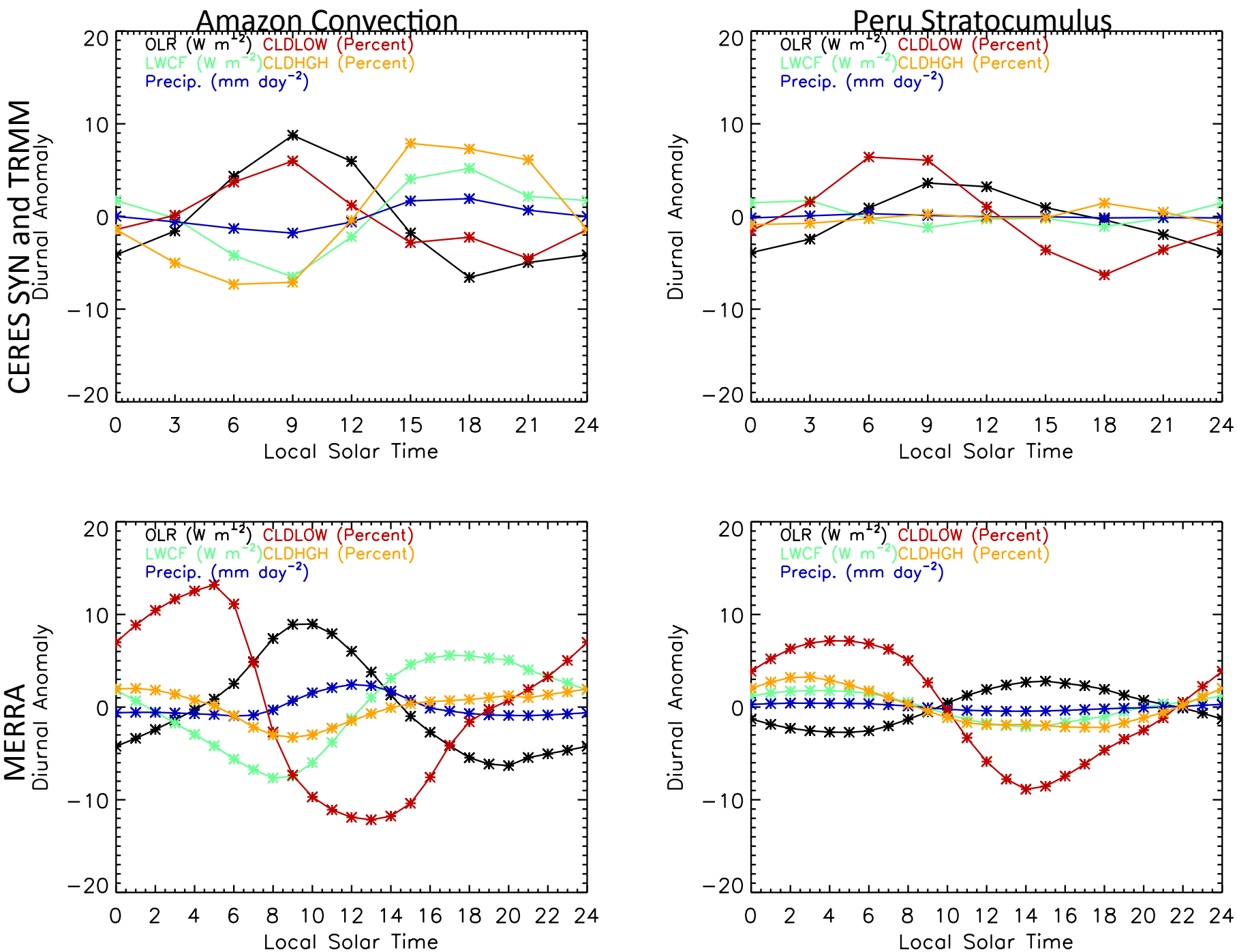
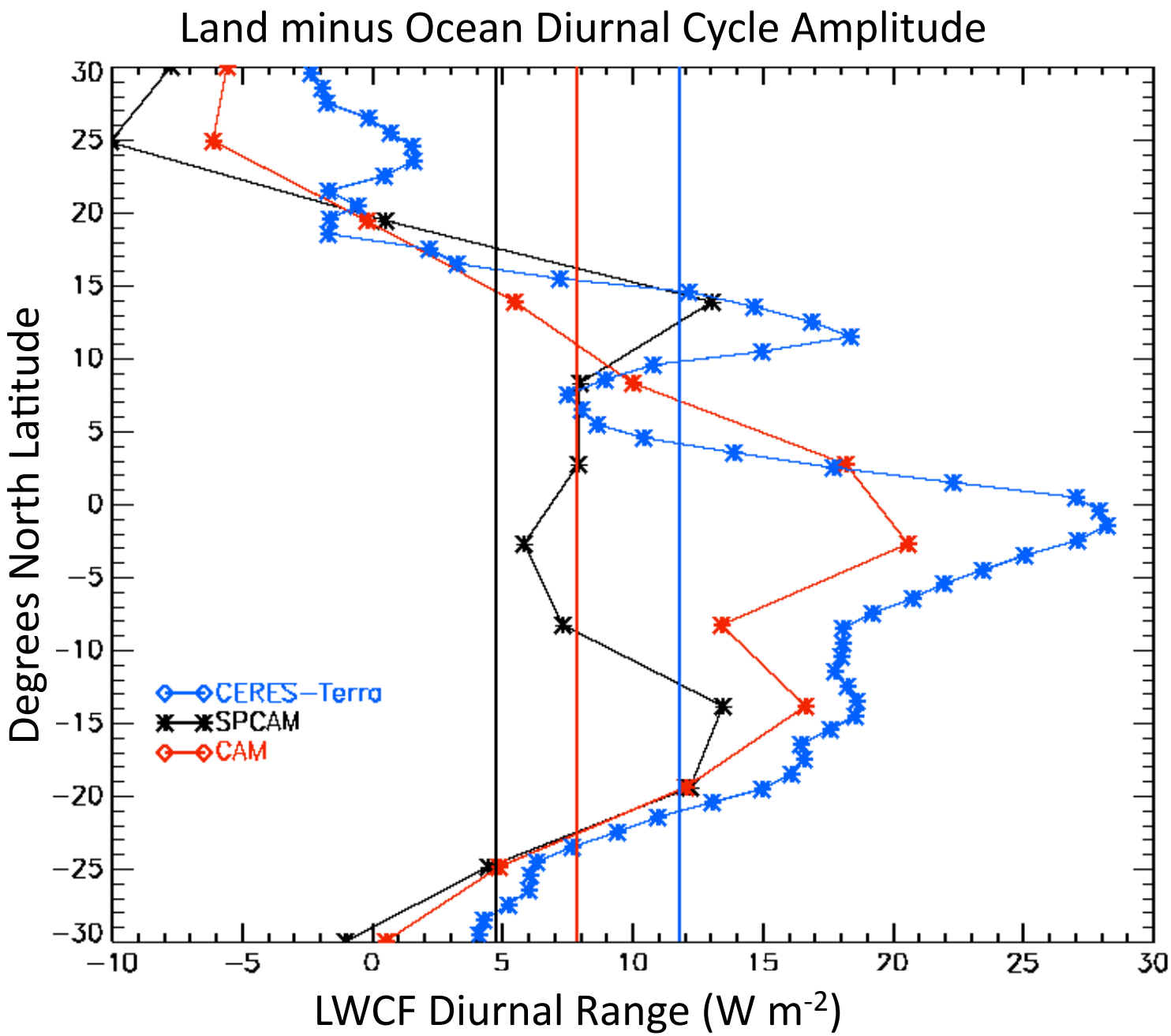
