Monthly Variations in the OLR Diurnal Cycle and its Implication to Monthly OLR Variability

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NASA Langley Research Center
Climate Sciences Branch
CERES Science Team Meeting
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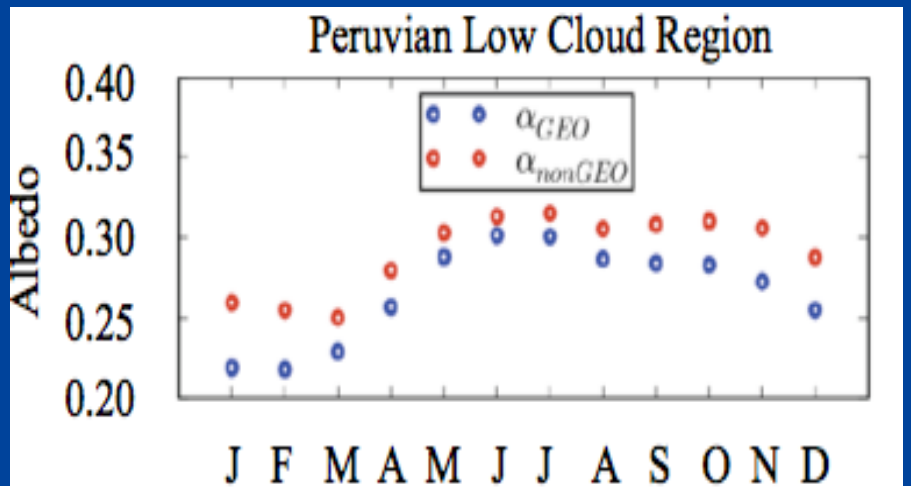
Main Points

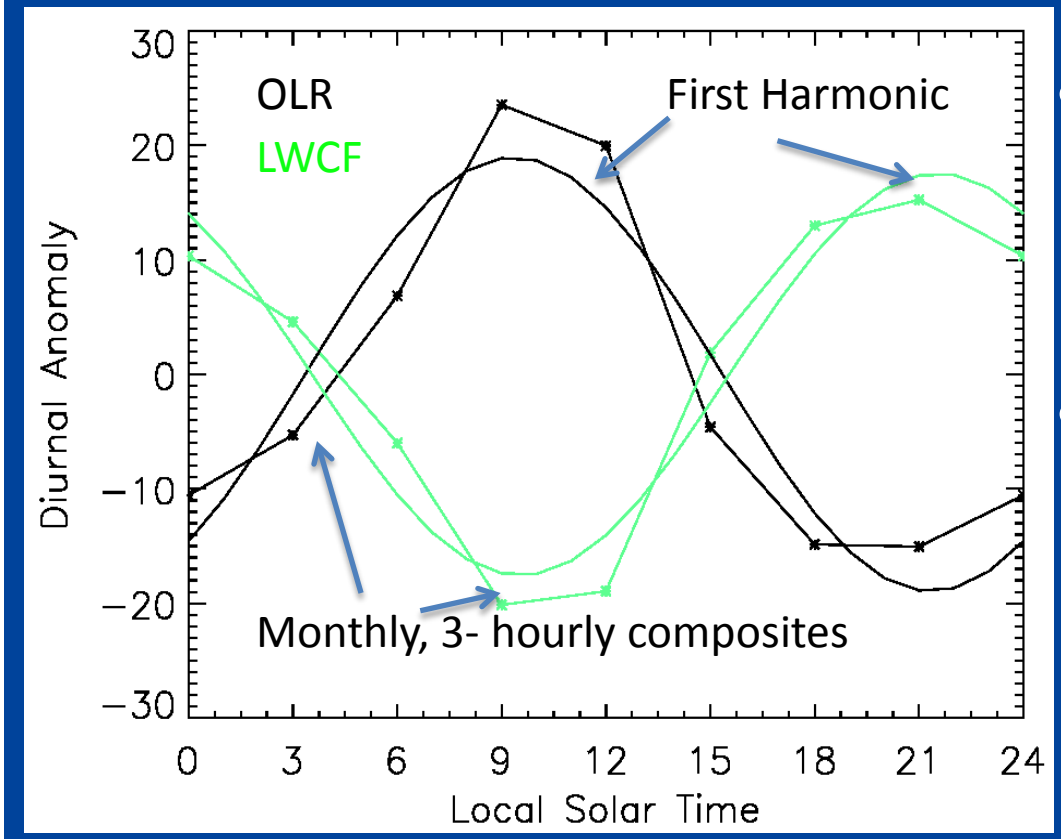
- Studying OLR variability is important for understanding the climate system and its response to natural and anthropogenic forcing.
- Monthly variability in the OLR diurnal cycle is strongest in land convective and desert regions.
- Significant correlations are found between OLR diurnal cycle amplitude and OLR anomalies at monthly timescales.
- Month-to-month variations in the OLR diurnal cycle shape contributes as much as 50% to the overall OLR variance in land convective regions.
- However, monthly OLR diurnal cycle shape contributions to OLR variability reduce to less than 20% when the spatial scale increases to 10°x10°.

Why Study Diurnal Cycle?

- The diurnal cycle is fundamental to earth system variability, because it places significant constraints on the behavior of
  - (1) atmospheric convection (and precipitation)
  - (2) surface temperature variability
  - (3) overall cloud behavior.
- Diurnal cycle leads to differences in the Earth Radiation budget and climate contrasted against a climate with different diurnal cycle characteristics or no diurnal cycle, especially in MSc and Land Convective Regions.
  - Bergman and Salby (1997) 5-15 W m^{-2} and 1-5 W m^{-2} errors in the time mean RSW and OLR, respectively.
  - Loeb et al. (2009) quote errors up to 30 W m^{-2} if diurnal cycle is neglected.



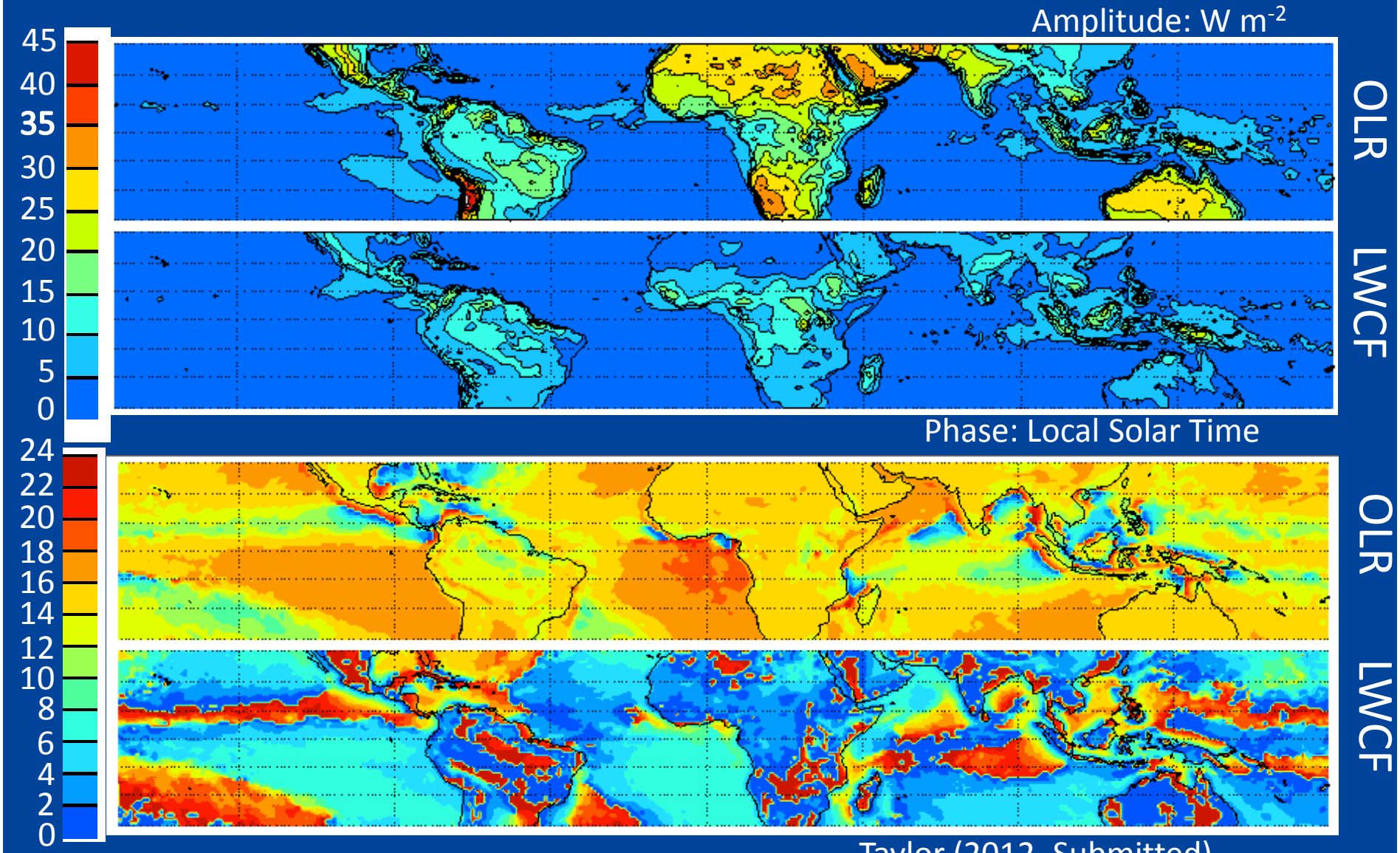
Data/Methodology



$$X'(t) = A\cos\left(\frac{2\pi t}{24hrs} - \phi\right)$$

- CERES Synoptic Data
  - 3-hourly CERES-Geo merged data product.
- Fourier Analysis is used to compute diurnal harmonics.

