Relationships between ocean-atmosphere surface heat and moisture fluxes and weather regimes

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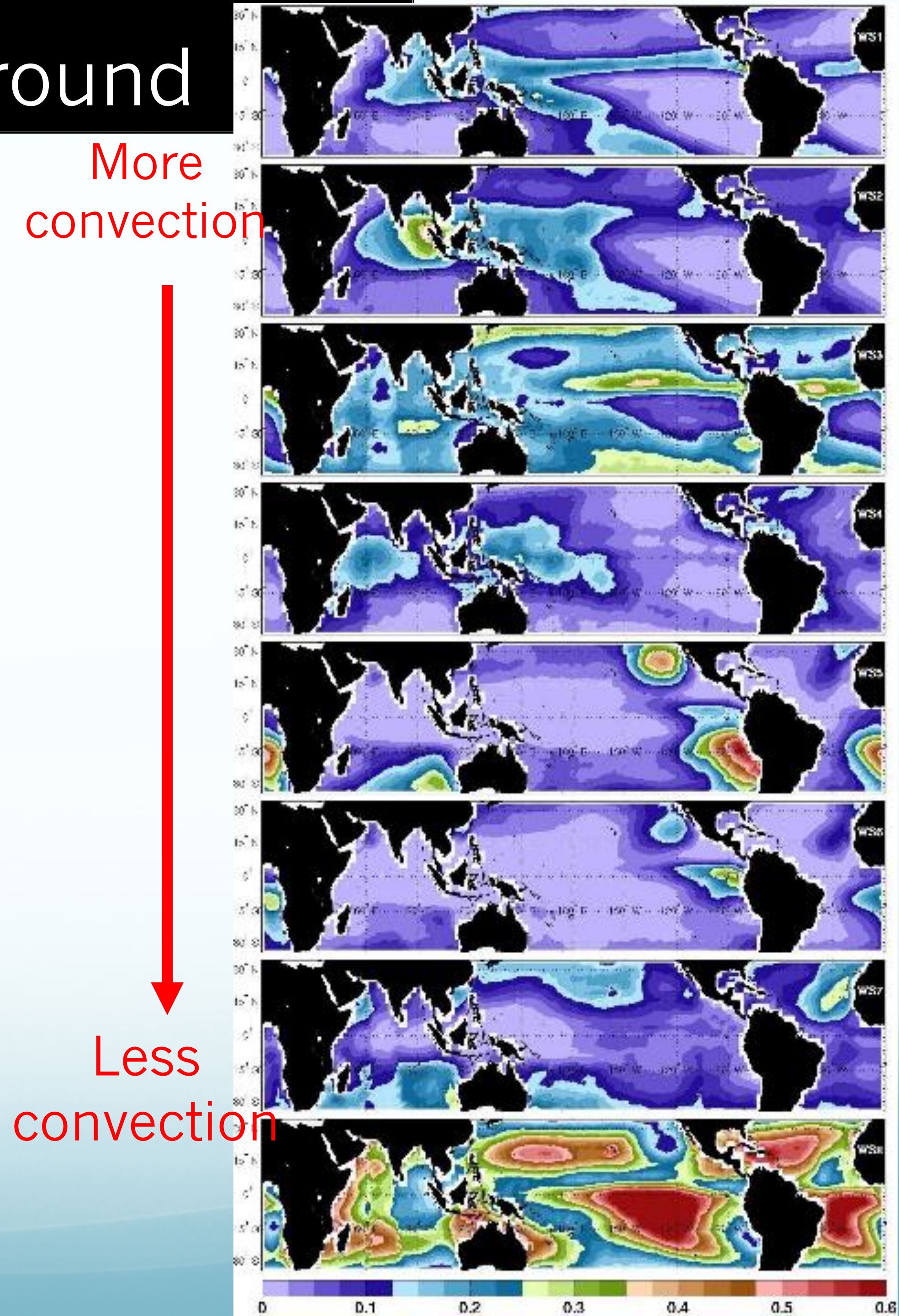
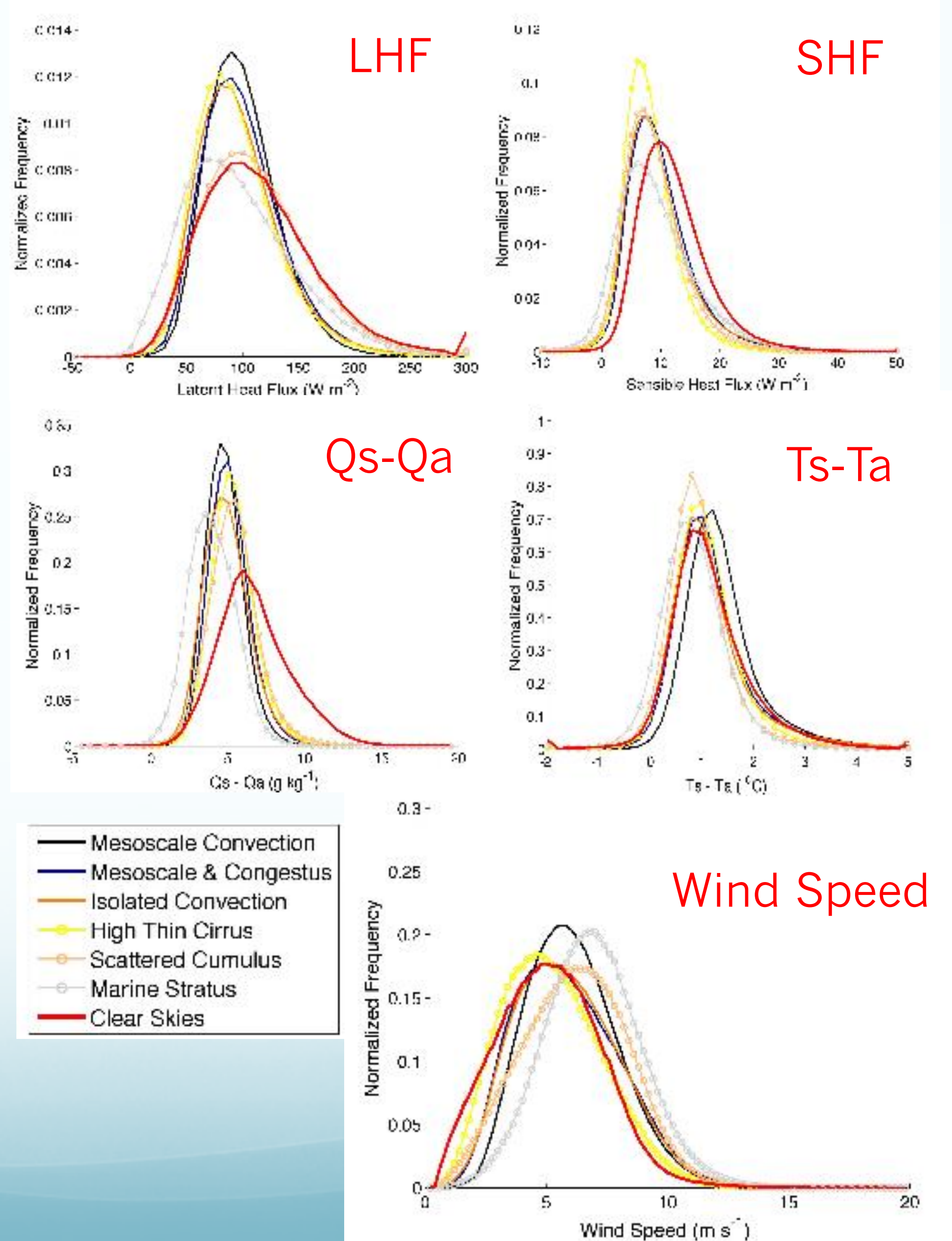
Motivation and background

- Use of ISCCP cluster weather states (Jakob and Tselioudis 2003)
  - Tropical convection and MJO (Tromeur and Rossow, 2010; Chen and Del Genio, 2009)
- Datasets:
  - ISCCP Extratropical Cloud Clusters (35N/S, 2.5°x2.5° 1985-2007, 3-hr)
  - SEAFLUX (1998-2007,0.25°x0.25° 3-hr), LHF/SHF/Surface Variables
- Product Homogenization:
  - Fluxes regridded and resampled to ISCCP 2.5x2.5
  - ISCCP 3-hr used to assign a daily class based on the most frequent cluster

