Impact of Shallow Cumulus on the Diurnal Cycle of Precipitation and Convective Cloud Populations over the Amazon

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1. Introduction and Objective

- GoAmazon 2014/5 observations show that shallow cumulus clouds dominate surface cloud radiative effects for both wet and dry seasons (Giangrande et al. 2017), but they are in gray zone and under resolved for km-scale convection-permitting models
- **Goal:** To examine the representation and impact of shallow cumulus clouds on the population of convective clouds and the diurnal cycle of precipitation over Amazon.

2. Model Setup

- Domain: 2600x1300 km, **Δx=2km**
- Simulation period: Mar 1-20, 2015
- Microphysics: Thompson
- **Control simulation: MYNN PBL**
- **ShCu simulation: MYNN PBL (EDMF)**


Model Domain

Eddy Diffusivity Mass-Flux (EDMF)
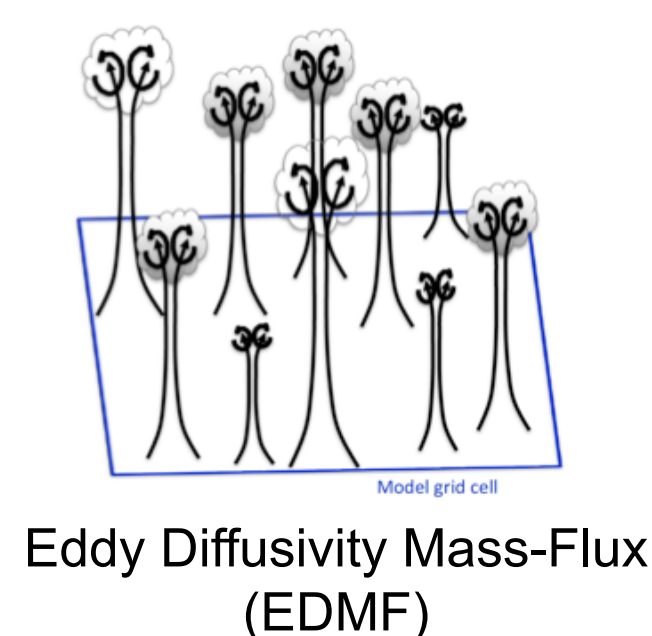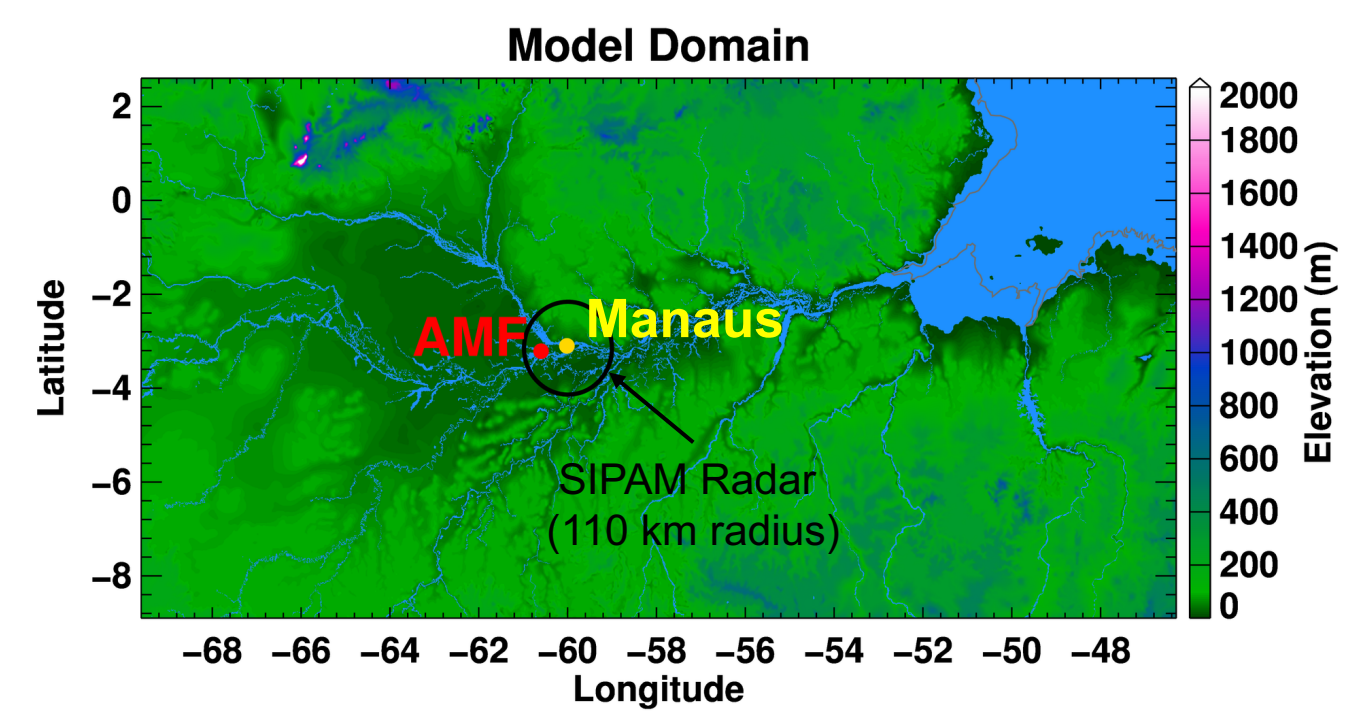
- New scale aware sub-grid mass-flux scheme for km-scale model simulations
- Multi-plume, stochastic entrainment in clouds, momentum transport
- Parameterized ShCu coupled to radiation
- New in WRF V3.9