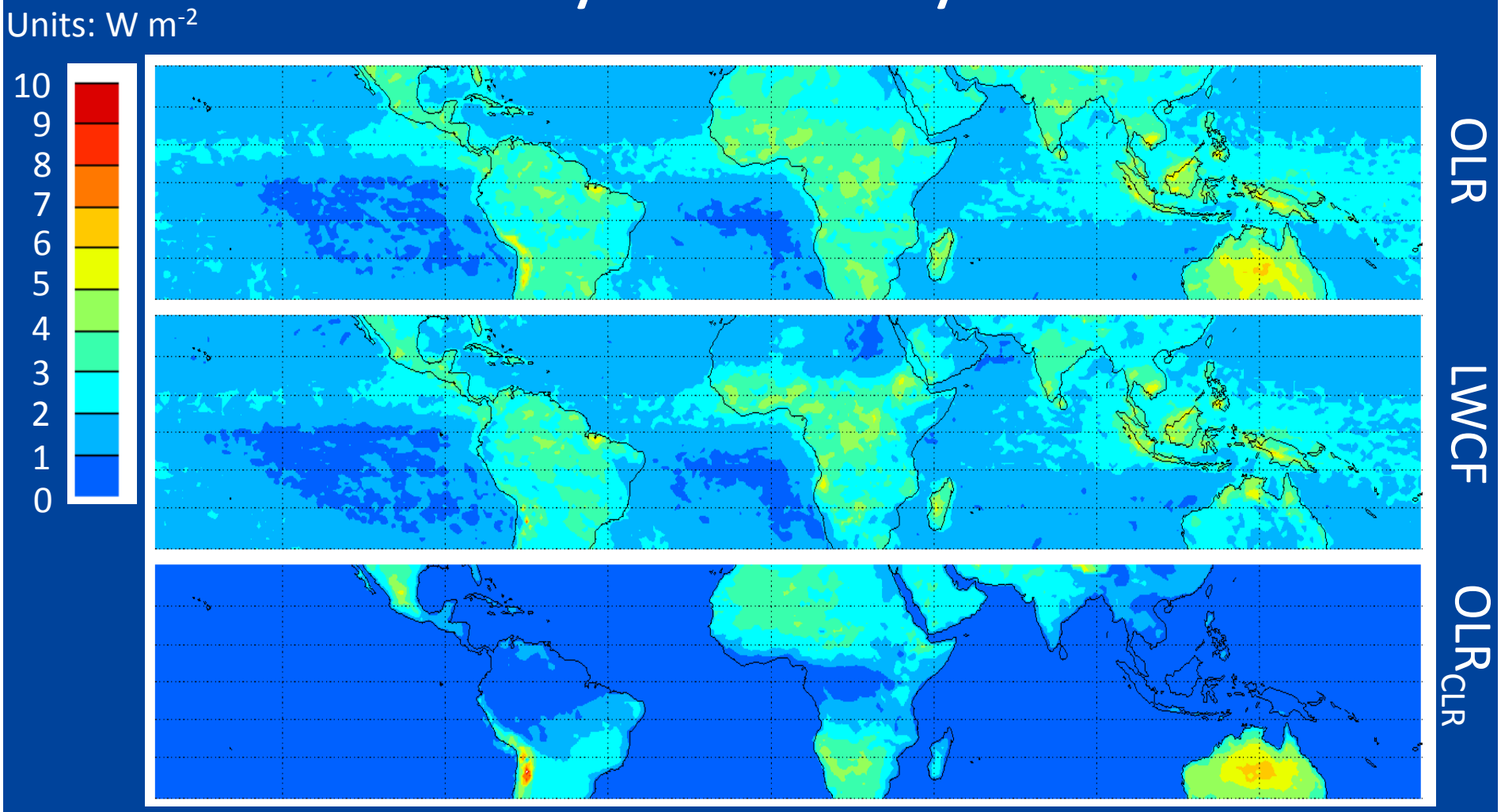
CERES Climatology



Taylor (2012, Submitted)

Does OLR Diurnal Cycle Vary?

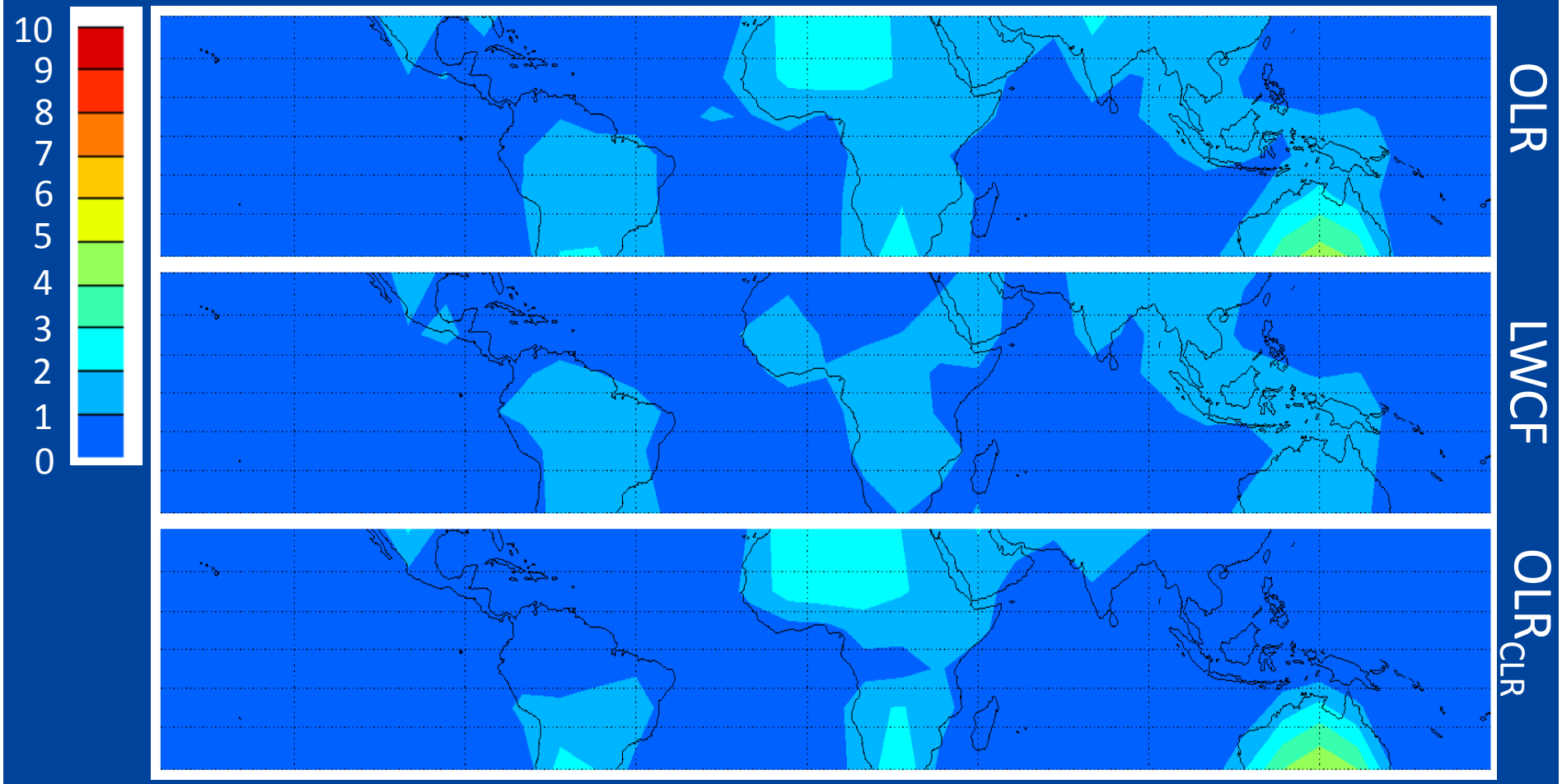
Diurnal Cycle Amplitude Monthly Variability: 1°x1°



Taylor and Loeb (In prep.)

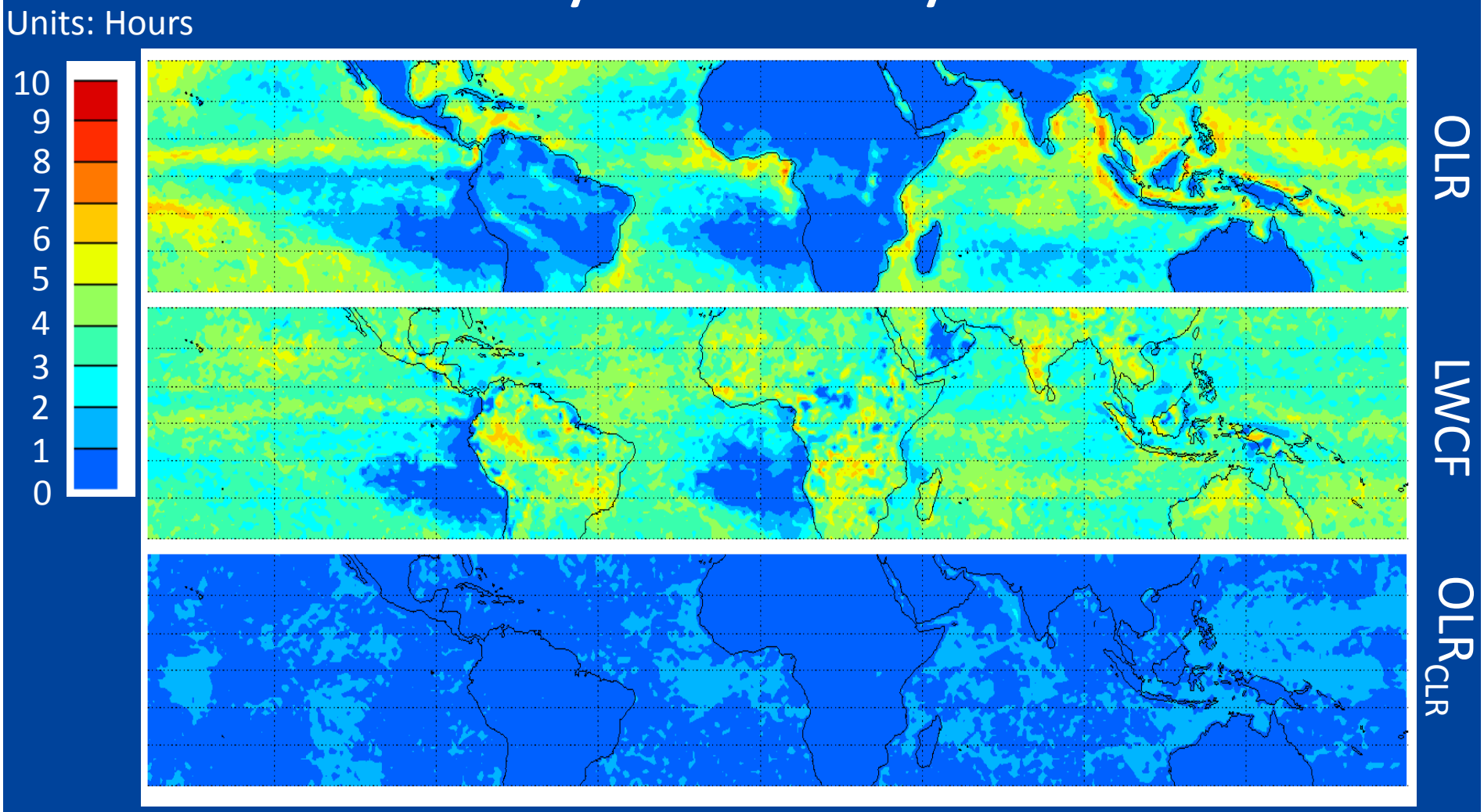
OLR Diurnal Cycle Amplitude Monthly Variability: 10°x10°

Units: W m^{-2}



Taylor and Loeb (In prep.)

