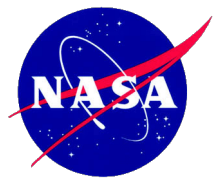

Coupled atmosphere and ocean boundary layer variability in the suppressed phase of the Madden-Julian Oscillation

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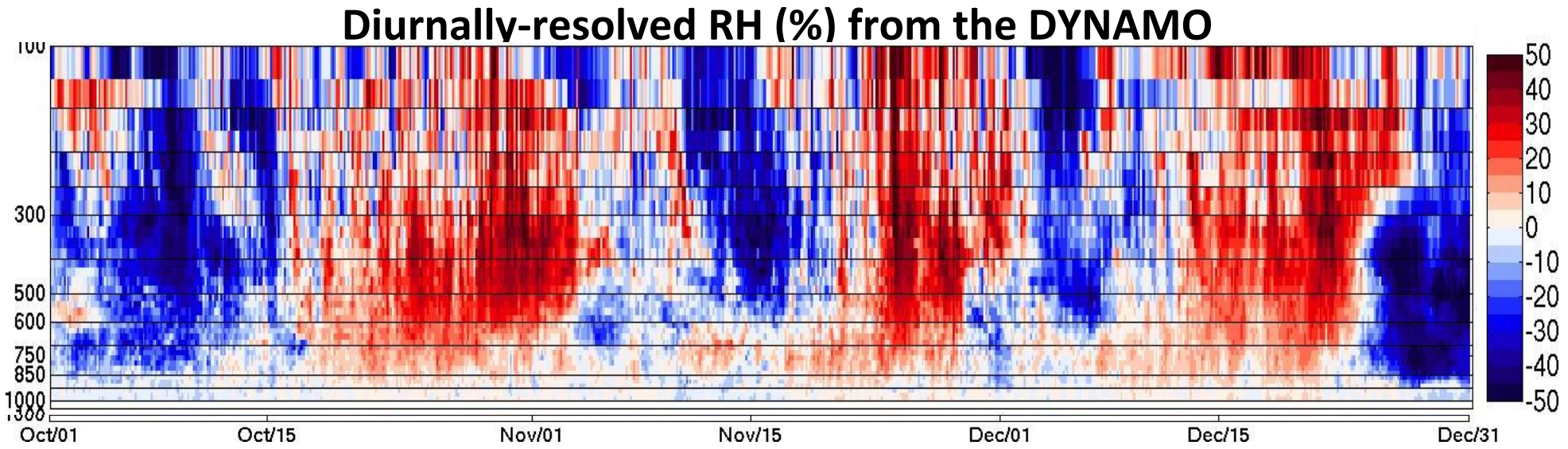
Motivation: MJO and Air-Sea Coupling

- Numerous studies have shown atmosphere-ocean coupling may play an important role in modifying the intensity, duration, and/or propagation of MJO events (DeMott et al. 2015)

- In particular, modeling studies have shown that resolving the diurnal cycle of the upper ocean mixed layer may be a critical component of the coupling

- However, the exact mechanism by which diurnal coupling is rectified onto the MJO time scale is not as well understood
  - *"[…] The suppressed phase ocean feedback to the atmosphere on diurnal time scales seems clear, but the mechanisms that rectify the diurnal moistening onto MJO time scales are not" – DeMott et al. 2015*

