Tropical diurnal cycle: A new perspective

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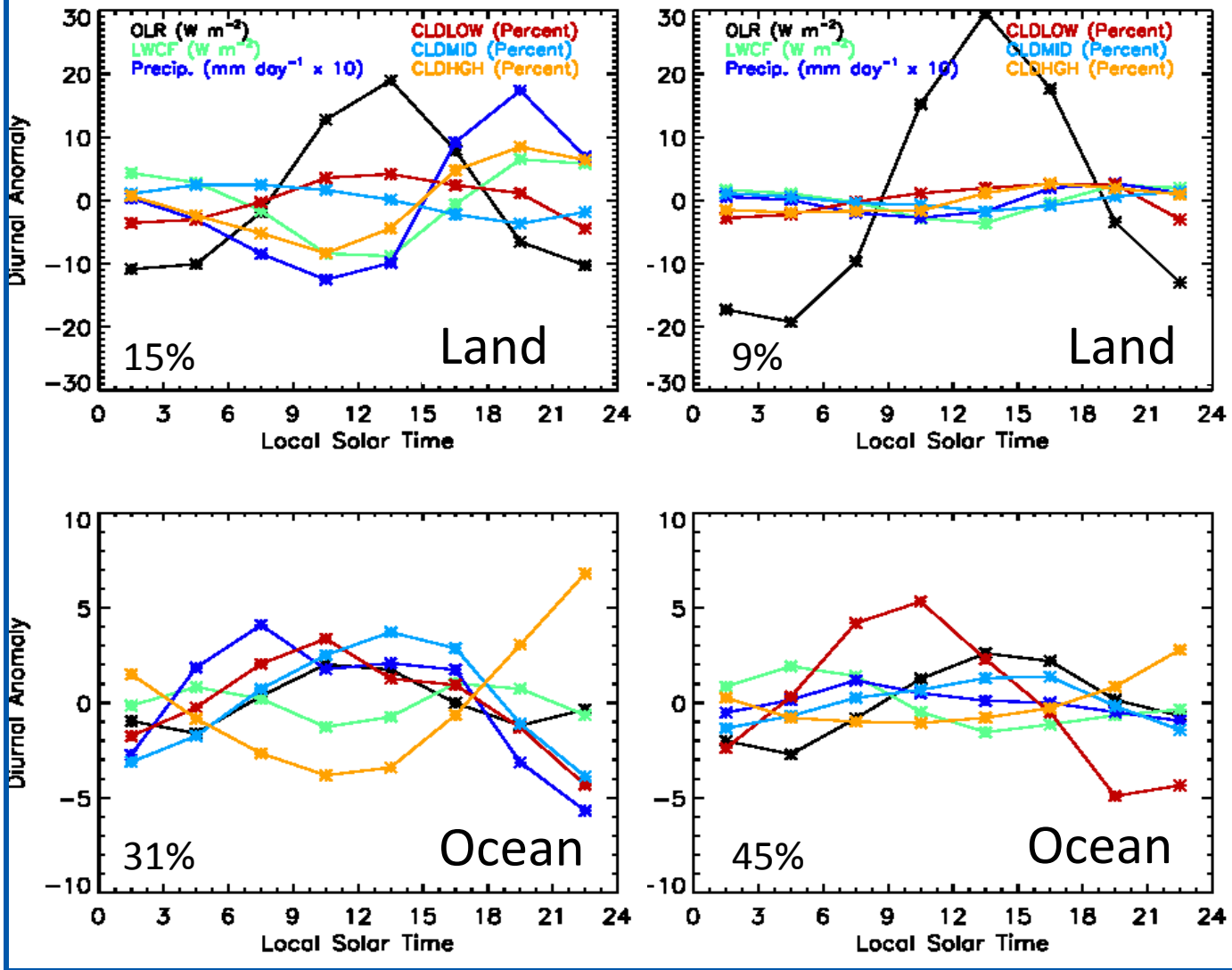
Background

- The diurnal cycle is a fundamental earth system variability.
- Significant diurnal cycle signals are evident in many geophysical datasets, including temperature, water vapor, clouds, radiation, and convective precipitation (e.g., Minnis and Harrison 1984a,b,c; Randall et al. 1991; Janowiak et al. 1994; Bergman and Salby 1996; Lin et al. 2000; Soden 2000; Yang and Slingo 2001).
- The diurnal cycle is traditionally thought to be the result of a long time average removing "weather noise."

Background: Diurnal Cycle Regimes

Convective

Non-Convective



- Convective and non-convective regimes are determined using climatological High Cloud amount (e.g., Bergman and Salby 1996).

- Convective: High cloud > 10 %
- Non-Convective: High cloud < 10 %

Traditional diurnal cycle regimes provide a statistically robust categorization.

