Shallow Clouds at Manus: Variability, Moistening Effect, and GCM Biases

Chidong Zhang, David Zermeno, and Arun Arunchandra
University of Miami
Stephen Klein and His-Yen Ma
LLNL

Zermeno et al. (2015); Arunchandra et al. (2015)

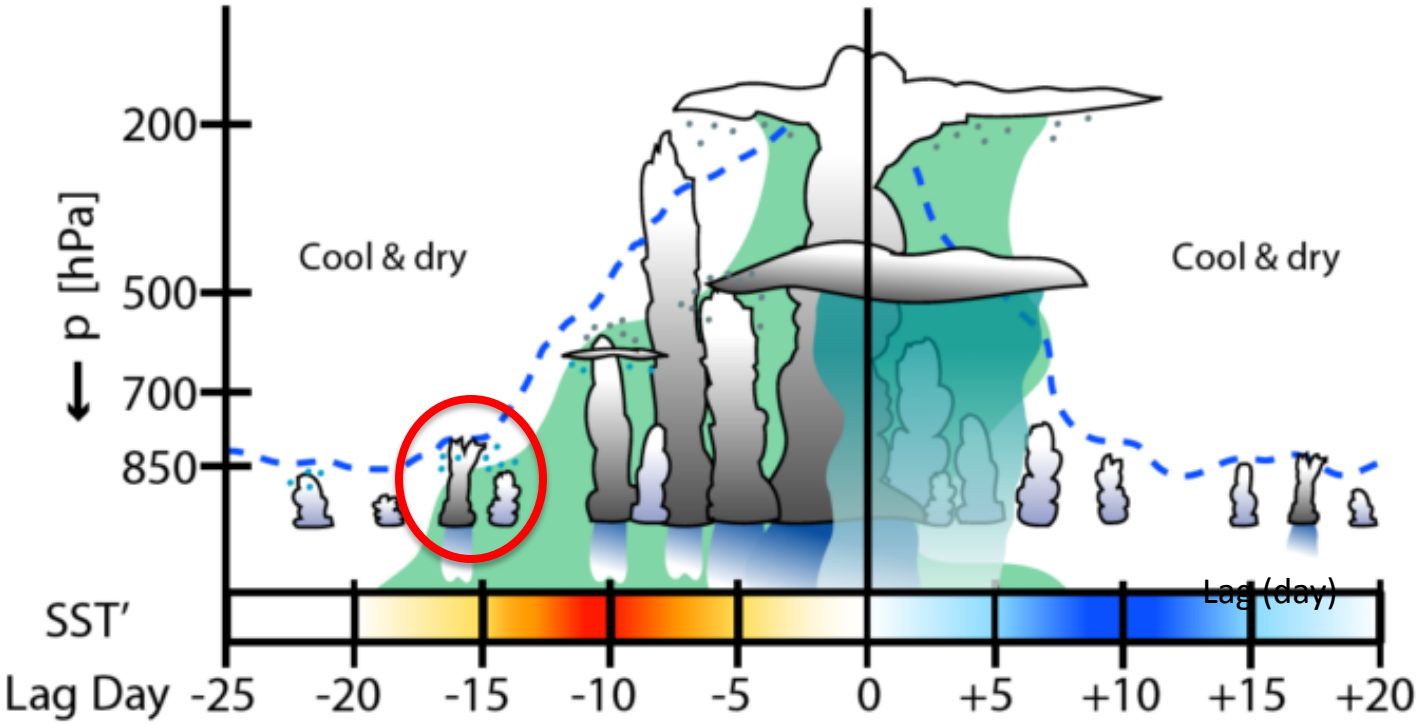
Shallow Clouds: Base height in the boundary layer; top height below the freezing level

Scientific Questions:

