Variations in Cloud Radiative and Moisture Profiles During AMIE

Fiaz Ahmed & Courtney Schumacher
Texas A&M University

Radiative-Moist Convective Equilibrium

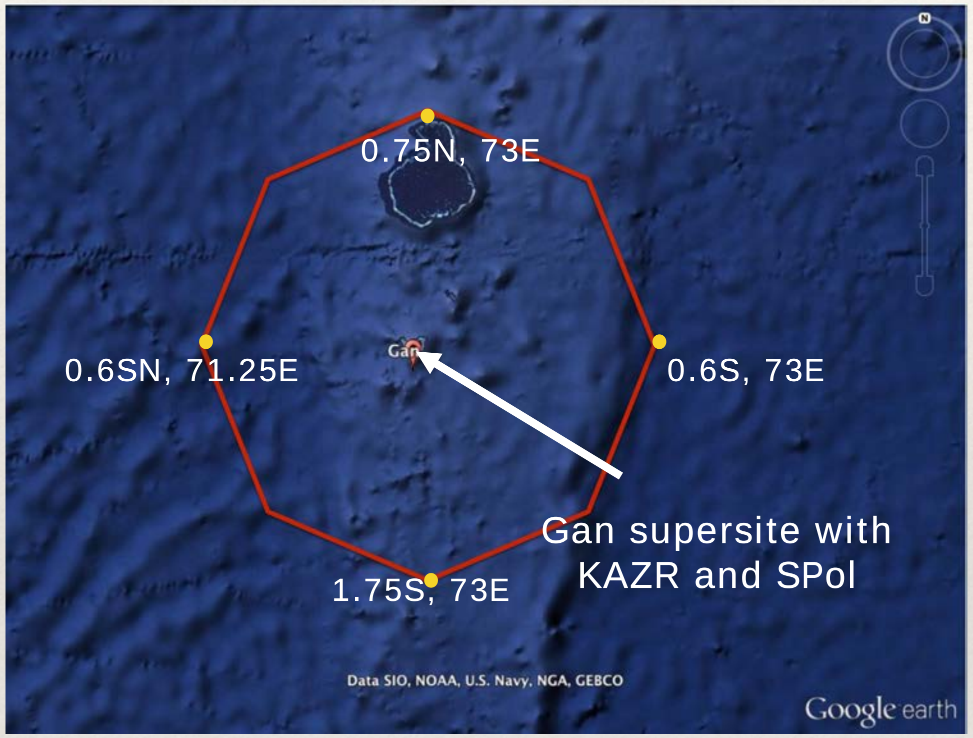
- The zeroth order approximate balance in the tropics is assumed to be between radiation, convection and surface fluxes (e.g: *Emanuel et al. 2007*)
- Some consequences -
  - Near moist adiabatic lapse rate
  - Narrow, intense areas of deep convection to distribute latent heat upwards
  - Wide, weaker areas of subsidence to balance adiabatic cooling

The Madden-Julian Oscillation

- Eastward moving disturbance in the intraseasonal timescale (*Madden and Julian 1971*)
- Non-linear cloud radiative interactions can trigger instabilities (*Raymond 2001*)
- AMIE/DYNAMO campaign in the Indian Ocean to study the MJO (*Yoneyama et al. 2013*)
- Comprehensive and concurrent measurements of radiation and convection over tropical ocean