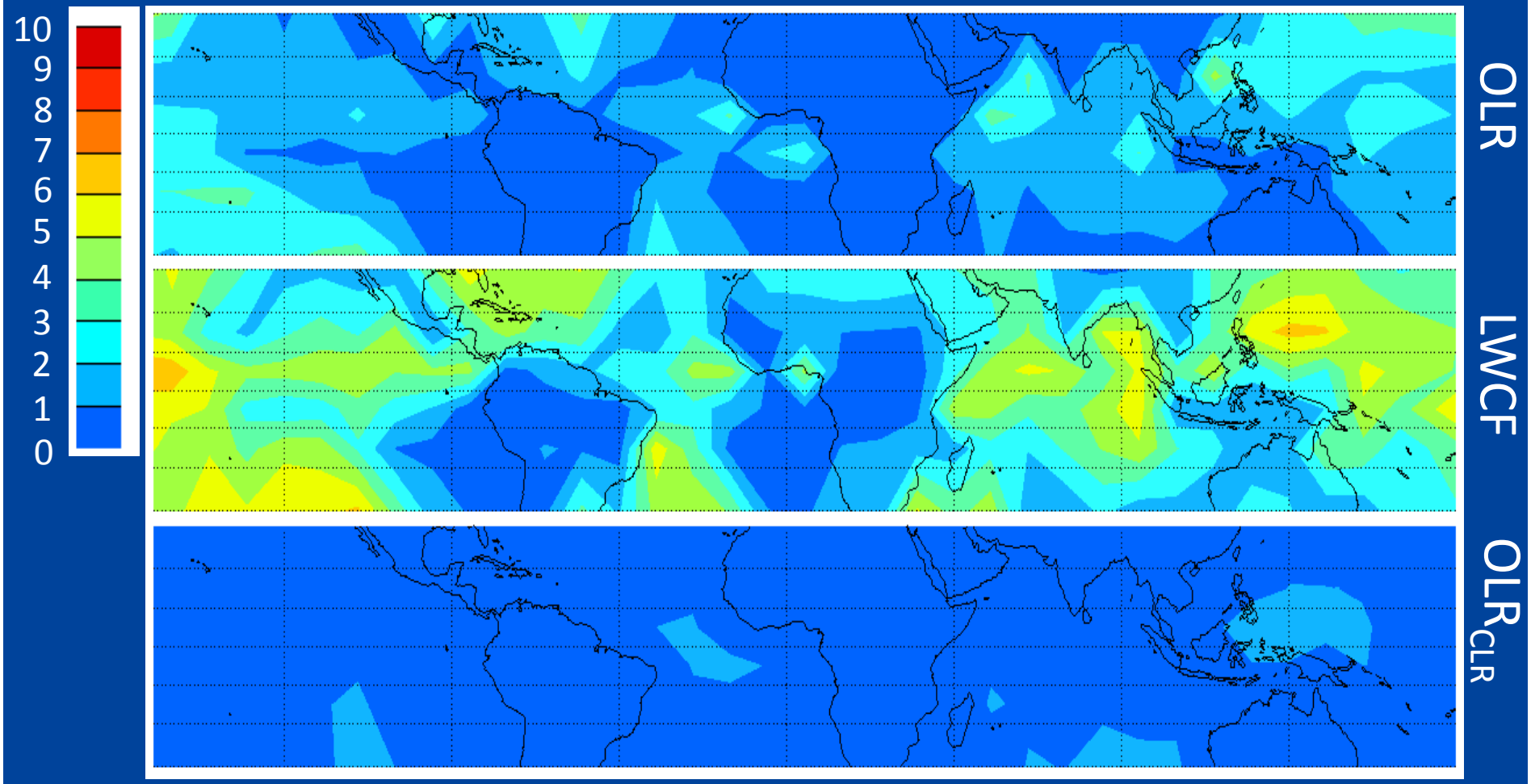
Diurnal Cycle Phase
Monthly Variability: 1°x1°



Taylor and Loeb (In prep.)

Diurnal Cycle Phase
Monthly Variability: 10°x10°

Units: Hours



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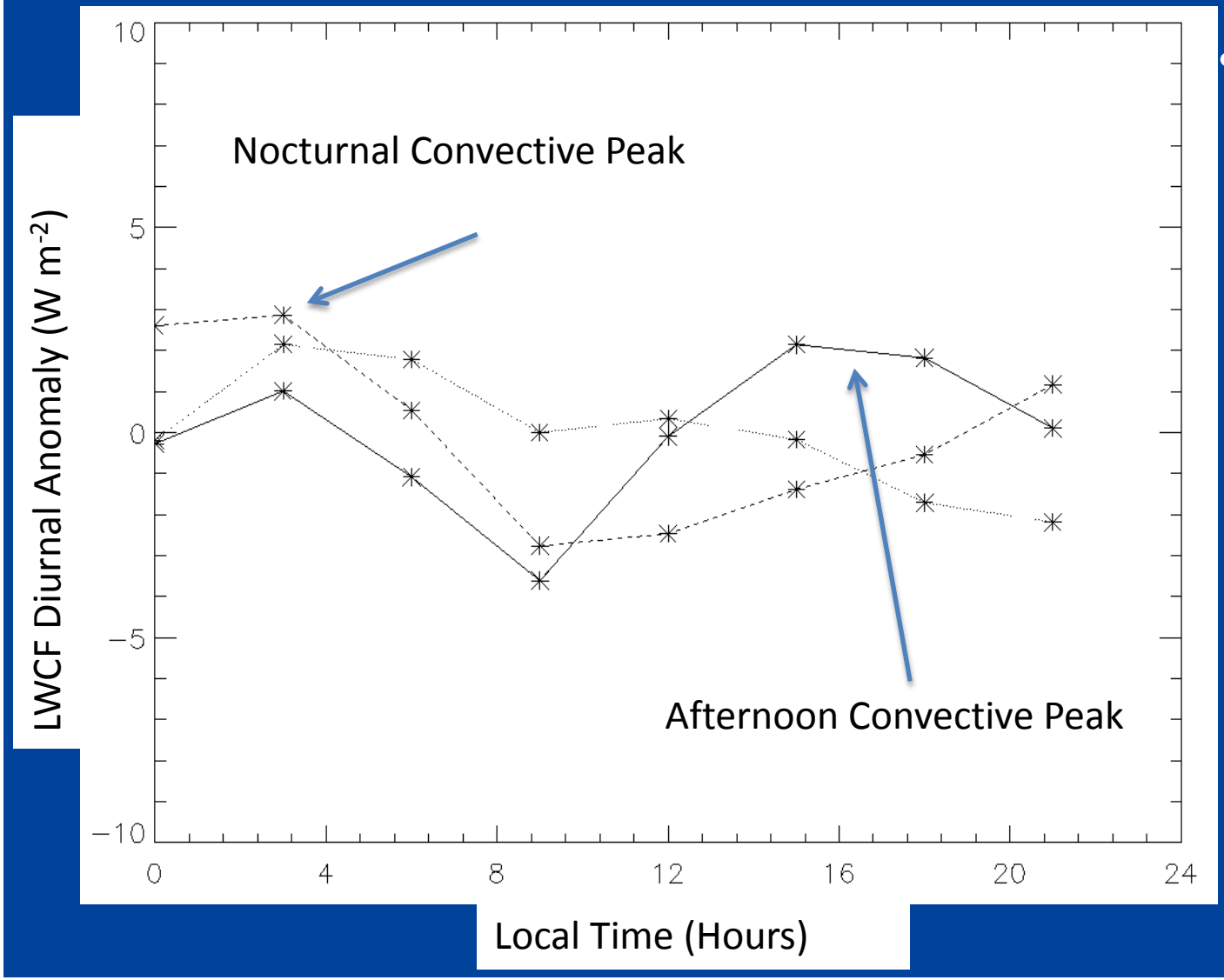
LWCF phase variability over ocean?

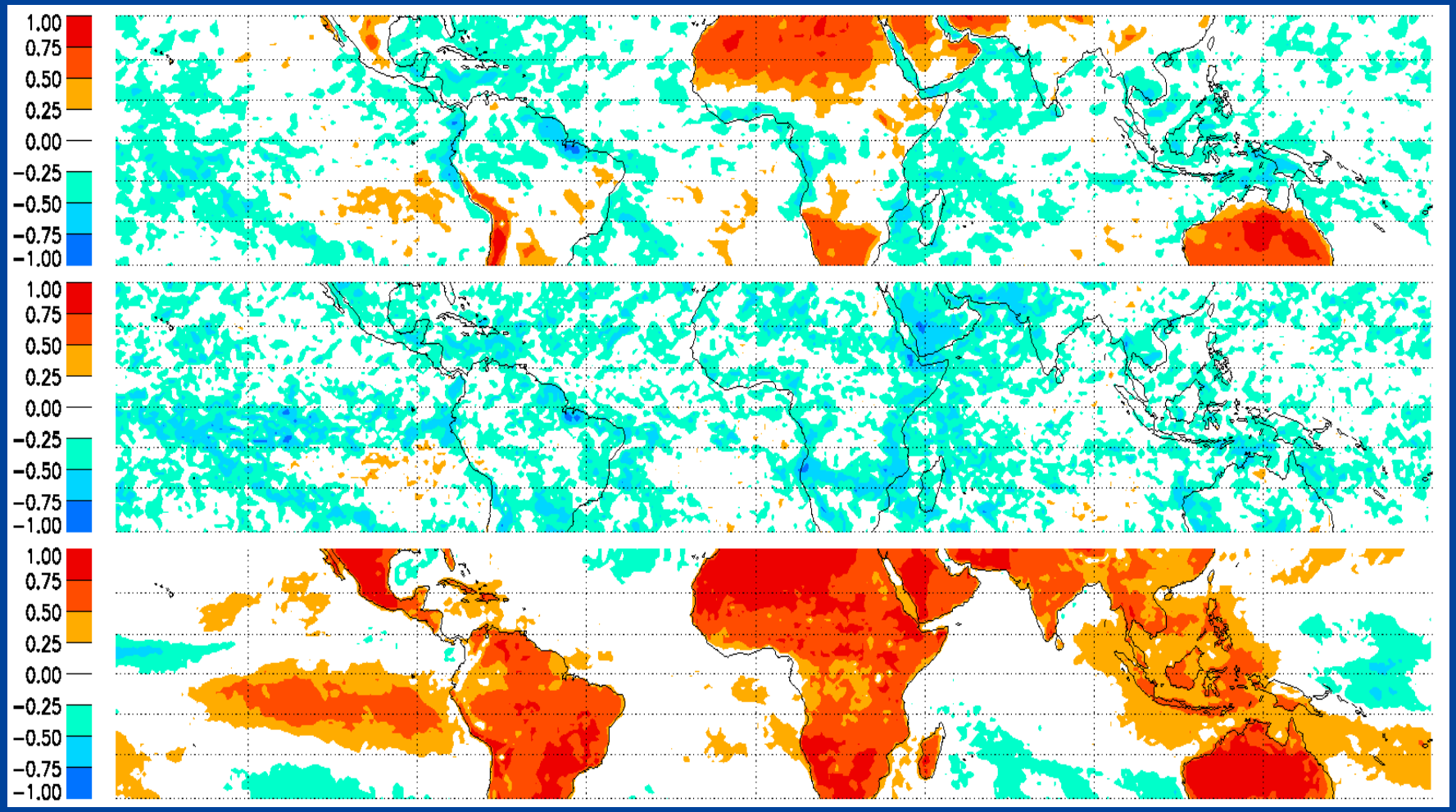


- Significant LWCF diurnal cycle phase variations are controlled by the relative importance of afternoon convective showers versus nocturnal convective systems to monthly LWCF.