3. T3 Cloud Products & CRSIM

Combined Sensor Cloud Classification
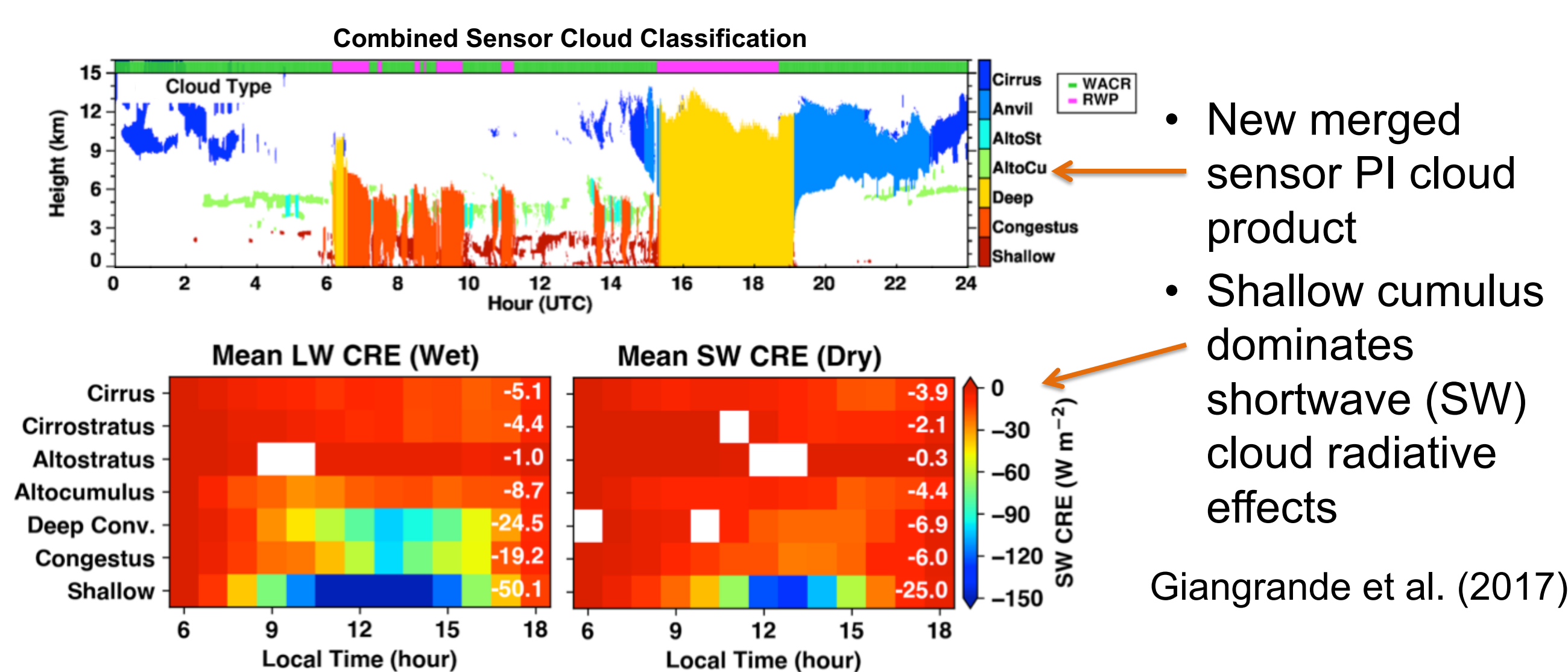
- New merged sensor PI cloud product
- Shallow cumulus dominates shortwave (SW) cloud radiative effects

Giangrande et al. (2017)

