# Local and large-scale controls of moisture variability in the shallow-to-deep transition during GOAmazon


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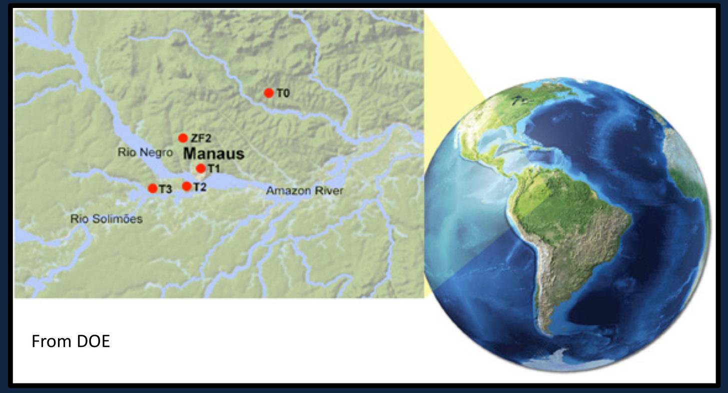
## 1. Introduction

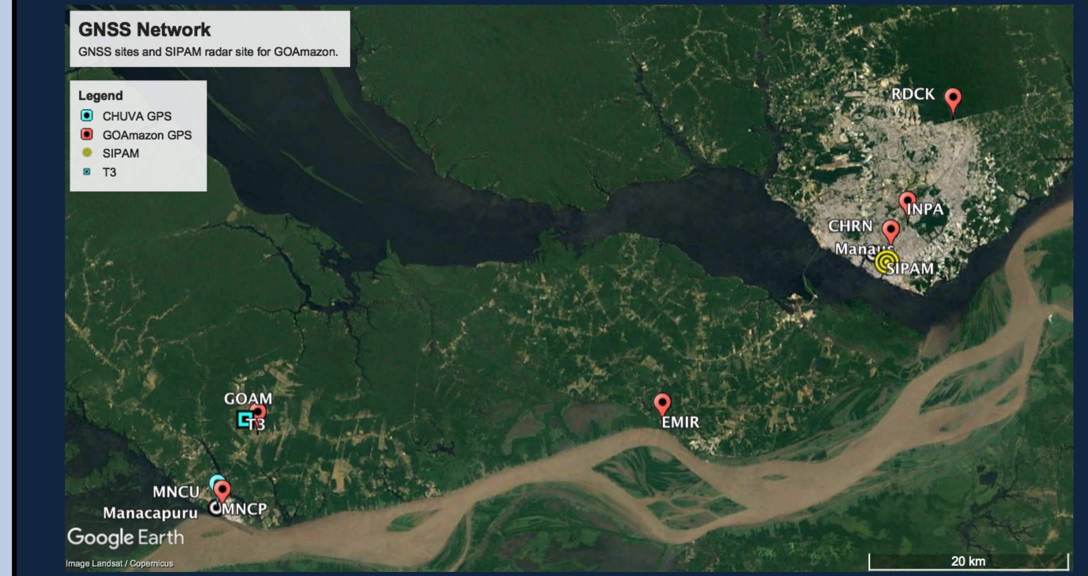
The mission of the GOAmazon and CHUVA experiments near Manaus is to advance our understanding of land-atmosphere processes and their impact on tropical hydrology and climate and to improve the representation of these coupled processes in climate models. Within this overall goal, these field observations, collected January 2014 through December 2015, provide a unique opportunity to examine land-based convective processes in the tropics, including the poorly represented shallow-to-deep transition.

**OBJECTIVE:**

In this study, we examine how convection develops with respect to different phases of Kelvin waves during GOAmazon. In particular, we aim to identify the important environmental factors contributing to observed periods of enhanced deep convection related to the waves.