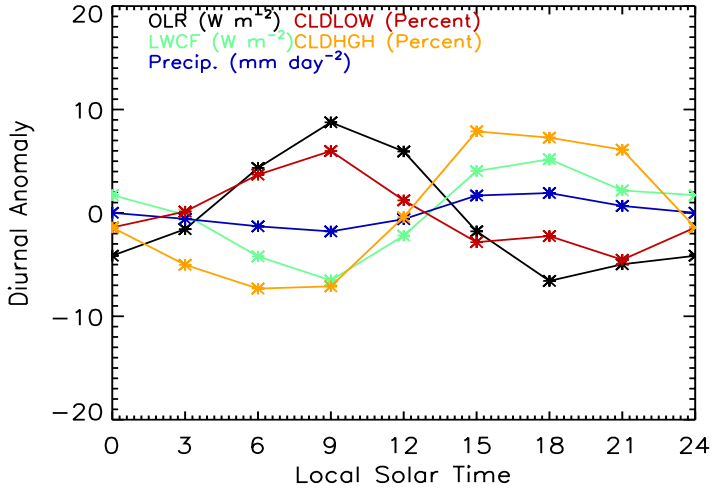
Background: Numerical Models

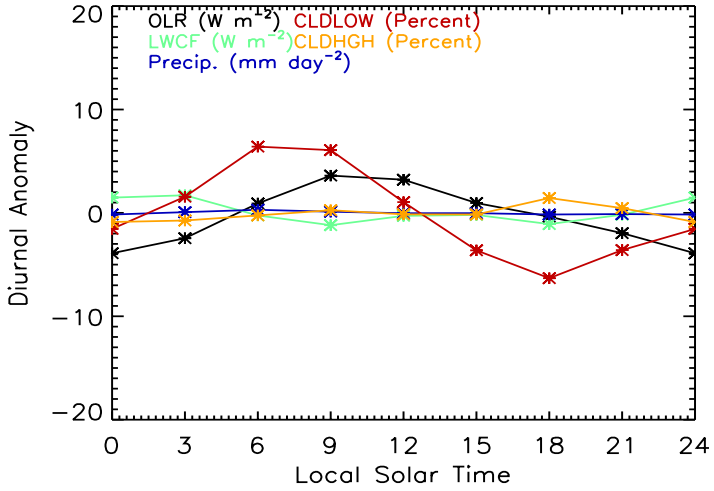
Amazon Convection

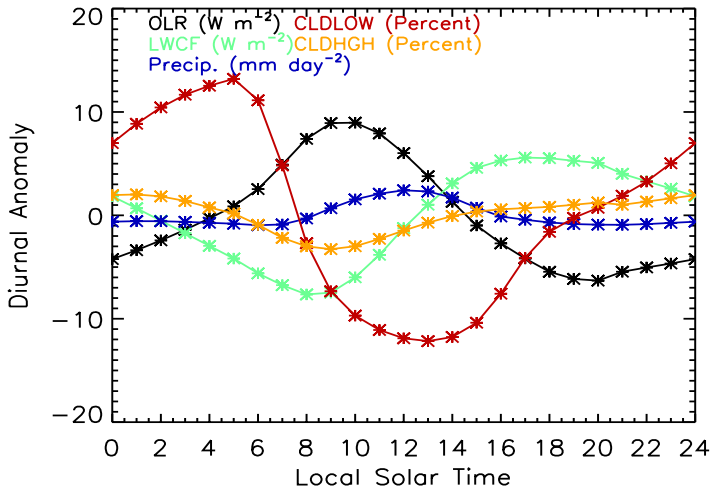
Peru Stratocumulus

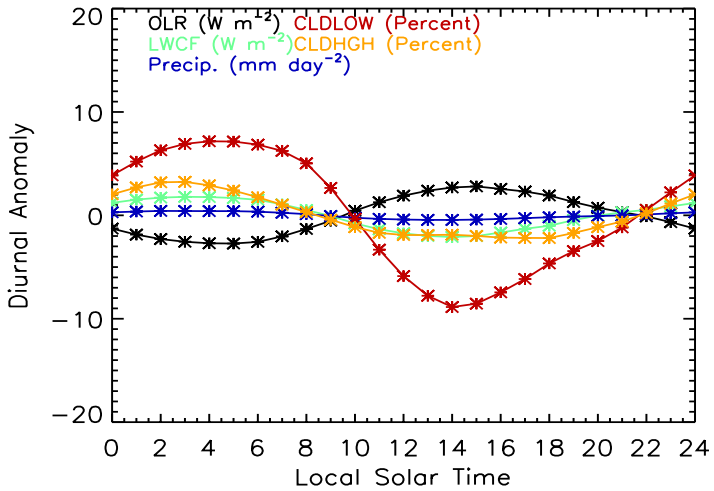
CERES SYN and TRMM

MERRA



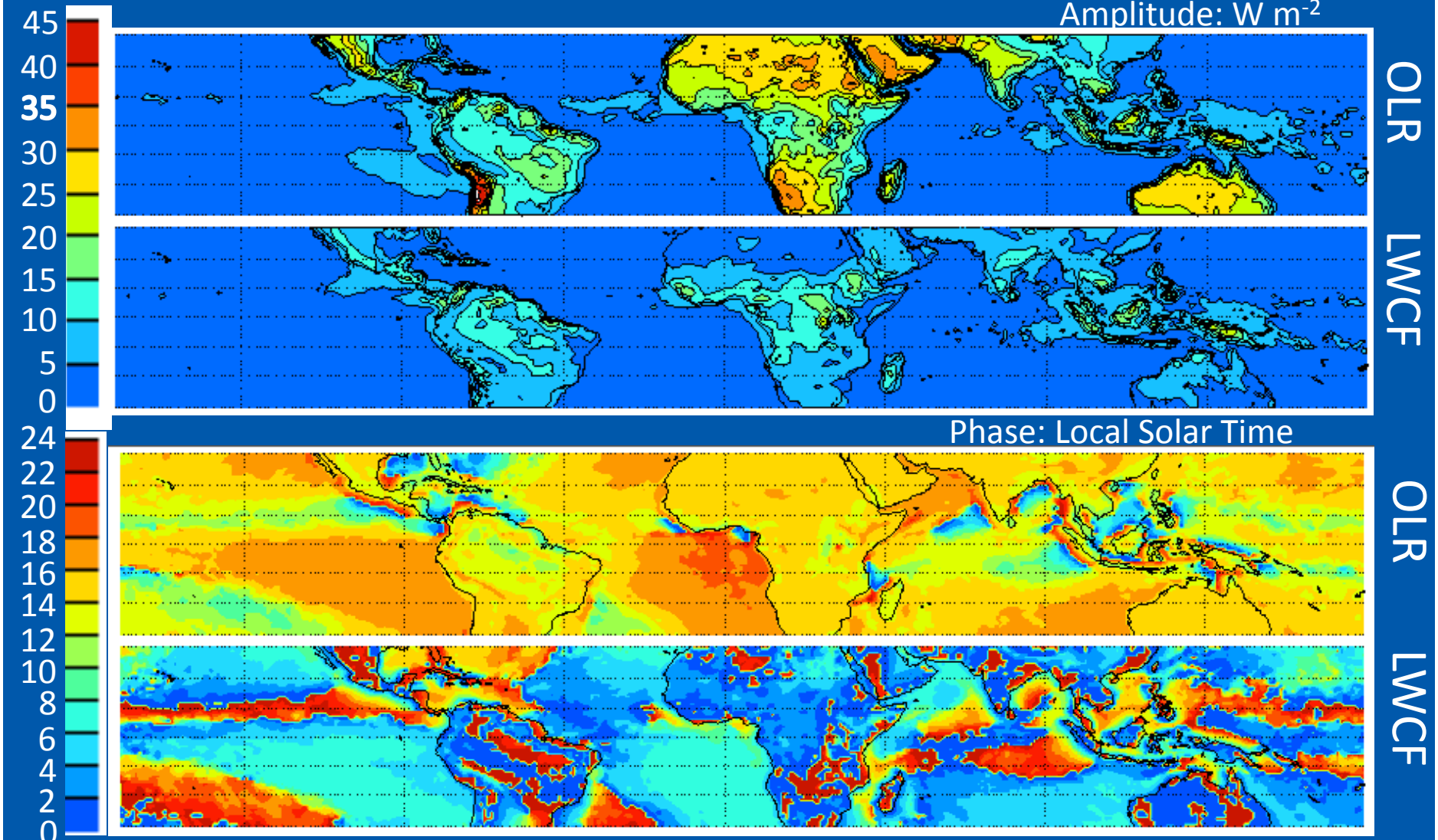




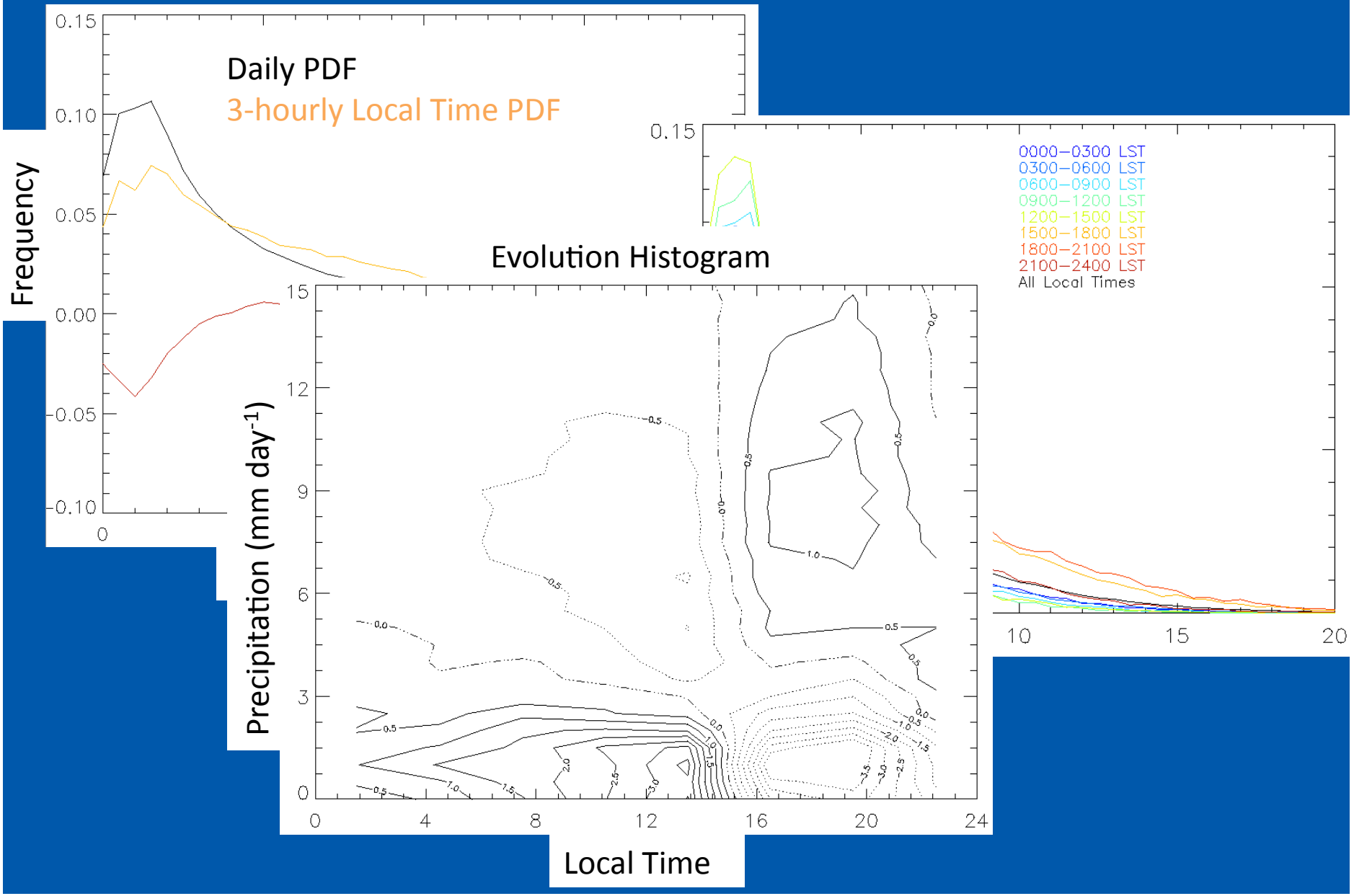


Numerical models have difficulty reproducing observed climatological diurnal cycles.