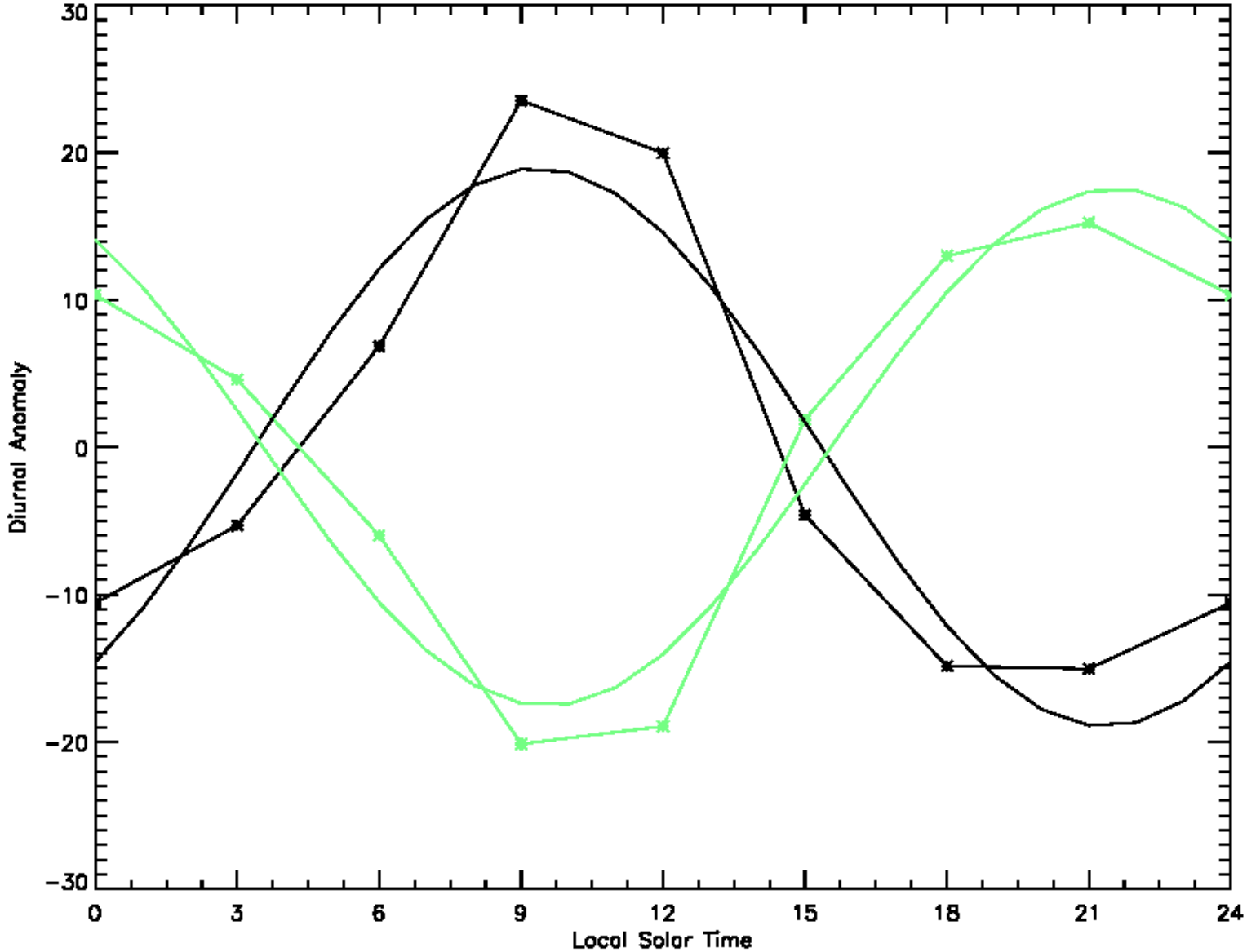
Controls on the Spatial and Seasonal Distribution of the Tropical Diurnal Cycle