Example of CRSIM ARSCL simulator for WRF simulation
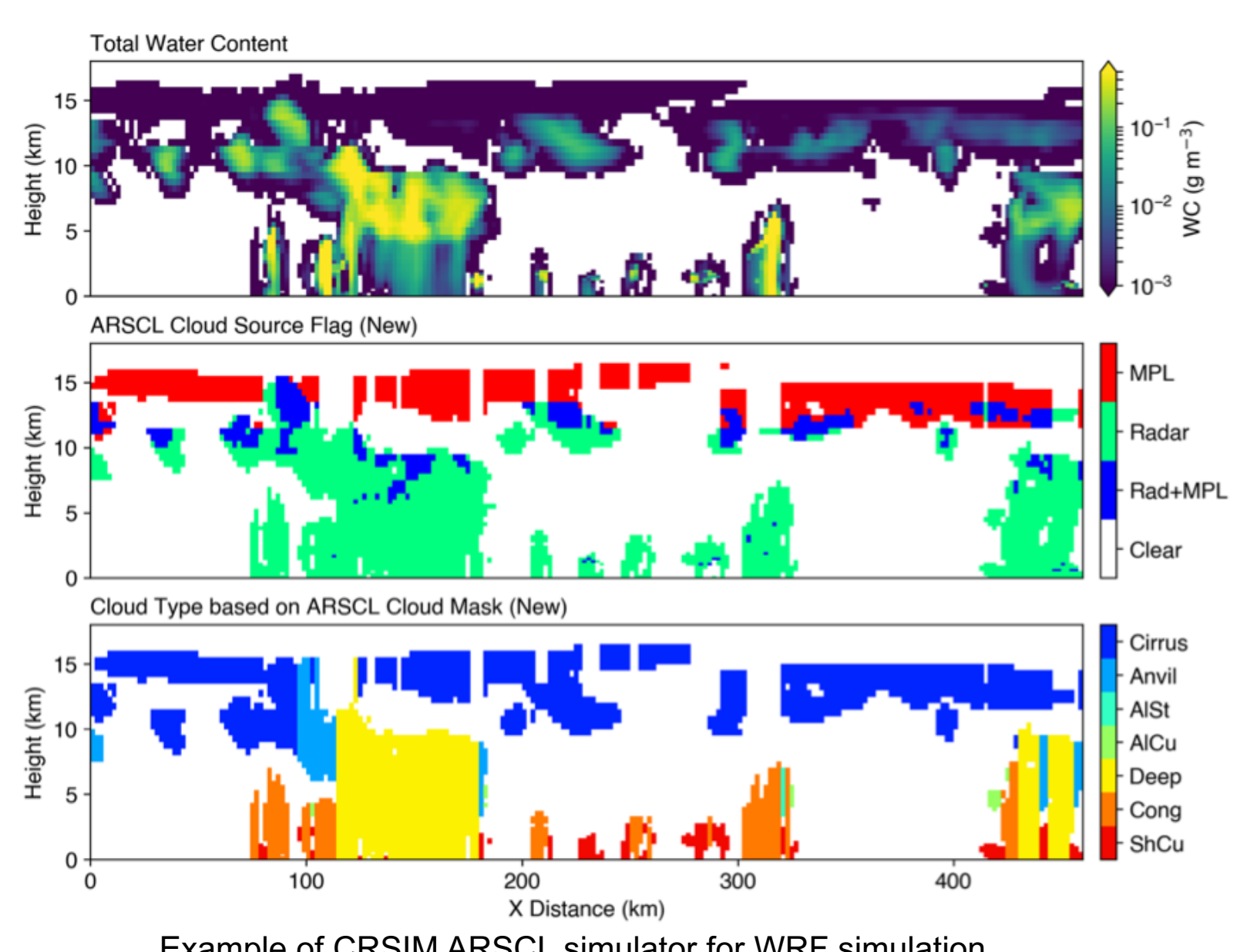
- CRSIM ARSCL simulator is applied to WRF output to mimic merged sensor product
- Cloud type frequencies derived from simple total hydrometeor content agree well with CRSIM output
- CRSIM does not yet consider sub-grid ShCu

4. Shallow Cloud Local Impact
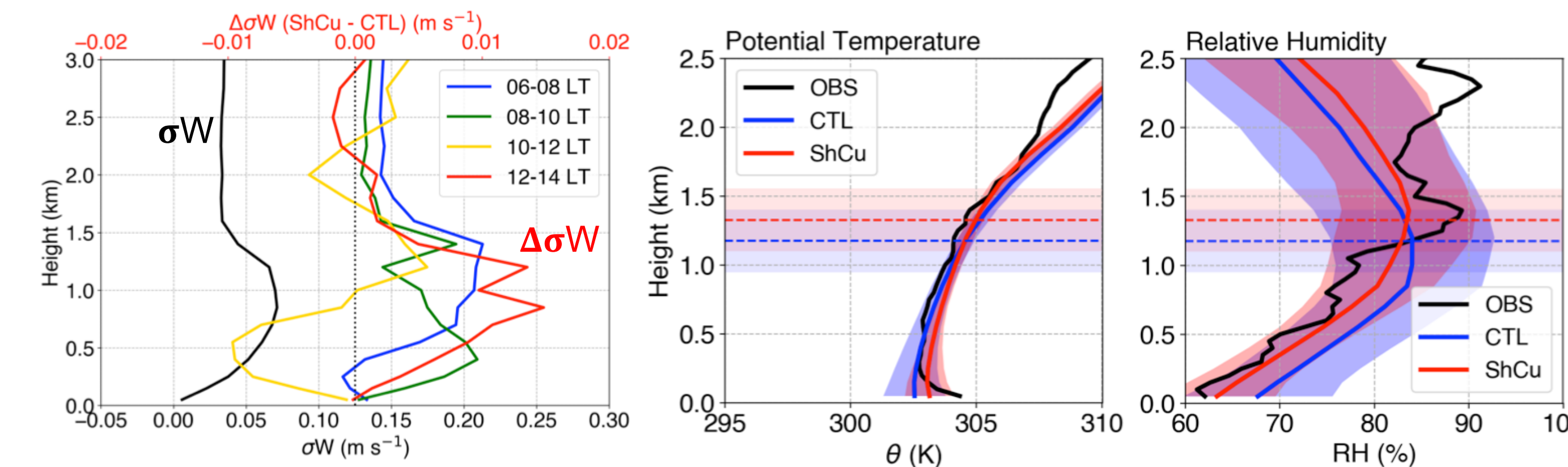
- Sub-grid mass-flux increases PBL vertical velocity variability
- PBL top is deepened, more moisture is transported upwards