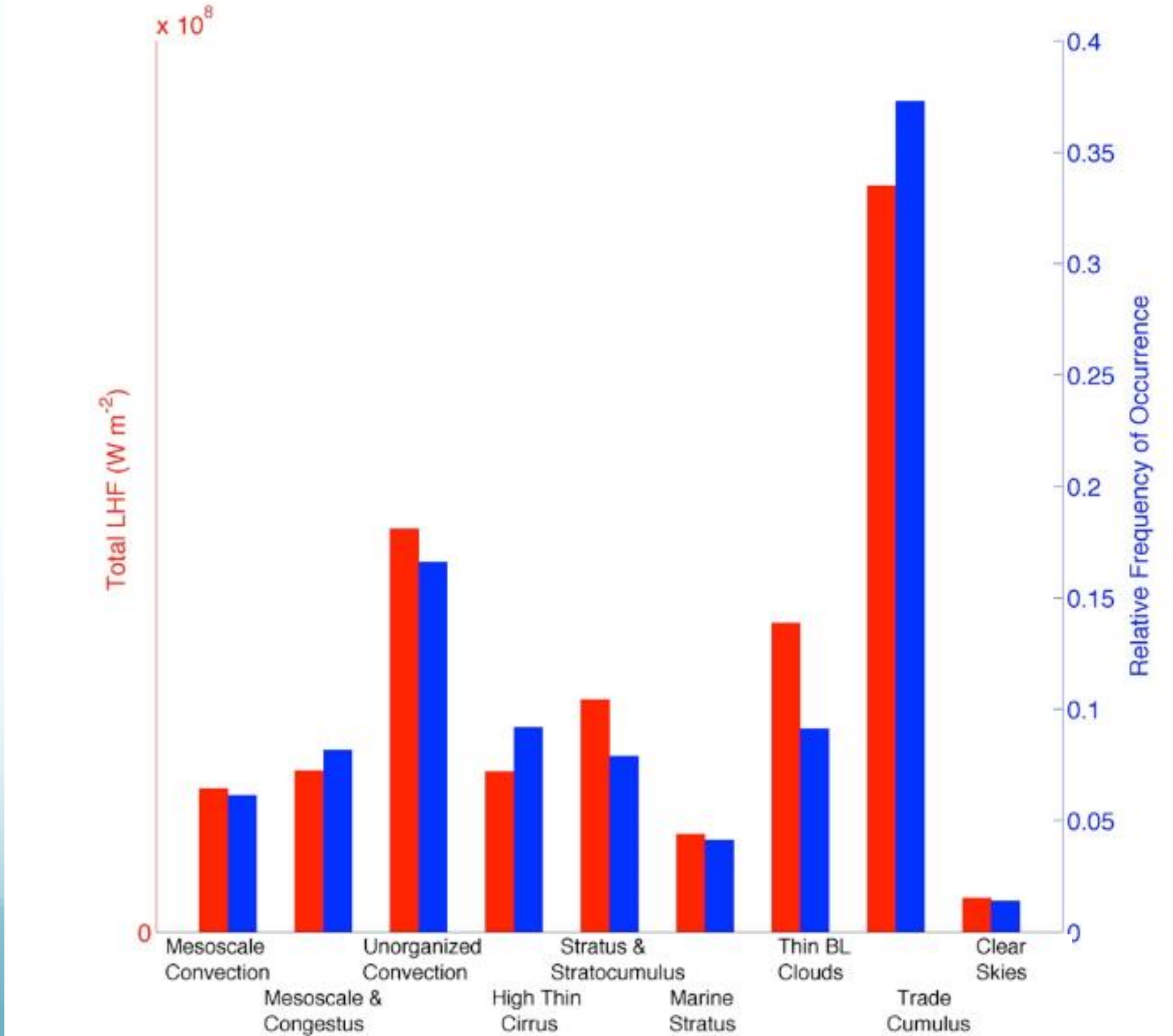


Decomposition of surface fluxes by weather state

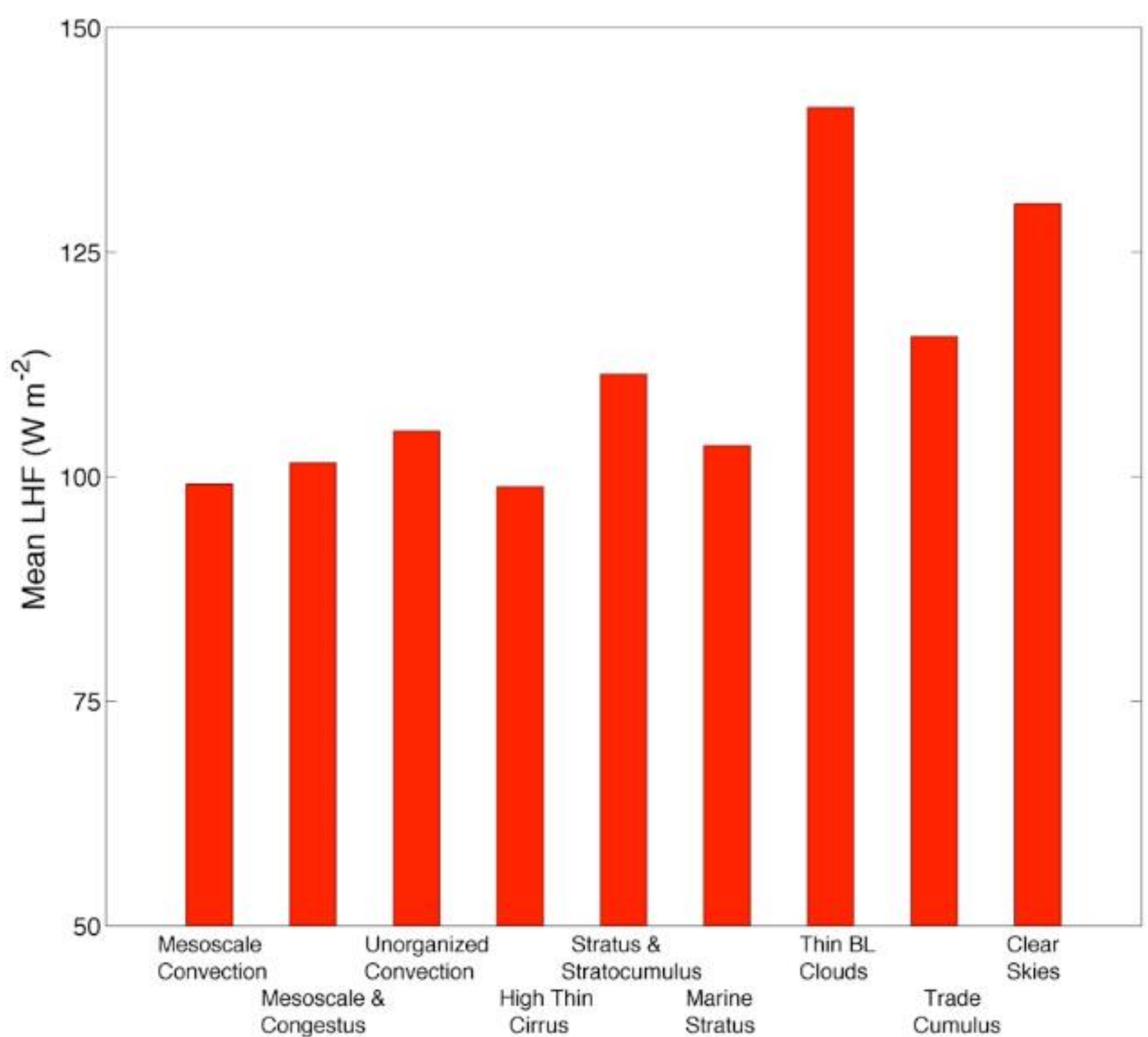
- Weather regimes result in distributions of fluxes with different mean and extreme characteristics
- These are associated with changes in the bulk variables, as should be expected
- Both wind speed and near-surface humidity gradients are particularly well stratified, though the latent heat flux means are less so
    - Indicates potential compensations