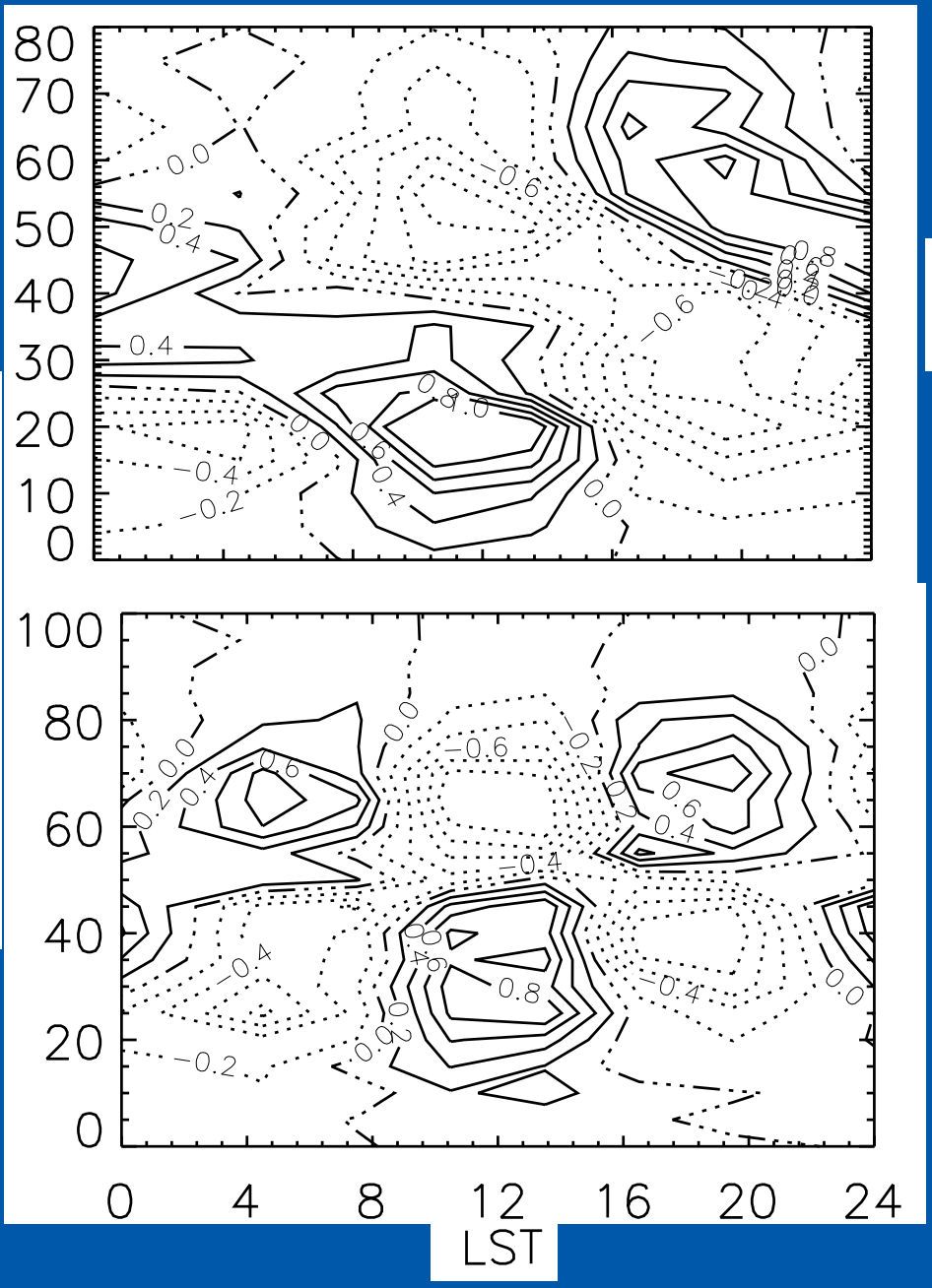
CERES Climatology
(Taylor 2012, In Press)



Computing an Evolution Histogram



LWCF Diurnal Evolution Histogram



Indian Ocean
(0-15 S; 55-95 E)

Different oceanic convective regions exhibit different LWCF diurnal cycles. One dominated by the first harmonic and one by the second.

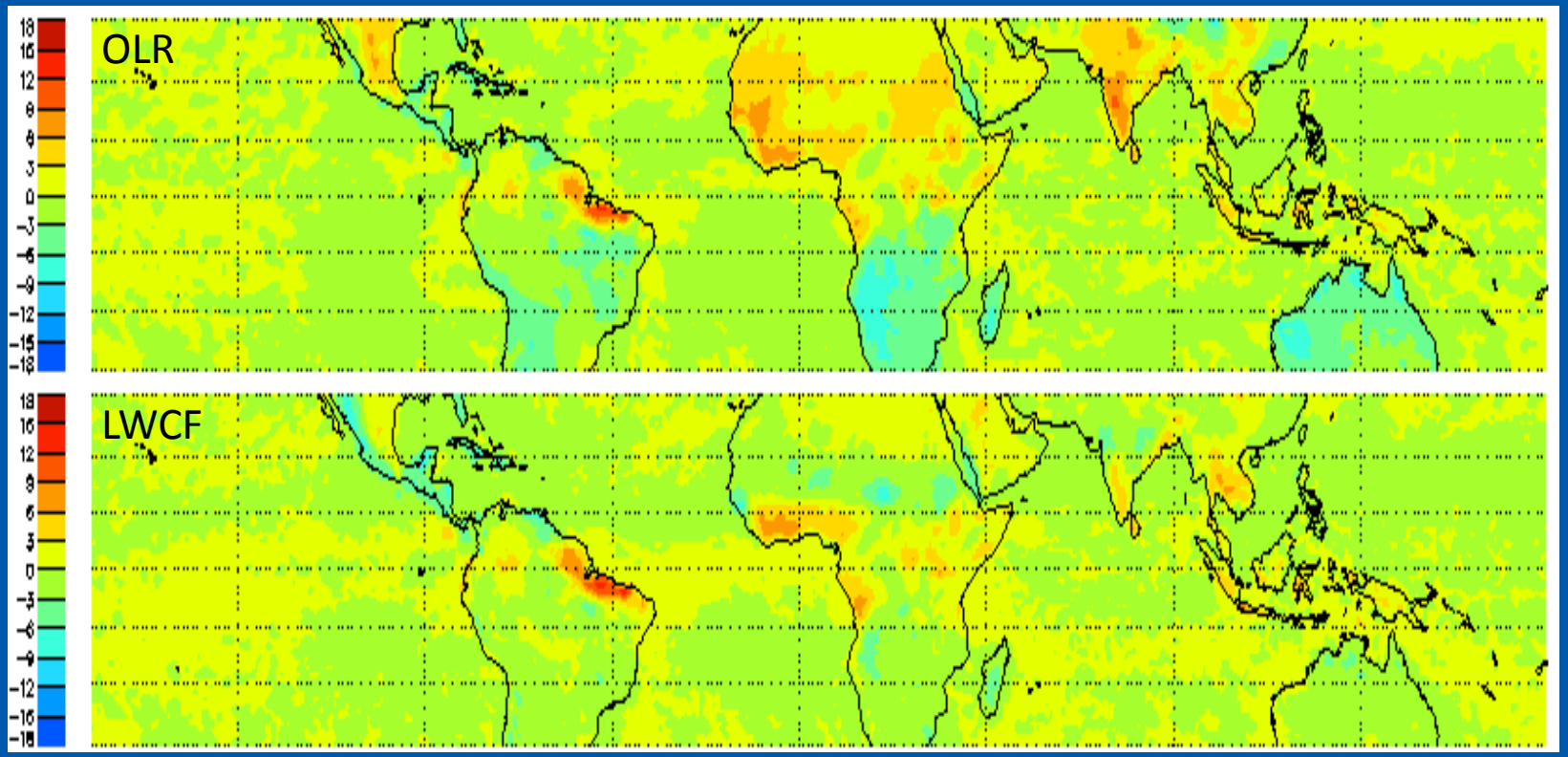
Tropical West Pacific
(10 S-10 N;160-180 E)