Motivation: MJO and Air-Sea Coupling

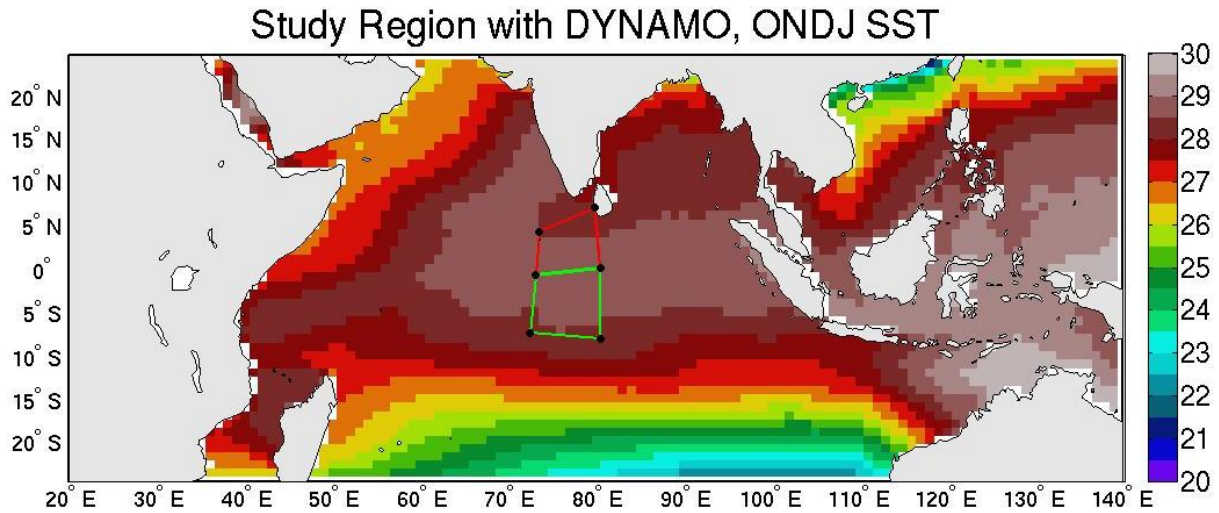


- Ruppert Jr. and Johnson (2015), using DYNAMO sounding array data together with ship observations, found a significant diurnal component to the 3-hourly resolved moisture tendencies.
  - *"… diurnal cycle of SST and air-sea fluxes drive a net boost to convective activity and cumulus moistening ... which would not exist without such a diurnal cycle"*

1. Is this preferential moistening observable over a more broad area?

2. If so, can we identify the importance of local surface evaporation vs. dynamical convergence to the observed moistening?

Datasets & Study Region



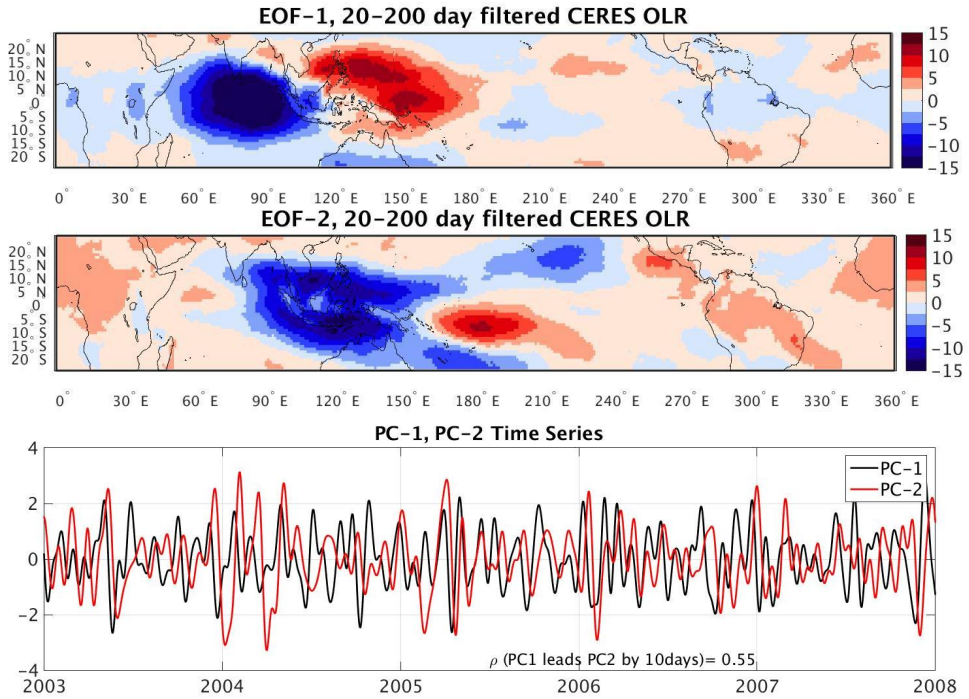
Study Period:

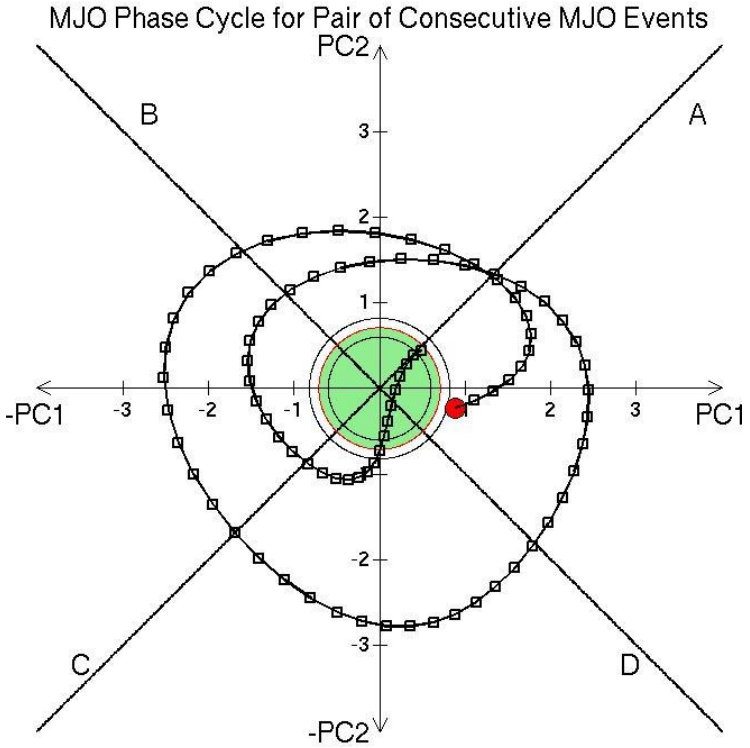
- March 2000 through December 2014

Datasets (all remapped to 1x1 degree):

- 3-hr SeaFlux-CDR (LHF/SHF/SST)
- 3-hr CERES-SYN (TOA/SFC Radiation)
- 3-hr MERRA-2 (PW, Moisture & DSE Convergence)
- 3-hr TRMM 3B42 (Rainfall)
- Daytime MODIS (Terra/AM, Aqua/PM Cloud Properties)