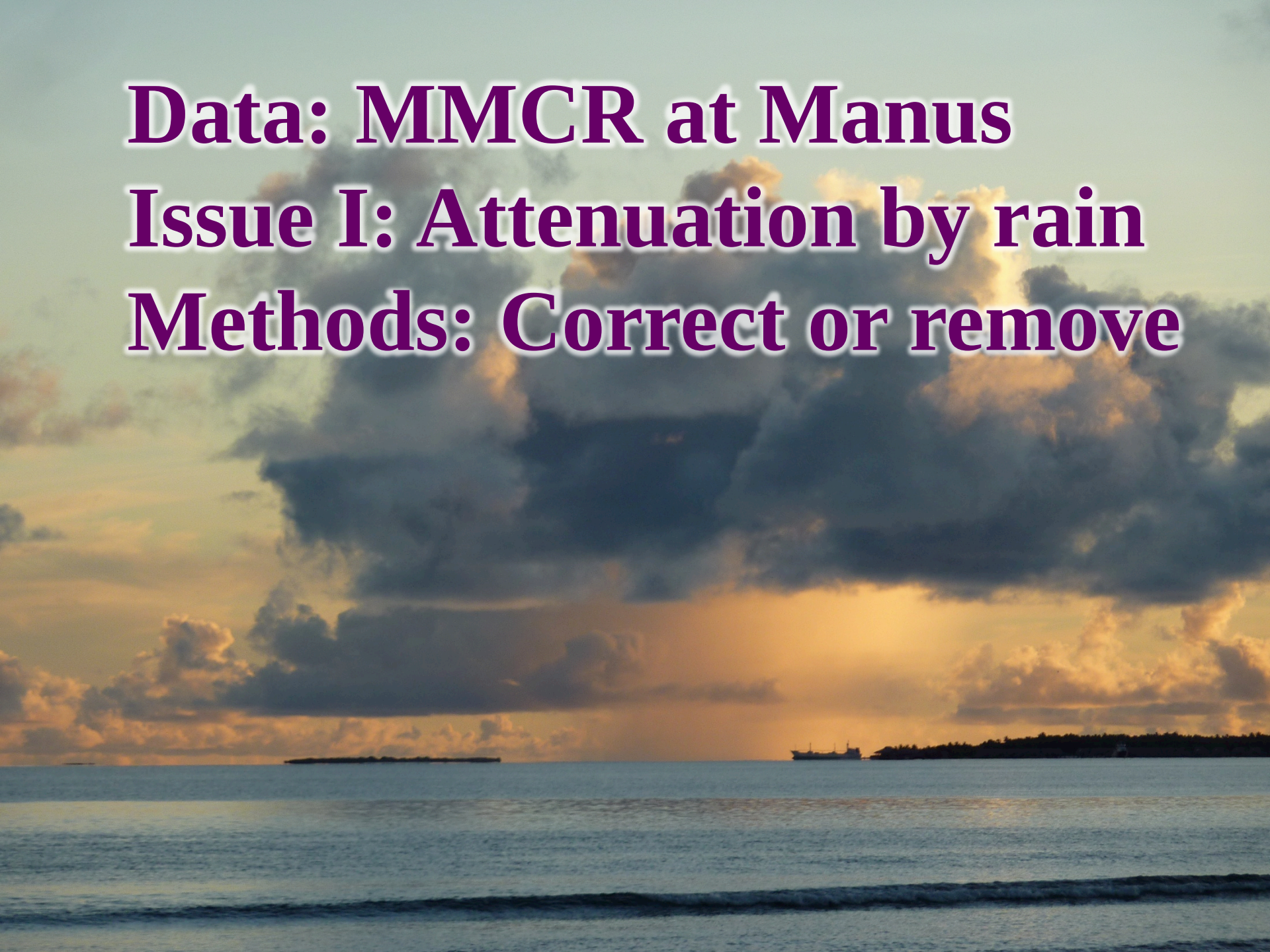
- **What is the moistening role of shallow cumulus clouds in the MJO?**
- **Are shallow cumulus clouds realistically reproduced by GCMs?**