Cloud Frequency

Cloud Radiative Effects
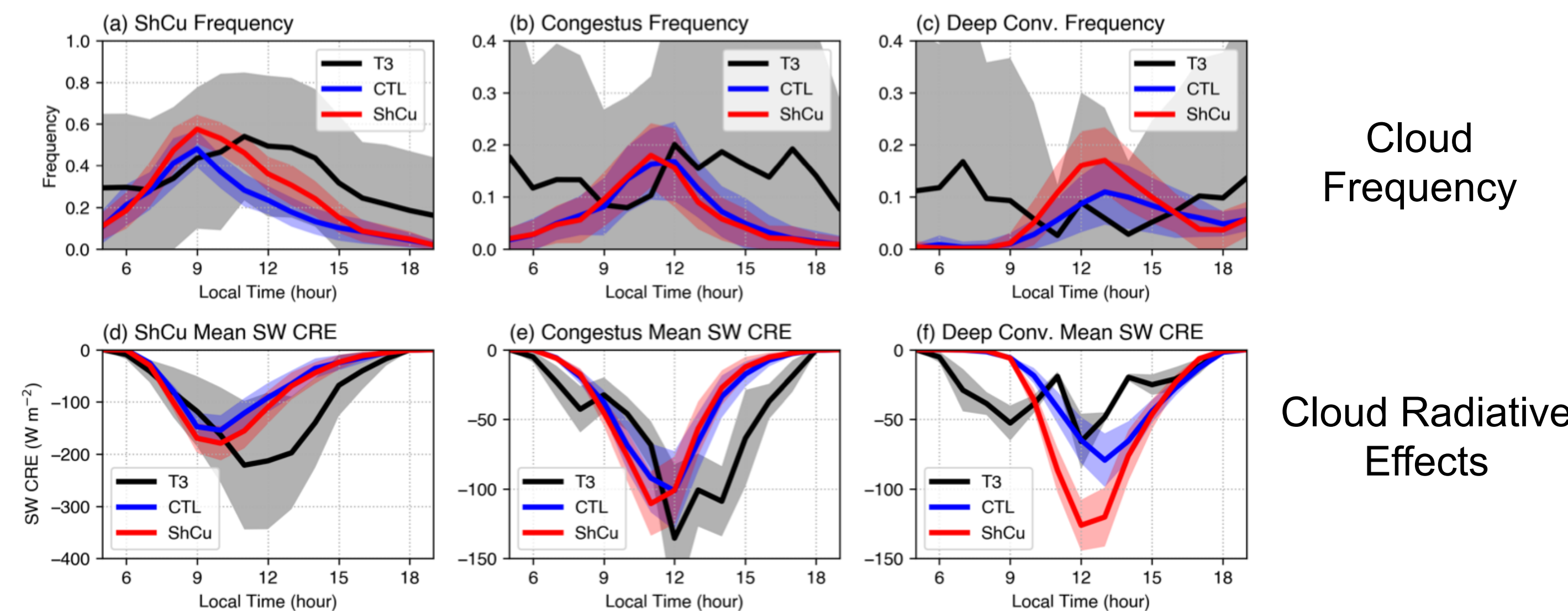
- EDMF increases late morning shallow cloud frequency
- Local mid-day deep convection at Manaus is enhanced
- Convective cloud radiative effects are stronger