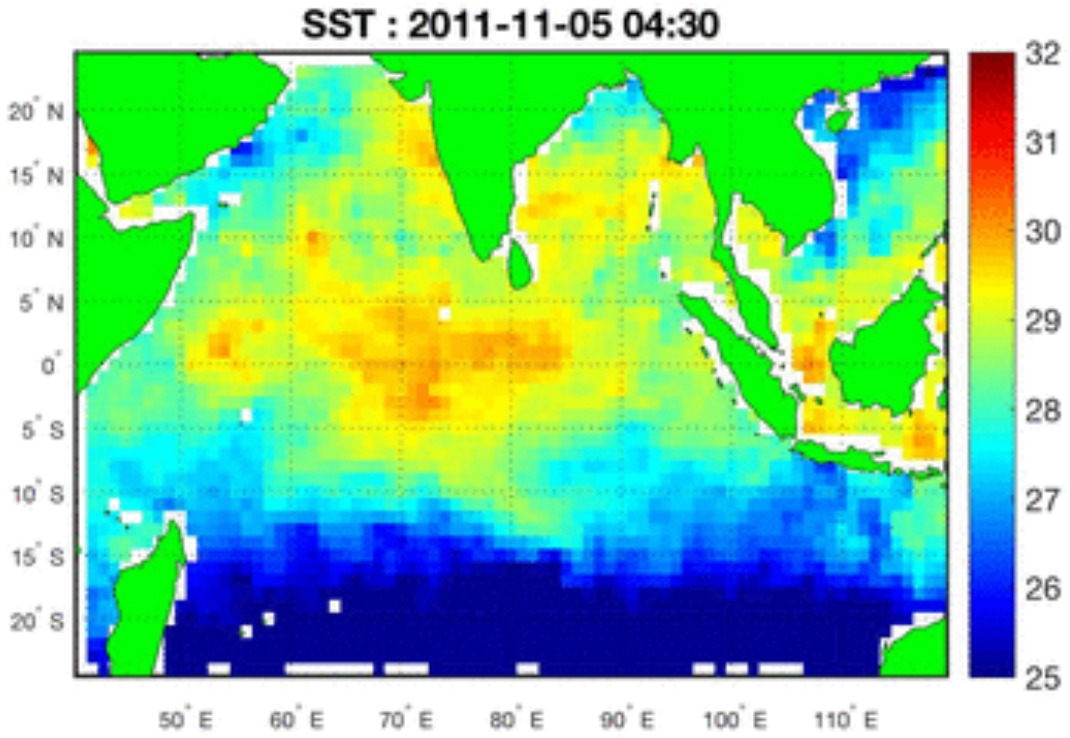
Identifying the MJO Suppressed Phase



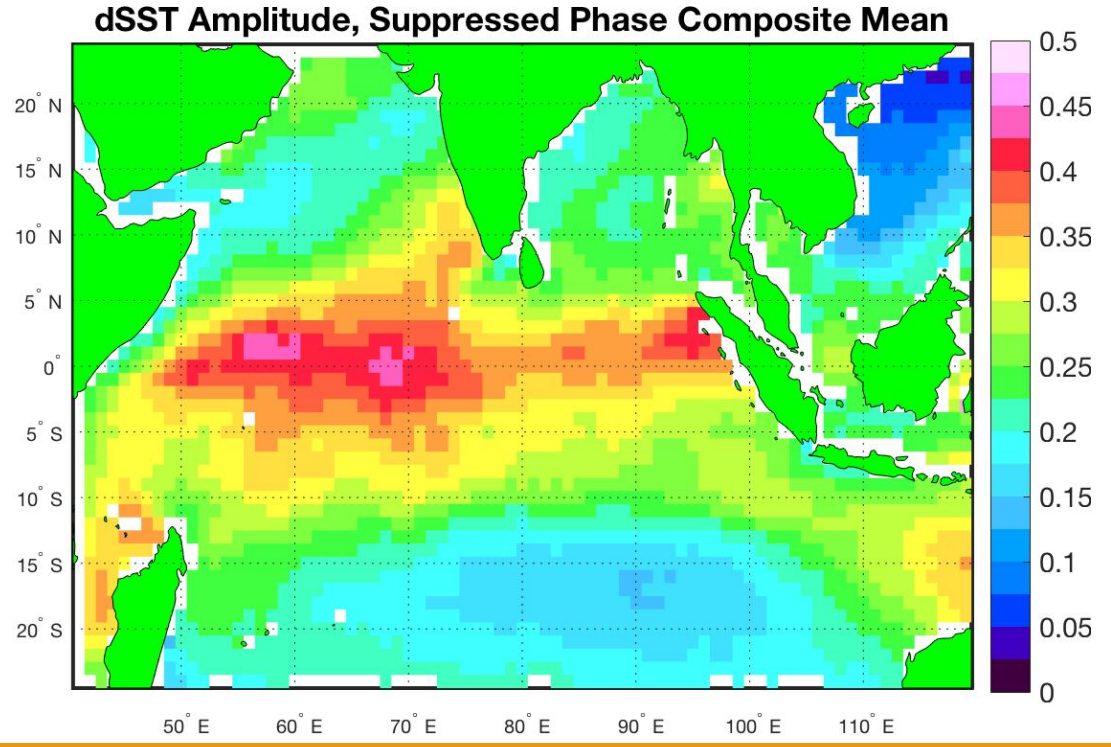


- Followed Matthews (2008) to define an index based only on the 1st two EOF/PC of 20-200 day filtered OLR
  - *Forms an (almost) quadrature pair of indices keyed only on the convective signal*
- Using phase space progression, we can identify start/stop dates for MJO cycles
  - "C" identifies the suppressed phase over the tropical Indian Ocean; End dates of Phase C agree within a few days of Ruppert Jr. and Johnson (2015) MJO onset dates