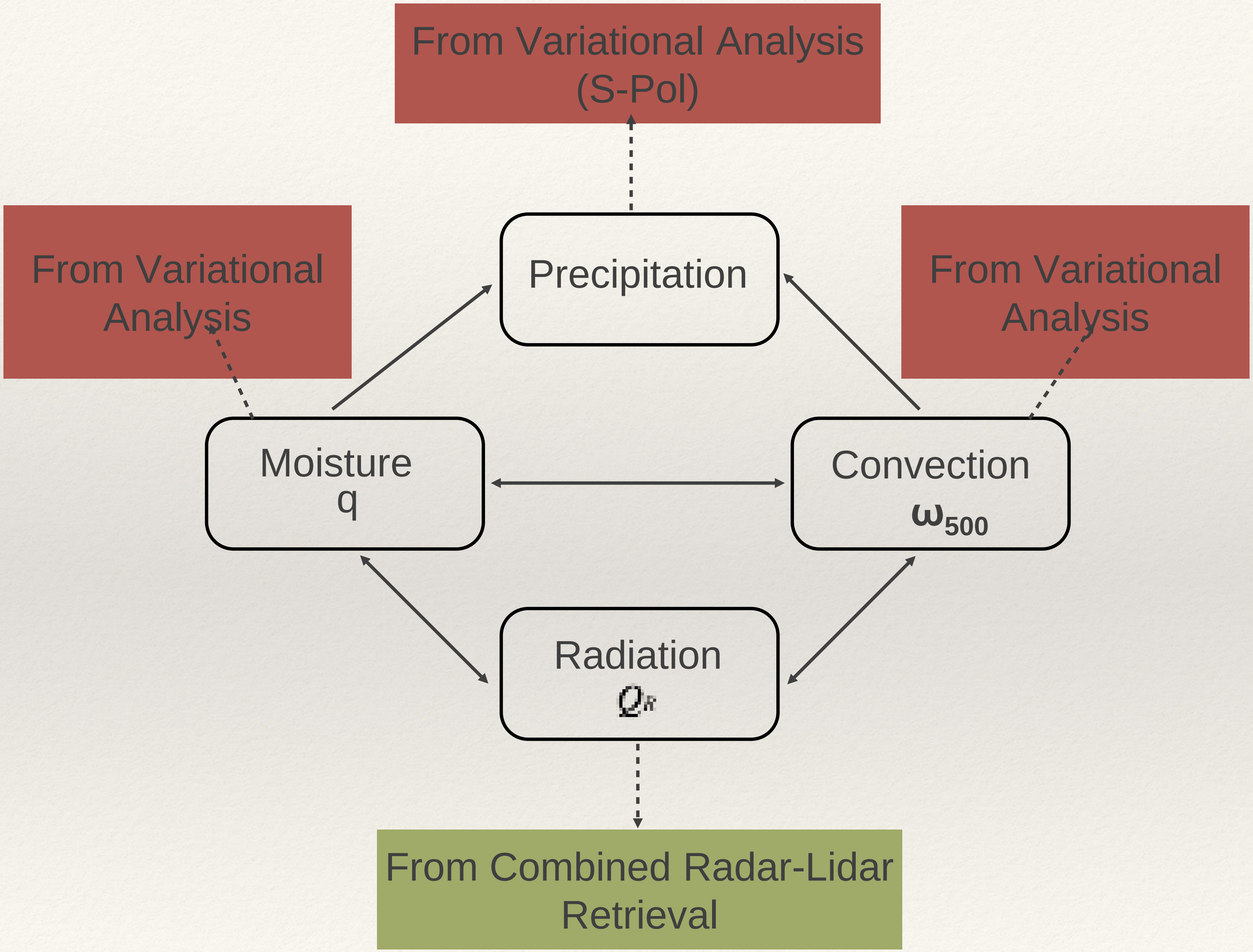
Dataset and Caveats

Variational Analysis Domain



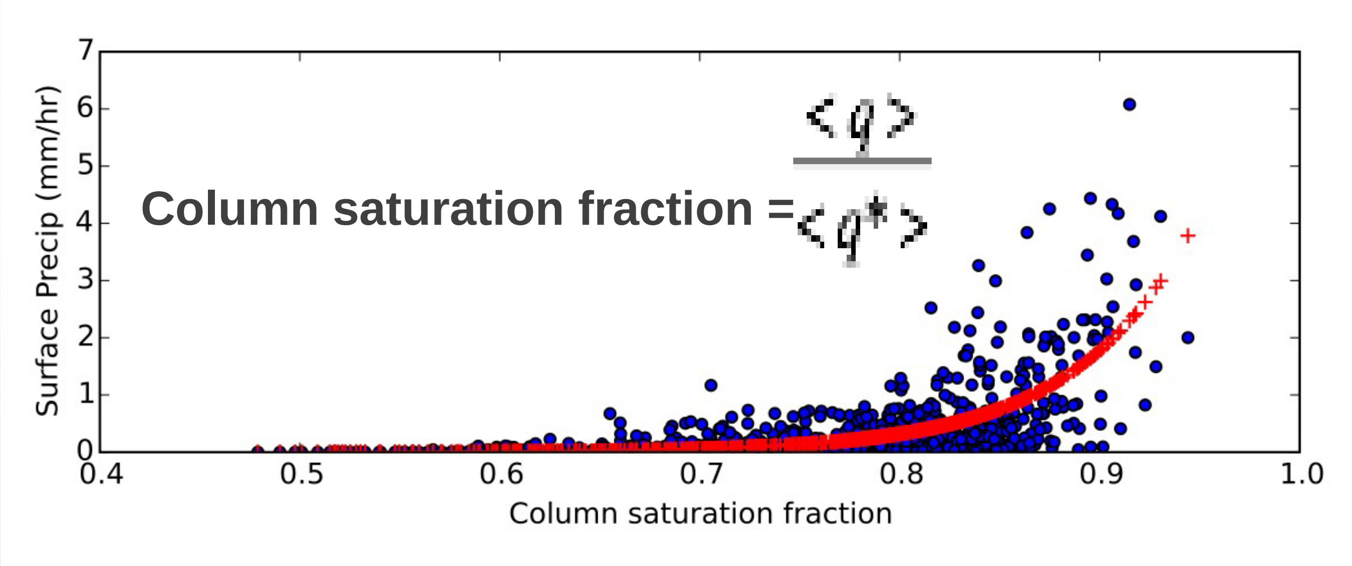
- Variational Analysis provides large scale forcing data (*Zhang and Lin 1997; Zhang et al. 2001*) *-from Shaocheng Xie at LLNL*
  - Developed using ECMWF analyses, constrained by surface rainfall (S-Pol and SMARTR)
- Radiative heating rates from radiative transfer model (*Mather et al.2007*). KAZR S-Pol merged cloud-precipitation statistics and ARM sounding as input. *-from Zhe Feng at PNNL*
  - Heavy attenuation when raining - underestimates upper level cirrus (*Feng et al.2014; Johnson et al.2015*)