Patrick Taylor
NASA Langley Research Center
Climate Sciences Branch
CERES Science Team Meeting
28 April 2011

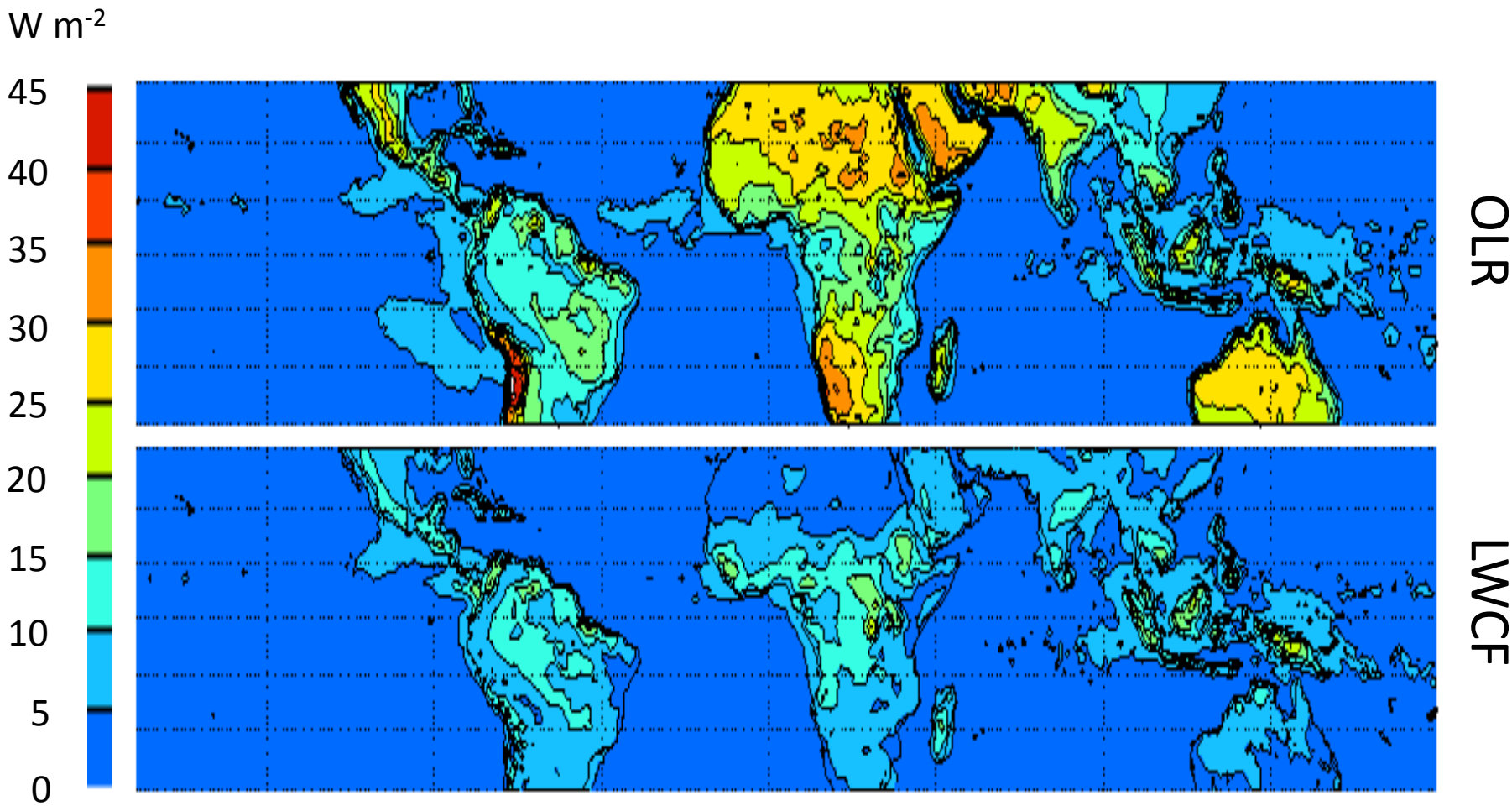

Amazon Convection
Peru Stratocumulus
CERES SYN and TRMM
MERRA
Diurnal Anomaly
OLR (W m^{-2})
CLDLOW (Percent)
LWCF (W m^{-2})
CLDHGH (Percent)
Precip. (mm day^{-2})
Local Solar Time


Land minus Ocean Diurnal Cycle Amplitude
Degrees North Latitude
LWCF Diurnal Range (W m-2)
CERES–Terra
SPCAM
CAM
30
25
20
15
10
5
0
−5
−10
−15
−20
−25
−30
−10
−5
0
5
10
15
20
25
30