Does OLR diurnal cycle variability correlate with OLR anomalies?

Correlation: A' vs. OLR'
1°x1°

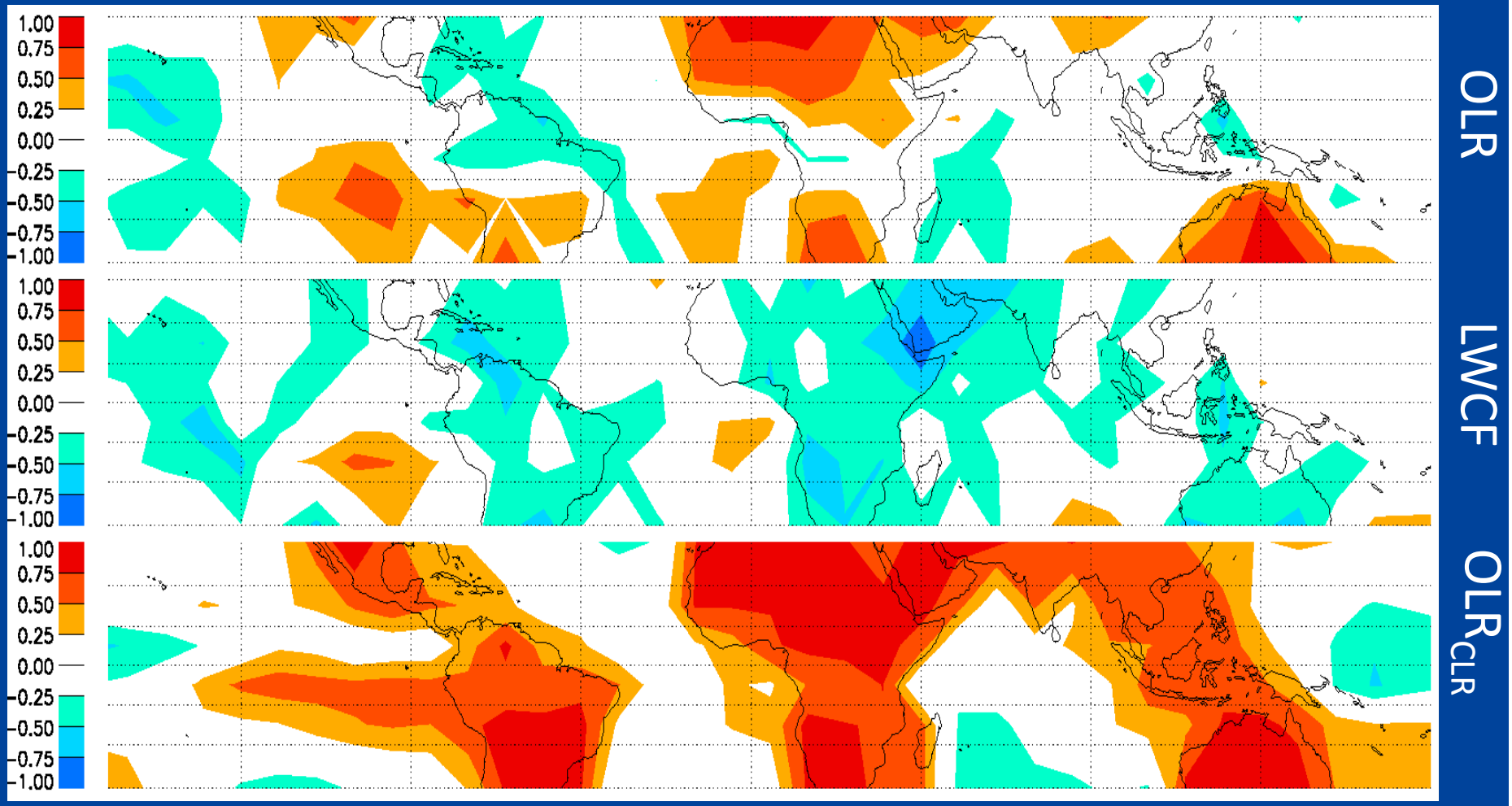
Units: W m^{-2}



Taylor and Loeb (In prep.)

Correlation: A' vs. OLR'
10°x10°

Units: W m^{-2}

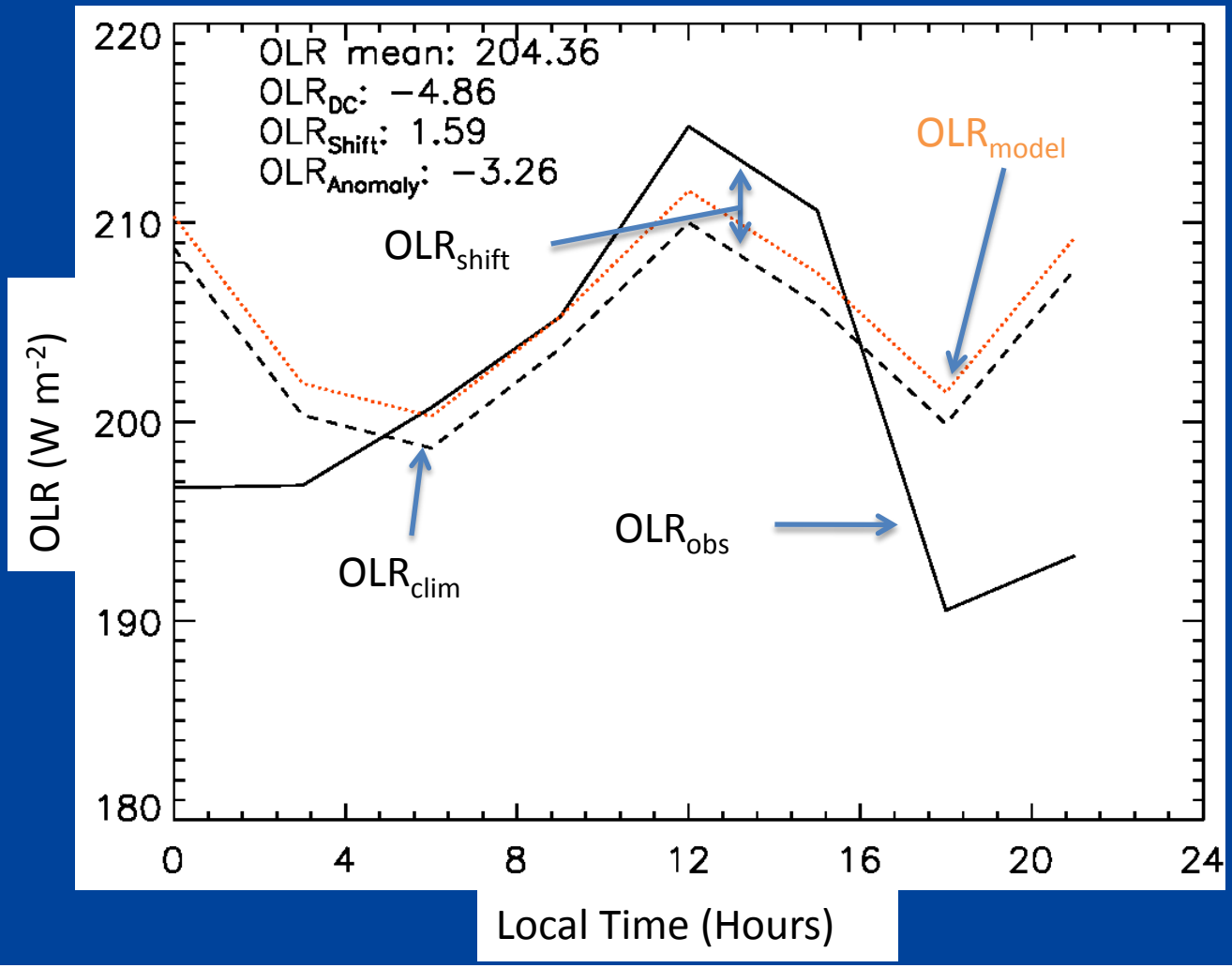


Taylor and Loeb (In prep.)

Quantifying diurnal shape contributions to OLR'

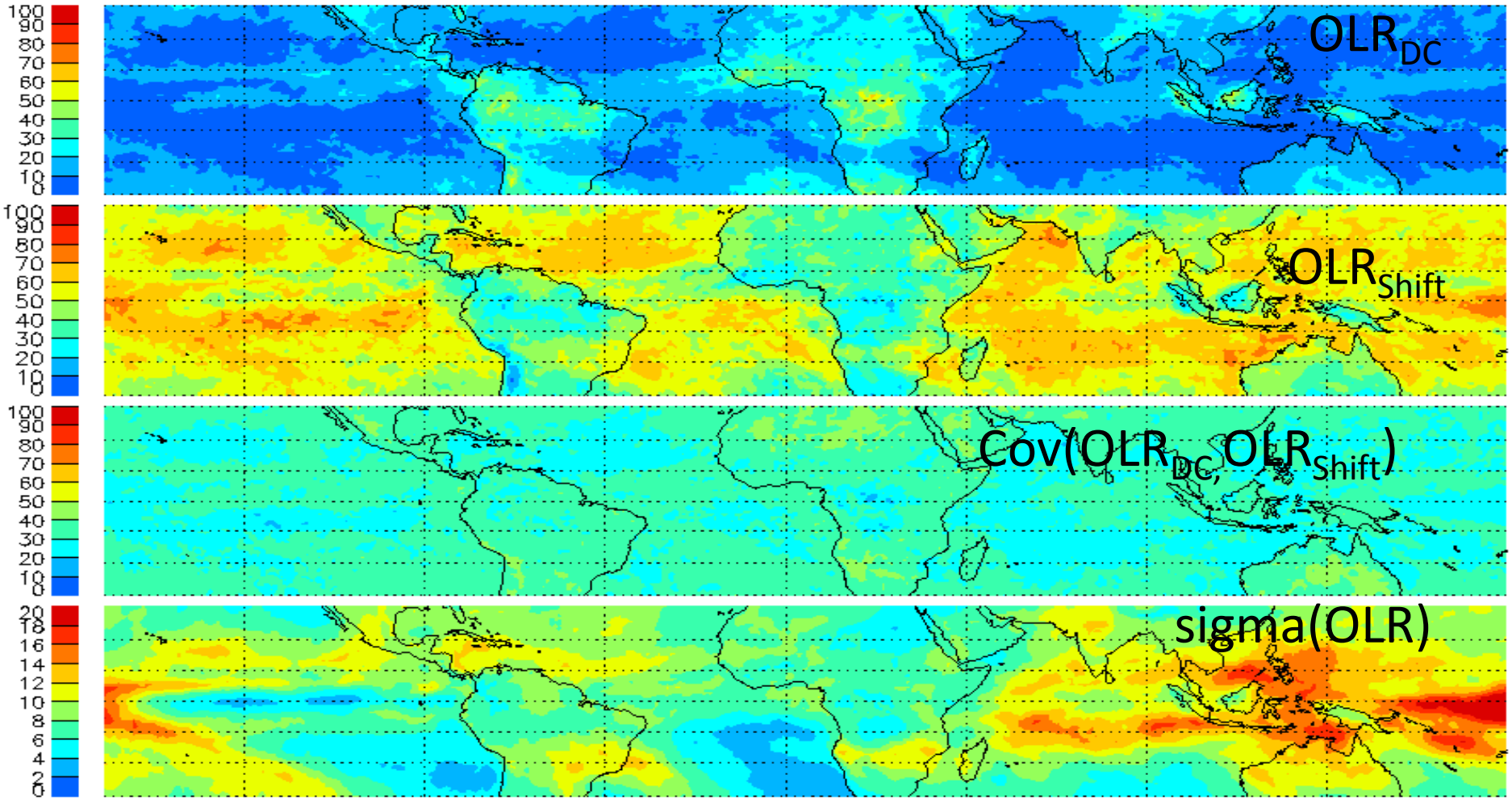
$$OLR_{model}(t) = OLR_{clim}(t) + \delta OLR_{shift}$$