Presumed Moistening Effects of Shallow Convection

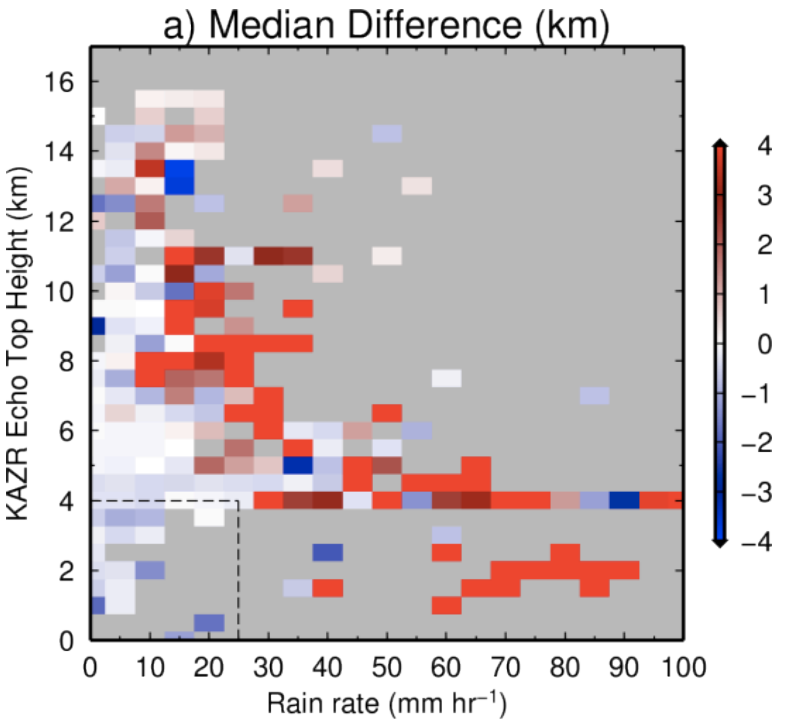
The Recharge-Discharge Hypothesis

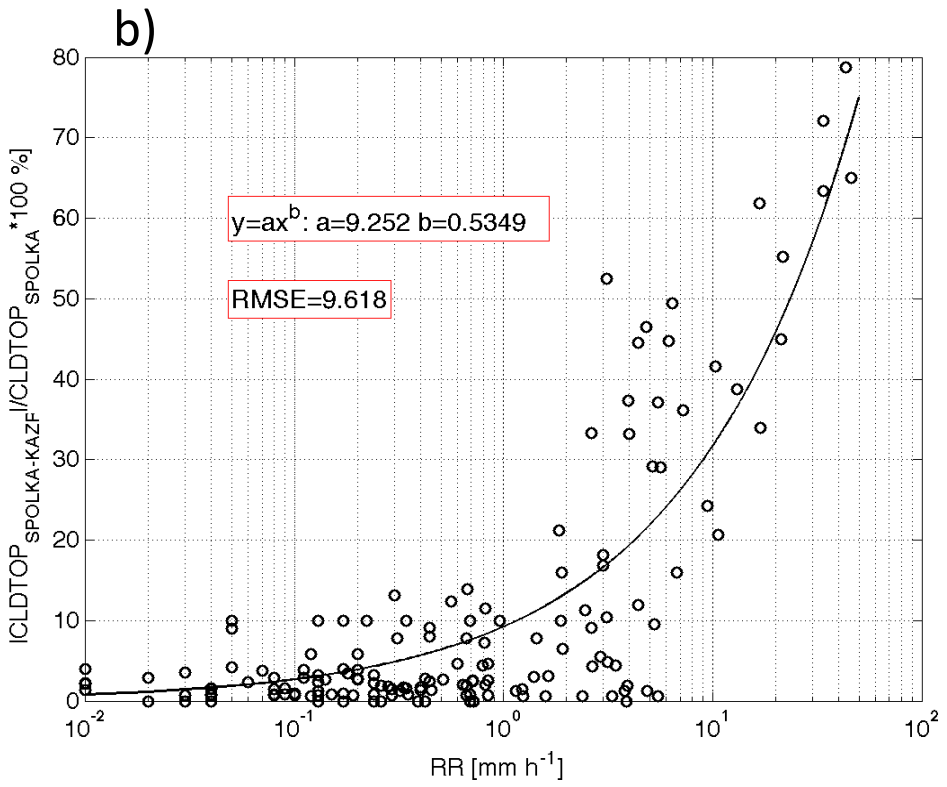


Benedict and Randall (2007)