Taylor (2012; J. Climate, In Press)

Is the diurnal cycle constant?

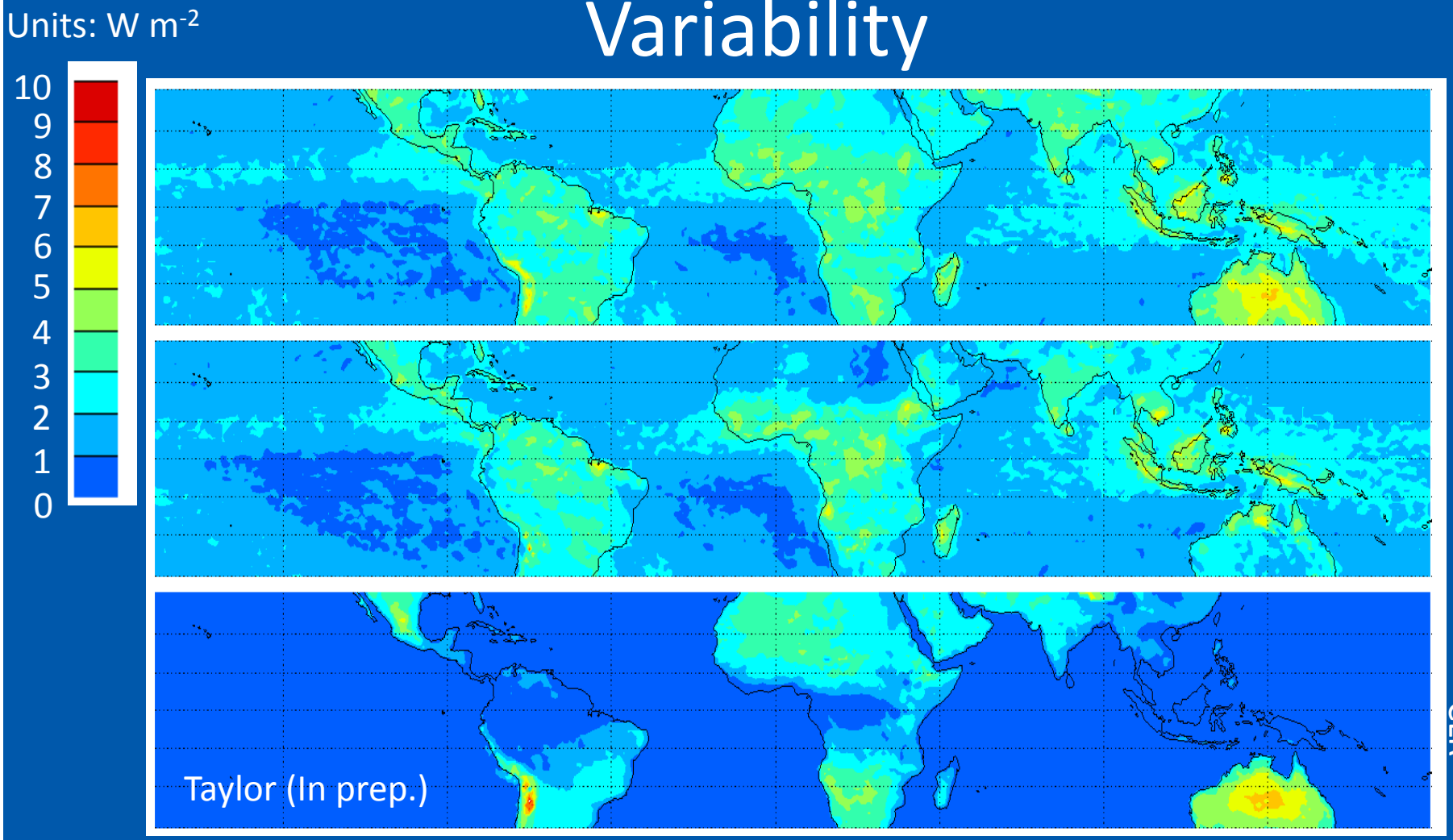
The traditional diurnal cycle perspective implies a constant diurnal cycle, or at least it is implied that diurnal cycle differences are explained by statistical noise.

Seasonality: MAM minus SON



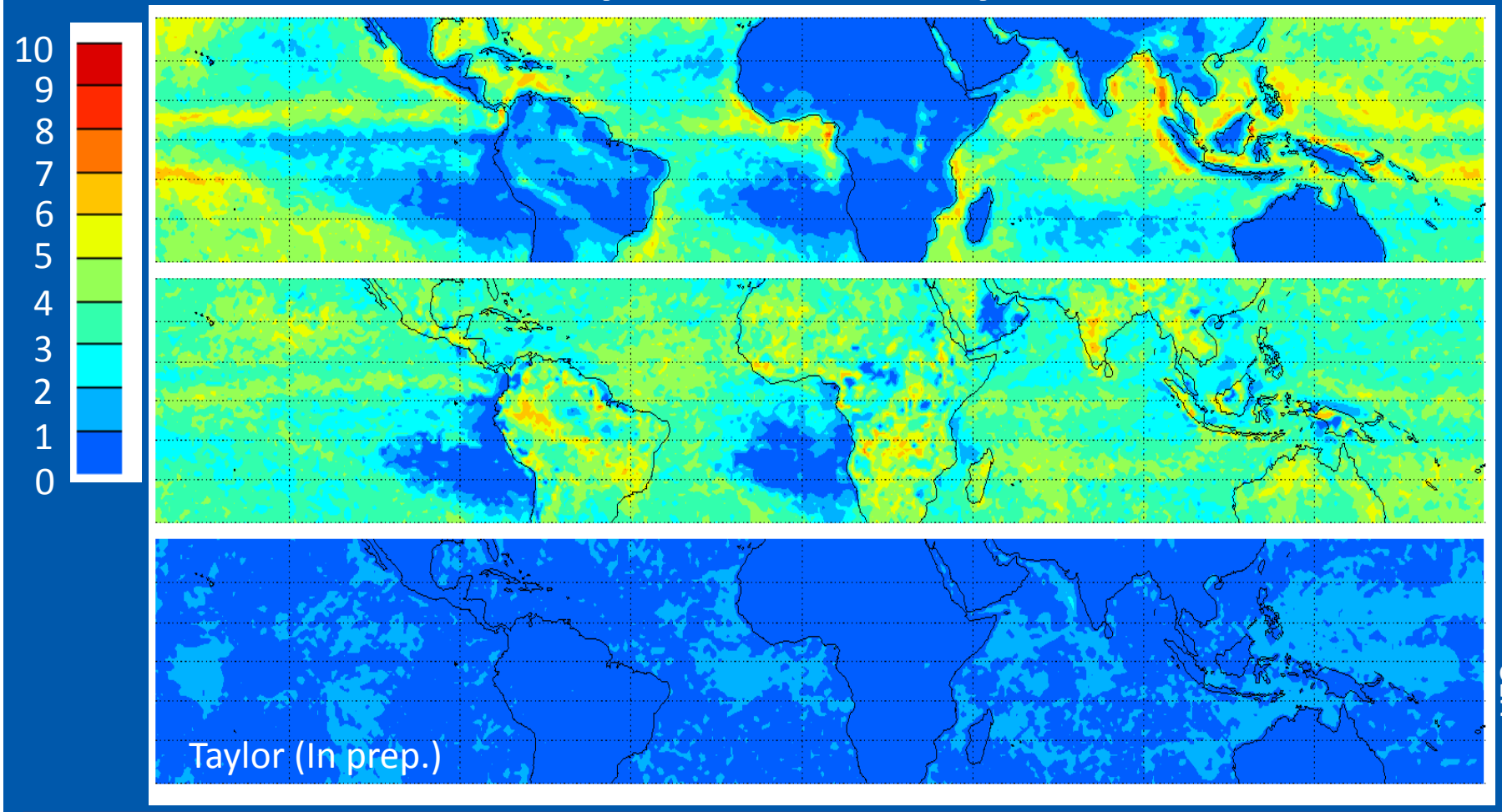
Diurnal cycle amplitudes are significantly different in transition seasons (MAM vs. SON), despite similar solar insolation.