$$\delta OLR_{dc} = \overline{OLR_{obs}(t)} - \overline{OLR_{model}(t)}$$



Contributions to Monthly OLR variability: 1°x1°

Units: % Variance Explained

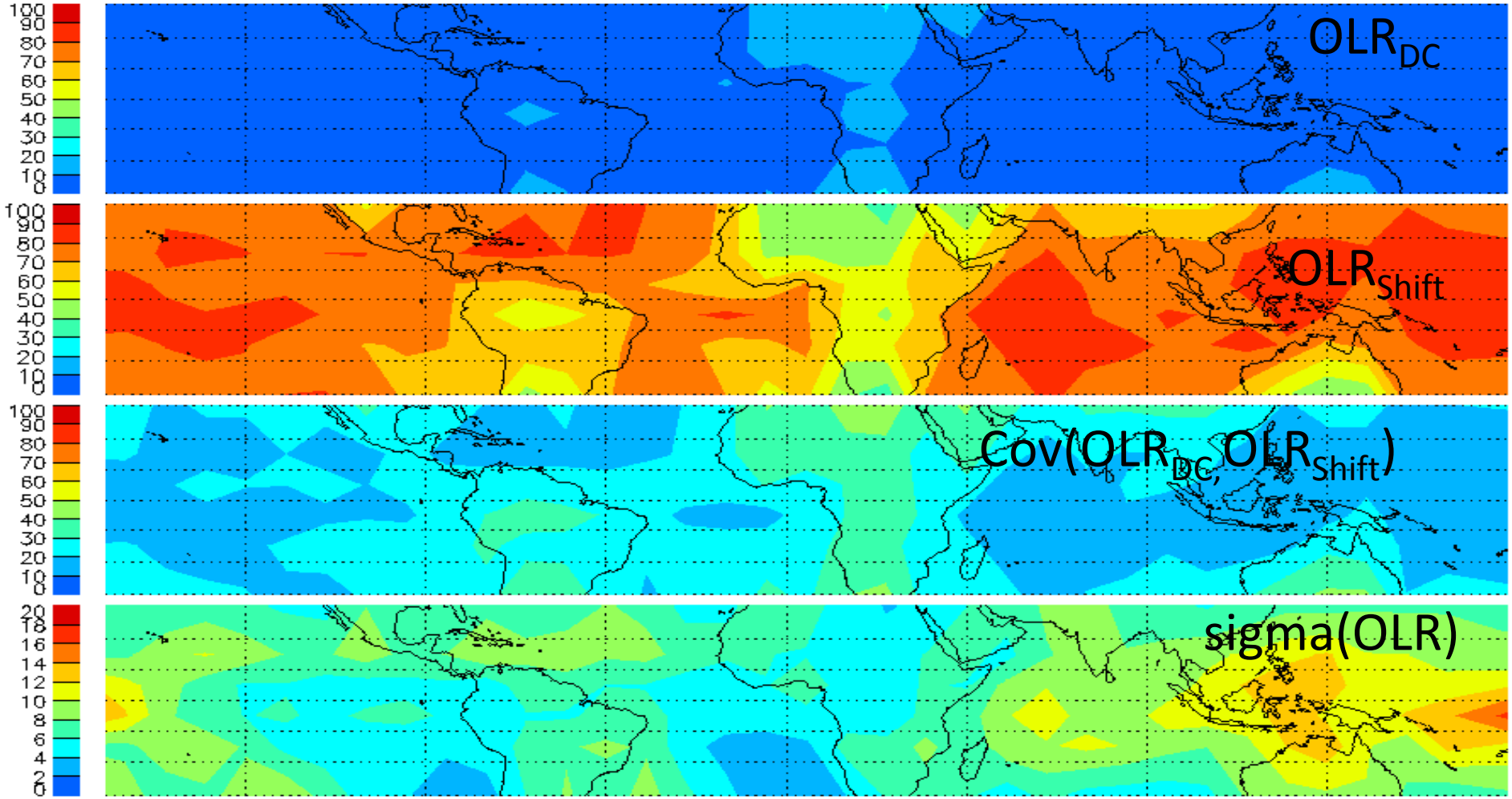


$$OLR'^2 = \delta OLR_{shift}^2 + \delta OLR_{dc}^2 + \mathrm{cov}(\delta OLR_{shift}, \delta OLR_{dc})$$

Taylor and Loeb (In prep.)

Contributions to Monthly OLR variability: 10°x10°

Units: % Variance Explained



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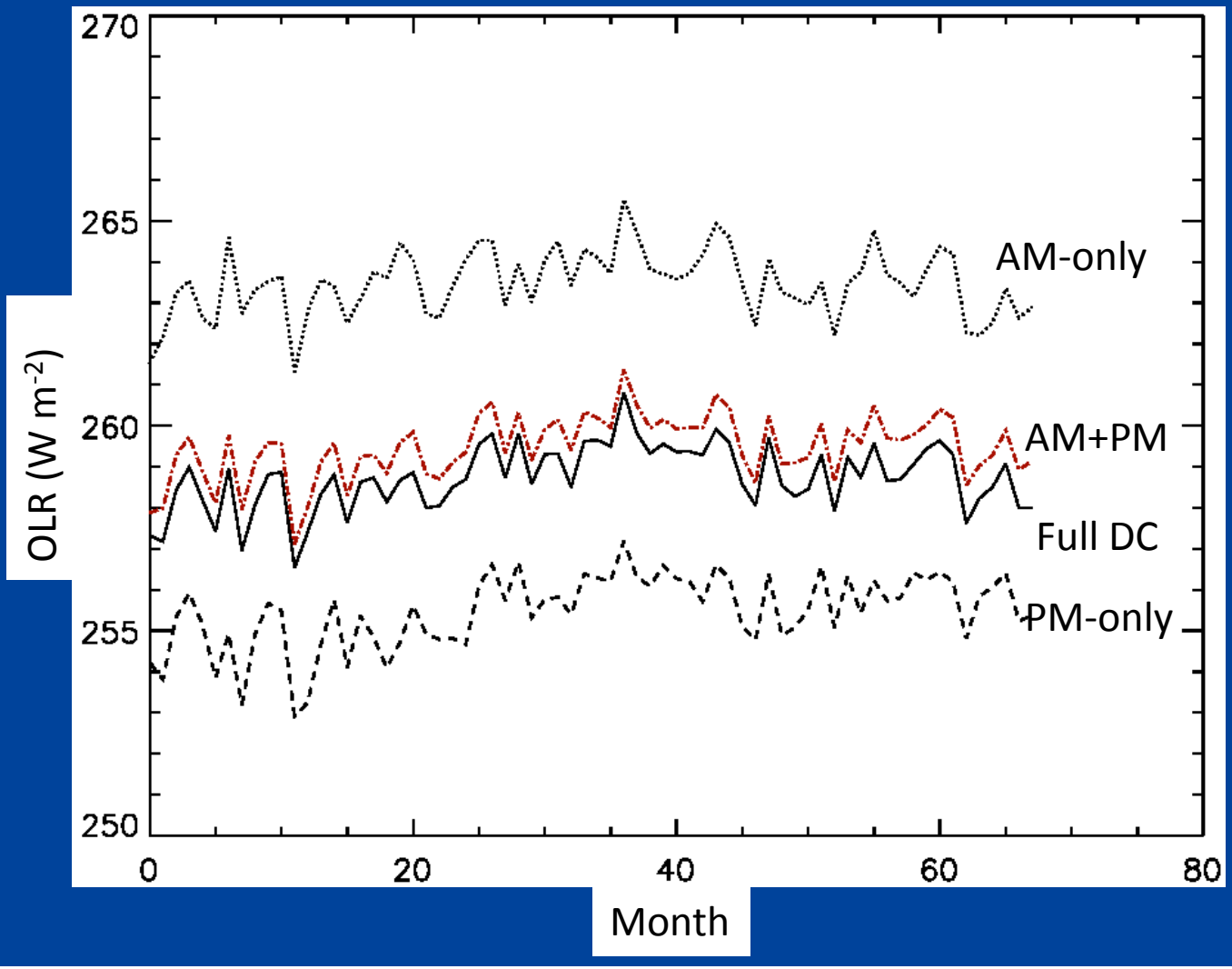
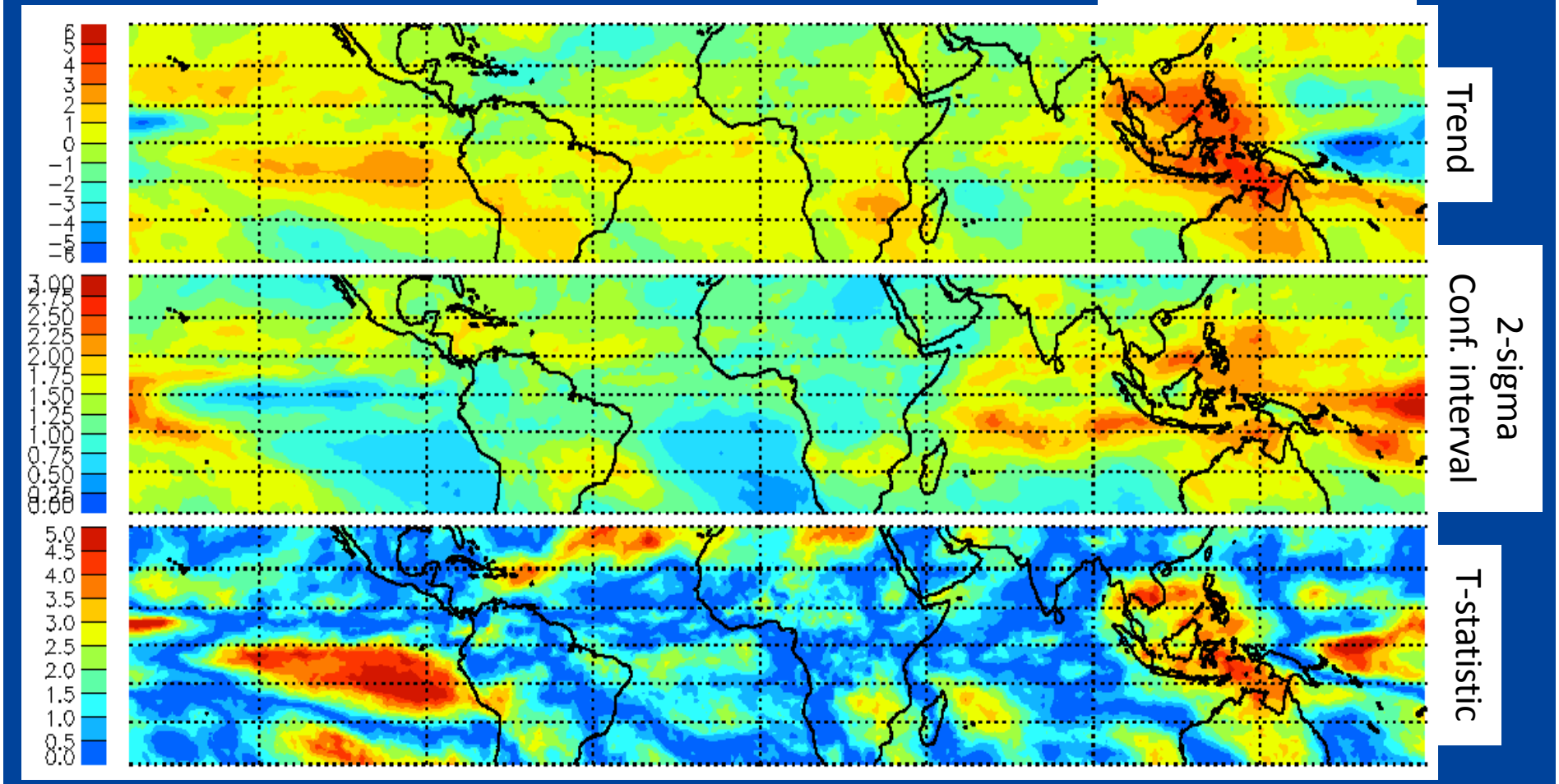
Implications for sun-synchronous sampling of OLR variability