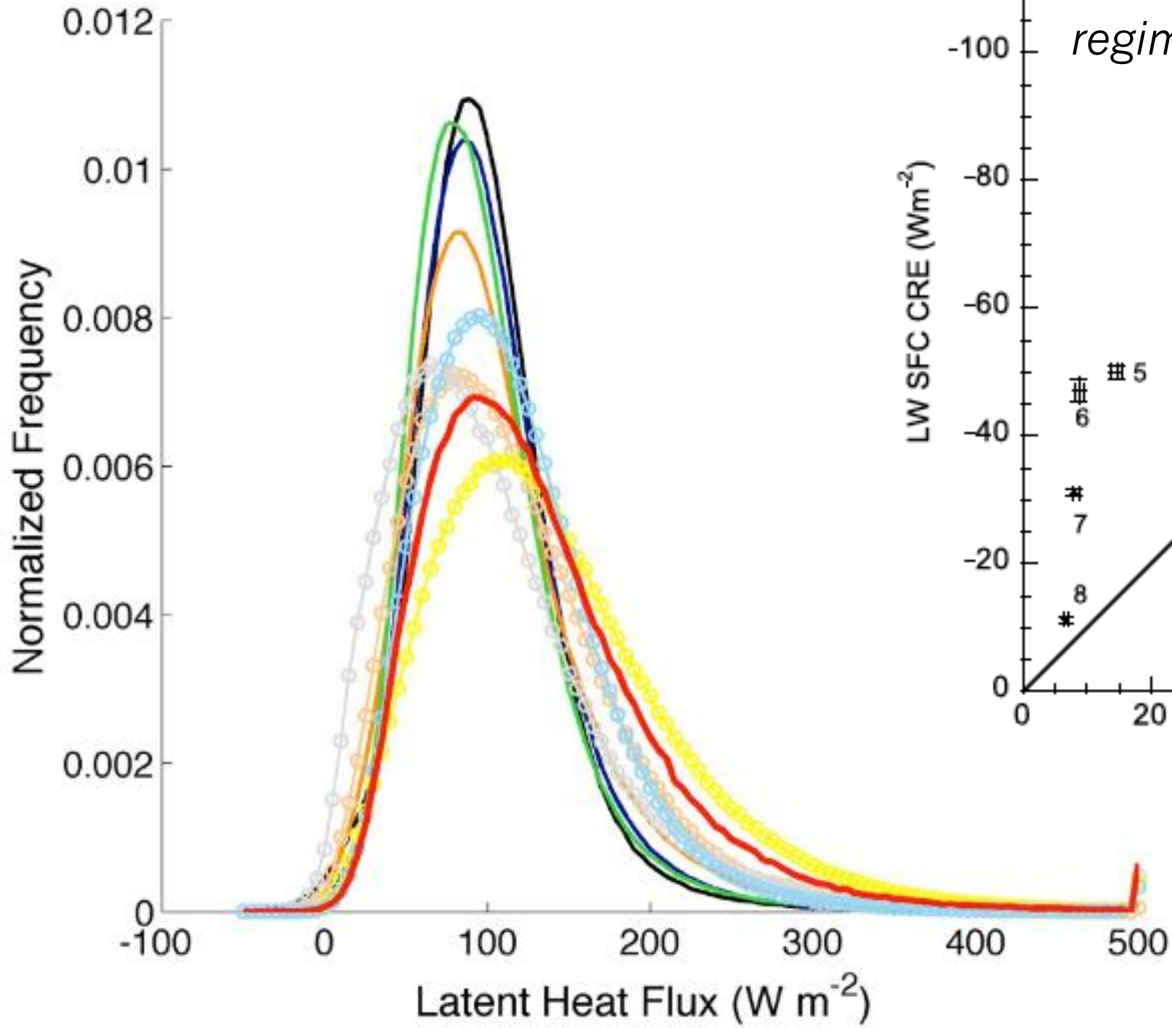
Extended Tropics

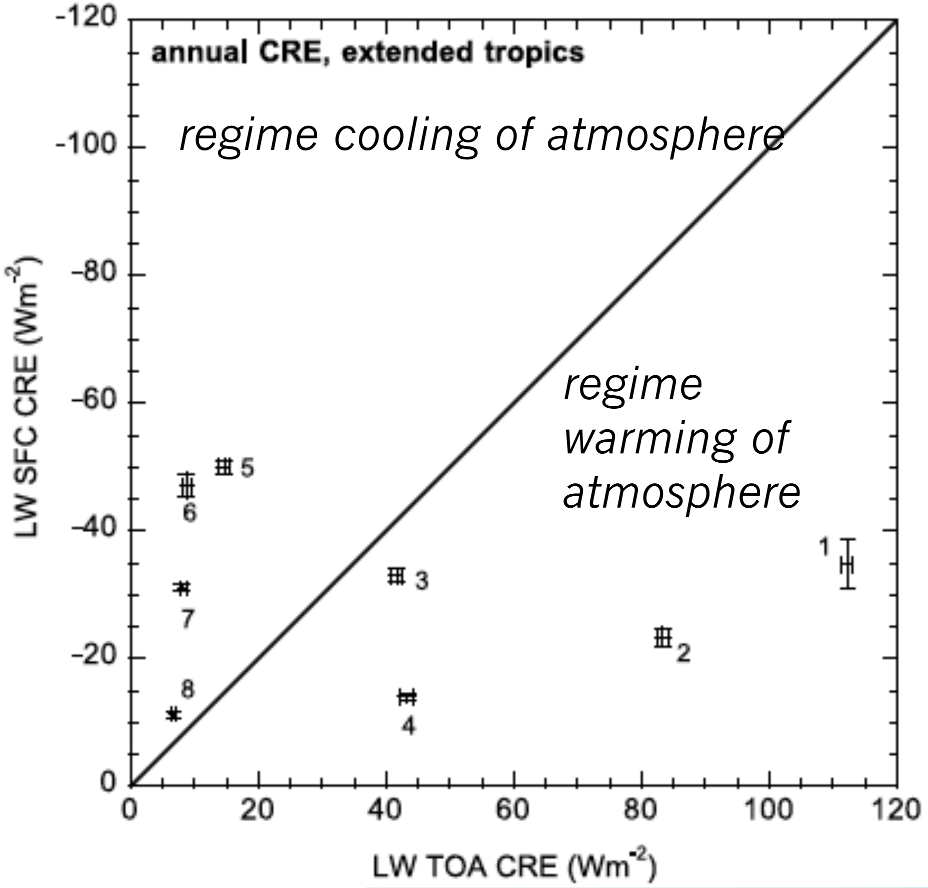


Extended Tropics



Cloud Radiative Effect

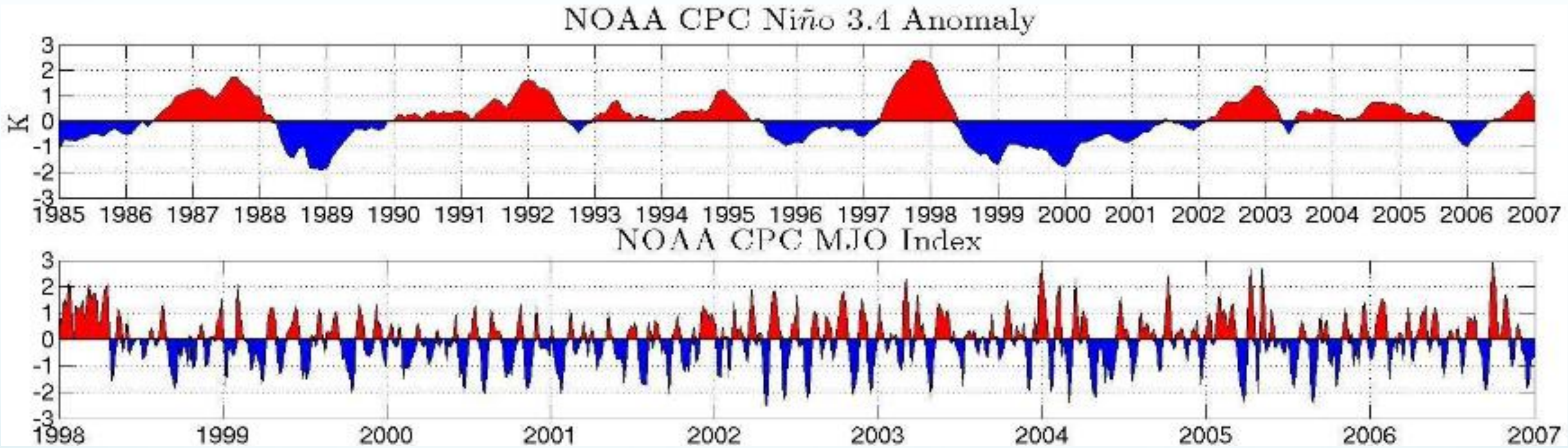




from Oreopoulos and Rossow (2011)

Compositing methodology

- Conditionally sample data using weather state classification (WS1-WS8; most convective to least convective)
- Further sampled based on compositing index to evaluate low-frequency coupled variability
- Use NOAA Climate Prediction Center (CPC) indices for ENSO and MJO