5. Shallow Cloud Impact on Precipitation

Precipitation at Manaus (Mar 1-20, 2015)
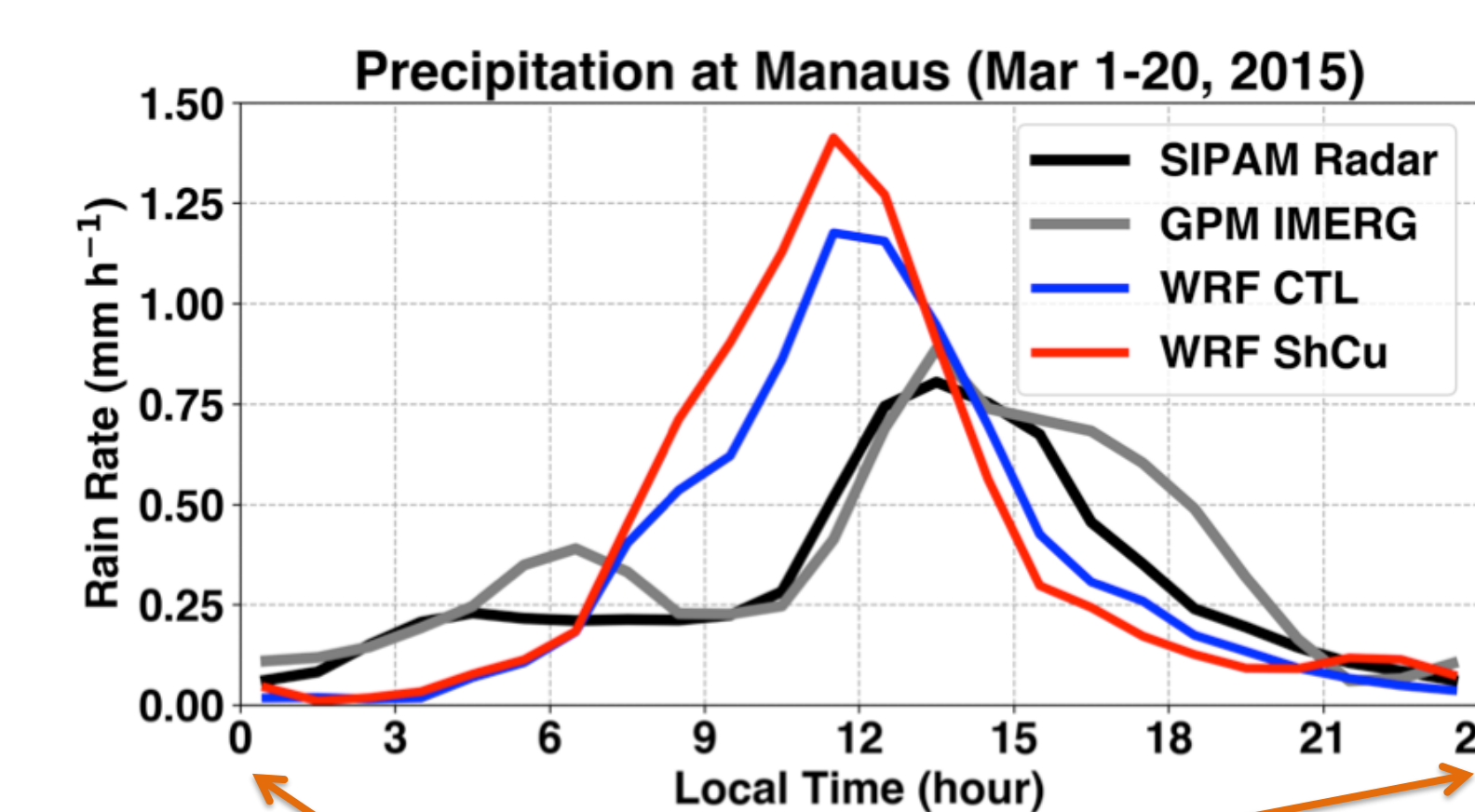
- WRF precipitation at Manaus is stronger and peaks ~2 h earlier than observations
- ShCu increases the bias at Manaus
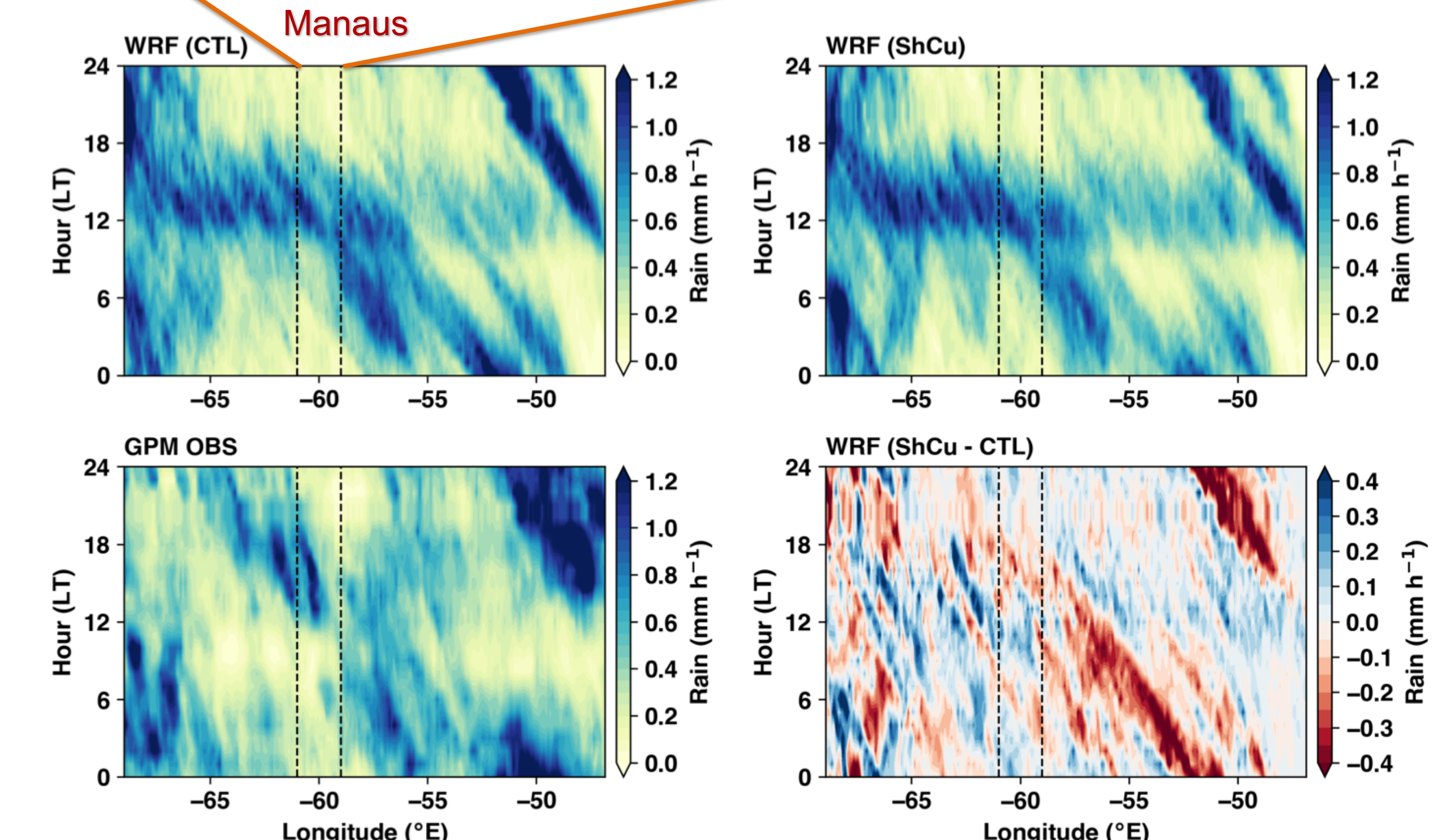
- ShCu simulation primarily increases local afternoon precipitation, but nocturnal precipitation from the east (non-MCSs) is significantly decreased