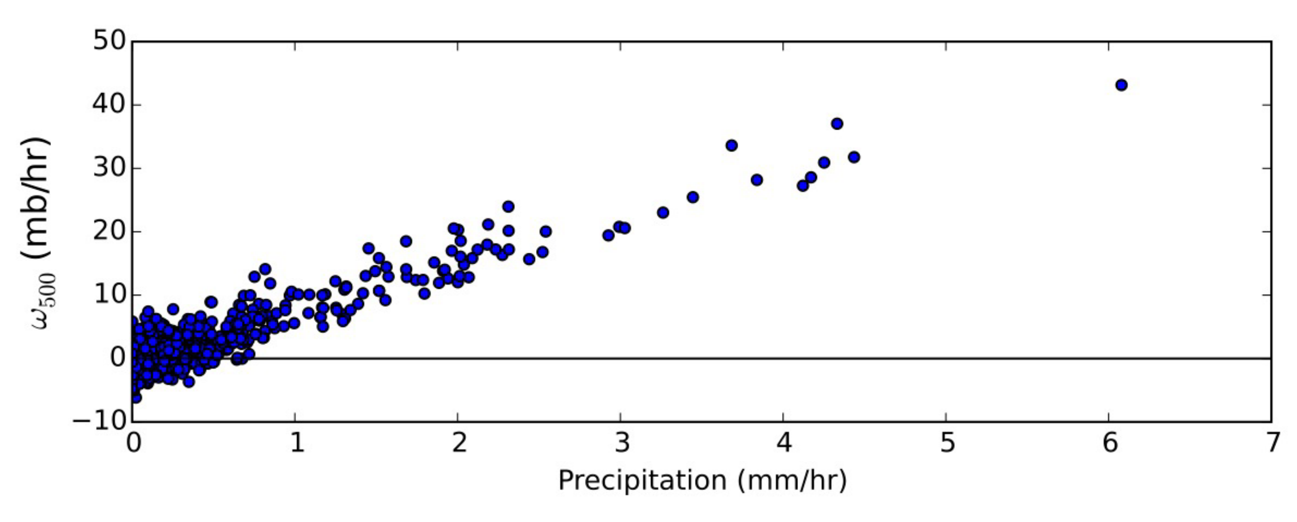
Feedbacks and Relationships

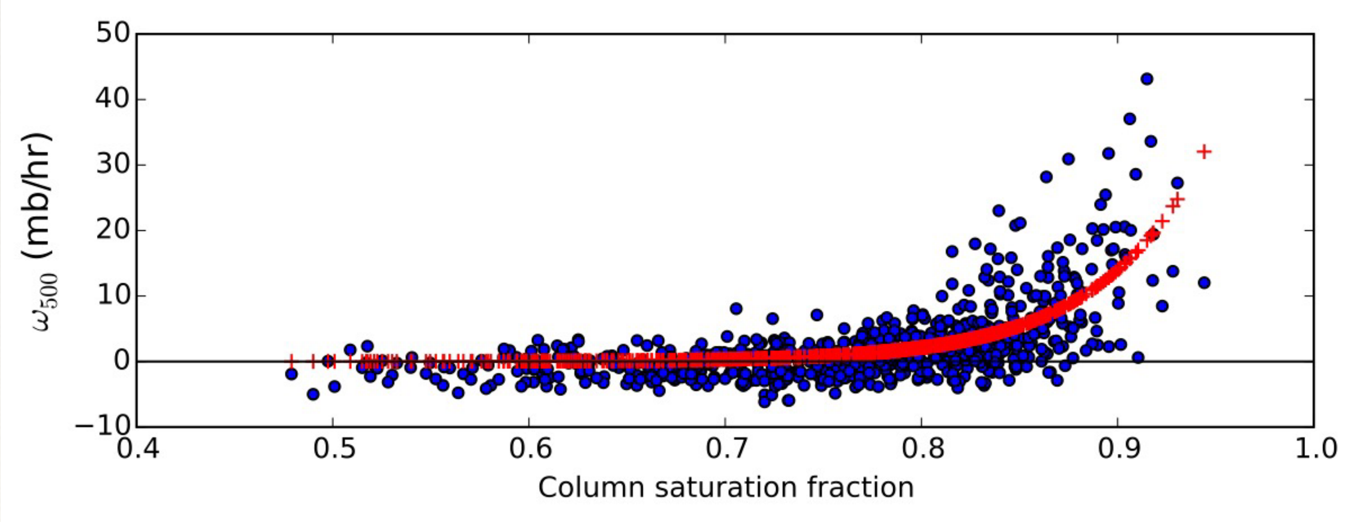


Column saturation fraction and its control of convection during AMIE

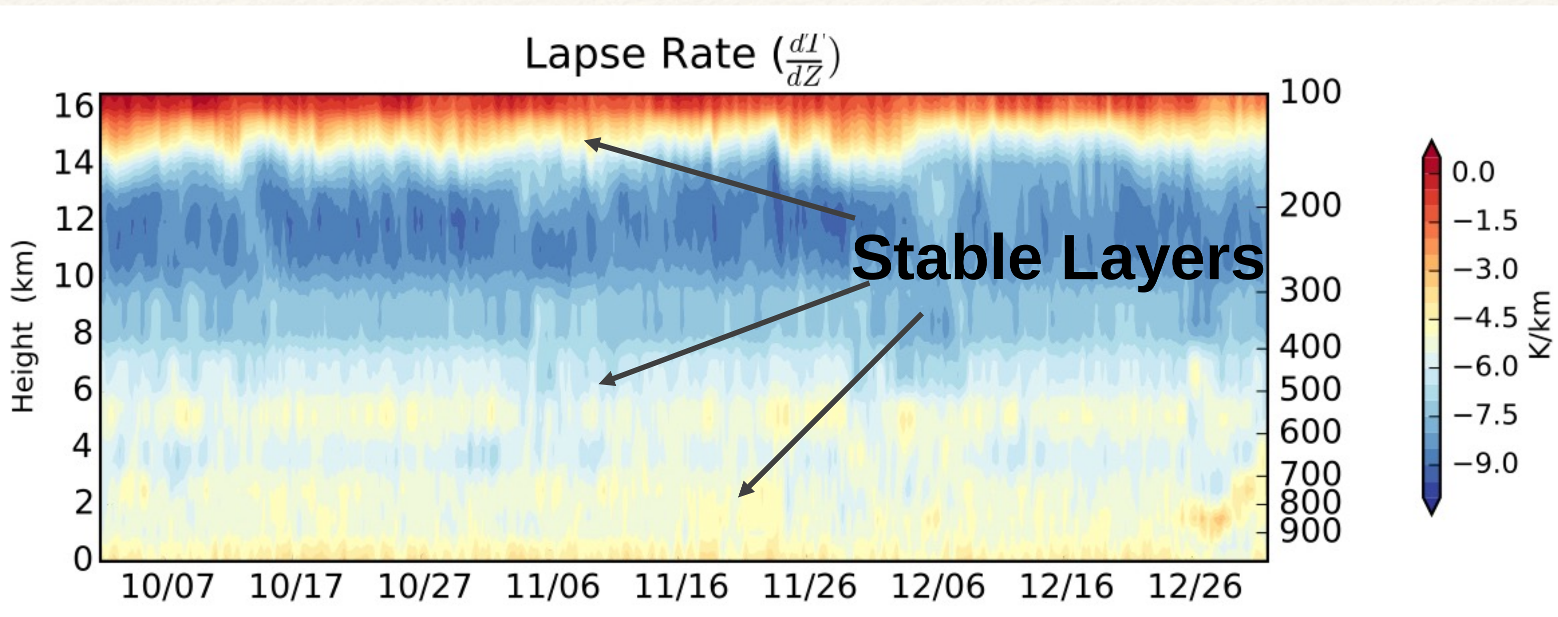
- Tropical precipitation is related to column moisture content (*Bretherton et al.2004*)
- Similar relationships exist between omega and moisture
- Precipitation and omega are linearly related when there is grid-scale ascent
- No relationship with cloud radiative effect