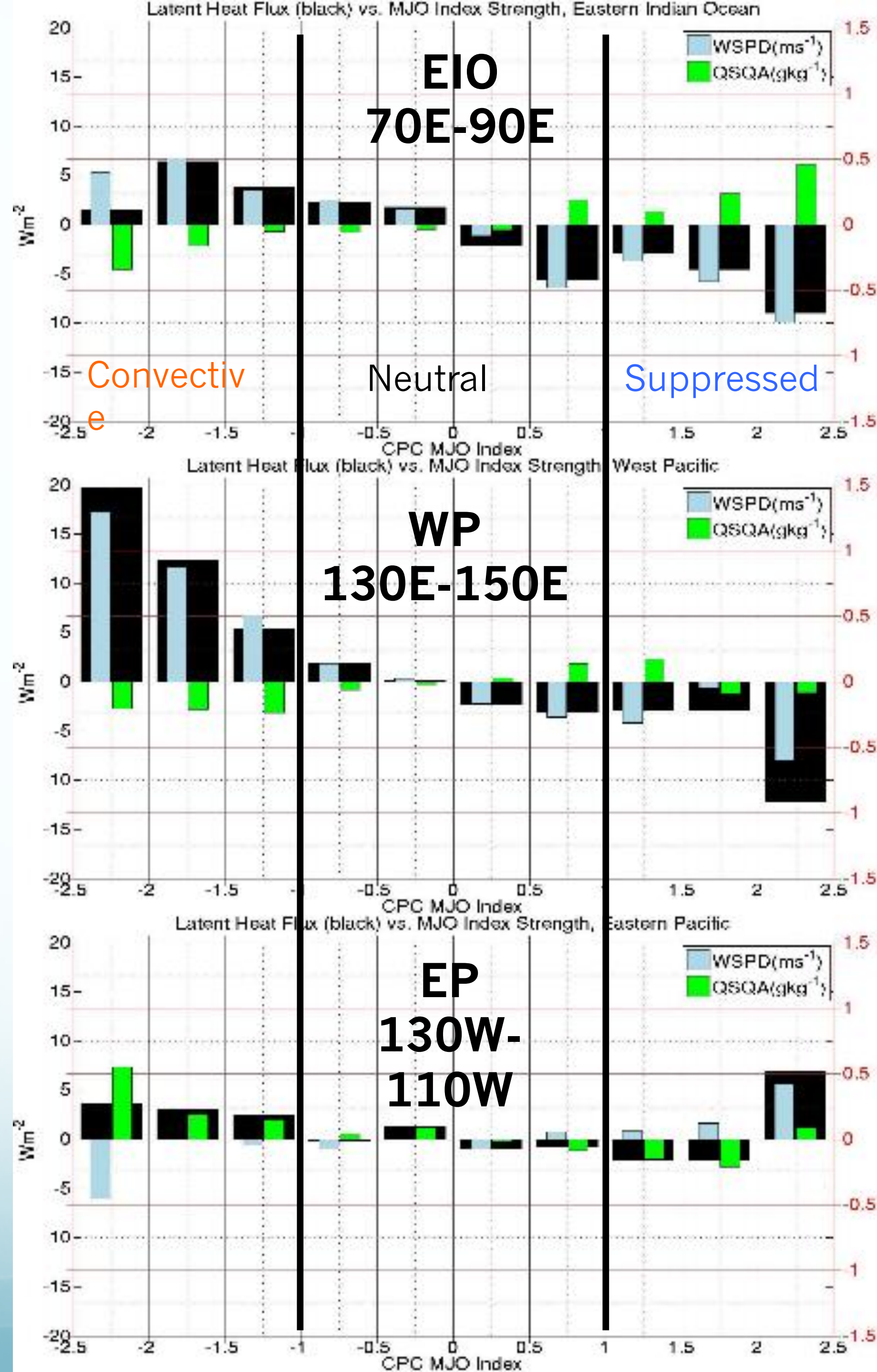
- Examining differences in means can be decomposed as changes in class mean (A), changes in RFO (B), and covariant changes (C)

$$\Delta\overline{X}_{(2-1)} = \sum_{i=1}^{K} RFO_i^1 \delta\overline{x}_i + \overline{x}_i^1 \delta RFO_i + \delta\overline{x}_i \delta RFO_i$$

A B C

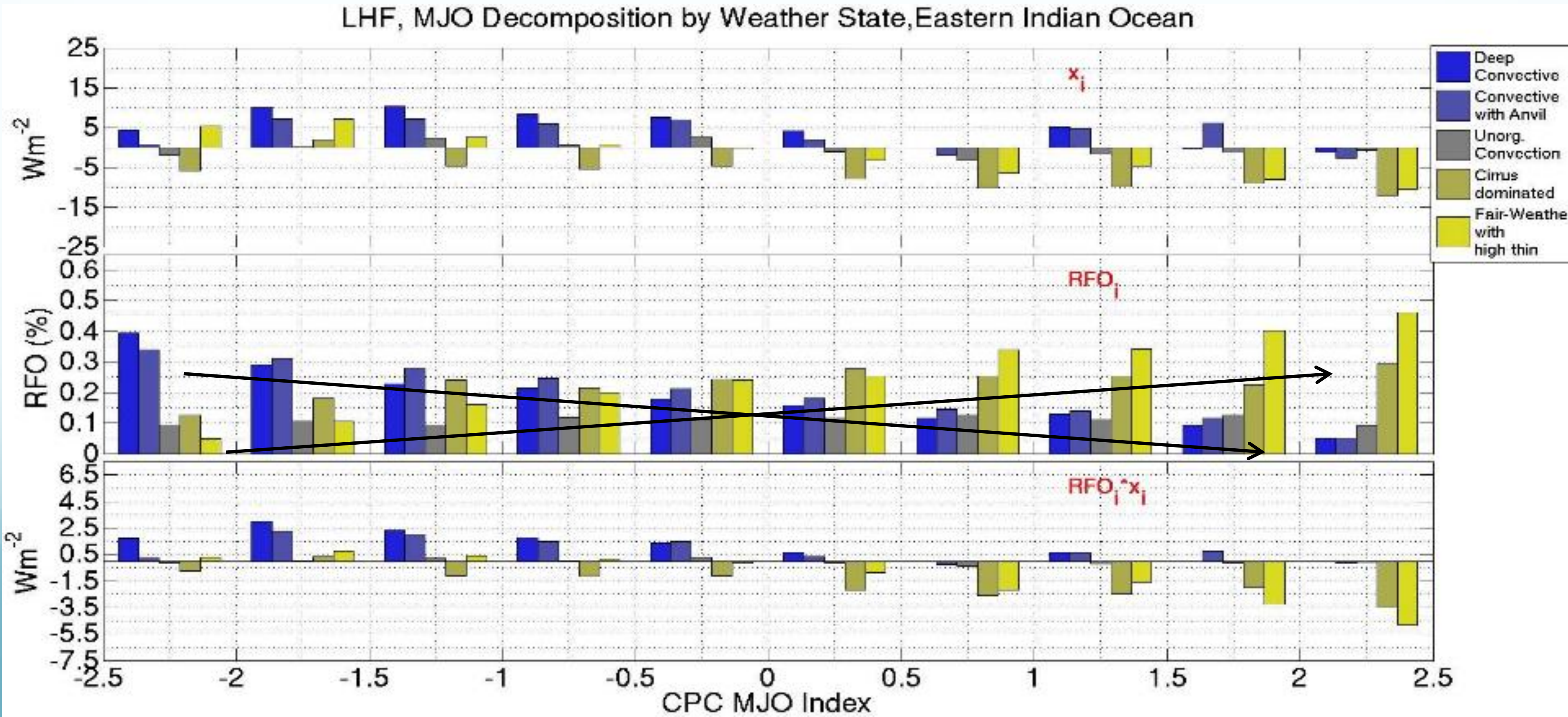
MJO Composites by strength

- Composite MJO based on index strength not time-lagging
- All three regions typically show increased evaporation during convective phase and decreased evaporation during suppressed phase
- The Indo-Pacific region changes → more wind-driven Eastern Pacific changes → more near-surface moisture gradient changes
  - But: EIO more coherent near-surface moisture changes than WP



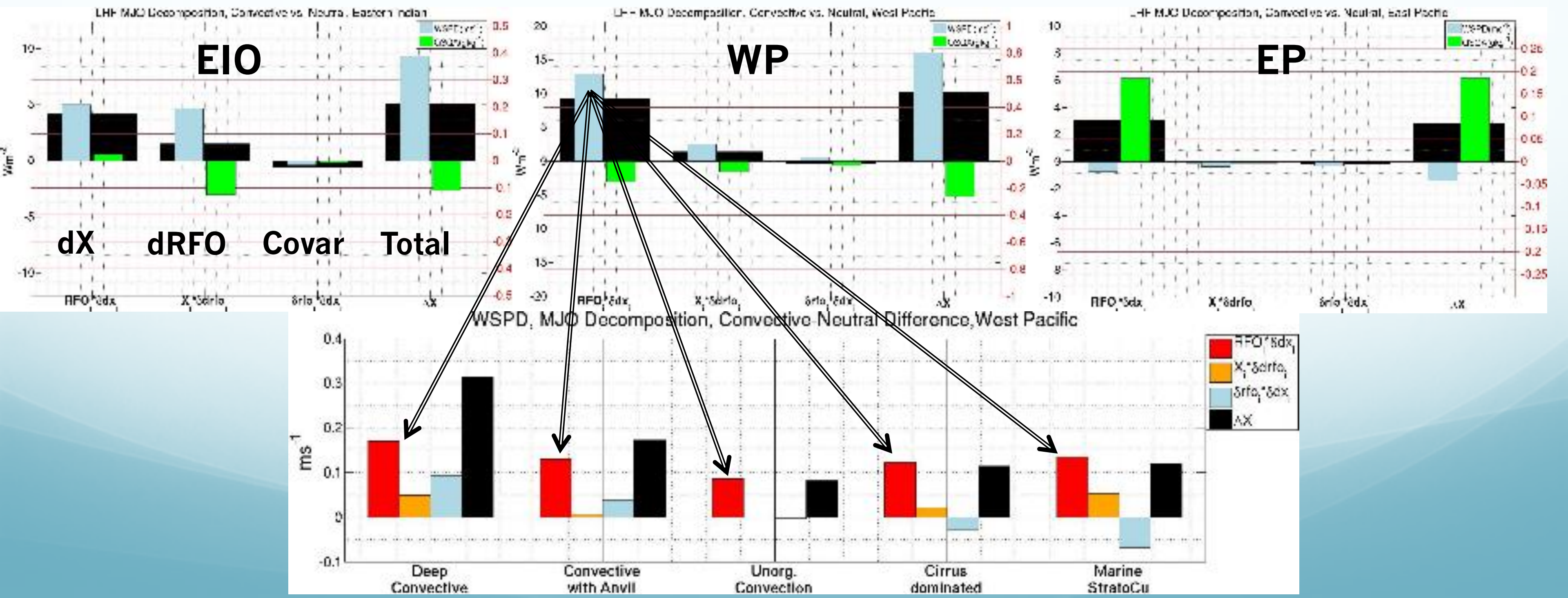
MJO Composites – Decomposition into Weather states