Summary and Future Work

- Sub-grid mass-flux (EDMF) treatment of shallow cumulus (ShCu) in convection-permitting WRF simulations are evaluated with GoAmazon 2014/5 observations
- EDMF increases PBL turbulence variability and late morning ShCu frequency by up to 40%
- Enhanced ShCu decreases congestus and deep convection east of Manaus in the morning, but increases them in late afternoon to evening, resulting in zonally non-uniform changes to precipitation diurnal cycle
- Future work will examine ShCu impact on shallow-to-deep convective cloud population transitions

6. Shallow Cloud Impact on Deep Clouds

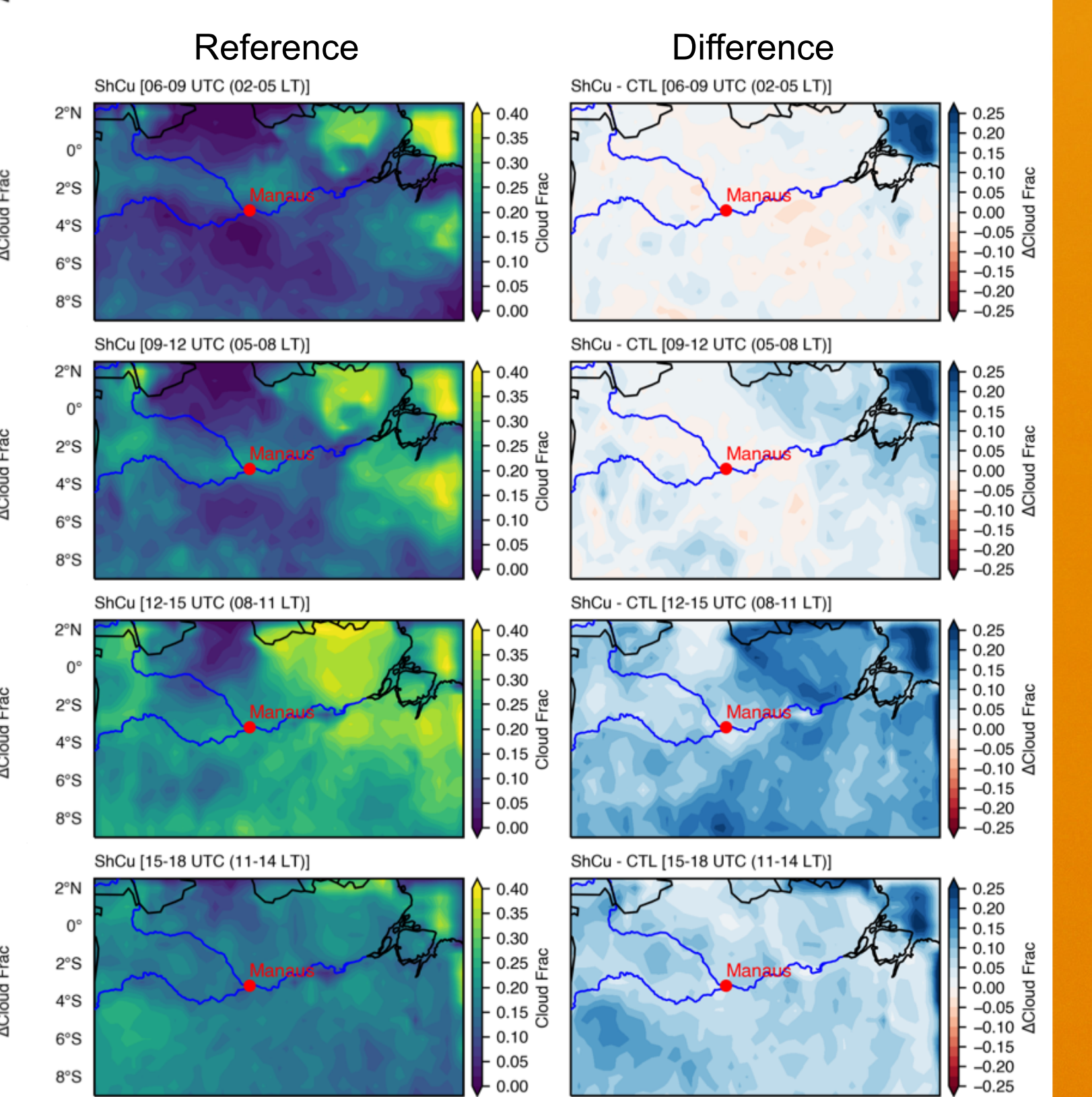Example of cloud types identified in WRF simulation
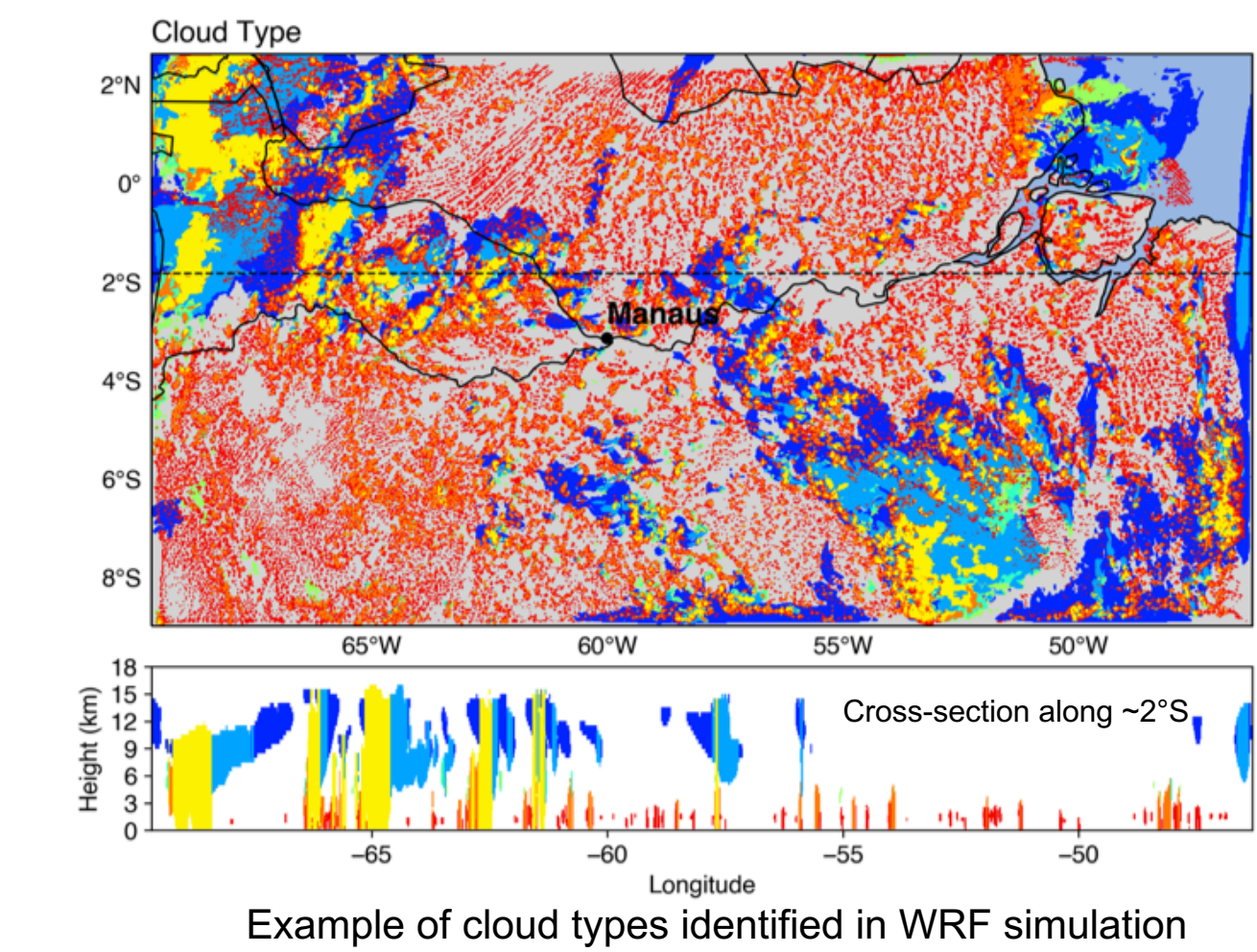
- Diurnal cycle of shallow, congestus, deep convective clouds are compared between two simulations
- Shallow cumulus cloud fraction relative increases are ~40% east of Manaus between morning and noon