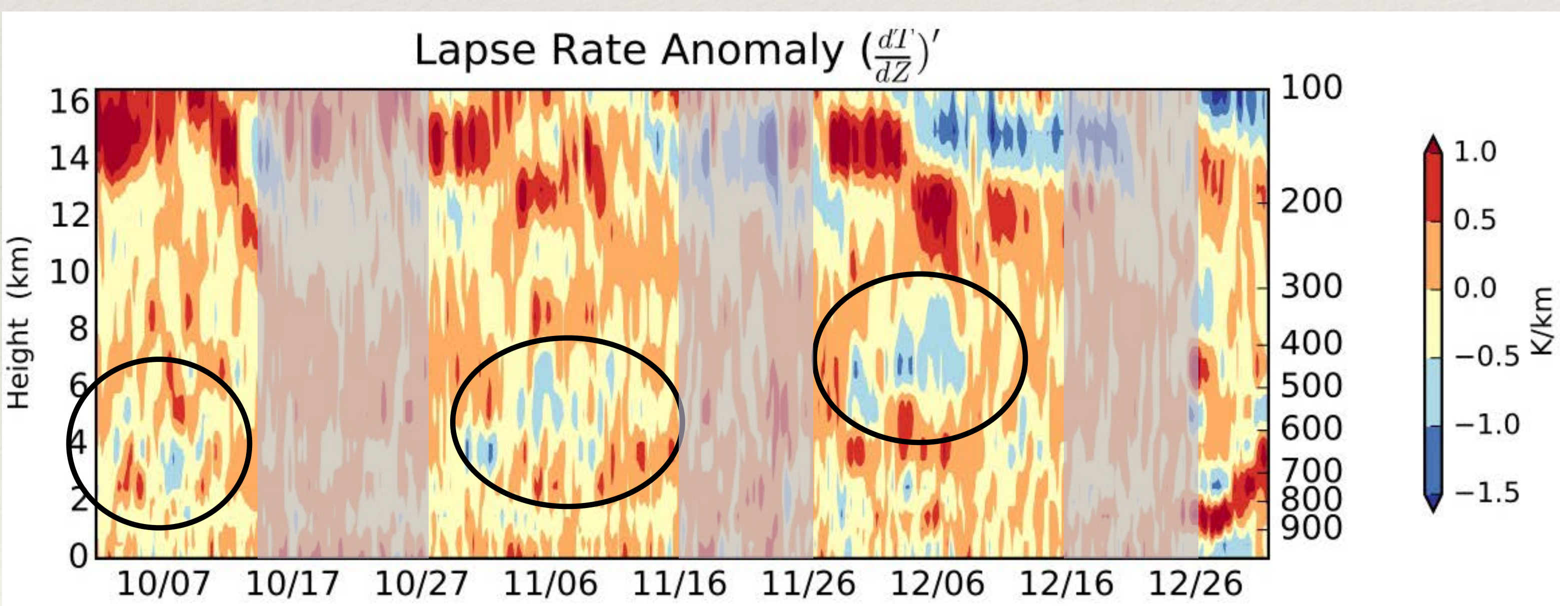






Lapse Rate and Stability

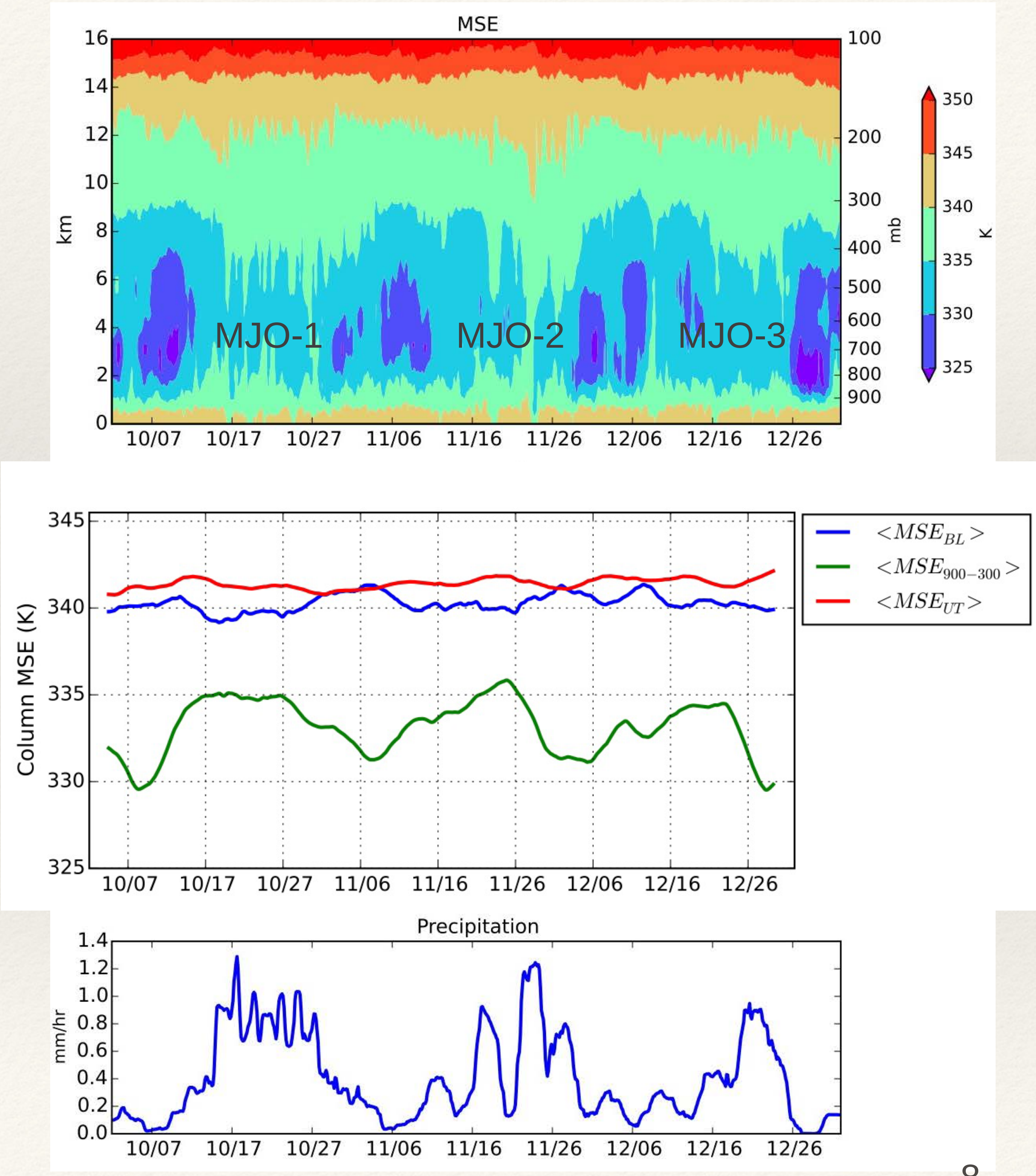




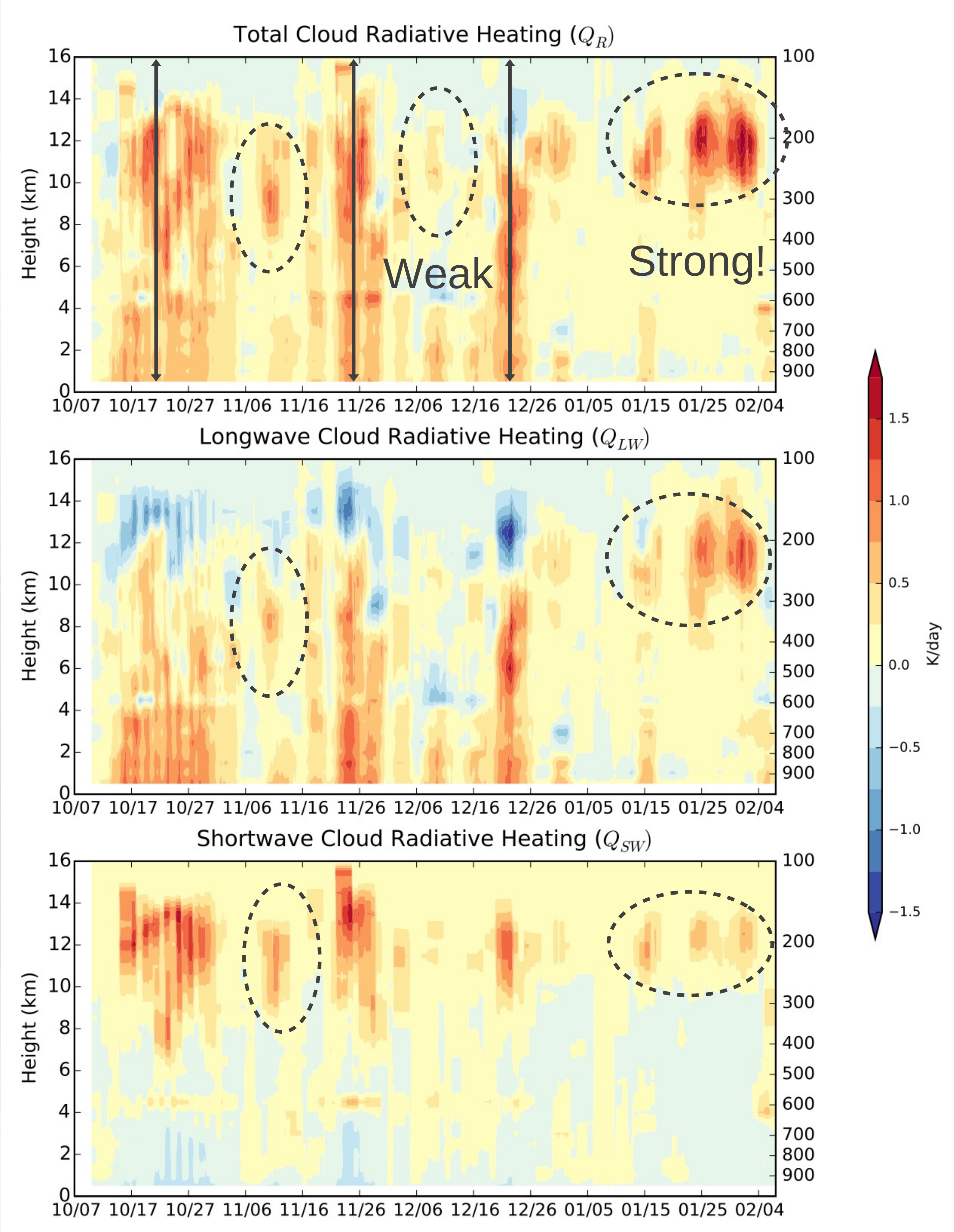
MJO1 MJO2 MJO3

- Three stable layers (*Johnson et al.1996*)
- Anomalies reveal mid-level instability between convective episodes
- Could potentially aid transition to deep convection or an imprint of convection itself