- Decompose LHF into weather state means and relative frequency of occurrence (RFO)
- Systematic variations of both weather state means and RFO with MJO index
- Both variations contribute to total impact of a given weather state on mean energy exchange associated with MJO evolution

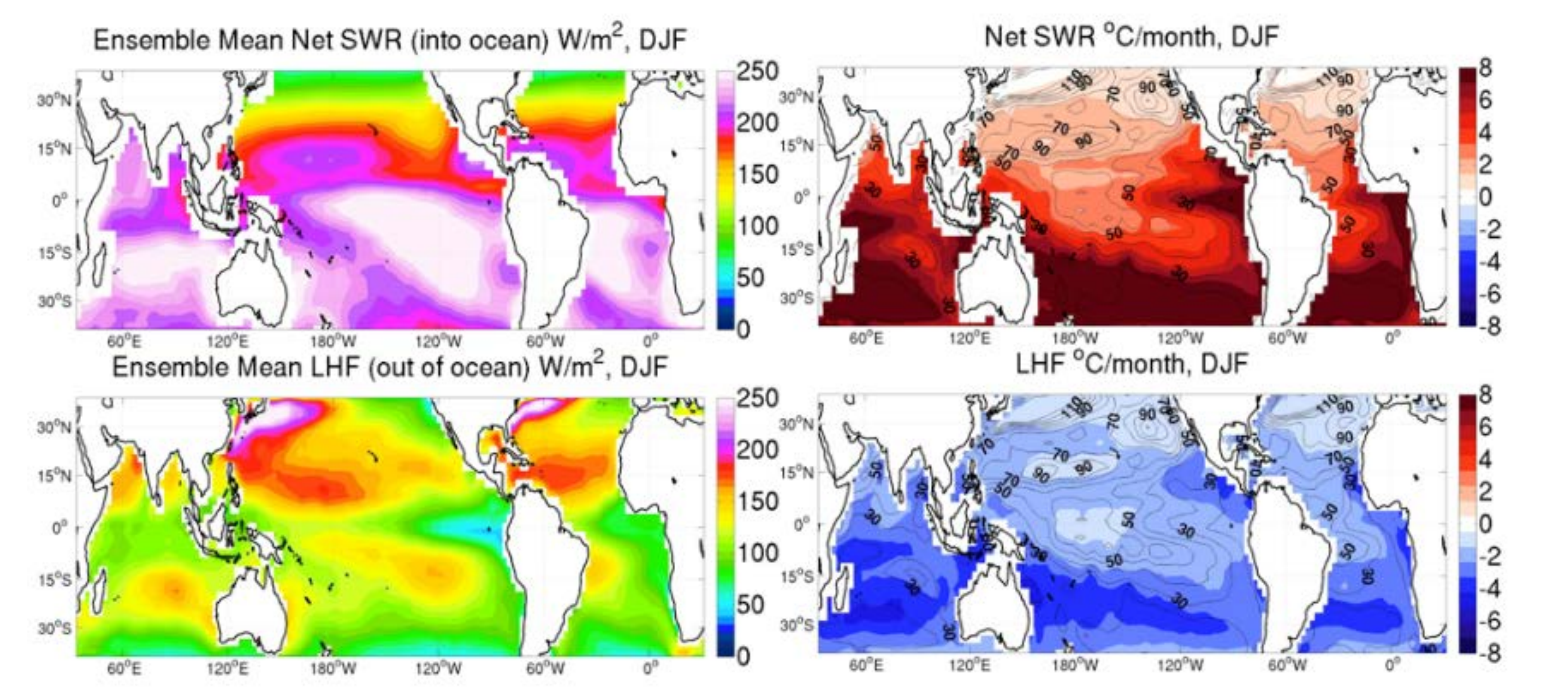


MJO Composites – Decomposition of changes

- The difference between convective, neutral, and suppressed conditions can be quantitatively decomposed into Mean-,RFO-, and covariant- driven change
- Convective vs. Neutral changes are primarily set by the systematic variation of class properties rather than RFO changes
- Changes in Western Pacific: wind speed. East Pacific: Qs-Qa. Eastern Indian: both



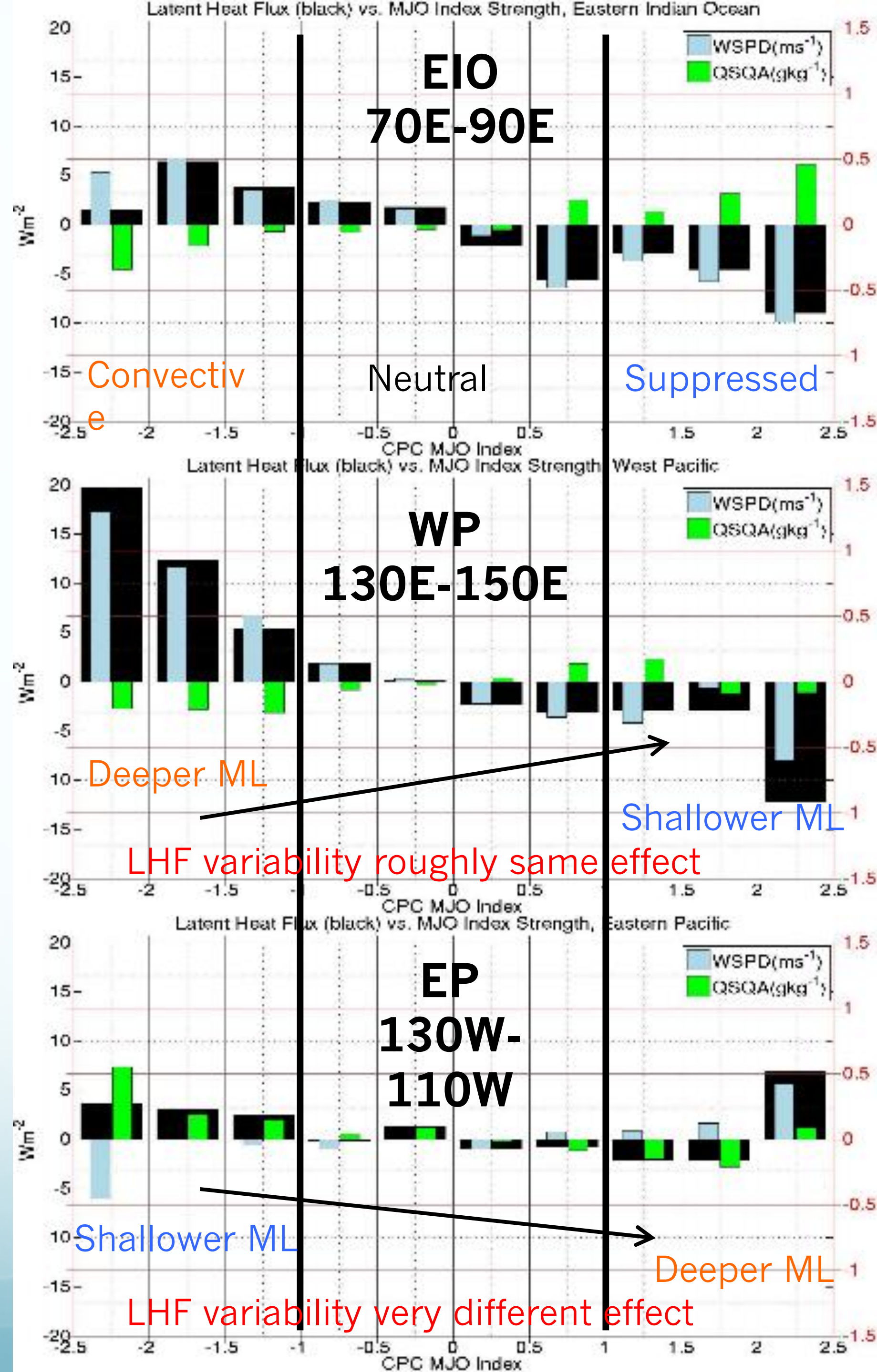
MLD and surface flux effects on SST tendencies