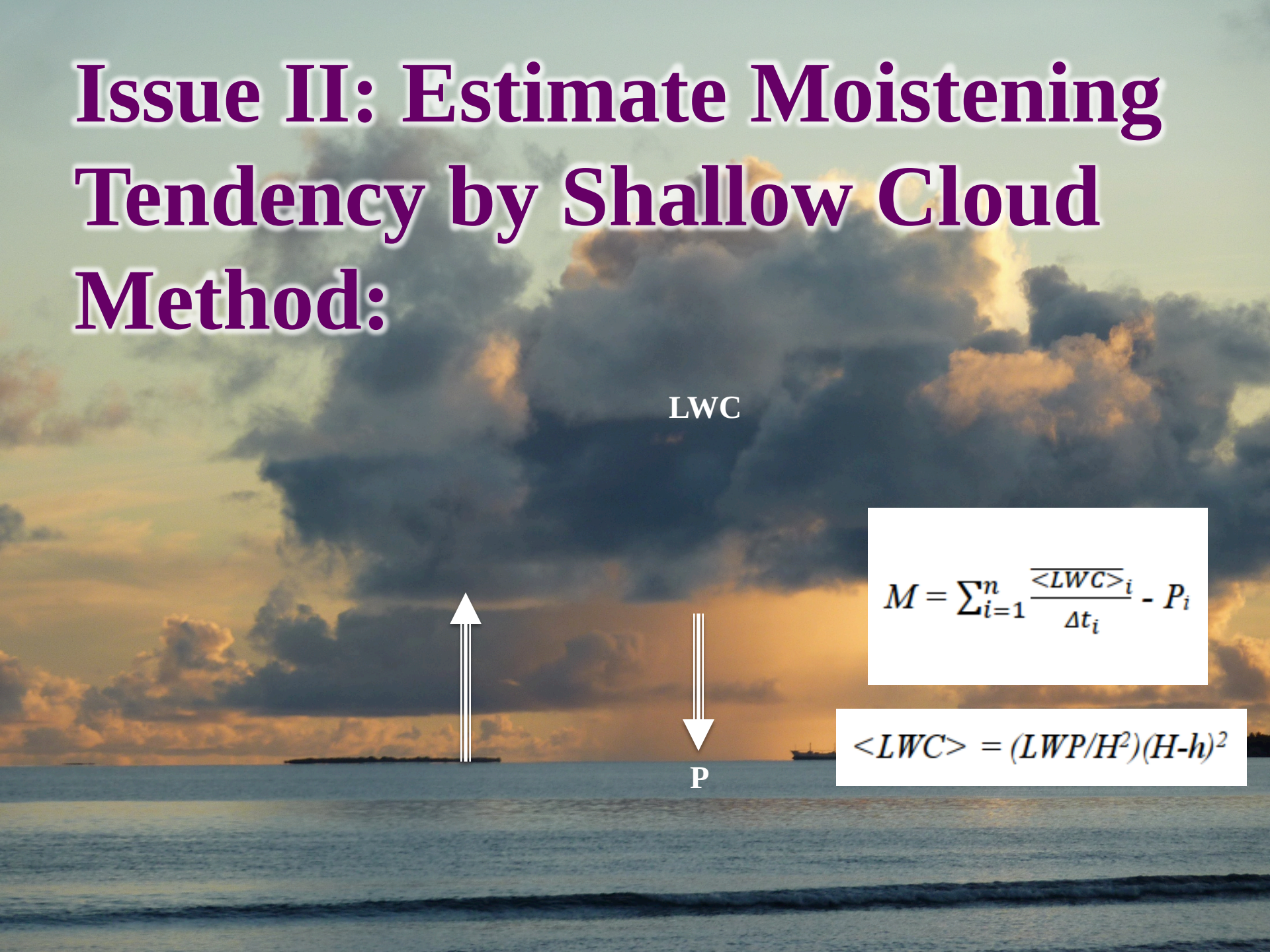

Data: MMCR at Manus
Issue I: Attenuation by rain
Methods: Correct or remove

Errors in Echo Top Height of Cloud Radars Detected by using AMIE/DYNAMO Cloud-Precipitation Radar Merged Product (Feng et al. 2013)