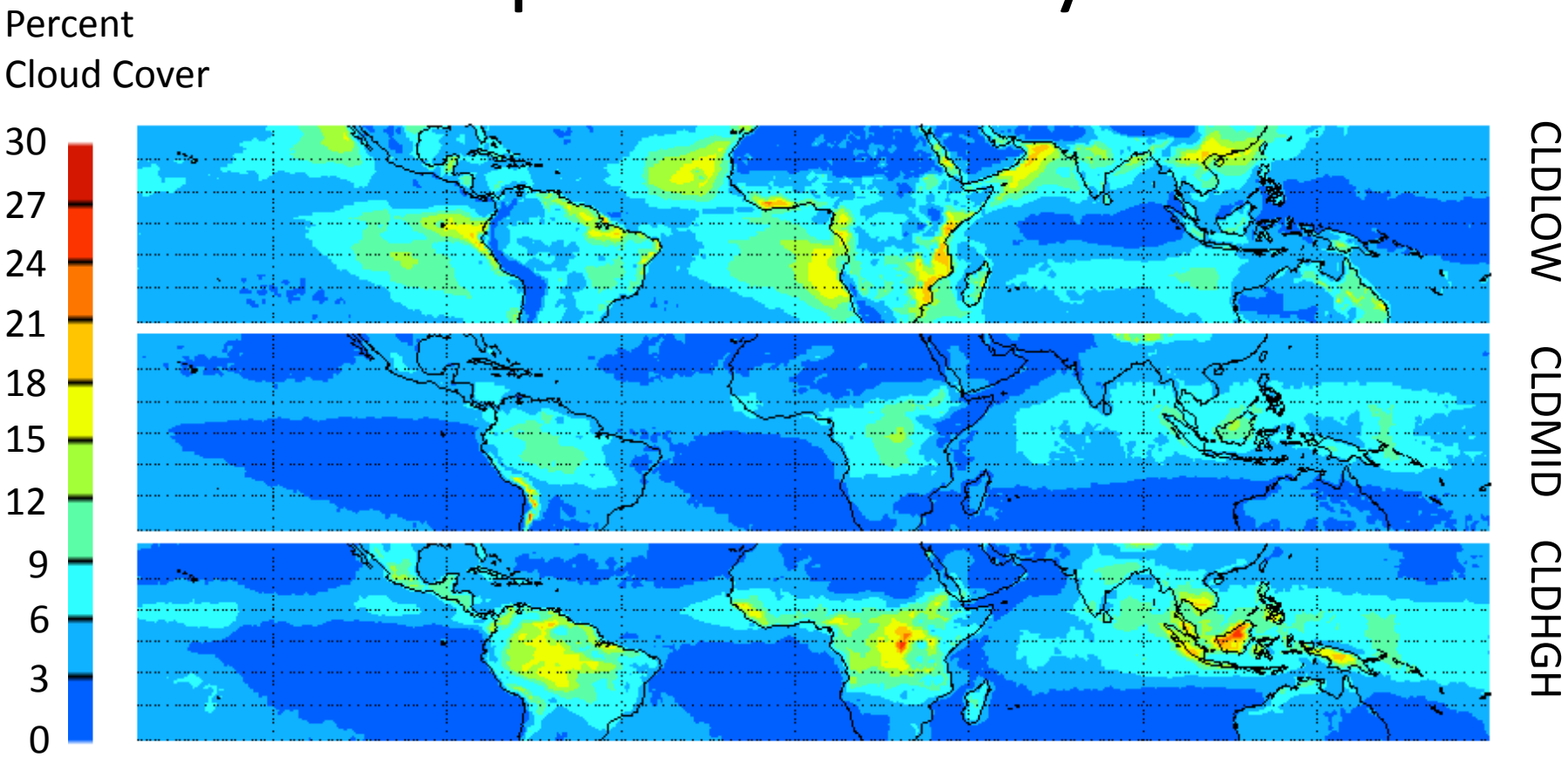
Methodology



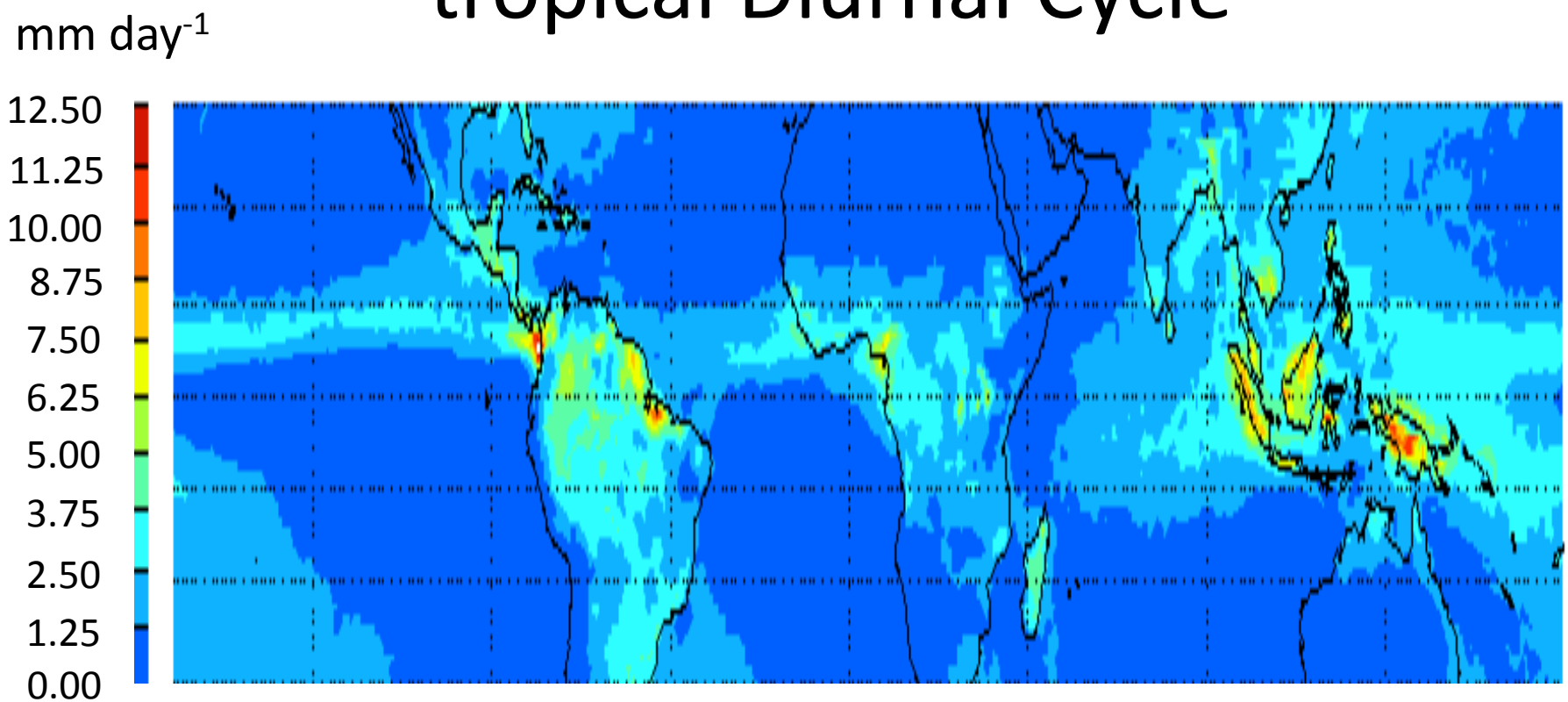
Annual Mean Tropical Diurnal Cycle