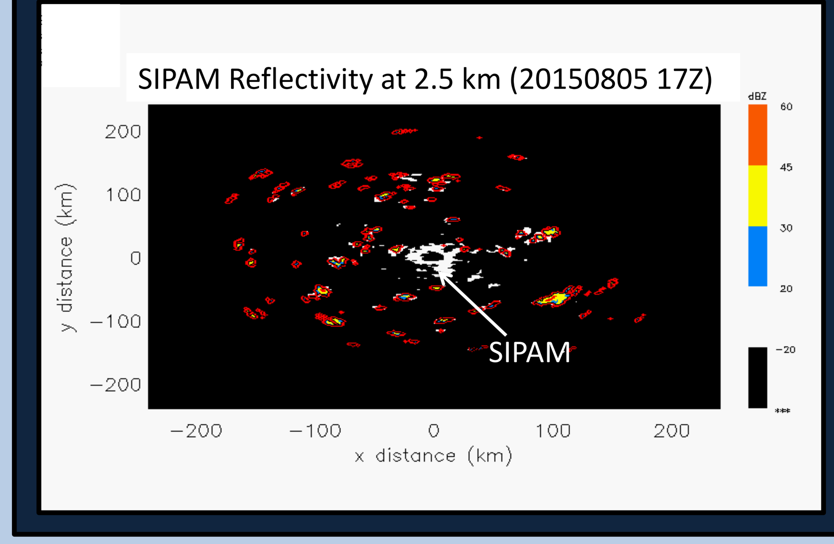

## 2. Data and Methods




| MEASUREMENT | INSTRUMENTS |
|---|---|
| Surface precipitation | Optical rain gauge (AOSMET) – T3<br>Tipping bucket – T3 (TB), ~T3 (TIWA)<br>Disdrometer (PARS2) – T3 |
| Cloud fraction (by type) | W-band Radar (WACR), Radar Wind Profiler (RWP), Ceilometer, Micropulse Lidar (MPL) Product (Zhe Feng and Scott Giangrande) |
| Rain area and MCS identification | S-band Doppler Radar (SIPAM) – Manaus |
| Column precipitable water vapor (PWV) | GNSS sites |
| Vertical profiles of u, q, T, div, w | Radiosondes and Variational Analysis (VA, Shuaiqi Tang) |
| Outgoing Longwave Radiation (OLR) | NOAA/PSD |

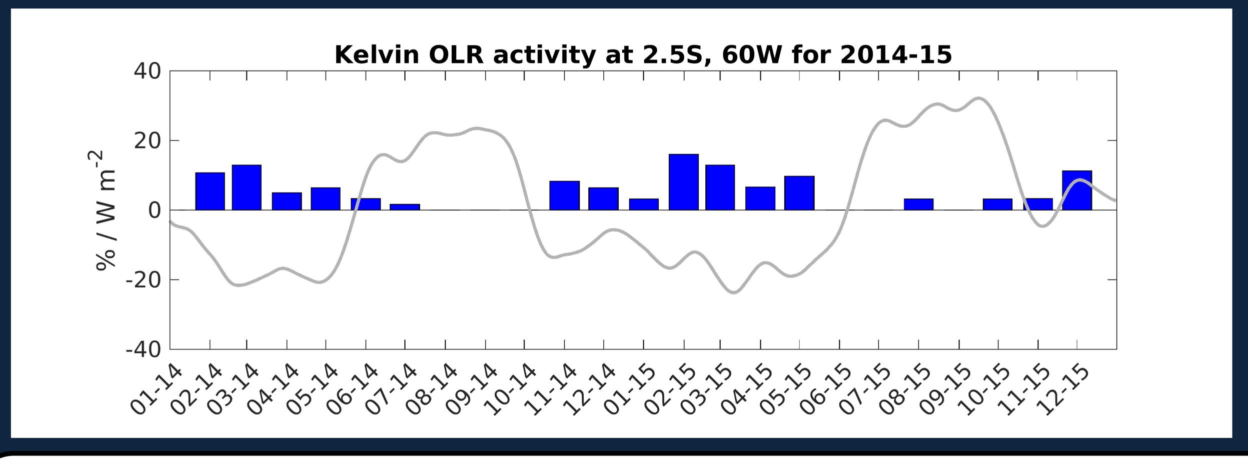
Primary Data Sets:

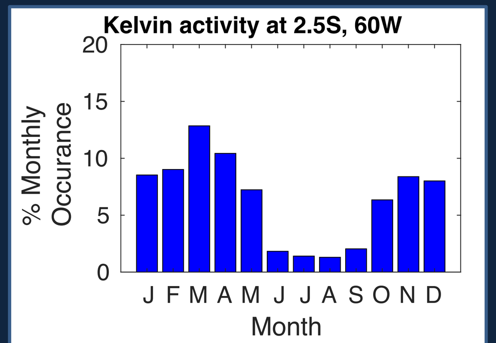
- GOAmazon/CHUVA data is used primarily from the DOE AMF site (T3), as well as from a GNSS network (red&cyan, left).
- The operational S-band radar (SIPAM, yellow circle) is used to provide a broader context for the column measurements. A feature-based algorithm with a 20-dBZ threshold is applied to SIPAM reflectivity to identify MCSs using a 100-km major axis threshold.
- NOAA OLR data at 2.5° resolution from 1980-2015 are used to identify daily Kelvin wave activity by applying a space-time filter following Wheeler and Kiladis (1999). In situ data are then composited by periods of suppressed (olra ≥ +1.5σ), neutral (-1.5σ ≥ olra ≥ +1.5σ), and active (olra ≤ -1.5σ) wave activity, where olra are filtered wave anomalies (Liebmann et al. 2009).