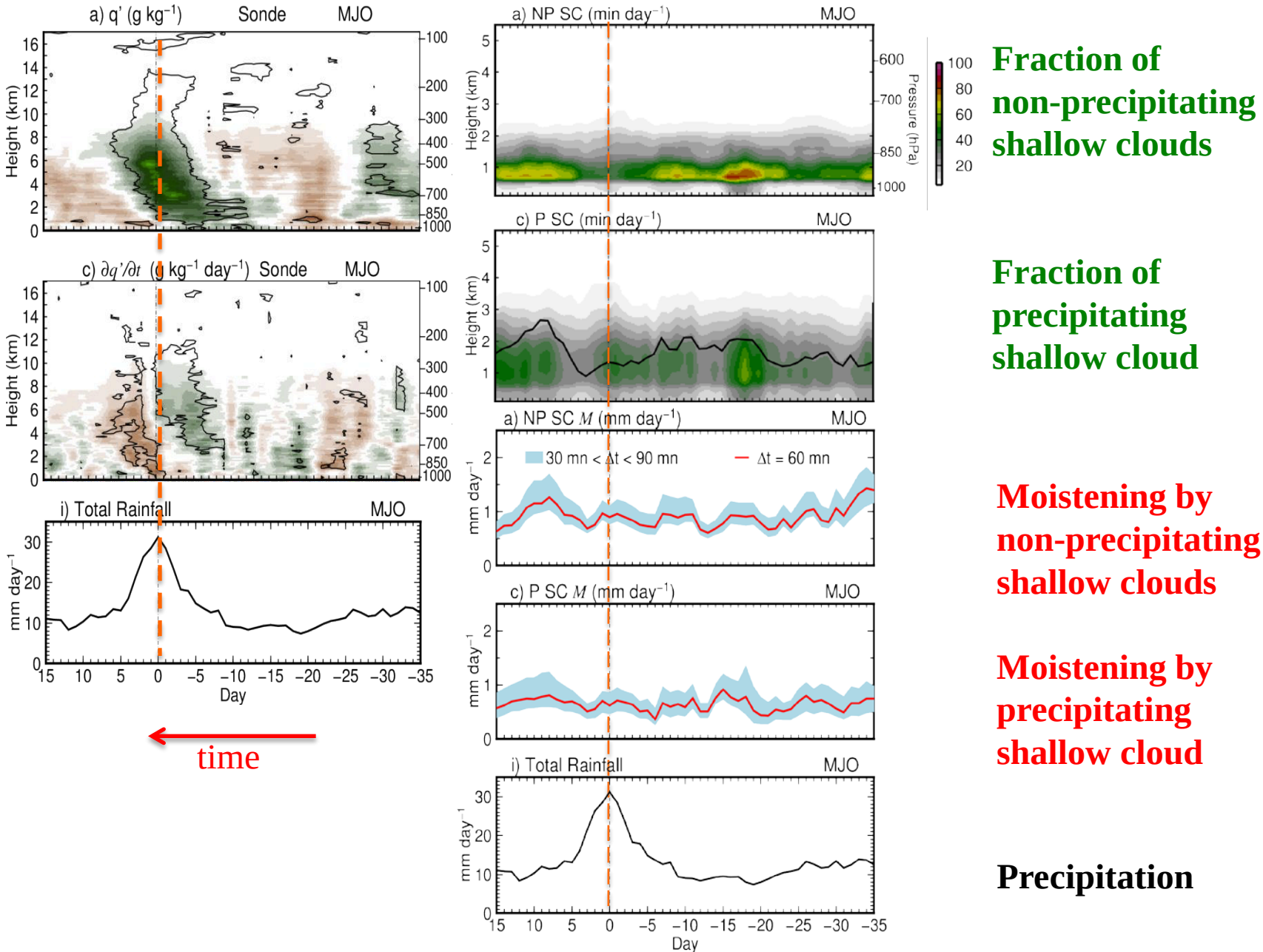
Issue II: Estimate Moistening Tendency by Shallow Cloud Method:



$$M = \sum_{i=1}^{n} \frac{\overline{<LWC>}_i}{\Delta t_i} - P_i$$

$$<LWC> = (LWP/H^2)(H-h)^2$$

Time Series MJO Composites of Shallow-Cloud Fractions and Moistening at Manus



Fraction of non-precipitating shallow clouds

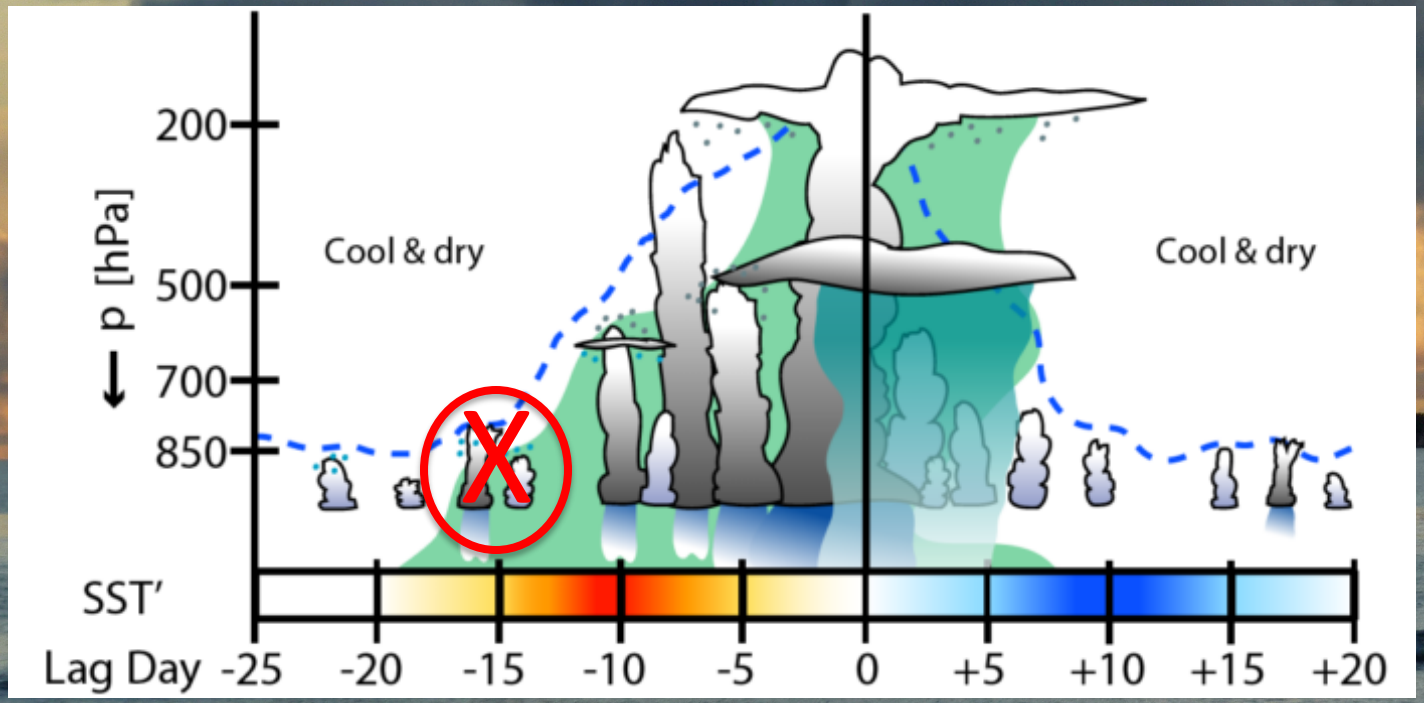
Fraction of precipitating shallow cloud

Moistening by non-precipitating shallow clouds

