M.S. Defense Announcement
Nicolas Leitmann-Niimi
Tuesday, February 28, 2023, at 1:30 pm

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Defense
ATS Large Classroom (101 ATS) or via Teams

Post Defense Meeting
Riehl Conference Room (211 ACRC)

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The Changing Nature of Convection Over Earth's Tropical Oceans from a Water Budget Perspective

Consistent spatiotemporal hydrologic measurements over Earth's oceans are only feasible with satellite remote sensing. The water budget components inside of an atmospheric volume are precipitation (P), evaporation (E) and horizontal water vapor divergence (divQ). Physically, the sum of these components leaves a residual term: the amount of water vapor stored inside the atmospheric volume. A time series of this sum can be created over the tropical ocean basins using state of the art observations: P and E from satellites, along with divQ from reanalysis. This time series reveals a residual term whose variances often outweigh the physically possible range of water vapor storage. This is a discrepancy between measurements and physical truth that indicates a lack of water budget closure in remote sensing observations. This study finds that variations in lack of closure are not random, and seeks to reveal physical sources for long-term, high amplitude trends so that errors in observations may be properly addressed in the future. Trends in the residual are particularly significant over the Tropical West Pacific (TWP), Southern Tropical East Indian (STEI) and Tropical Central Pacific (TCP), where the difference between the maximum and minimum residual in each time series is 0.99, 1.95 and 0.91 mm/day, respectively. Closure is better over the Tropical Western Indian (TWI), Tropical Eastern Pacific (TEP) and Tropical Atlantic Ocean (TAO) where the ranges are only 0.66, 0.73, and 0.59 mm/day, indicating trends are not as significant. Time trends in this residual term have little semblance to either E or divQ, leaving satellite observations of P as the most likely source of consistent error.

This study finds that the first-order explanation for biases in precipitation lies in shifting convective organization. Convective organization changes are quantified using the amount of rain explained by three different regimes of convection (shallow, deep isolated and deep organized), which are dubbed convective rain states (CRS). A second-order explanation lies in relative ice amount. Relative ice amount is represented by ice-rain ratio (IRR), the amount of ice per amount of rain present in the atmospheric volume as determined from spaceborne radars. Changes in CRS can cause biases because rainfall spatial correlations related to well-known beam-filling errors are likely

responsible for over-and underestimation of precipitation, while changes in the relative ice amount in individual convective rain states can cause the precipitation to be under or over-estimated due to scattering effects. Over the TCP these changes are purely dictated by the El-Nino Southern Oscillation (ENSO), with organization becoming a clear function of SST. Over the STEI there is a circulation that stems from the Indian Ocean Dipole (IOD), leading to a CRS and IRR dependence on vertical wind shear. Finally, over the TWP, CRS is neither a simple function of SST nor shear, but rather seems to arise from a deeper ocean change of state: a coupling/decoupling of west Pacific SST with central and east Pacific SSTs, suggesting that two different mechanisms may be at play when it comes to shifts in convective organization: water vapor convergence when the TWP is anomalously warmer than the rest of the ocean, and low-level shear when it is not. While these proposed mechanisms would explain much of the observed biases, this study cannot address quantitative biases, as these depend on algorithm details and vary from one algorithm to another – although the qualitative trends are consistent among them.