Moist Static Energy Variation



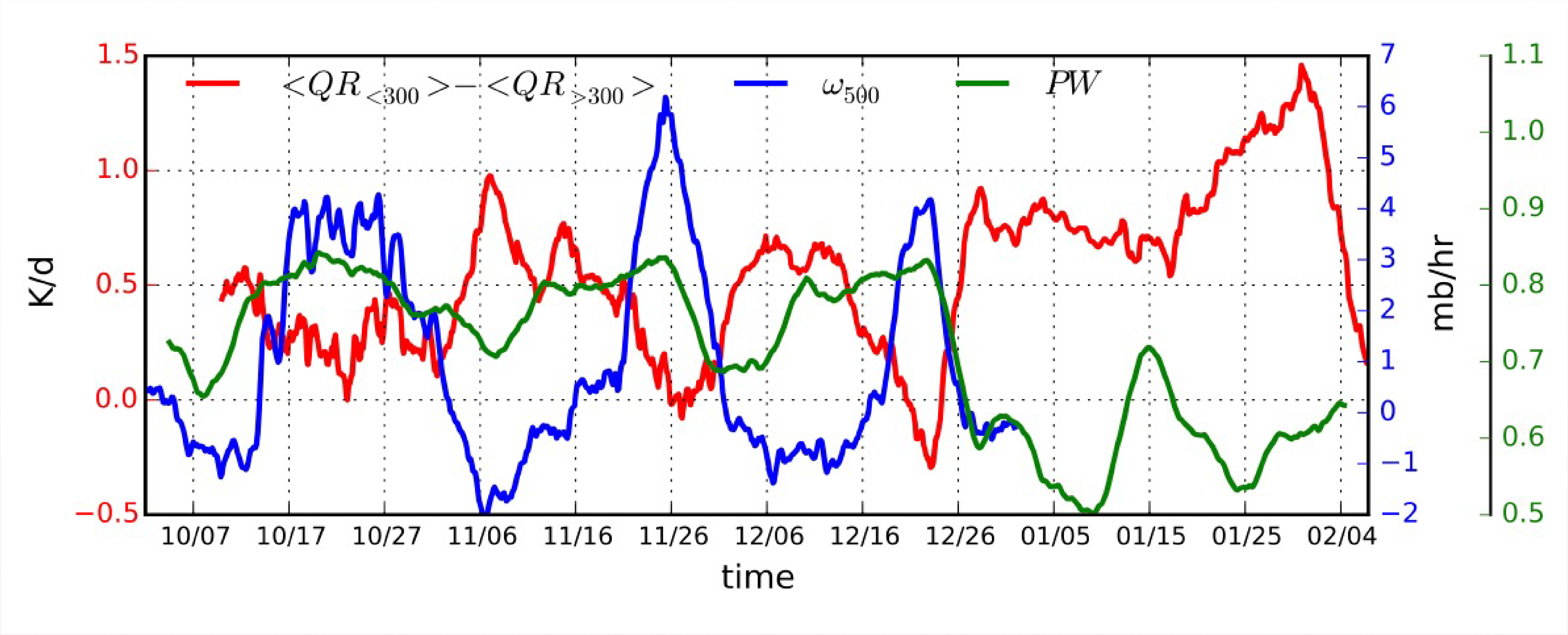
- Moist Static Energy= $Lq+C_pT+gz$
- Greatest changes in MSE happen within the 8km level - scale height of water vapor
- The anomaly in the boundary layer is opposite signed to that of the free troposphere