What are the implications for satellite sampling of the ERB?



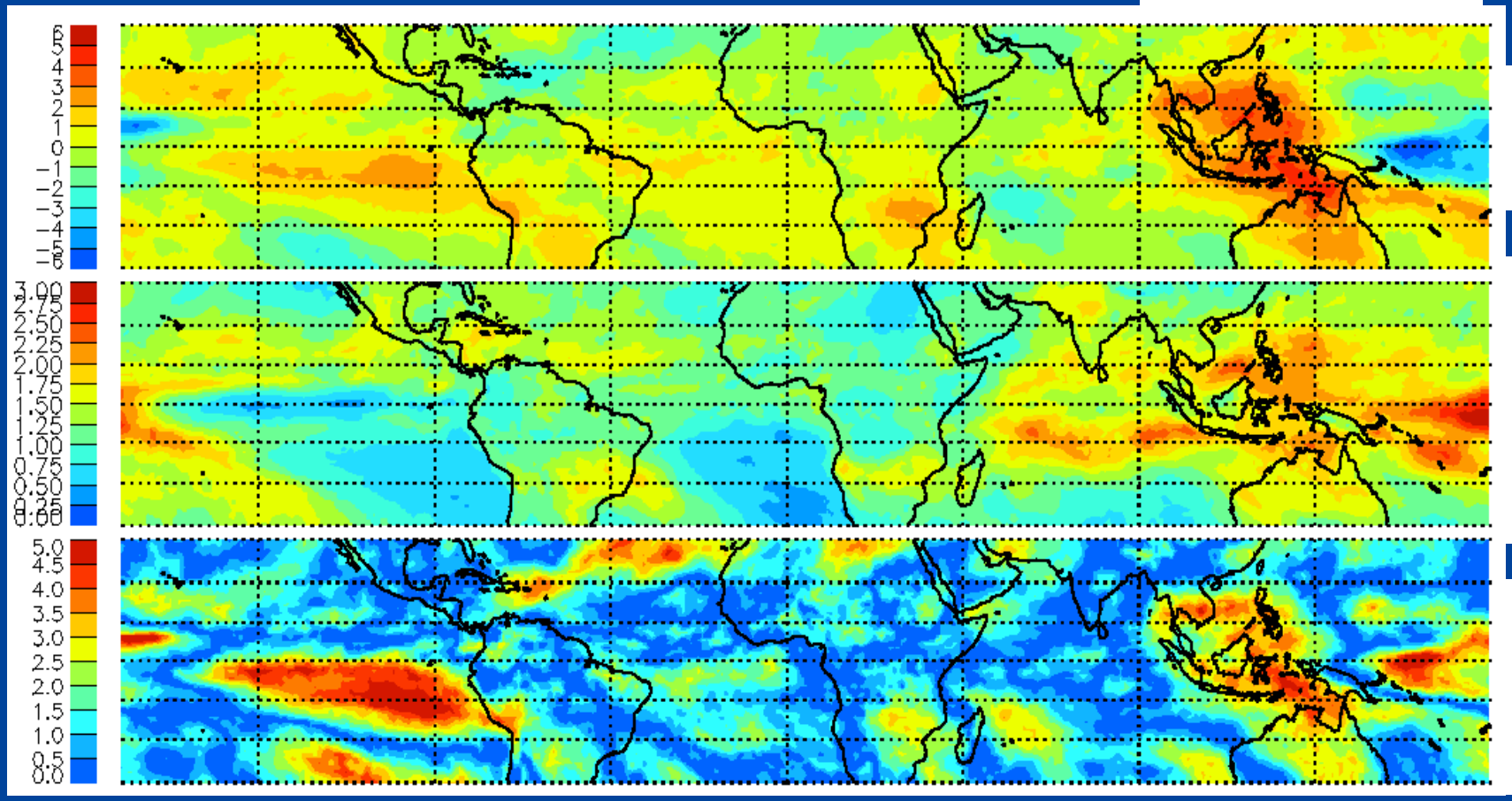
Regional 68-Month OLR Trends: Full Diurnal Sampling

Units: W m^{-2} yr^{-1}

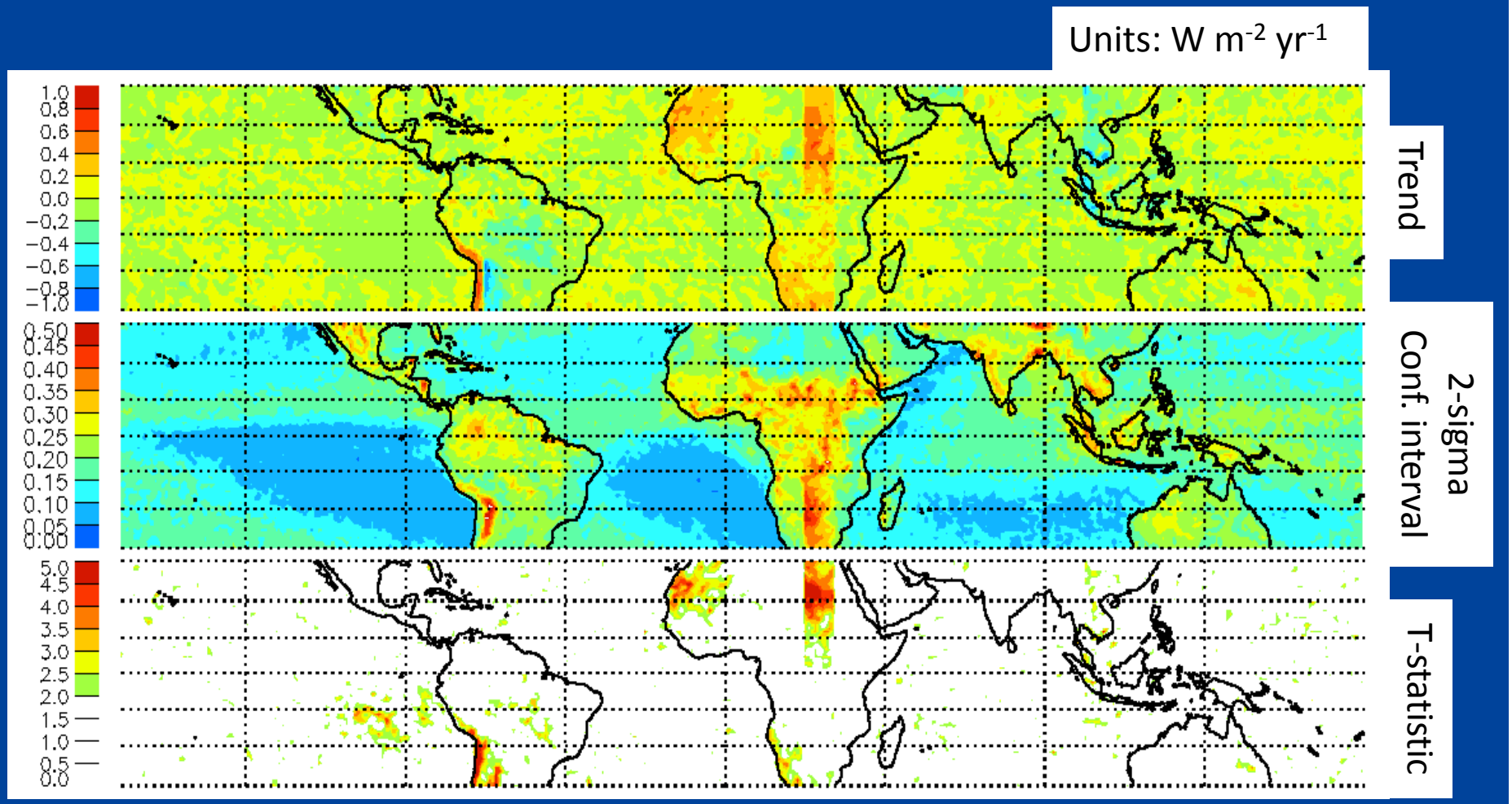


Regional 68-Month OLR Trends: Sun Synchronous Sampling (Terra)

Units: W m^{-2} yr^{-1}



Regional 68-month OLR difference trends: Terra minus Full DC



68-month Tropical Mean OLR Trends

	Full DC	AM-Only	PM-Only	AM+PM
Slope ($W\ m^{-2}\ yr^{-1}$)	0.16	0.07	0.29	0.18
2-sigma conf.	0.12	0.12	0.12	0.11
T-stat	2.7	1.2	4.7	3.6