Annual Mean spatial distribution of tropical Diurnal Cycle

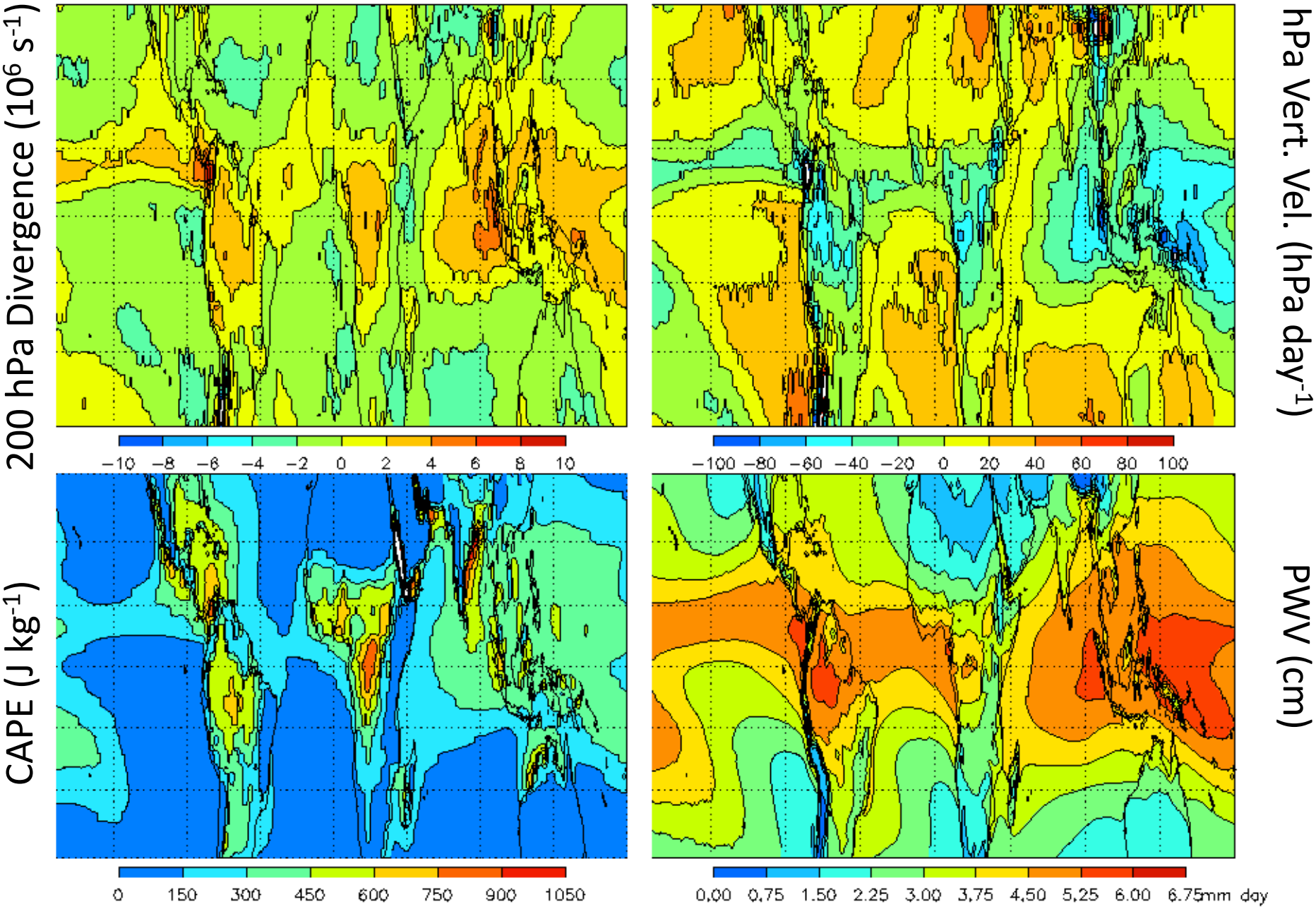