OLR Diurnal Cycle Amplitude Monthly Variability



Diurnal cycle first harmonic amplitude exhibit significantly variability over land.

Diurnal Cycle Phase
Monthly Variability: 1°x1°

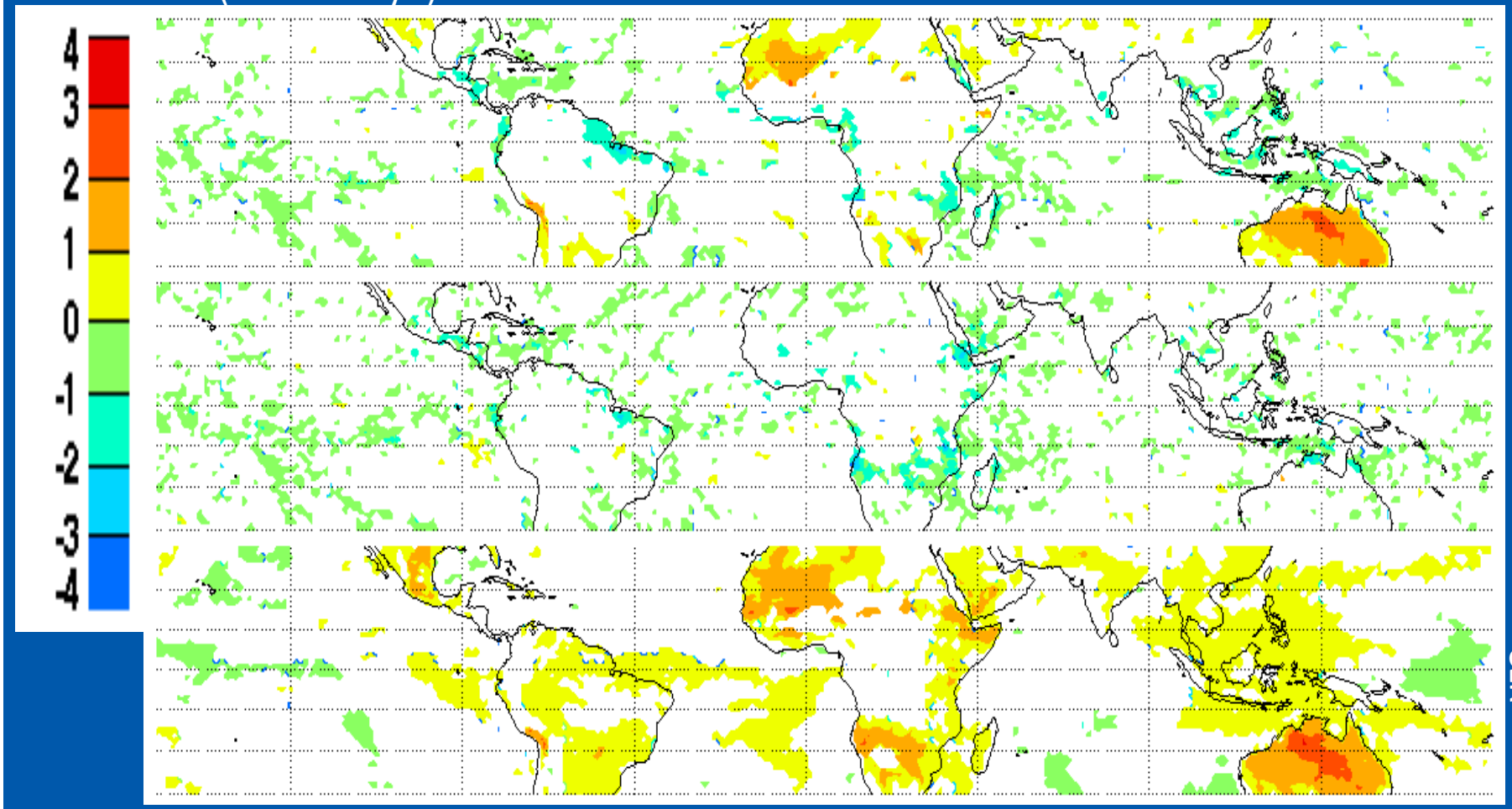


Month-to-month OLR and LWCF diurnal cycle first harmonic phase exhibit significantly variability over land and ocean.

What drives diurnal cycle amplitude and phase variations?

