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Local and remote moist static energy constraints on rainfall across southern Africa

Benjamin I Cook, Amy McNally, Kimberly Slinski, Weston Anderson, and Mahmoud Osman

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Abstract

The ocean and land surface both influence rainfall in southern Africa, but recent work has highlighted the often complex, inconsistent, and heterogenous connections between these processes and rainfall in the region. Here, we use a moist static energy (MSE) framework to more deeply investigate the connections between southern Africa rainfall and the ocean and land surface during the wet season (October–March). South of 13°S, rainfall is negatively correlated with saturated MSE in the free troposphere at 650 hPa (h^*_{650}), especially over the western (Angola, Namibia) and southern (South Africa) regions of our domain and during the core months (December–February) of the wet season. This correlation is much weaker over the wettest region in the east (Malawi, Mozambique, Zambia, Zimbabwe), though all areas have strongly positive and significant correlations between rainfall and surface MSE (h_{surf}) and the vertical MSE gradient ($h_{surf} - h^*_{650}$; Δh_{vert}). High levels of h^*_{650}, indicating strong stability constraints, are associated with warmer conditions in the tropical Indian and Pacific Ocean basins, patterns typically associated with El Ni˜no, a classic expression of the ocean forced "remote" pathway. However, in the wetter eastern part of our domain (where h^*_{650} constraints on rainfall are weaker), h_{surf}, and by extension Δh_{vert}, are strongly correlated with sea surface temperatures in the southwest Indian Ocean, a pattern similar to positive phases of the Subtropical Indian Ocean Dipole. Soil moisture (surface and root zone) and leaf area index (LAI) are strongly and positively correlated with h_{surf} in the first half of the wet season (October–December), but these correlations are much weaker in January–March, suggestive of a shift from a supply-limited to an energy-limited evaporative regime. Our analyses highlight how interactions between MSE and rainfall vary seasonally and spatially across southern Africa, including the shifting connections with local land surface and remote ocean processes.

Corresponding author: Benjamin I Cook, benjamin.i.cook@nasa.gov