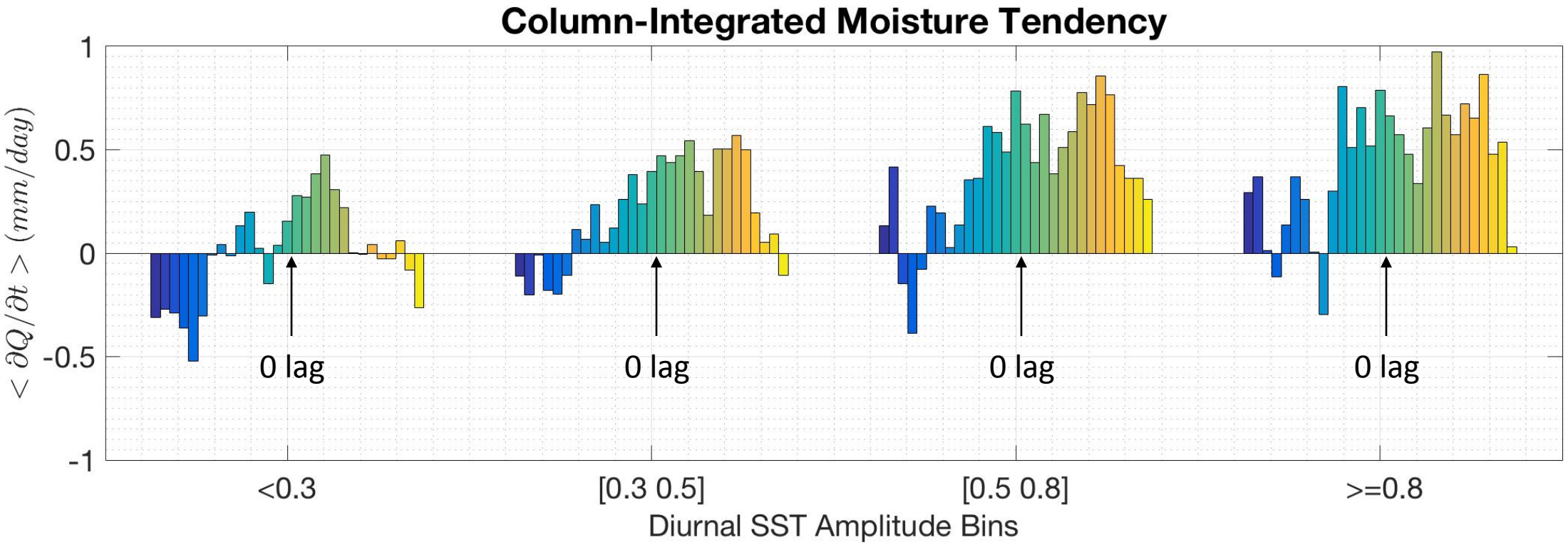
Diurnal Warming Signal



- Diurnal warming is ubiquitous throughout the tropical Indian Ocean (10S-15N, 50E-110E) throughout the suppressed phased of the MJO
- Average values are 0.3-0.4°C