Moistening by precipitating shallow cloud

Precipitation

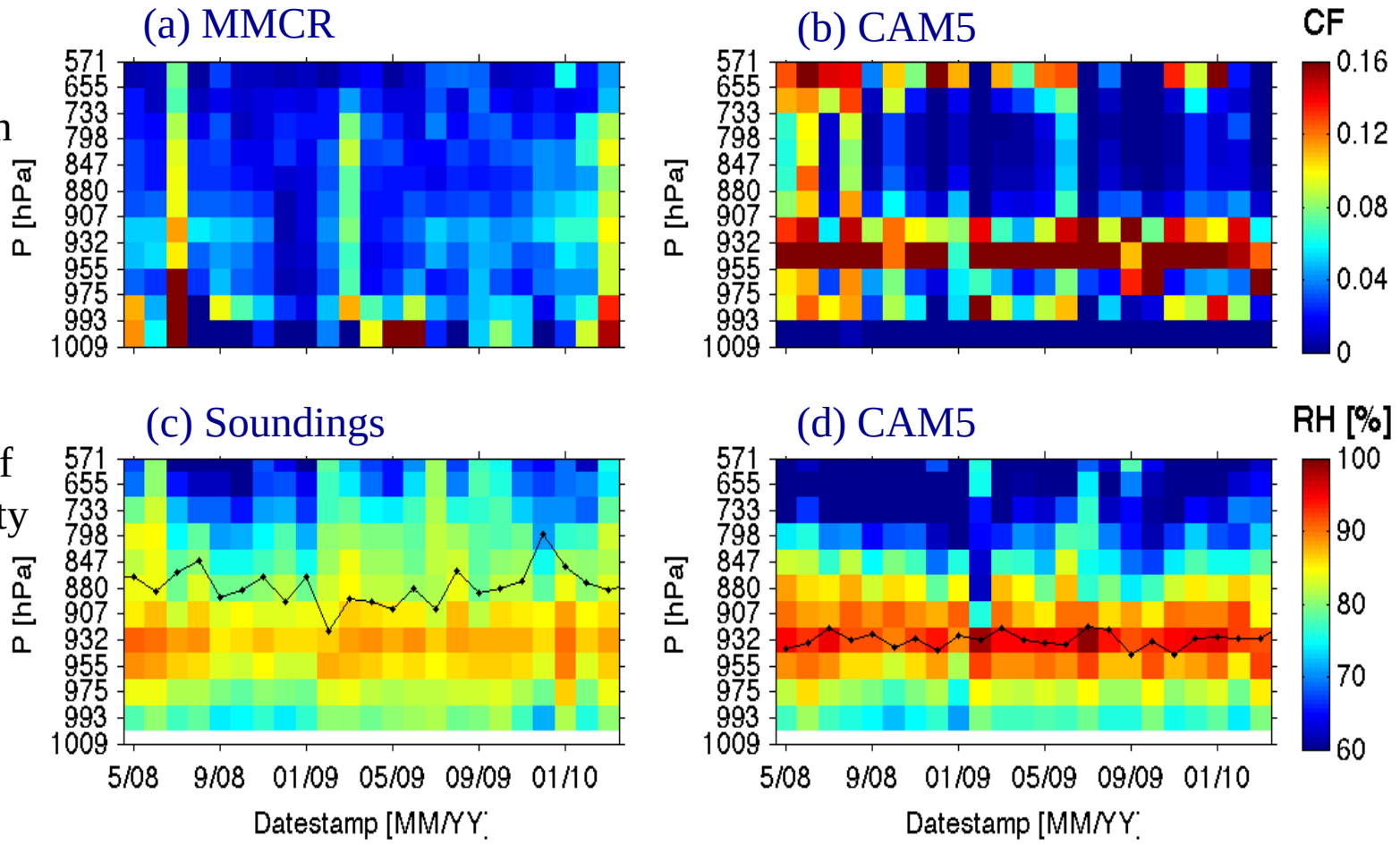
Result I: Shallow cumulus clouds provide an important background moistening effect, but they alone do not explain the observed increase in the lower-troposphere moisture leading to the growth of deep convection of the MJO.