Difference	AM-Only	PM-Only	AM+PM
Slope ($W\ m^{-2}\ yr^{-1}$)	-0.10	0.13	0.02
2-sigma conf.	0.06	0.04	0.02
T-stat	3.3	6.5	1.4
Stdev	0.42	0.38	0.15
f^2	0.27	0.22	0.03

$$\Delta t = \left[\frac{12s^2}{m_{\mathrm{est}}^2}\sigma_{\mathrm{var}}^2\tau_{\mathrm{var}}\right]^{1/3}(1+f^2)^{1/3},$$

$$f^2 = (\sigma_{\mathrm{meas}}^2\tau_{\mathrm{meas}})/(\sigma_{\mathrm{var}}^2\tau_{\mathrm{var}}).$$

Leroy et al. (2008)

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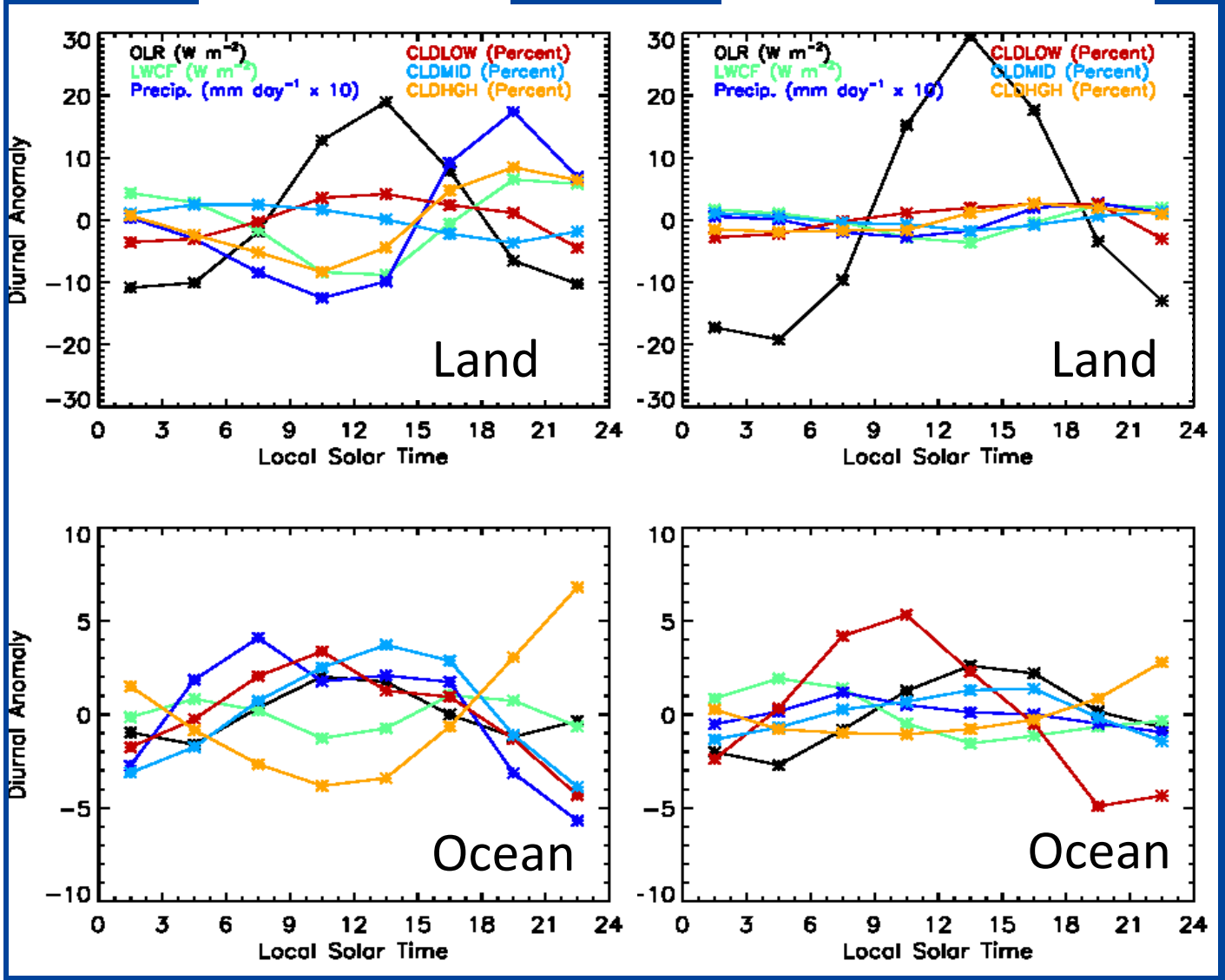
Diurnal Cycle Regime Composites

Convective | Non-Convective

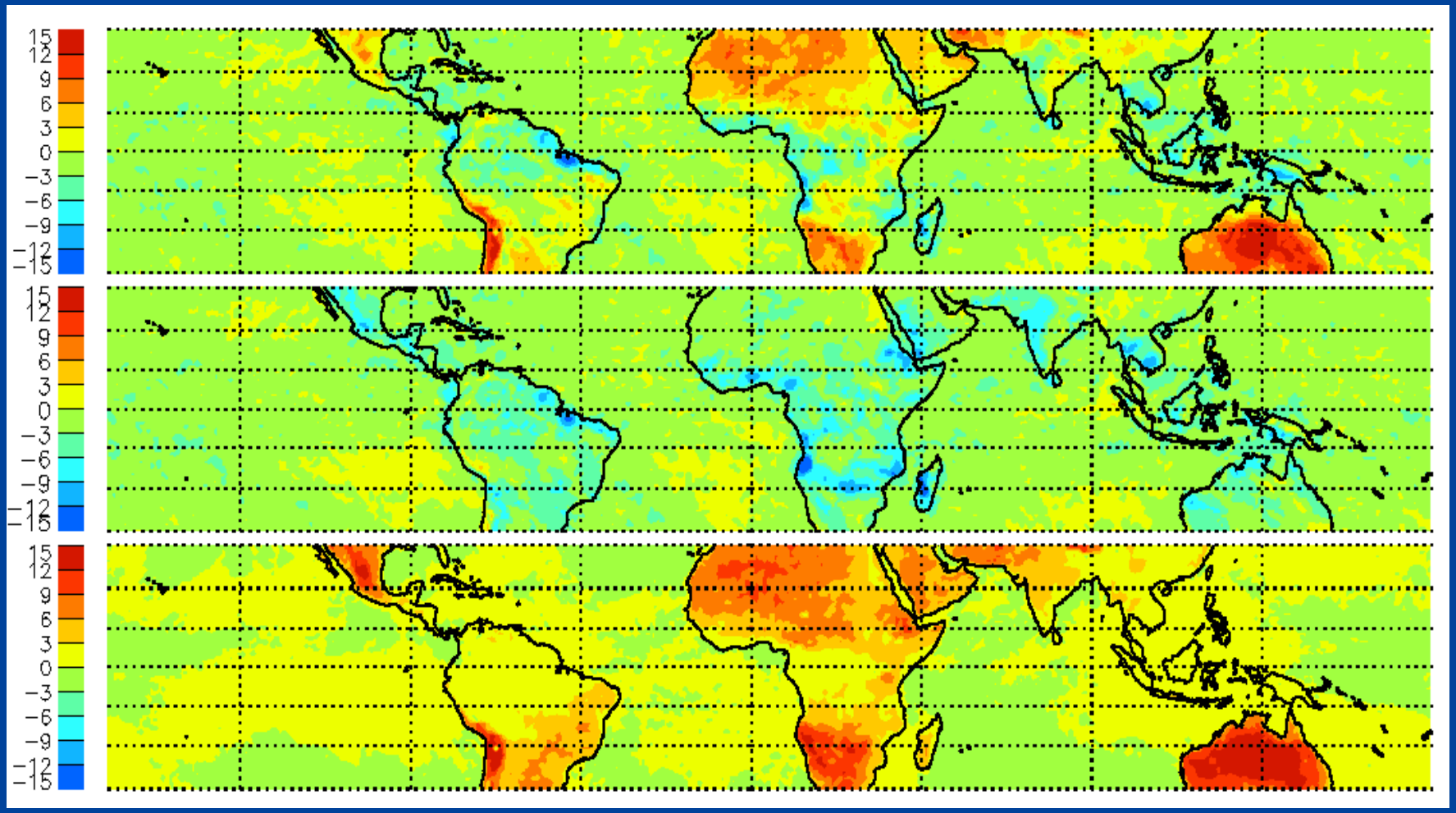


- Convective and non-convective regimes are determined using climatological High Cloud amount (e.g., Bergman and Salby 1996).