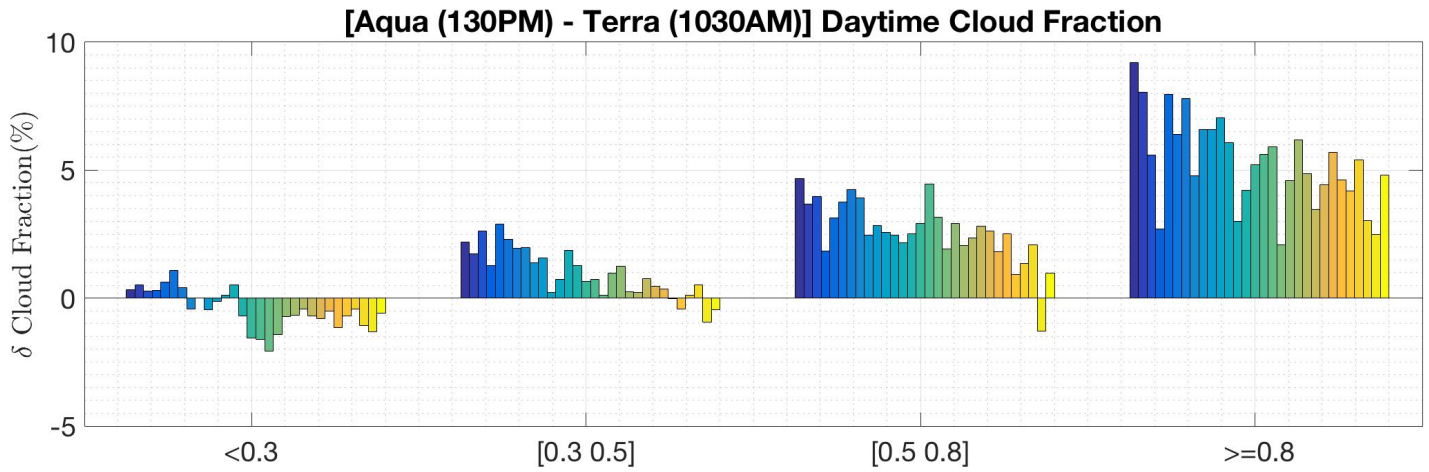


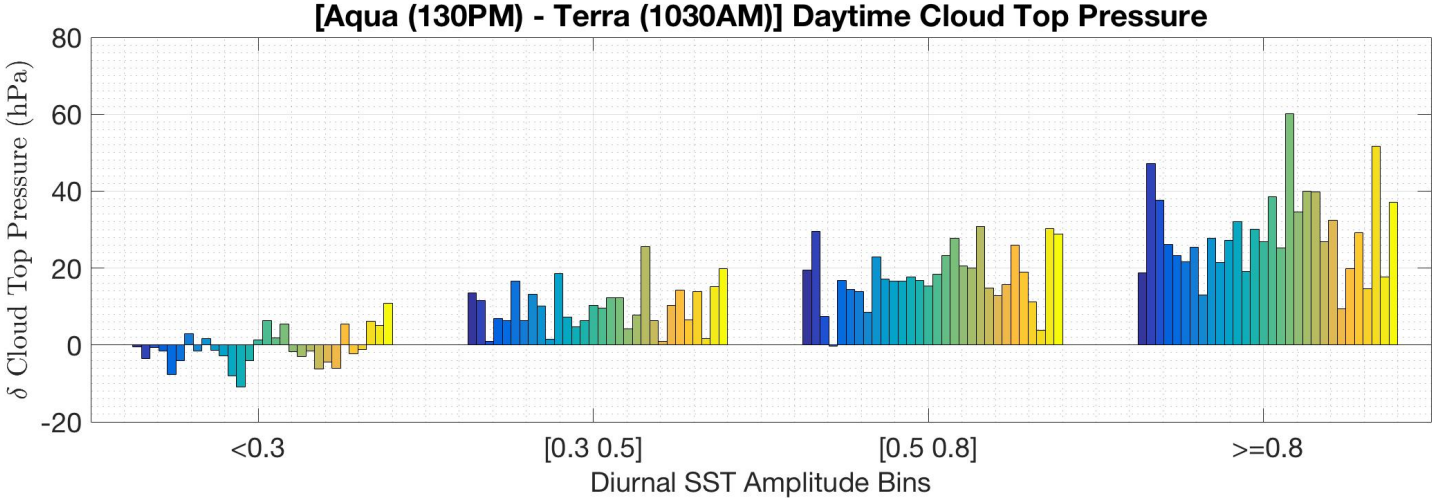
Do we see a signal of preferential moistening?