Annual Mean spatial distribution of tropical Diurnal Cycle

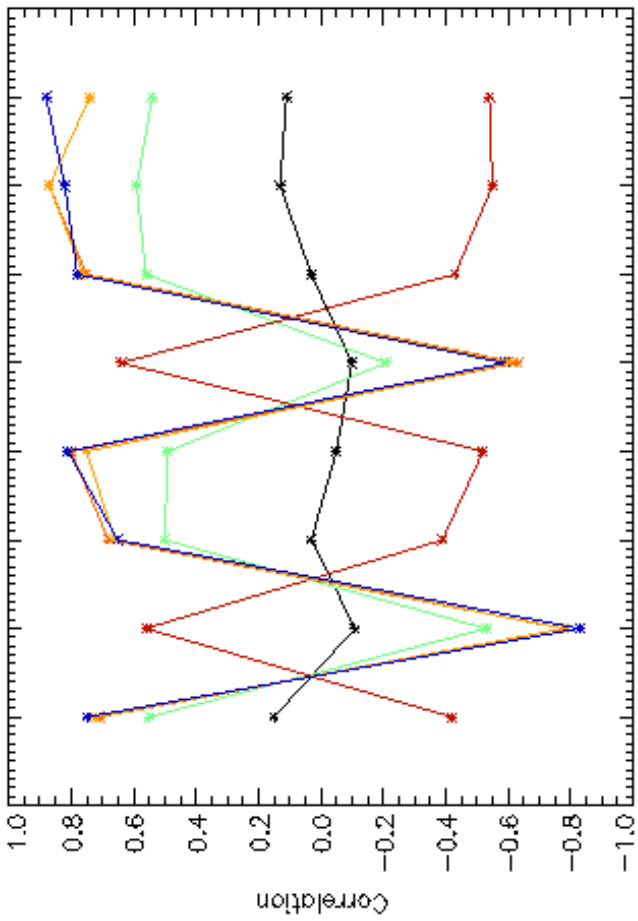


Why do we see these patterns?