Deep Cloud Fraction
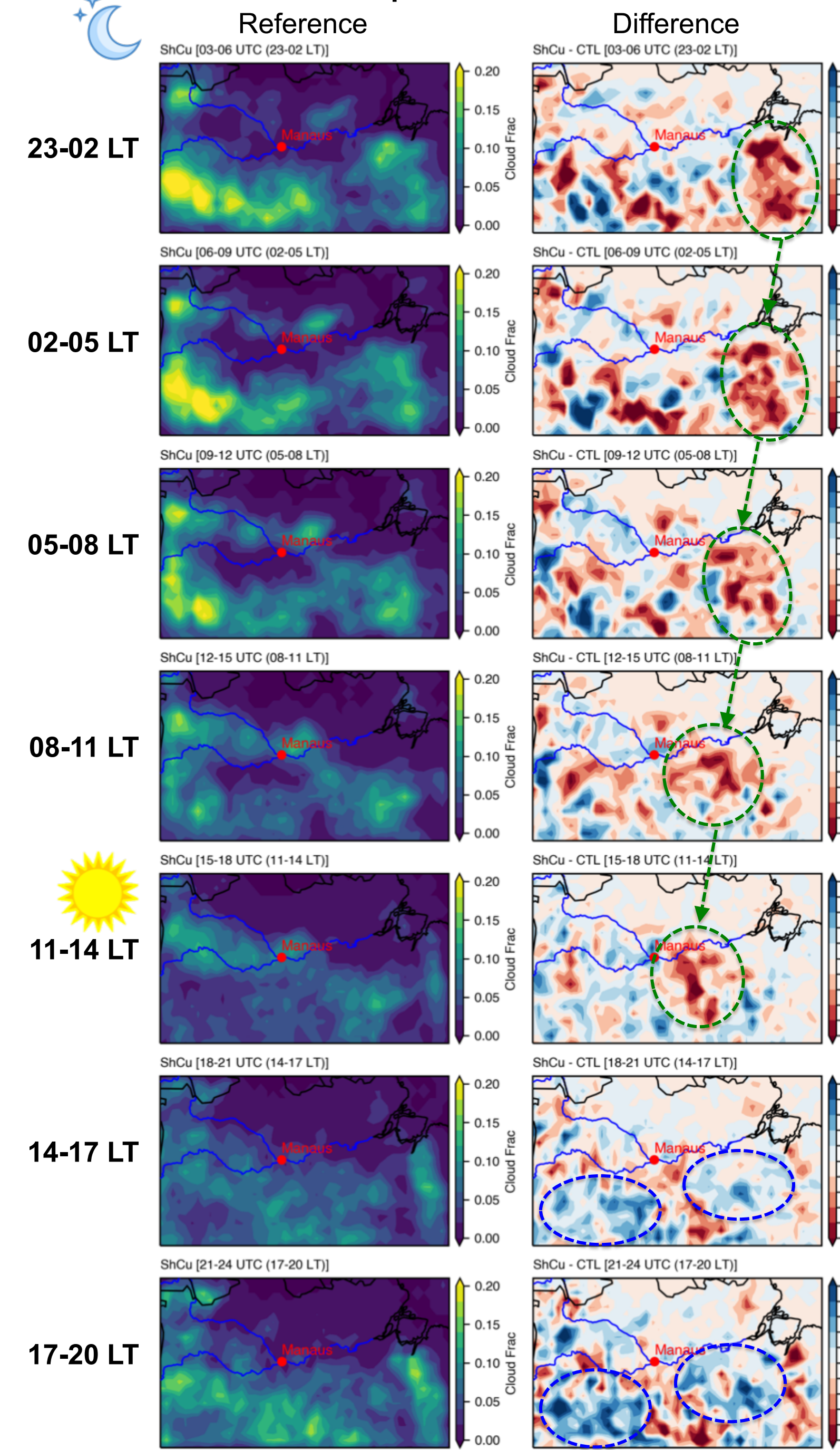
Shallow Cloud Fraction

- Enhanced ShCu substantially decreases deep convective and congestus cloud fractions east of Manaus during the morning hours, but increases them in late afternoon to evening

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