- Stratified by lag the moisture tendency — from MERRA-2 precipitable water — all pixels by diurnal SST amplitude bins
- There is a generally enhanced atmospheric moistening (~0.1-0.2 mm/day) that begins earlier in the suppressed phase for location experiencing higher diurnal warming

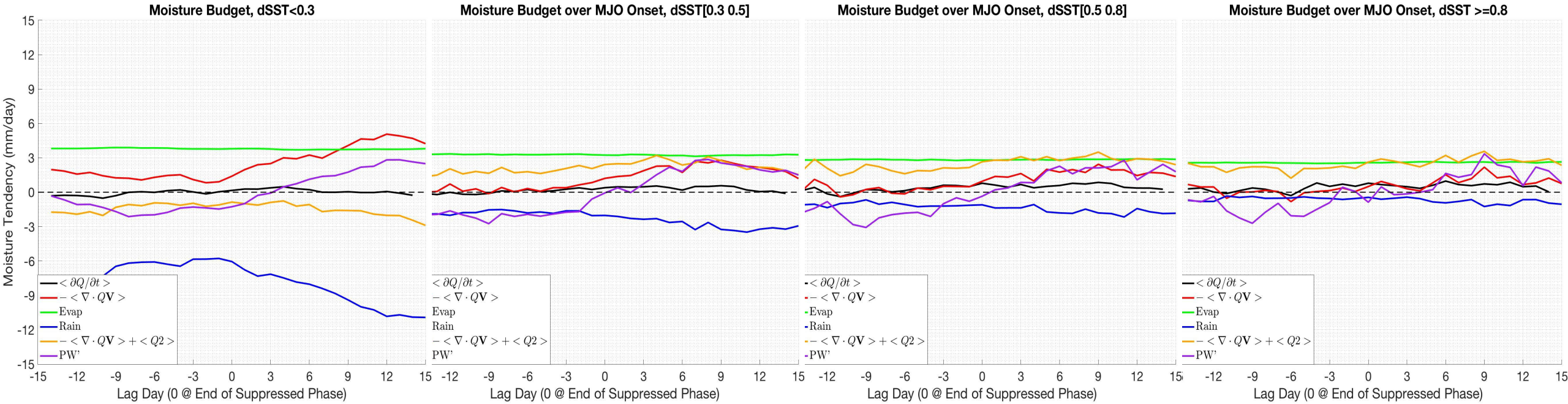
Diurnally Forced Convective Signal





- Examine ***differences*** between the Aqua (1330) and Terra (1030) daytime cloud properties
- Cloud fractions show a clear expansion as a function of diurnal warming strength, with greater than 5% areal cloud fraction change over the 3-hour period between observations.
- However, there is an *increase* in cloud top pressure. Thus, Aqua is observing a more clouds with less vertical development.
- Ruppert and Johnson (2015) show that most vertical development takes place later than the Aqua overpass. It is possible that we are seeing new convective development rather than simply enhanced development of the existing clouds.

Moisture Budget & Diurnal SST Variability



- The moisture tendency is generally a small residual from offsetting individual components. Moving from low to high diurnal warming, the largest change is in the reduction of rain. While it is possible that an “enhanced diurnal cycle” could be present the overall relationship is for regions of high diurnal warming to coincide with much reduced overall rainfall.
- Surface evaporation remains remarkably stable as a budget component. This is a result of offsets between increased (Qsfc–Qair) and decreased wind speeds. As it remains steady while other terms decrease in magnitude, its relative contribution to the total budget increases.

Summary

1. **Is this preferential moistening observable over a more broad area?**
   - Yes , we see preferential moistening as a function of the diurnal SST amplitude
   - Yes , we see enhanced daytime convection as a function of the diurnal SST amplitude
   - Due to the limited temporal sampling from MODIS, it is not possible to observe the afternoon development

2. **If so, can we identify the importance of local surface evaporation vs. dynamical convergence to the observed moistening?**
   - Maybe, local evaporation remains a steady contributor for different diurnal warming amplitudes due to offsets. Thus it should become relatively more important to the observed total moistening.
   - Caveat 1: Turbulent flux estimates from space can be highly uncertain under certain conditions. The budget as estimated remains out of balance.
   - Caveat 2: Reanalyses (such as MERRA-2) do not include high-frequency SST forcing, so their dynamics are not going to capture response to diurnal SST warming.