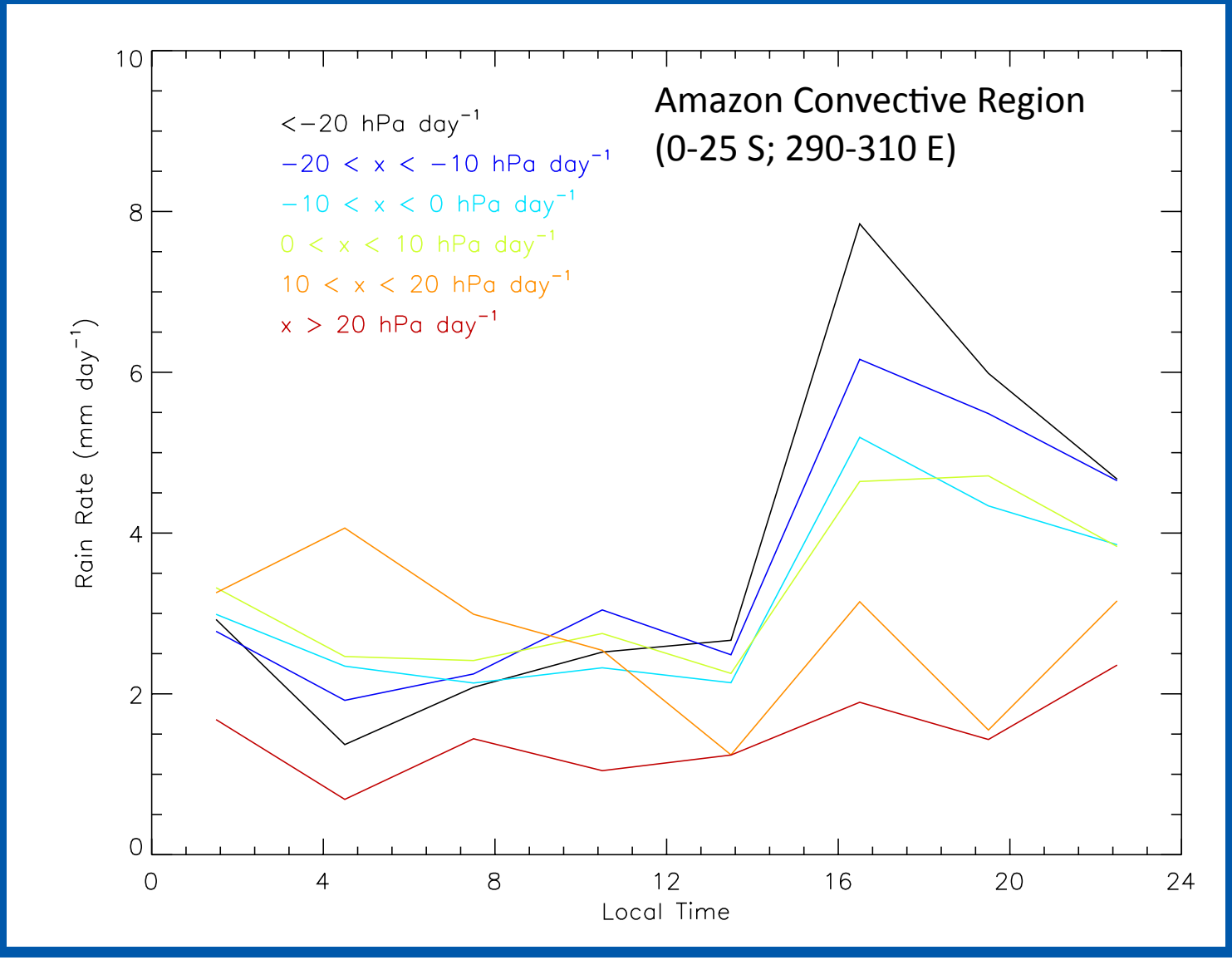
Diurnal Cycle Amplitude Sensitivity to 500 hPa Omega

Units: W m^{-2} $(10\ hPa\ day^{-1})^{-1}$



Taylor (In prep.)

Rain Rate Diurnal Cycle by 500 hPa Omega



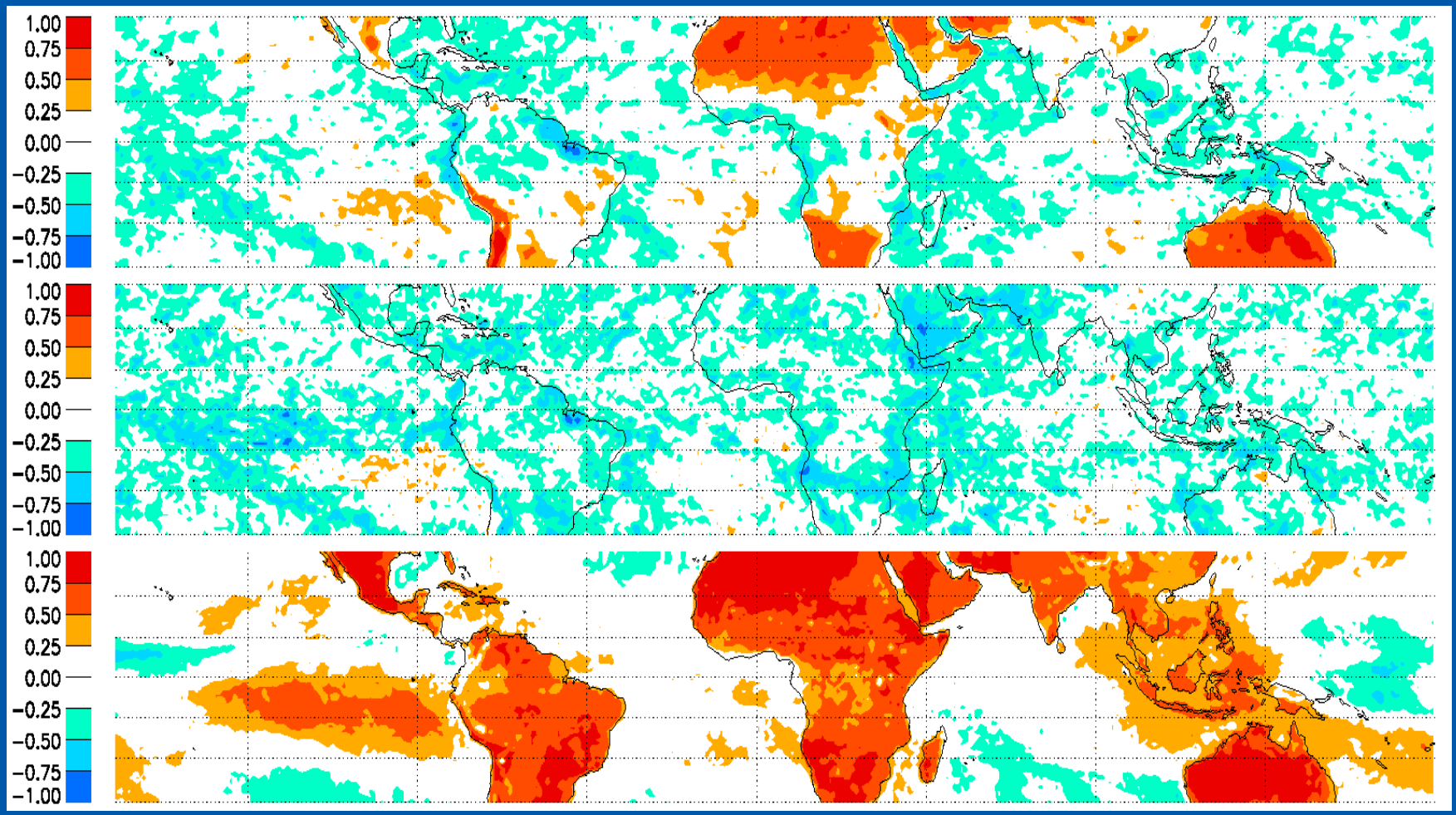
A new perspective: “multiple” diurnal cycles

The atmospheric column and cloud response to the forcing by solar insolation is dependent upon atmospheric dynamic and thermodynamic state.

Is this behavior important for system mean state and variability?

Correlation: A’ vs. OLR’ (1°x1°)