1. The net shortwave and latent heat flux tendencies are the largest components of the surface heat flux budget.

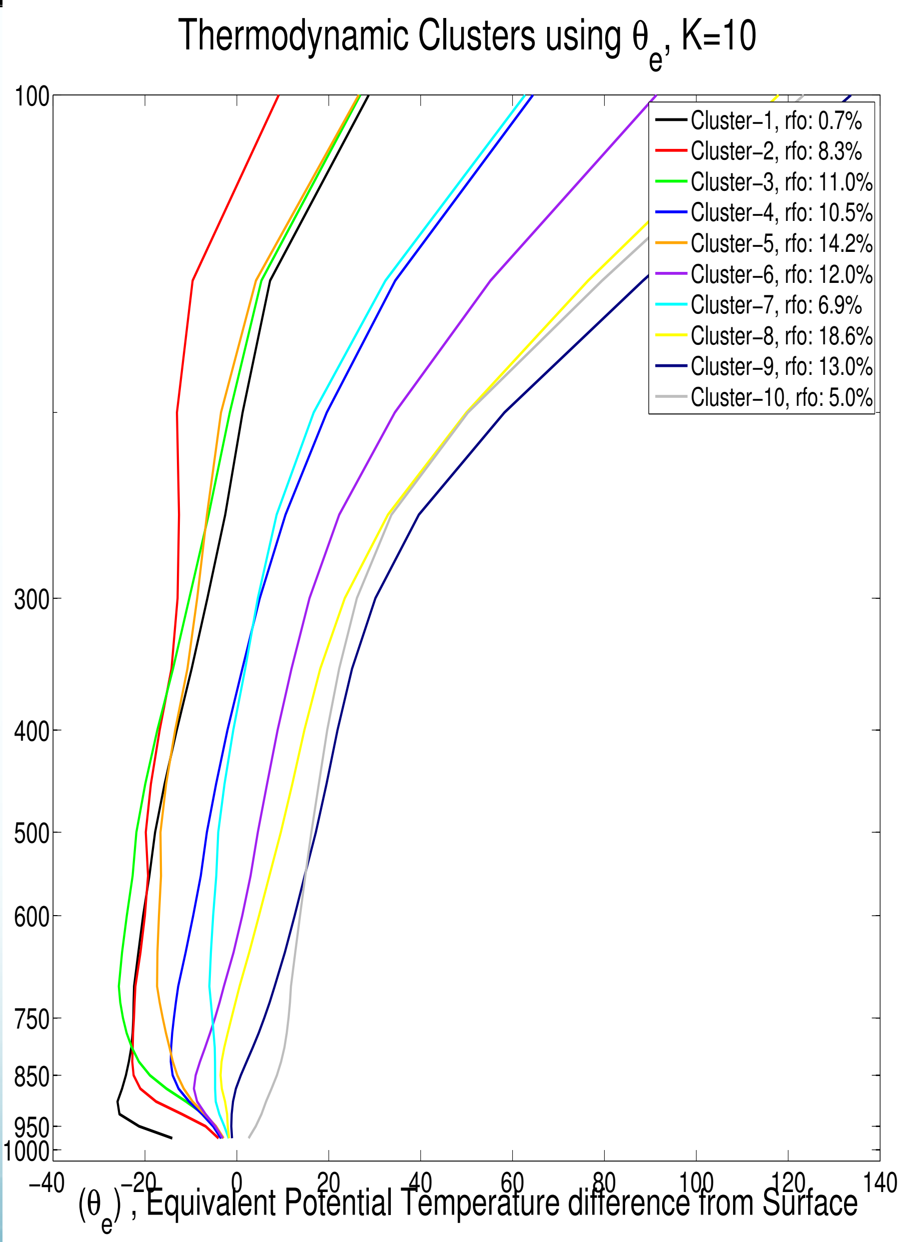
2. The mixed layer depth is an important contributor to the observed surface heat flux tendency pattern.

- EIO and WP: deeper ML in convective; EP: slightly deeper ML in suppressed
- WP: LHF variability has roughly same effect on SST tendency throughout MJO. EP: LHF much higher effect on variability during convective phase
- EIO: Even shallower ML in suppressed phase, but still large LHF due to Qs-Qa difference: LHF variability strongest effect during suppressed phase

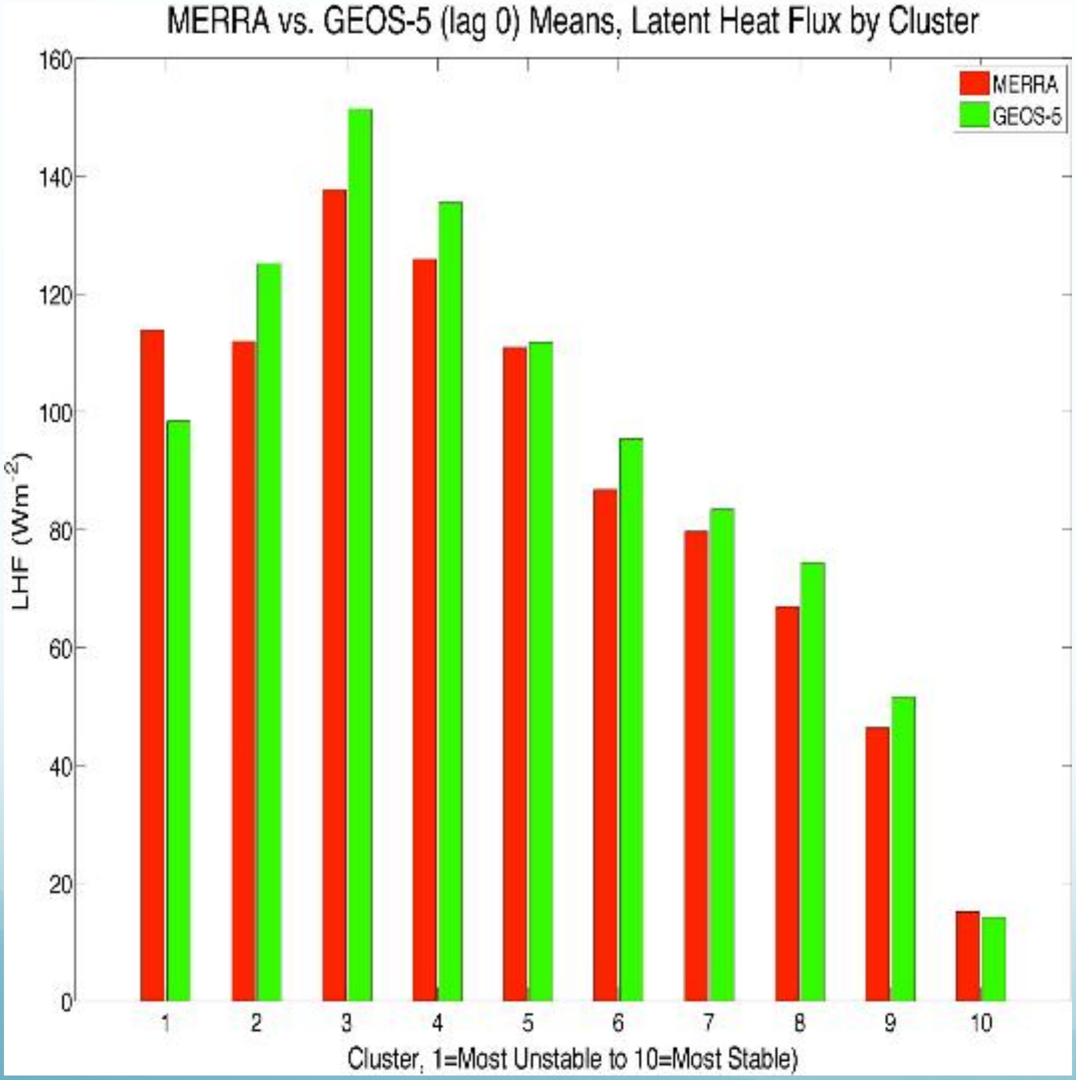


But what regimes?

- Weather states based on cloud properties can be more difficult to intercompare between satellite observations and models
- To compare MERRA/GEOS-5 we have chosen to use temperature and humidity profile information from the model
  - Easier to intercompare/access state variables in “model world”
- Combined T/Q information into a single thermodynamic variable (θ_e)
  - K-Means cluster analysis to obtain 10-clusters

