITCZ, a zonally-elongated band of deep convective clouds and low-level wind convergence at low latitudes. Controls on its mean position and possible migrations on different timescales remain an active area of research. An emerging theoretical framework links the ITCZ to the atmospheric energy balance and transport. While these energetic constraints have been shown to provide insight into the dynamics of annual and zonal mean ITCZ shifts, relatively little work has explored their implications on shorter timescales. More specifically, it remains unclear if the energy flux equator (EFE) can provide a good predictor of subseasonal ITCZ migrations.

In this study, we want to investigate to what extent the EFE tracks the ITCZ location on timescales shorter than seasonal. To do this, we perform idealized aquaplanet simulations, which lack any zonal asymmetry, with different mixed layer depths. The simplified model physics and lower boundary allow for conceptual progress in the absence of poorly understood and constrained feedbacks. In our simulations, a lag between the EFE and the ITCZ exists even for very shallow mixed layer depths, ranging from about one month for a 0.2m mixed layer depth to about two months for a 20m mixed layer depth. One important consequence of this lead-lag relation is that there are times during the seasonal cycle when the EFE and the ITCZ reside on opposite sides of the equator, and, hence, the gross moist stability (GMS) of the Hadley circulation near the equator is negative. This primarily happens within the retreating Hadley cell. By using the energy budget, we show that the seasonal evolution of the energy transport, and therefore of the EFE, is almost in phase with the seasonally varying insolation forcing. The ITCZ, which is determined by the mass and moisture budgets rather than the energy budget, cannot however adjust that rapidly, due to dynamic and thermal inertia of the atmosphere and ocean. Therefore, the required energy transport is achieved not through shifts in the location of the Hadley cell's ascending branch and ITCZ to track the EFE but through changes in the cell's vertical structure into one with negative GMS.