| Active days (42) | Suppressed days (43) |
|---|---|
| 2014: 1/20, 2/7, 2/11, 3/12, 3/15, 3/28, 4/1, 4/2, 5/1, 5/9, 6/30, 11/2, 11/23, 11/27, 11/28, 12/11, 12/13<br>2015: 1/24, 2/1, 2/2, 2/9, 2/10, 2/17, 2/18, 2/26, 3/6, 3/20, 3/21, 3/30, 3/31, 4/17, 4/18, 5/2, 5/6, 5/19, 8/26, 9/21, 10/25, 12/16, 12/25, 12/30, 12/31 | 2014: 1/17, 2/9, 3/9, 3/10, 3/26, 3/30, 4/4, 4/5, 4/23, 4/24, 5/3, 5/7, 5/15, 8/18, 9/2, 10/30, 10/31, 11/11, 11/12, 11/25, 11/30, 12/13, 12/21<br>2015: 1/26, 1/29, 2/6, 2/7, 2/24, 2/25, 3/8, 3/25, 3/26, 3/27, 3/28, 4/14, 5/4, 9/23, 10/22, 11/13, 11/21, 11/22, 12/19, 12/27 |

## 3. Kelvin Waves Over the Amazon

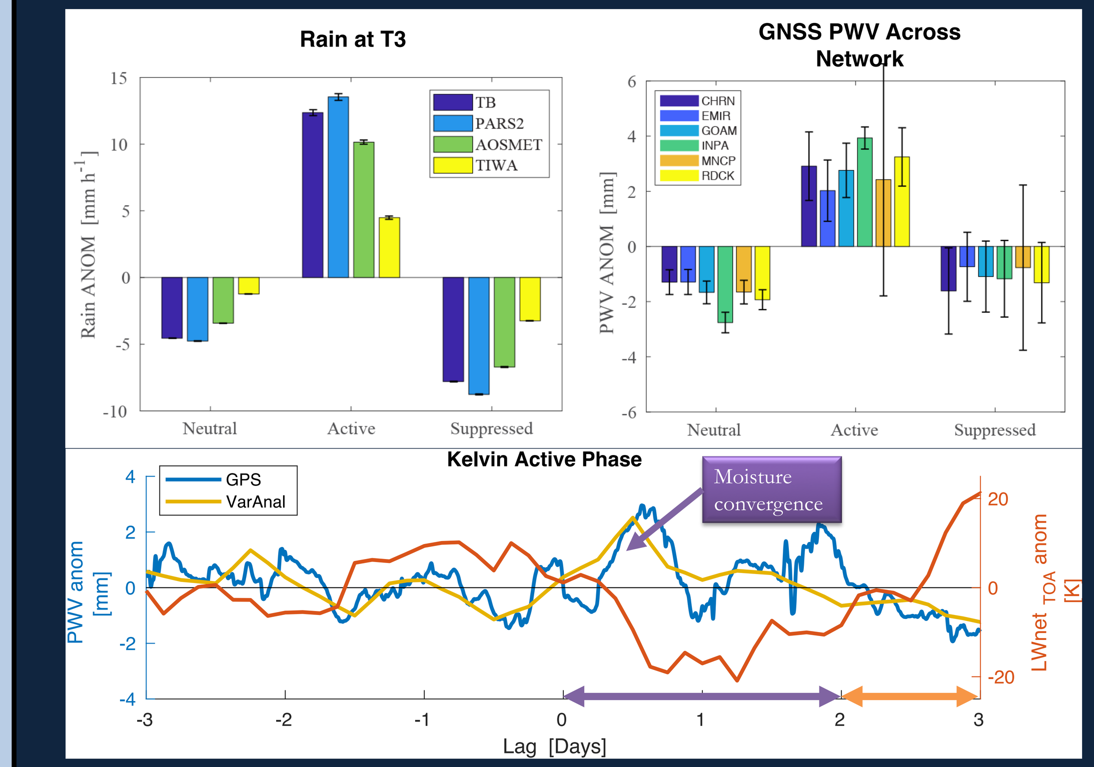


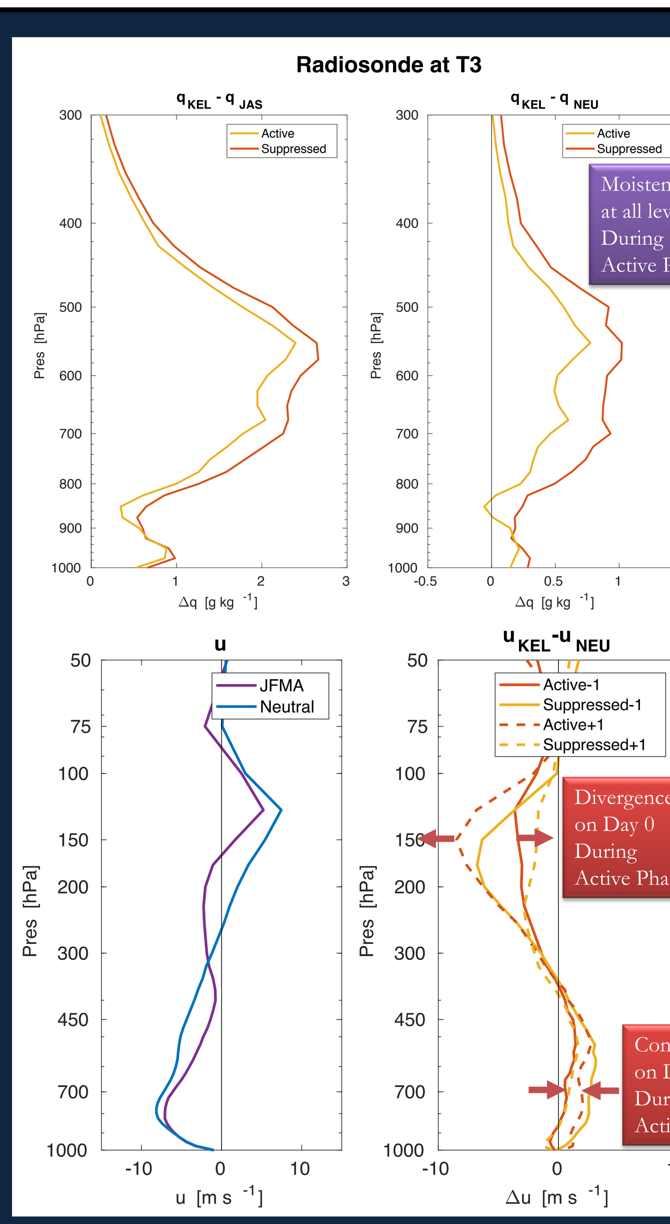




Percent occurrence of active Kelvin phase per month over 1980-2010.

**Seasonality:**

Kelvin wave activity during GOAmazon (blue bars, left panel) is most frequent during the wet season when anomalous deep clouds are evident (detrended 120-day OLR, gray line, left panel). This activity is consistent with the climatological Kelvin activity over the region shown above (right panel) and noted by Liebmann et al. (2009).




**PWV and Rainfall:**

- The active phase of the Kelvin waves enhances precipitation relative to the neutral and especially the suppressed phase of the wave. The neutral days include those during the dry season, placing the neutral rain anomalies at less than zero (top left panel).
- The modulation of PWV by the Kelvin wave is consistent across the GNSS network indicating the scale of the wave's influence on tropospheric moisture (top right panel).
- Composite PWV anomalies with respect to the 20-day mean at ±3 days (bottom panel) for the active Kelvin phase highlights the strength of the GPS PWV high time resolution capturing the roughly 8 hour increase in PWV prior to deep convective onset at T3. This increase in PWV indicates the convergence of moisture into the column at this time. The VA PWV are in general agreement (and are very similar to the radiosonde PWV not shown) but are only available at 4-5xdaily and will have difficulty in active precipitation.
- The PWV anomalies are generally at or below the 20-day mean prior to the onset of convection and remain above the 20-day mean for about 2 days following this onset.