Units: W m^{-2}

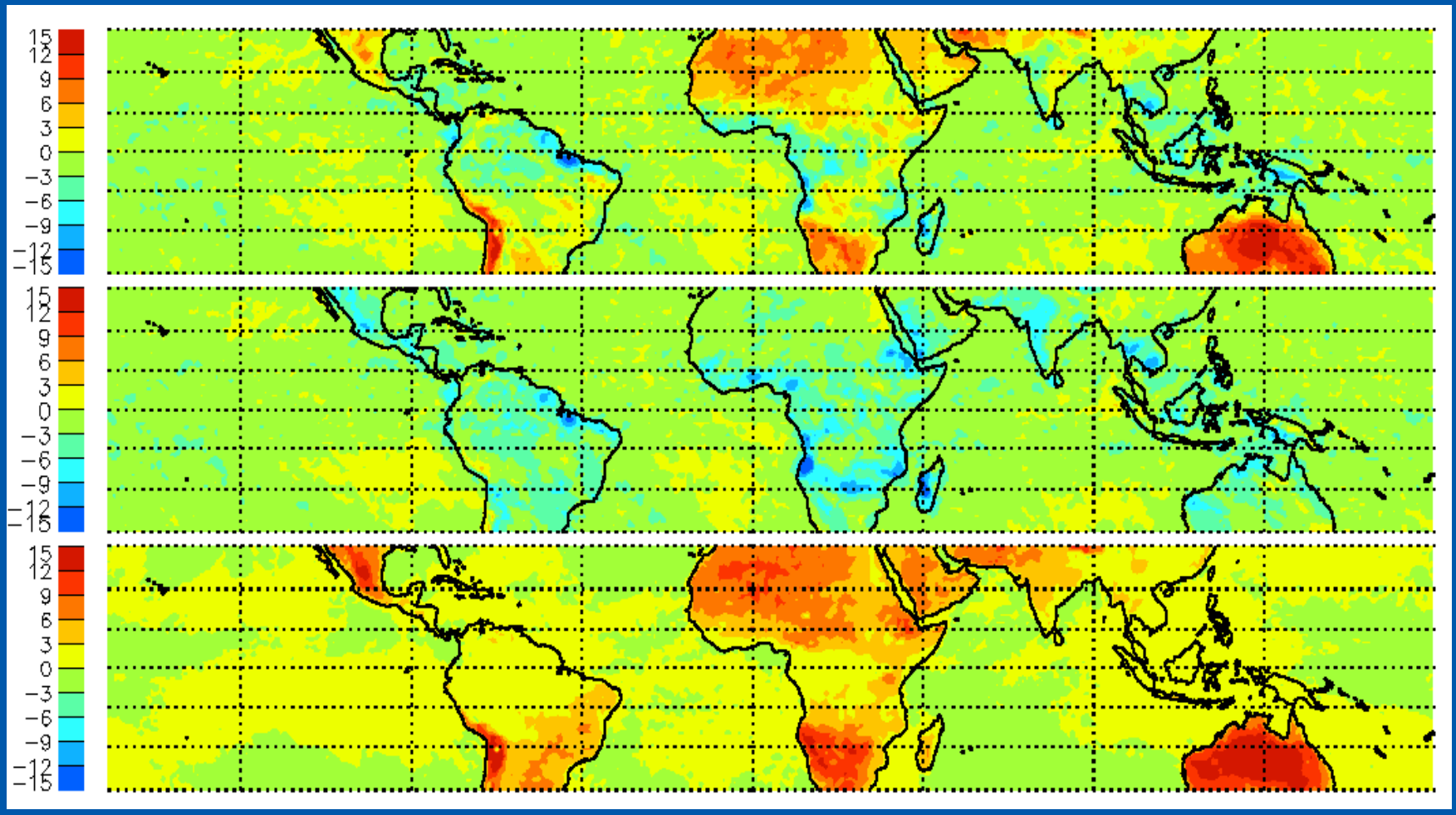


Regional, deseasonalized covariability between diurnal cycle amplitude and monthly flux anomalies is found.

OLR: A'(+1 sigma)-A'(-1 sigma)

Units: W m^{-2}

Taylor (In prep.)



When there is a 1-sigma OLR anomaly there is a also a stronger diurnal cycle amplitude.

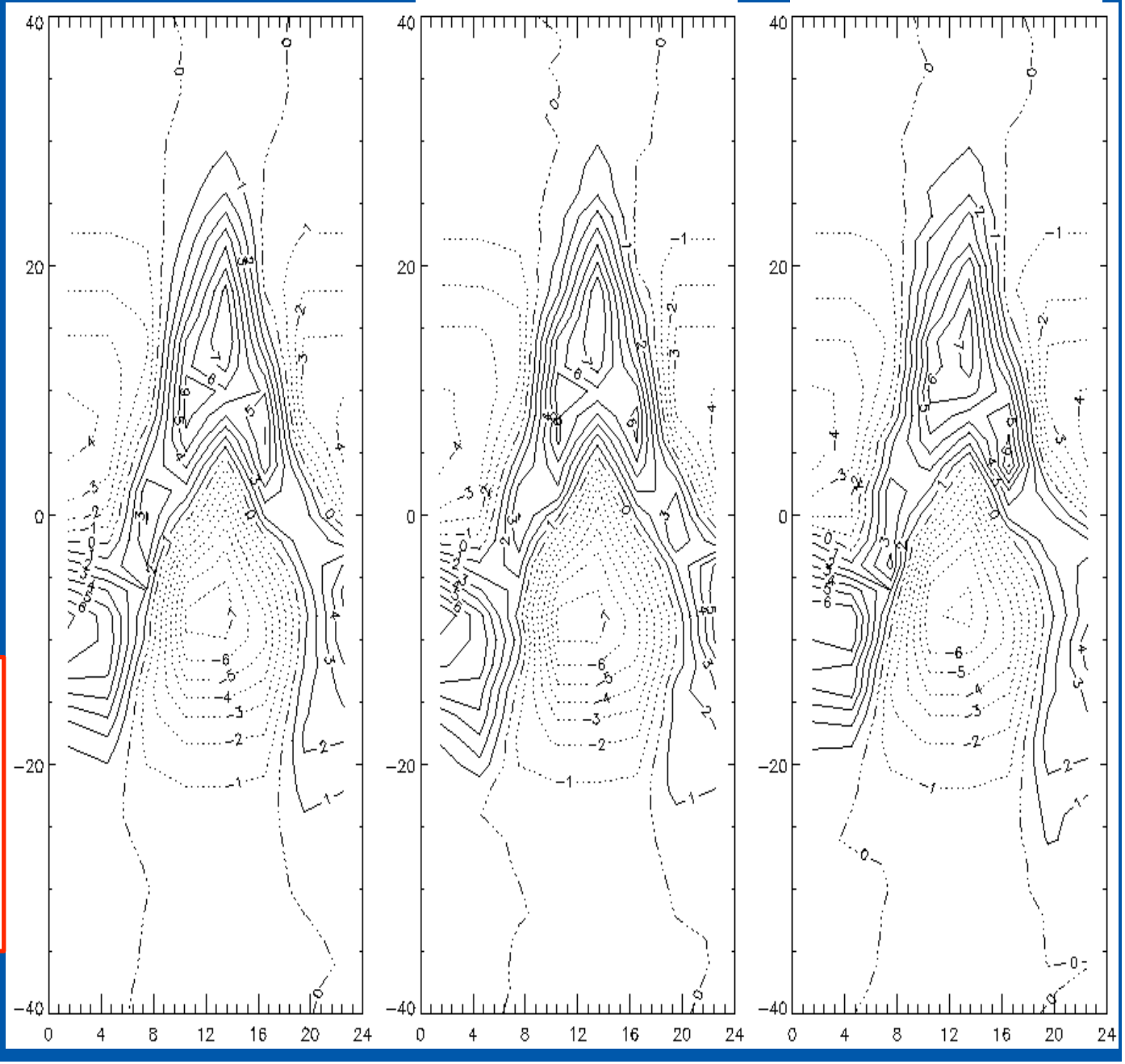
OLR Diurnal Cycle: Dependence on monthly anomaly

Amazon Convective Region
(0-25 S; 290-310 E)

OLR diurnal cycle probabilities are nearly indistinguishable from plus and minus OLR anomalies.