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

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

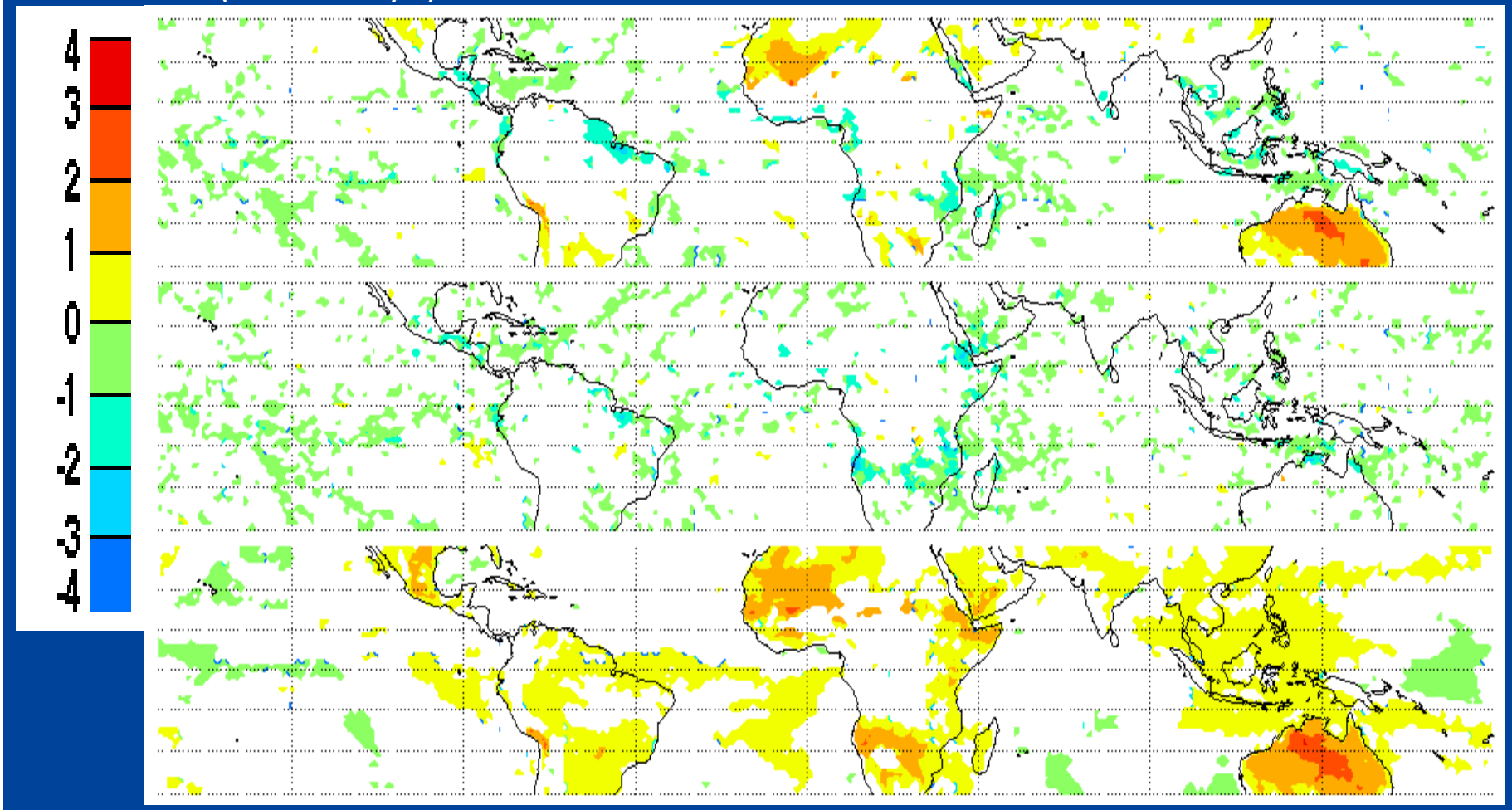
Units: W m^{-2}



Taylor and Loeb (In prep.)

OLR Diurnal Cycle Amplitude Sensitivity to 500 hPa Omega

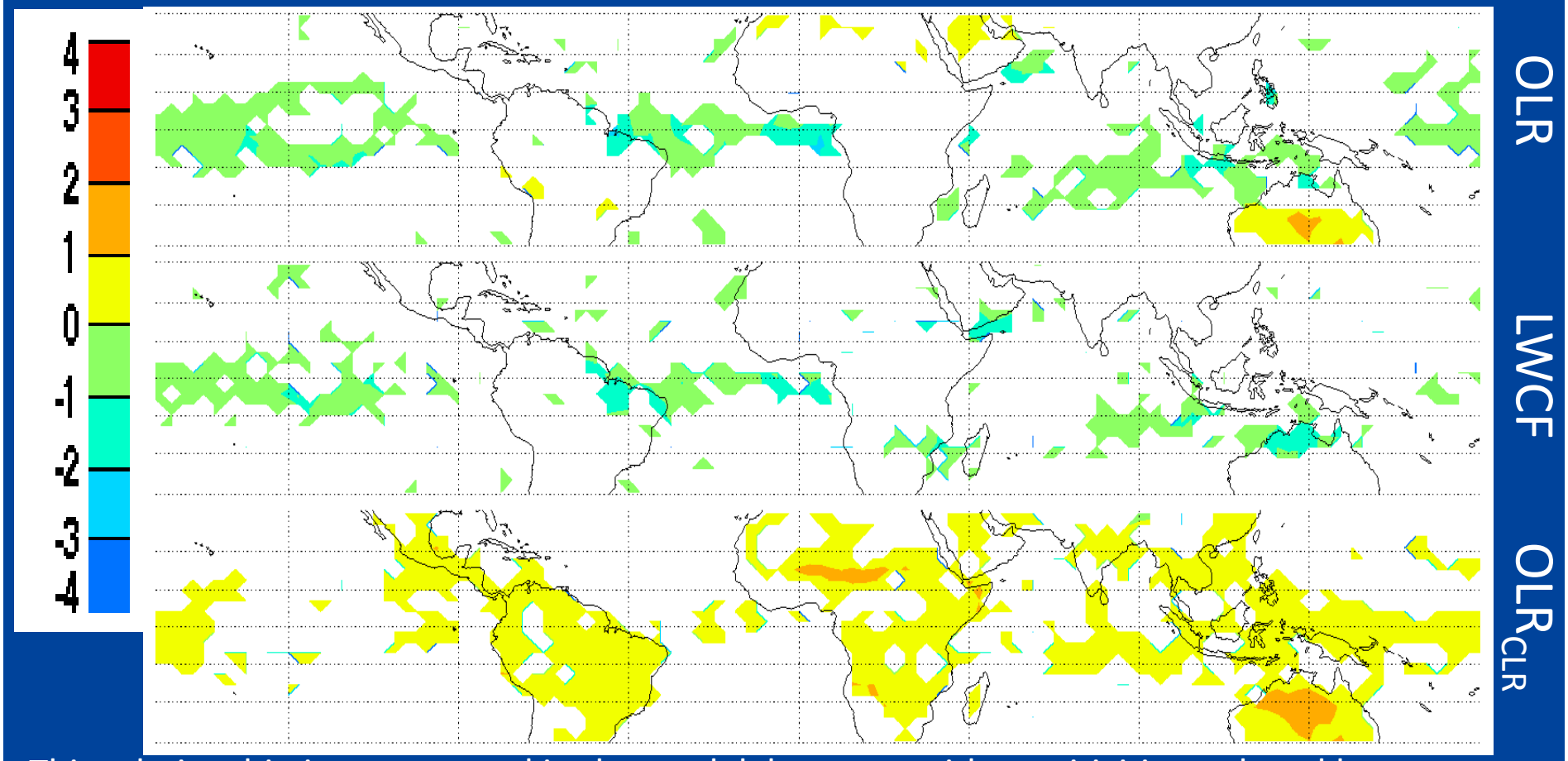
Units: W m^{-2} (10 hPa day^{-1})$^{-1}$



Taylor (In prep.)

OLR Diurnal Cycle Amplitude Sensitivity to 500 hPa Omega: CanAM4

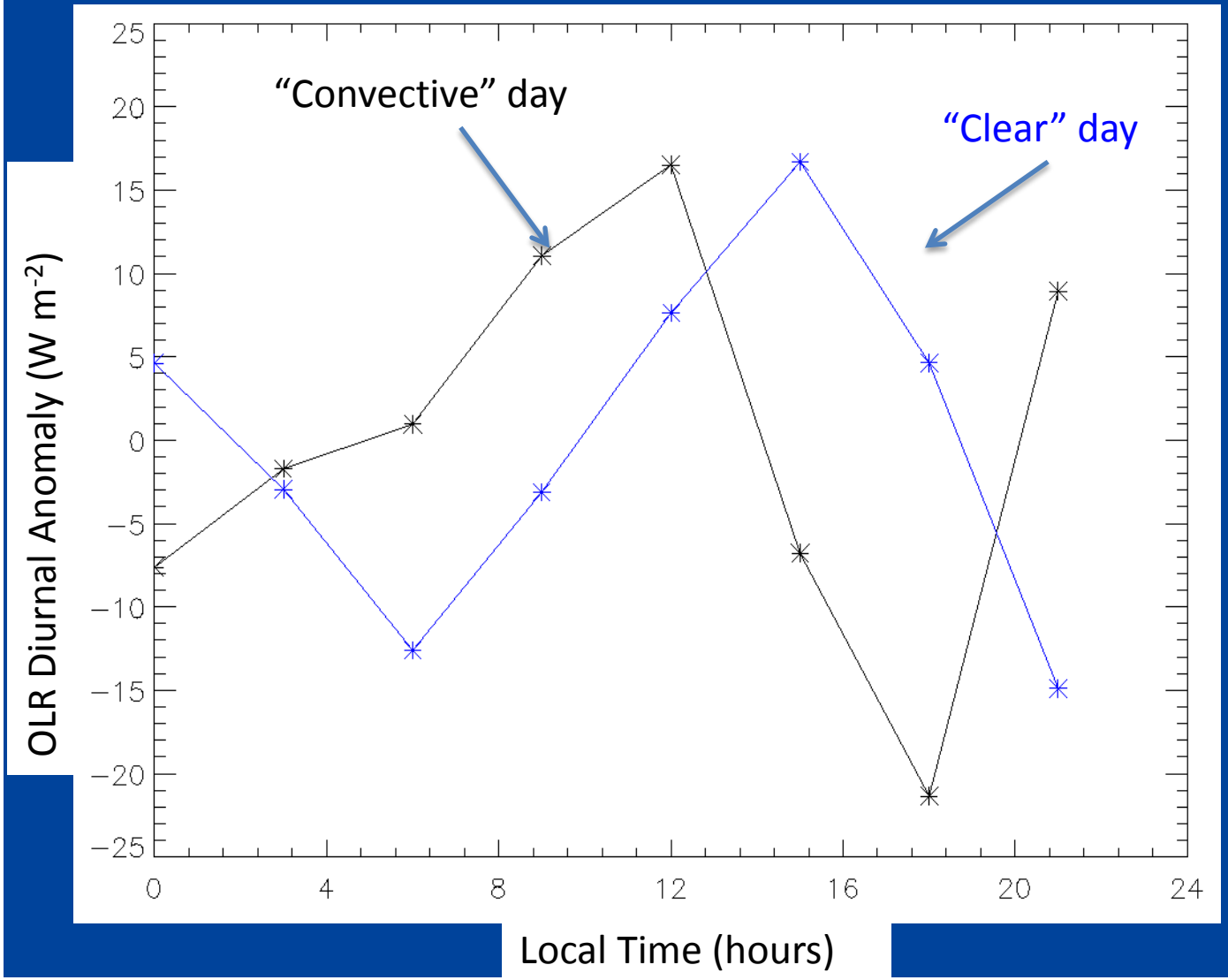
Units: W m^{-2} (10 hPa day^{-1})$^{-1}$



This relationship is represented in the model, however with sensitivities reduced by as much as 50%.

Taylor and Cole (In prep.)

Land convective OLR amplitude variability?



- Significant OLR diurnal cycle amplitude variations at 1x1 spatial scales is determined by the number of "clear" vs. "convective" days that occur in the region for a given month.

68-month Tropical Mean RSW Trends

	Full DC	AM-Only
Slope ($W\ m^{-2}\ yr^{-1}$)	-0.04	0.02
2-sigma conf.	0.12	0.12
T-stat	0.7	0.4

Difference with Full DC	AM-Only
Slope ($W\ m^{-2}\ yr^{-1}$)	0.06
2-sigma conf.	0.02
T-stat	8.4
Stdev	0.14
f^2	0.03

68-month GOES Region (40-175 W) RSW Trends

	Full DC	AM-Only
Slope ($W\ m^{-2}\ yr^{-1}$)	0.12	0.18
2-sigma conf.	0.20	0.20
T-stat	1.3	1.8

Difference with Full DC	AM-Only
Slope ($W\ m^{-2}\ yr^{-1}$)	0.05
2-sigma conf.	0.02
T-stat	6.9
Stdev	0.13
f^2	0.01

How can A’ and OLR’ be related?

PDF of OLRMAX and OLRMIN