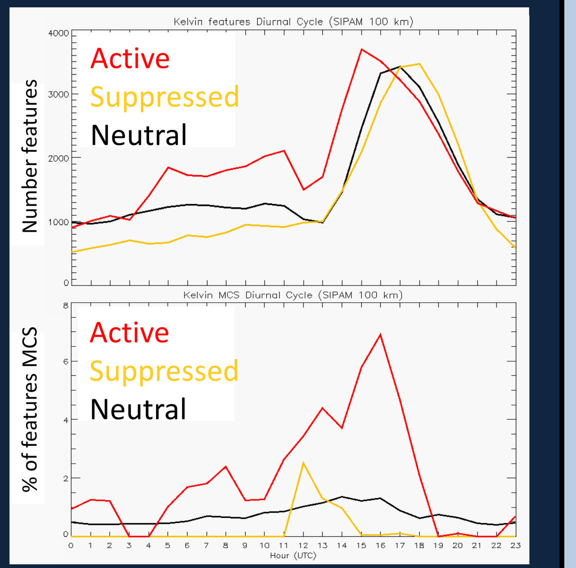
**Vertical Profiles:**

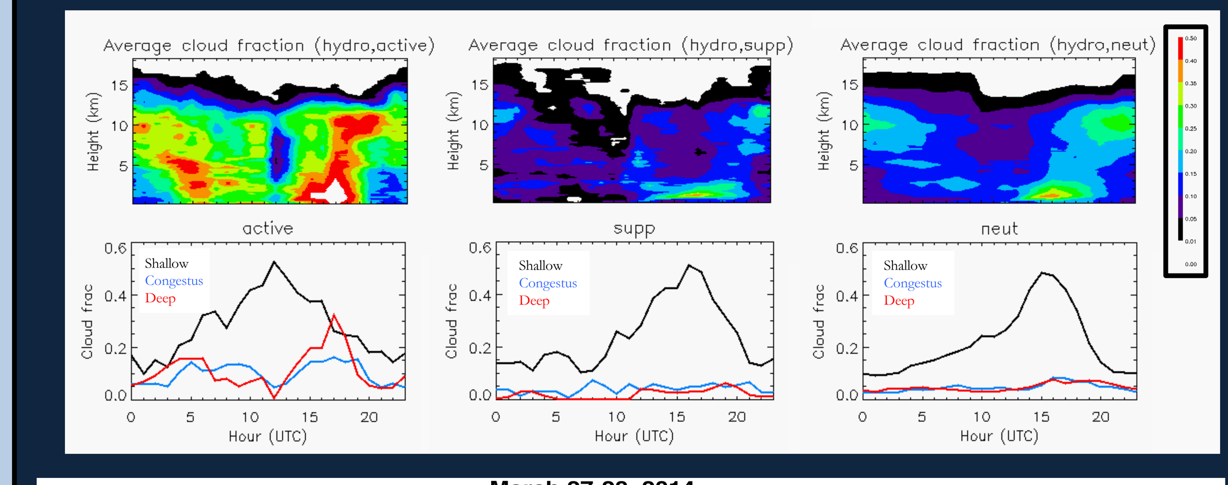
- The increase in PWV during the active phase of the Kelvin wave is seen here to be distributed throughout the column but primarily in the mid troposphere (top right panel).
- The active phase of the Kelvin wave is coincident with anomalous divergence aloft and weaker anomalous convergence at low levels, with the opposite pattern during the suppressed phase (bottom right panel).
- Key Question: What is more important to supporting convection, the increase in mid level moisture or the enhanced divergence aloft?