Cloud Radiative Heating

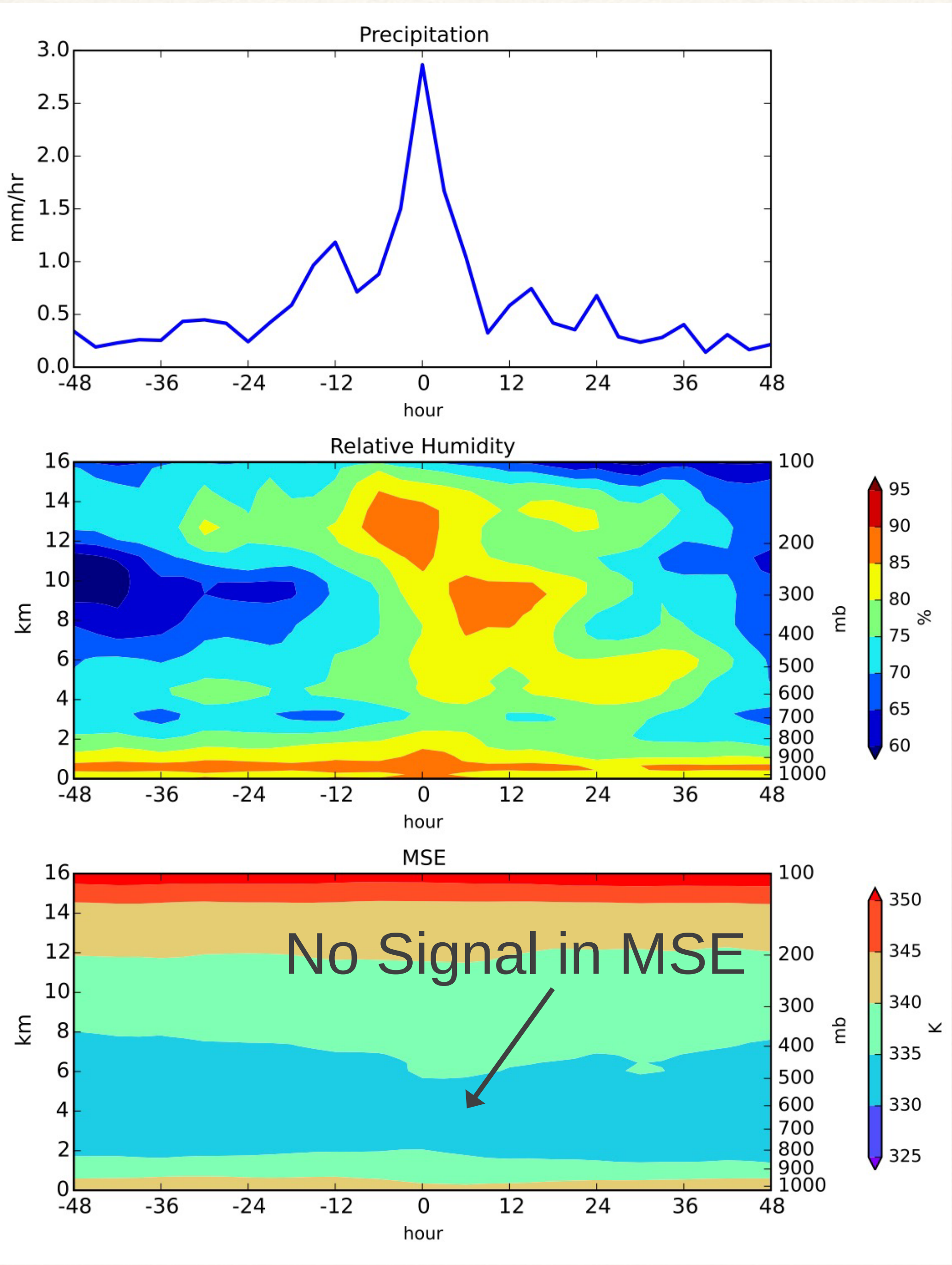
- Cirrus clouds precede MJO active phase (*Del Genio et al. 2012*)
- Moist-Radiative interactions could manifest as deep convective instabilities *(Bony and Emanuel, 2005; Sugiyama 2009)*