OLR' > +1-sigma

OLR' < -1-sigma



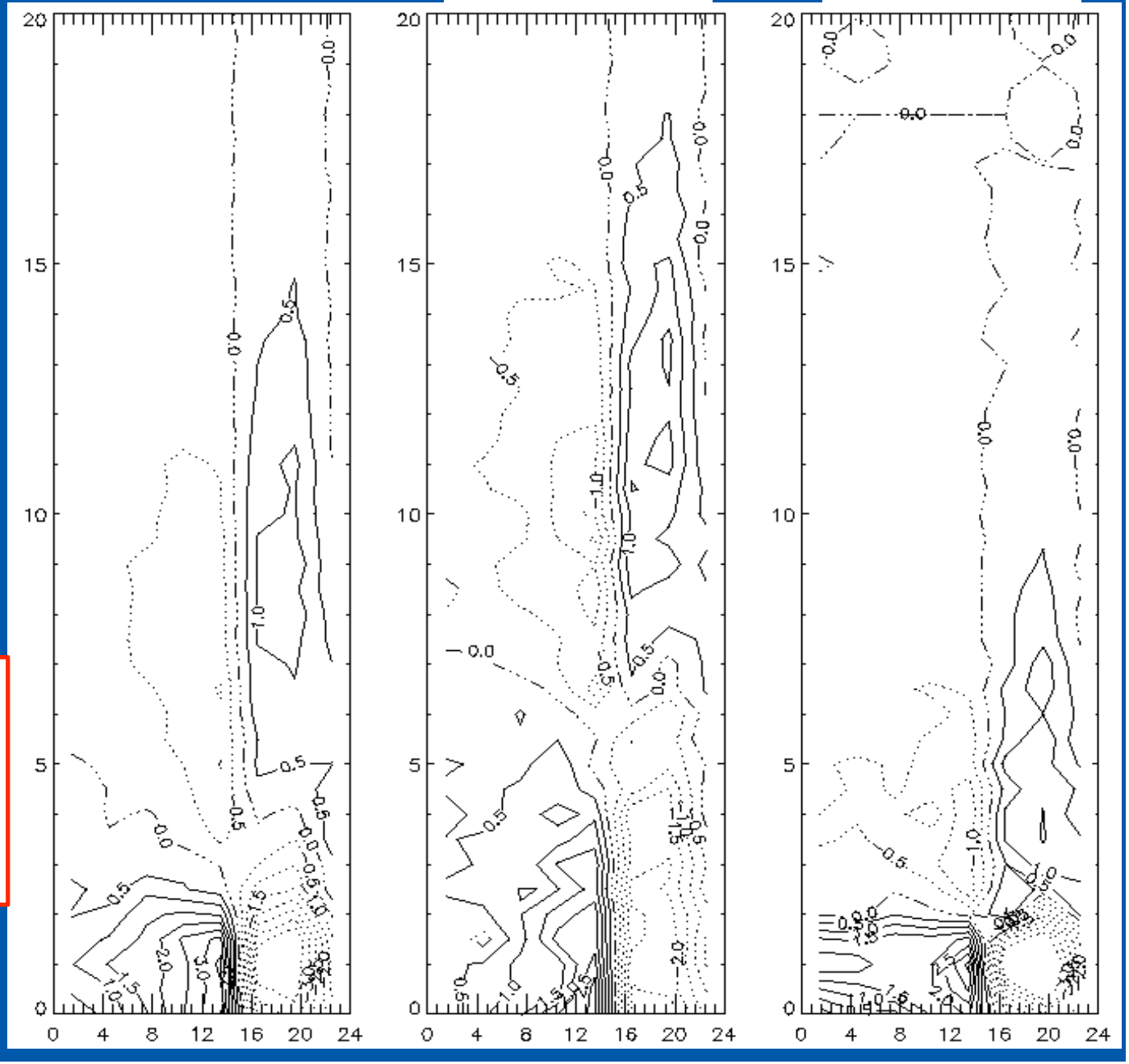
Rain Rate Diurnal Cycle: Dependence on monthly anomaly

Amazon Convective Region
(0-25 S; 290-310 E)

Increased probability of high rain rates between 1600-2000 LST when P'> +1-sigma

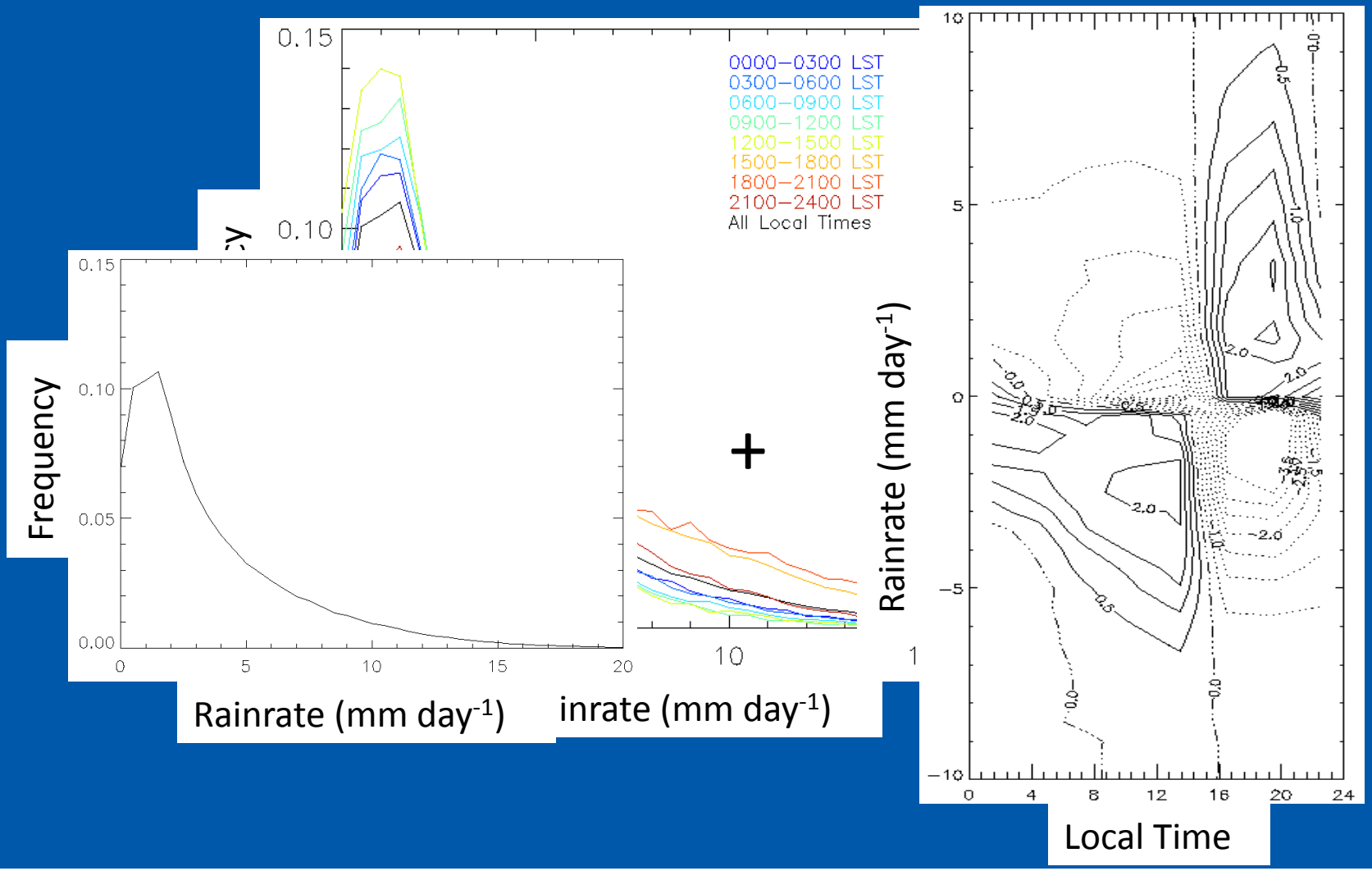
P' > +1-sigma

P' < -1-sigma



Systematic Bias?

$$PDF(hr,x)=PDF(x) + PDF'_{DC}(hr,x)$$



Systematic Bias?

- Monte Carlo Simulation approach
  - P’ > +1-sigma (5.0 mm day^{-1}): replacing with the mean diurnal cycle leads to a 0.5 mm day^{-1} underestimate of the average rain rate.
  - P’ < -1-sigma (2.3 mm day^{-1}): replacing with the mean diurnal cycle leads to a 0.6 mm day^{-1} overestimate of the average rain rate.

Summary and Conclusion

- A “new” perspective on tropical diurnal cycle was discussed.
- Evidence suggests that diurnal cycle variations result from the sensitivity of the cloud response to the diurnal cycle of solar insolation under different atmospheric dynamic and thermodynamic states.
- Using a monte carlo simulation approach one may expect 10-20% systematic biases in convective regions if variations in the diurnal cycle are not considered.
- This may be a useful test of GCM physics analyzing the model response to the solar forcing under different atmospheric conditions.
- Further analysis compositing at the daily level is required.