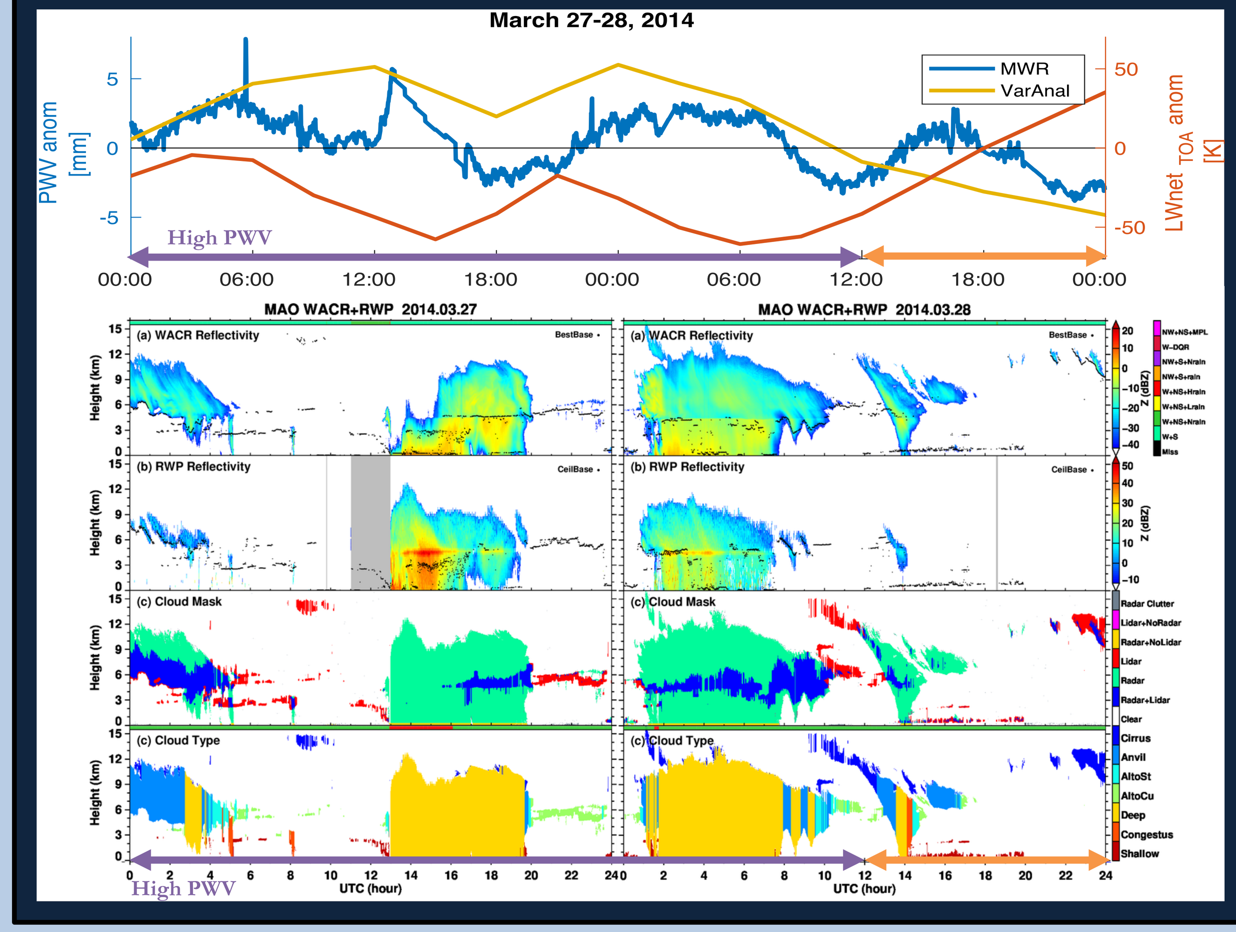
## 4. Kelvin Waves and the Diurnal Cycle

**Precipitation Features (> 20 dBZ) Within 100 km (right panel):**

- The number of features peaks just after local noon (UTC-4) with the active phase peaking earlier and with a greater number of features overnight into early morning, especially compared to suppressed phase.
- The % of MCSs during the active phase peaks at 16 UTC (12 LT), with MCSs also observed overnight into the early morning. MCSs occurred at all hours of the day during neutral periods but at a lower frequency compared to active periods. Few suppressed MCSs.




**Cloud fraction by type at T3:**

- Clouds contributing to rain at the ground (hydro) highlight a shallow-to-deep transition during the afternoon quicker and earlier during active phases (top panel, top row).
- Fraction of shallow clouds peak earliest for active periods with overall higher cloud fraction associated with deep convection (top panel, bottom row).
- Days with afternoon deep convection have shallow clouds increasing during the morning and persisting throughout the day, about half those days also have congestus clouds, and a few show deep convection prior to afternoon peak (earliest for active, latest for suppressed) (top panel, bottom row)
- Active case (bottom panels) shows deep convection near 13Z that persists into the next day. This is similar to "diurnal dancing" seen over Western Pacific Warm Pool (Chen and Houze 1997).

## 5. Conclusions and Future Work

- Kelvin waves present during wet season and modify the local environment through increasing moisture as well as upper level divergence ahead of the peak convection. Both likely contribute to the wave support of convective outbreaks.
- MCSs more numerous and contribute more to total rain during active period and persist into the next day.
- Shallow-to-deep transition occurs earlier and quicker during active phase, with shallow clouds remaining throughout the deep convective period for all phases.
- Future work involves 1) separating out days with MCSs propagating into the region to focus on local shallow-to-deep transition, 2) considering additional large-scale influences (e.g., WIG waves), and 4) evaluating model capability to reproduce diurnal response.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