Comparison of Monthly Low-Cloud Fraction and Mean Relative Humidity between Manus Observations and CAM5 Simulations

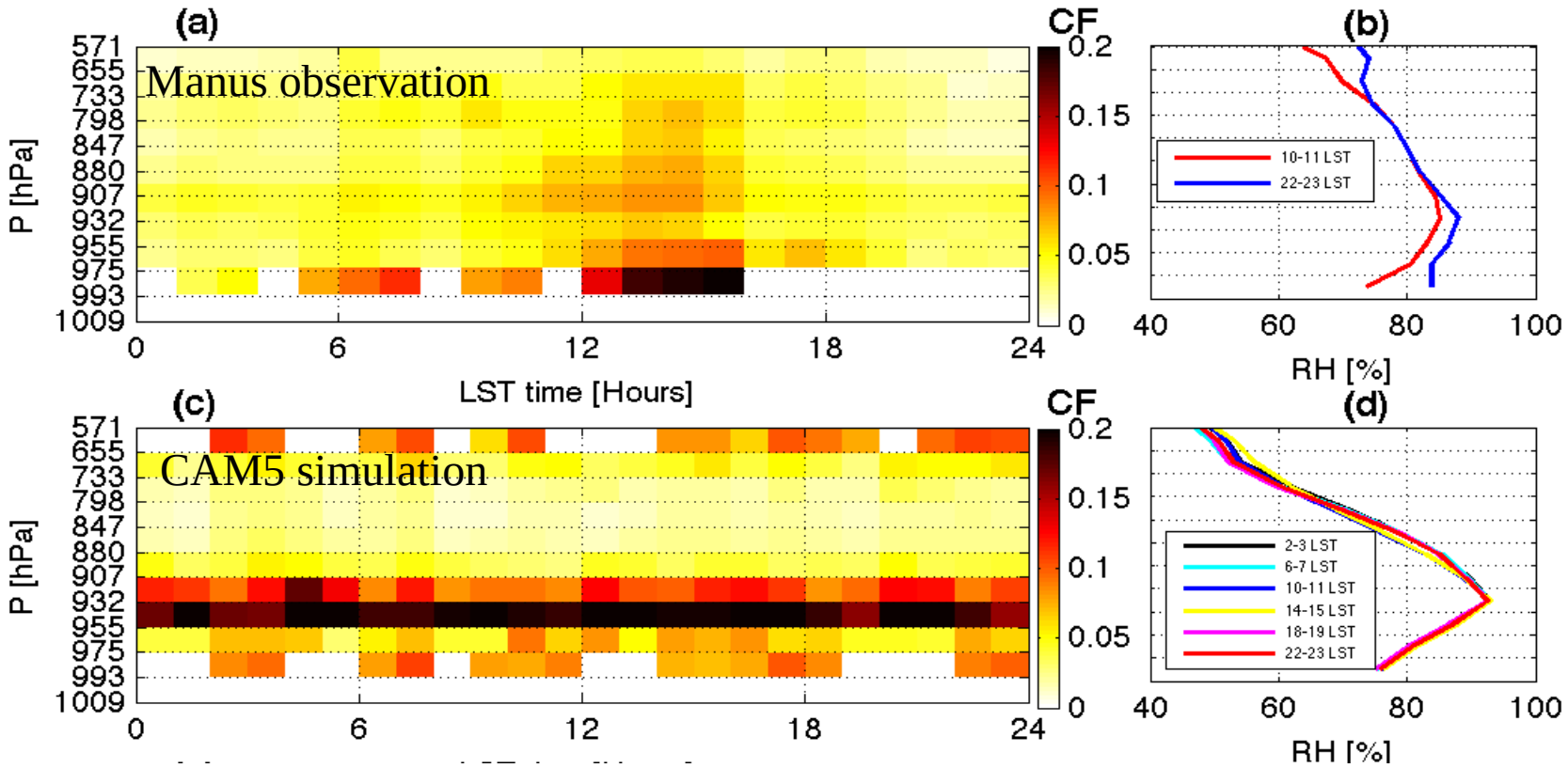
Monthly Fraction of Low Clouds

Monthly Mean of Relative Humidity



The spurious amount of low clouds near the top of the boundary layer in CAM5 is due to a lack of turbulence mixing as indicated by the erroneously high relative humidity there.

Comparison of the Diurnal Cycle in Low-Cloud Fraction and Relative Humidity between Manus Observations and CAM5 Simulations



- Excessive humidity accumulates near the top of the boundary layer because it cannot be removed by insufficient boundary-layer turbulence and shallow cumulus scheme;
- The microphysics scheme produces the spurious thin layer of low clouds.