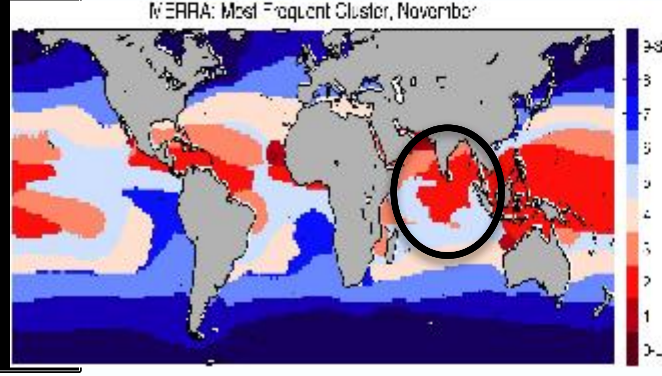


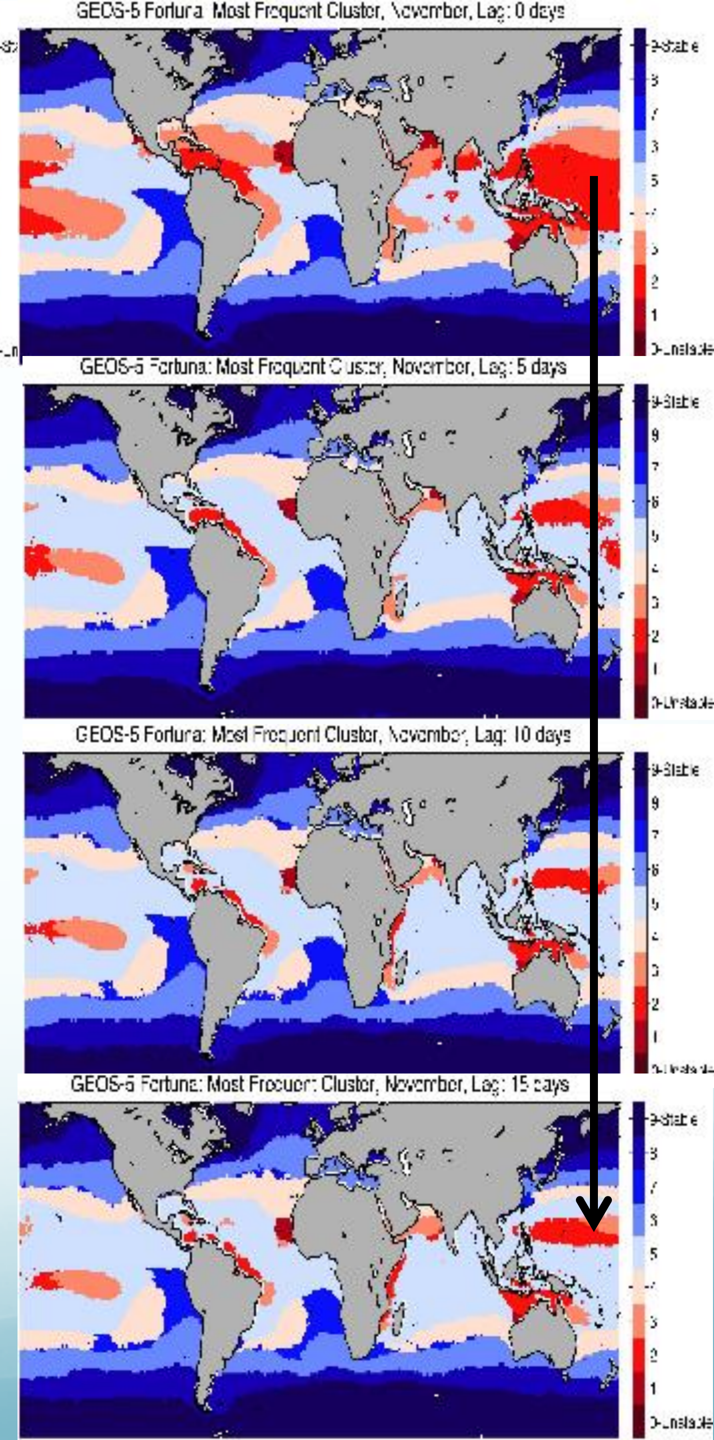
LHF Regime Mean Differences



- Can sort out overall biases as function of stability regime
- Overall, GEOS-5 shows systematically higher evaporation rates, but this "bias" is higher for more unstable conditions (~15Wm^{-2}) vs. more stable (~5Wm^{-2})
- Closest agreement in neutral condition and very stable conditions

LHF Regime Frequency Differences

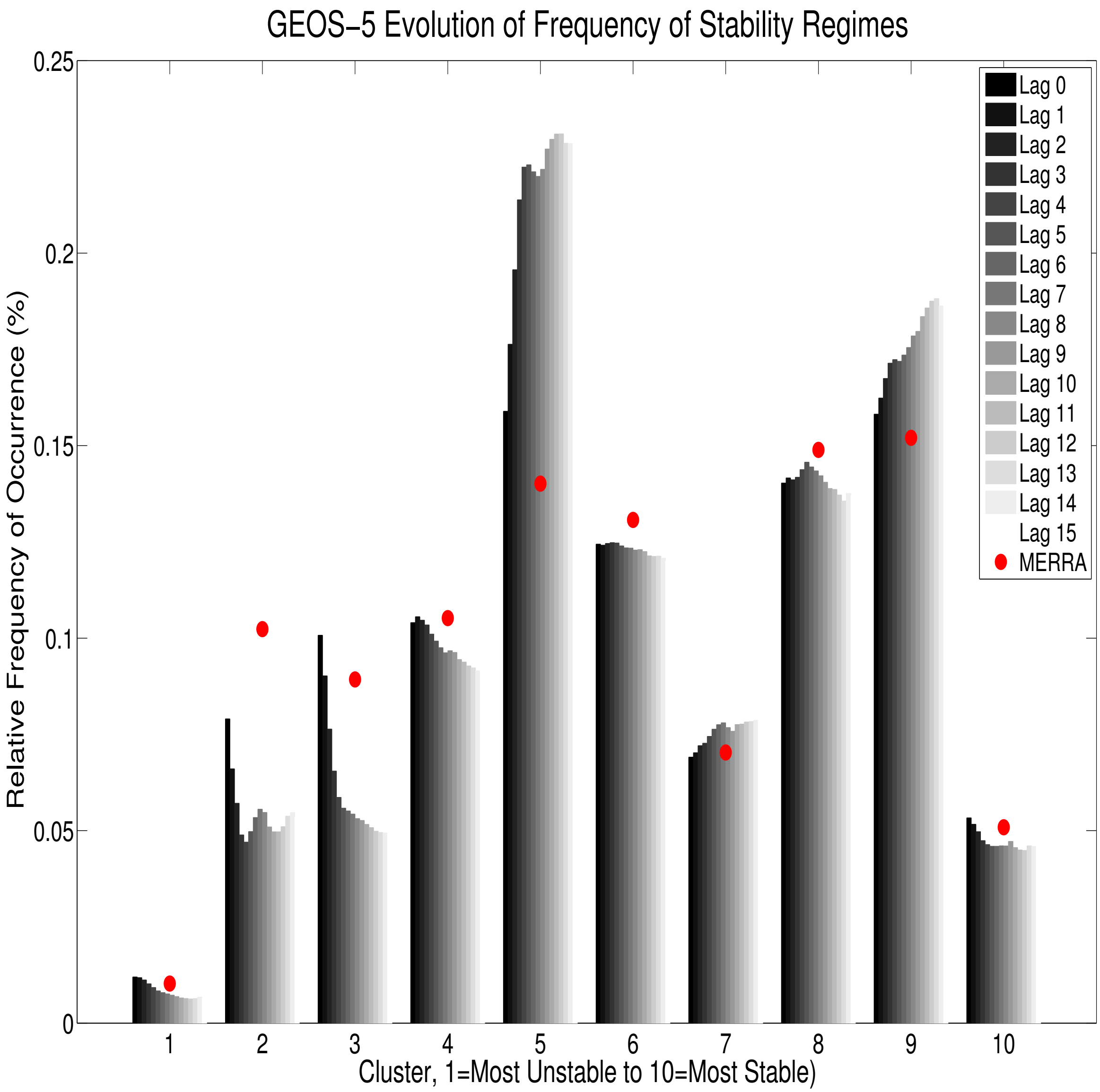




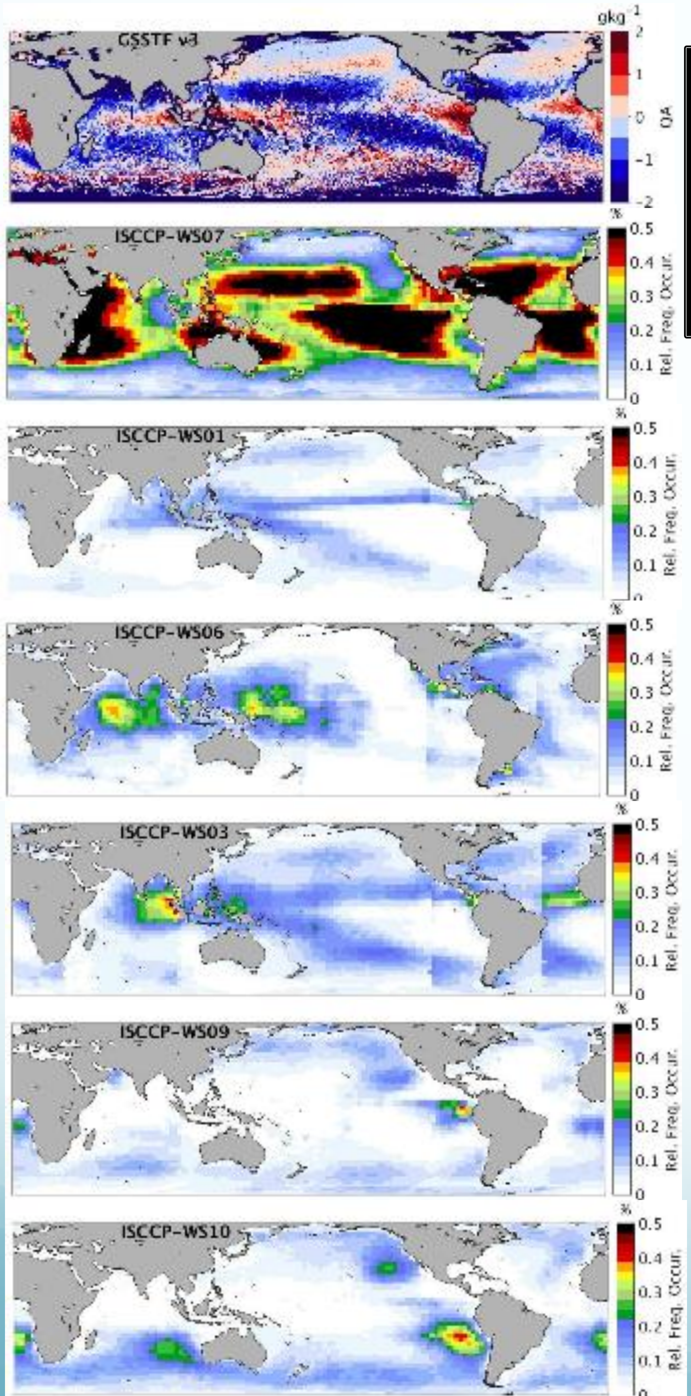
- In addition to difference between regime means, the frequency of regime can also impact difference in total mean fields
- For day 0 —*when GEOS-5 is most data constrained* —relative frequency of occurrence of regimes is remarkably similar to that in MERRA, albeit with some difference
- Moving away from initialization however, GEOS-5 is unable to maintain proper distribution of unstable regimes, particularly over West Pacific and Atlantic Warm Pool