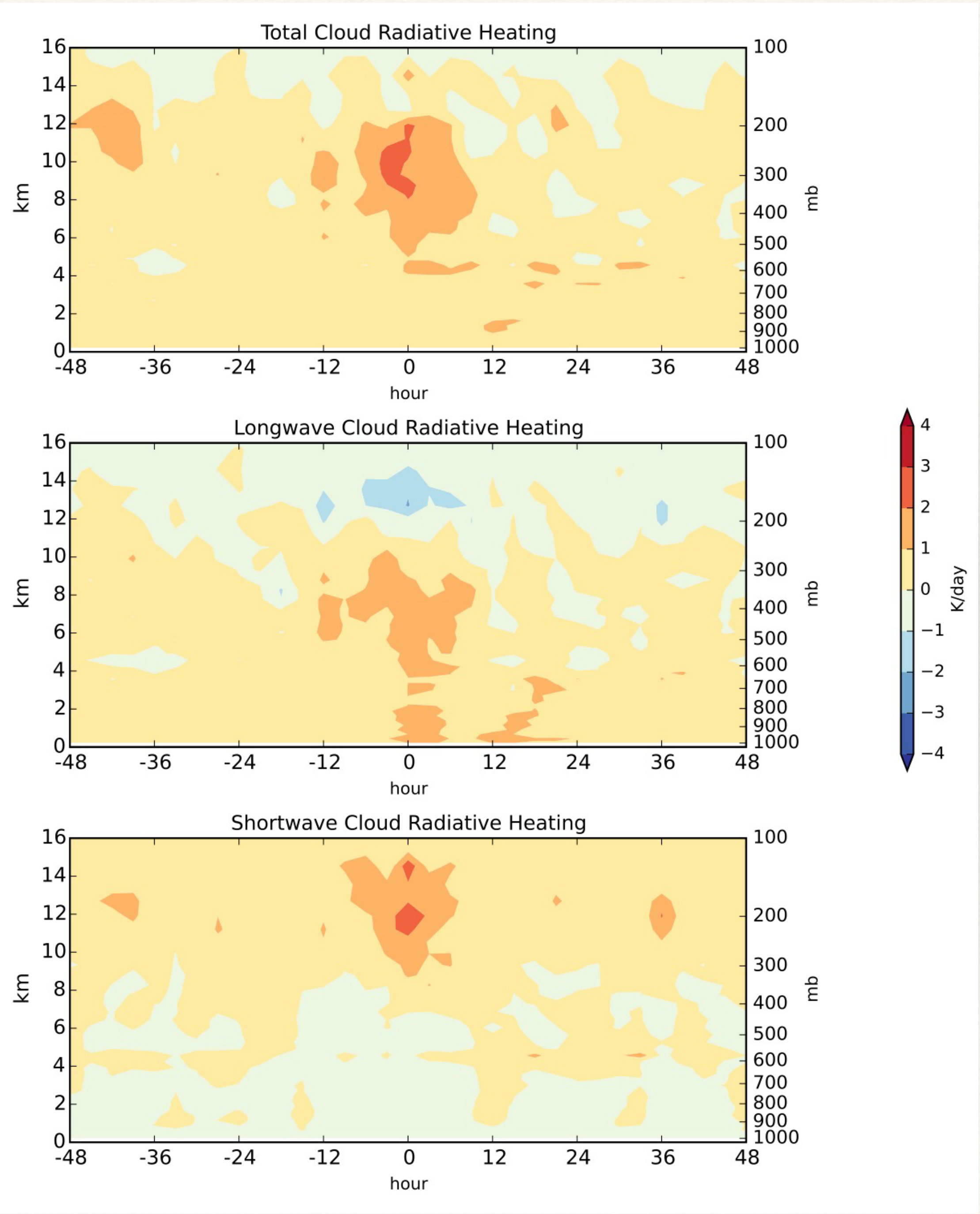
Upper-level Radiative Heating



- Upper level heating peak lags precipitable water and grid-scale ascent
- 4th MJO convection on Gan Island began on 02/13

Kelvin Wave Composites

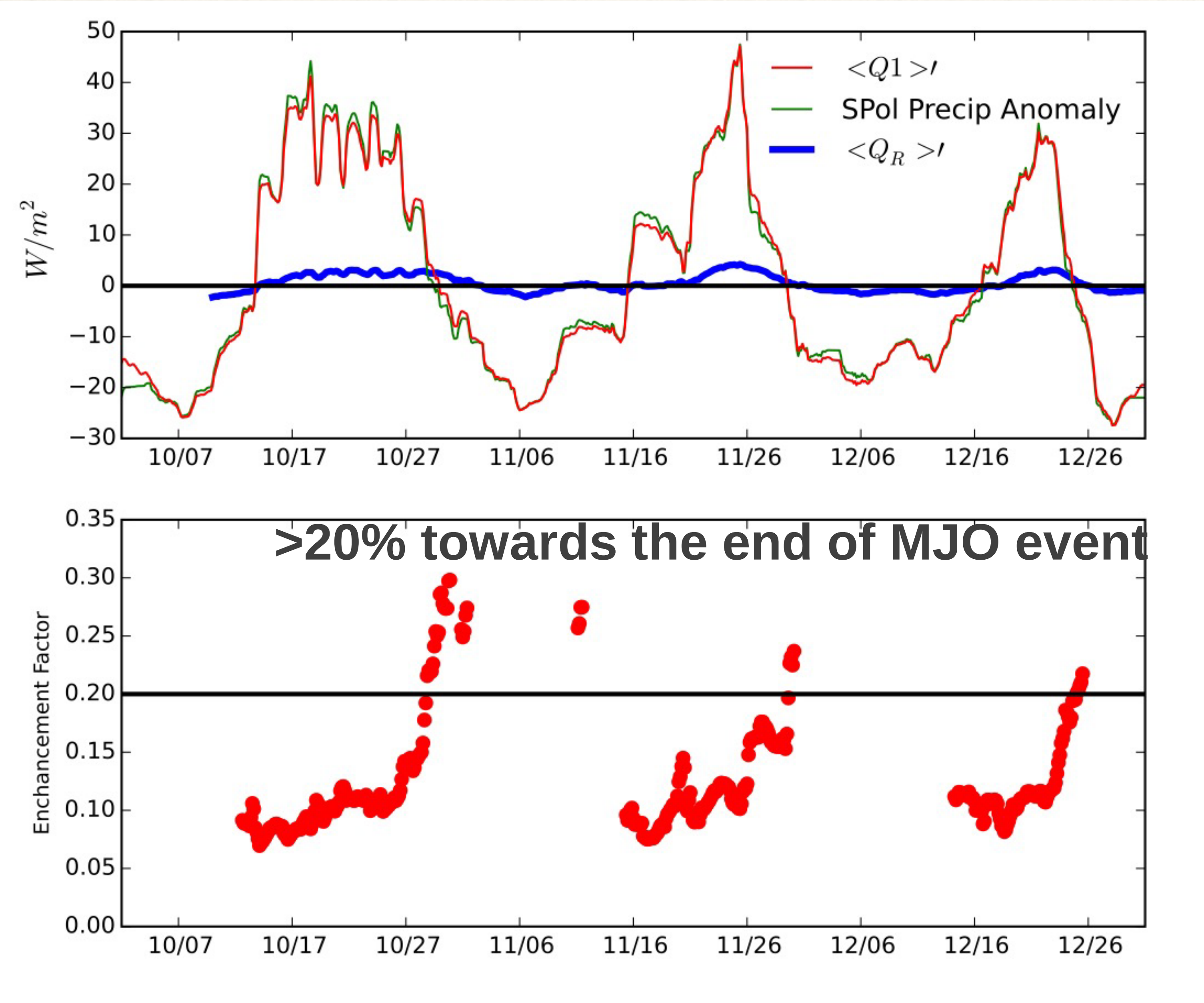




Conclusions

- Radiation and moisture variables were analyzed for a grid-sized domain (300km Dia.) during AMIE
- Mid-level moisture perturbations dominate MSE variation with MJO
  - Evidence for vertical advection involvement in moisture amplification
- Upper-level cloud radiative heating peaks before MJO active phase
  - confirms satellite observations (e.g: Virts and Wallace, 2010)
  - implicates radiative warming anomaly in moistening (via reduced subsidence or “pumping” (Sherwood 1999))
- Kelvin waves do not show signal in moist static energy profiles

Is there a Radiative-Convective Instability?



- Lee et al.2001 concluded that if the latent heating is “enhanced” by >20%, there could be radiative-convective instabilities.
- Lin and Mapes, 2004 (TOGA-COARE); Johnson et al.2015 (AMIE/DYNAMO)