LHF Regime Frequency Differences – Another View

- Looking globally, transition of stability regimes as function of lag for each regime
- Because regimes frequencies partition full distribution, compensation between regimes
- *There is clear preference for GEOS-5 to eliminate most unstable profiles within first few days toward more neutral profile*



Retrieval Biases and Cloud Weather States



- The structure in the retrieval (Qa, top) biases appear to be co-aligned with patterns of cloud weather states
  - WS are defined using ISCCP cloud-top histograms
- The largest biases in several of the Qa retrievals are aligned best with Global WS 7 (Tselioudis et al. 2012)
  - Mostly clear, w/ thin boundary layer cloudy

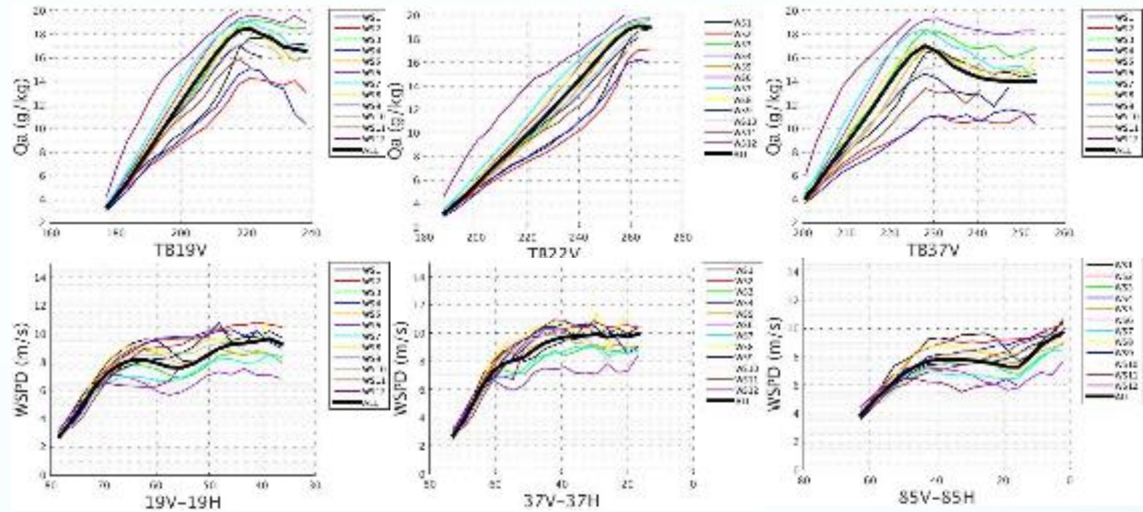
Cloud impacts on passive microwave empirical retrieval algorithms

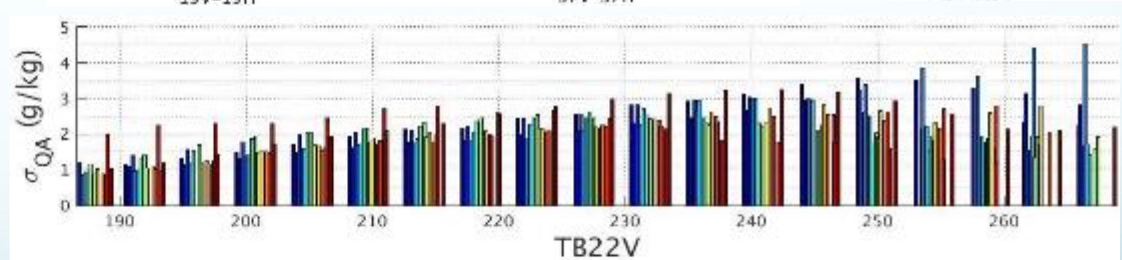
Binned Qa and Wspd vs. observed F15 TBs

- Near-surface humidity, air temperature, and wind speed retrievals show strong regime-dependent conditional biases

- Conditional-RMS also appears dependent on cloud weather state, but to lesser extent

- *When the underlying component of the conditional biases are regionally dependent, it is likely the application of "grouped" retrievals will result in regional biases*





New Opportunities – Retrievals using new algorithm

- Passive microwave provide direct information on the clouds in the atmospheric FOV

- We can decompose the observed , TB_{obs}, into clear-sky and cloudy-residual components,

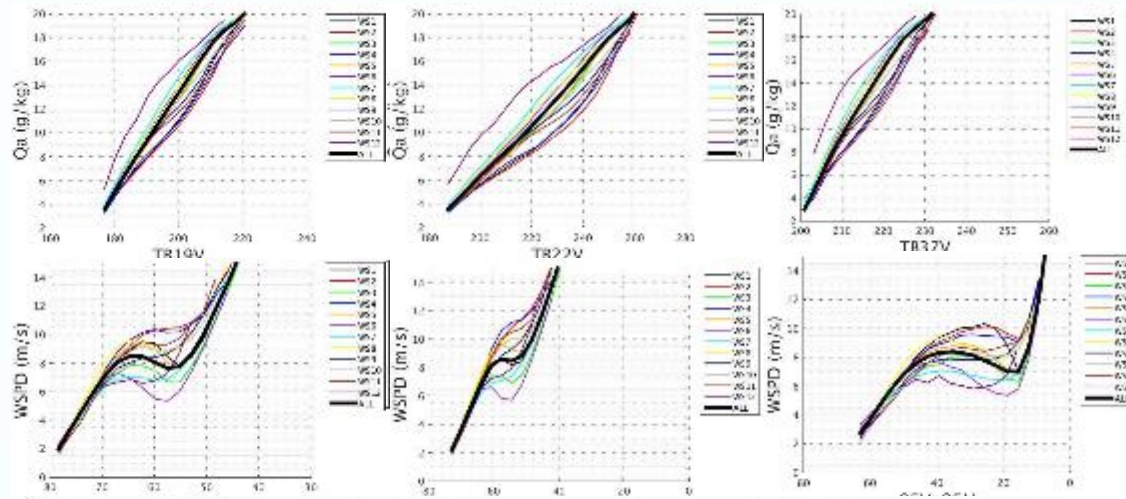
$$TB_{obs} = TB_{clr} + TB_{cld}$$

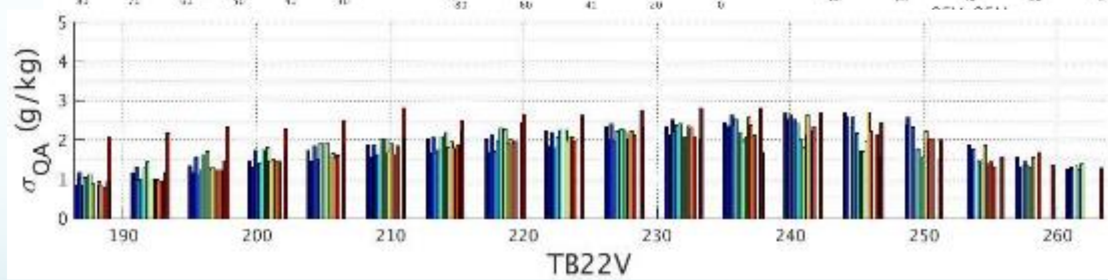
- Then retrieve using:

$$\{Qa, Ta, Wspd, SST\} = F^{-1}(TB_{clr})$$

- Conditional-Bias and RMS of near-surface parameters against the Clear-Sky TB appear smaller and more consistent across all of the weather regimes

Binned Qa and Wspd vs. Clear-Sky simulated F15 TBs





Summary

- Cloud-based weather states can be used to provide improved understanding of surface energy flux variability, model performance, and satellite retrievals of near-surface properties
- MJO variability is particularly well decomposed using ISCCP weather regimes from convective to neutral and suppressed states
- Different regions in the tropics show MJO variability being driven by different processes, with differing effects on SST due to MLD variability
- To fully realize air-sea coupling effects, cloud regimes most likely need to be coupled with at least boundary layer winds

Many thanks to Bill

- ***Birthing the idea of SeaFlux***
- ***Giving me a chance for leadership***
- ***Protecting against Clivarians***
- ***Warning/encouraging about creating a data set***
- ***Making me think about seasonal/diurnal variability***
- ***Urging me to challenge the status quo***
- ***And much more***