Reanalysis Dynamic and Thermodynamic Variables



Ocean



Precipitation

CLDHGH

CLDMID

CLDLOW

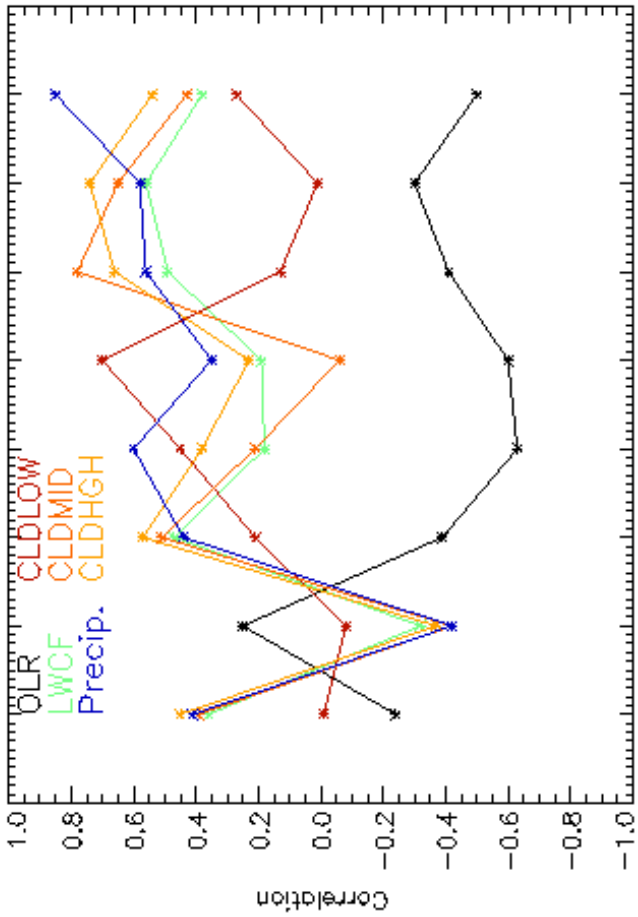
PWV

CAPE

500 hPa Vert. Vel

200 hPa Divergence

Land



Precipitation

CLDHGH

CLDMID

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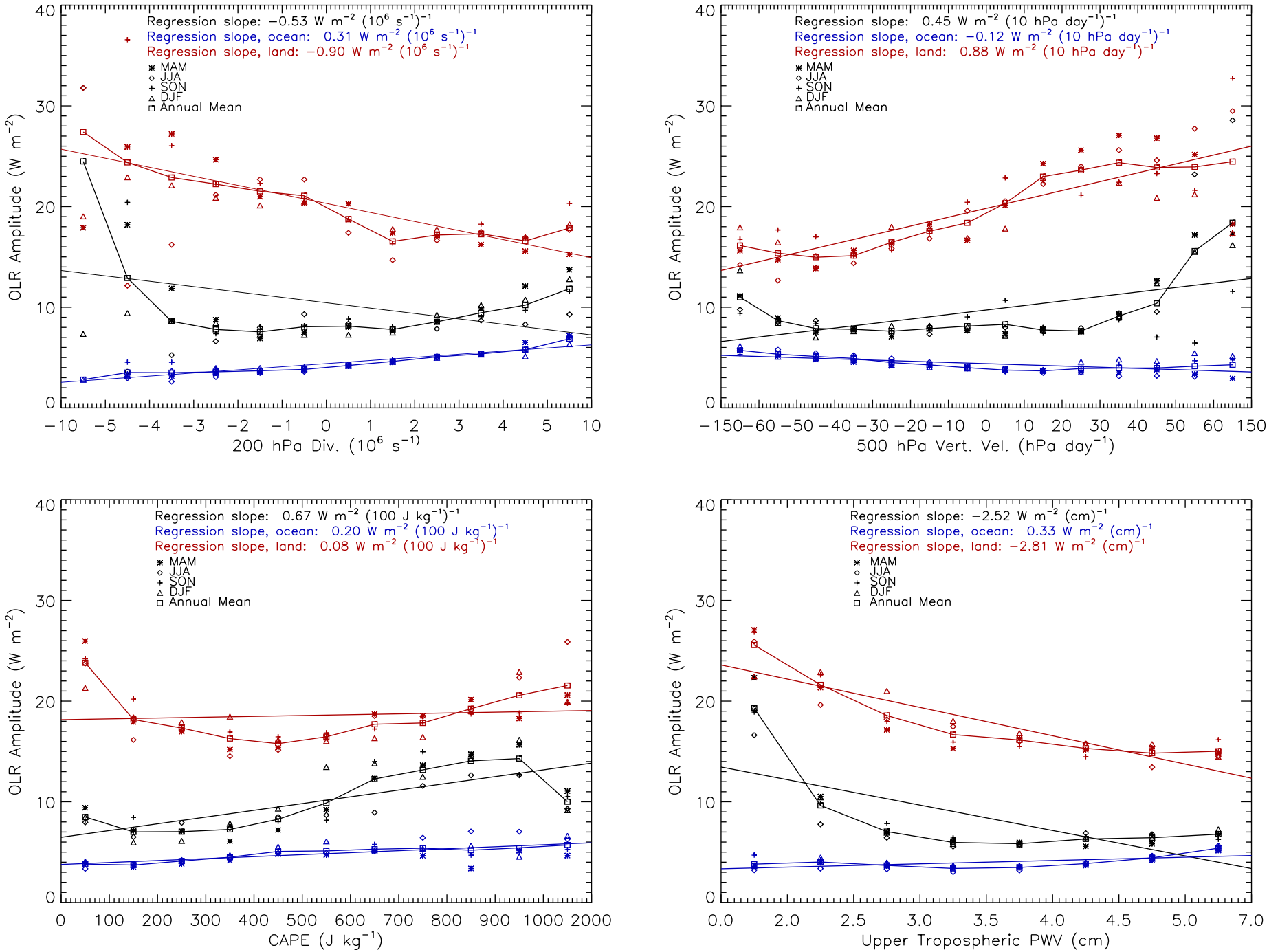
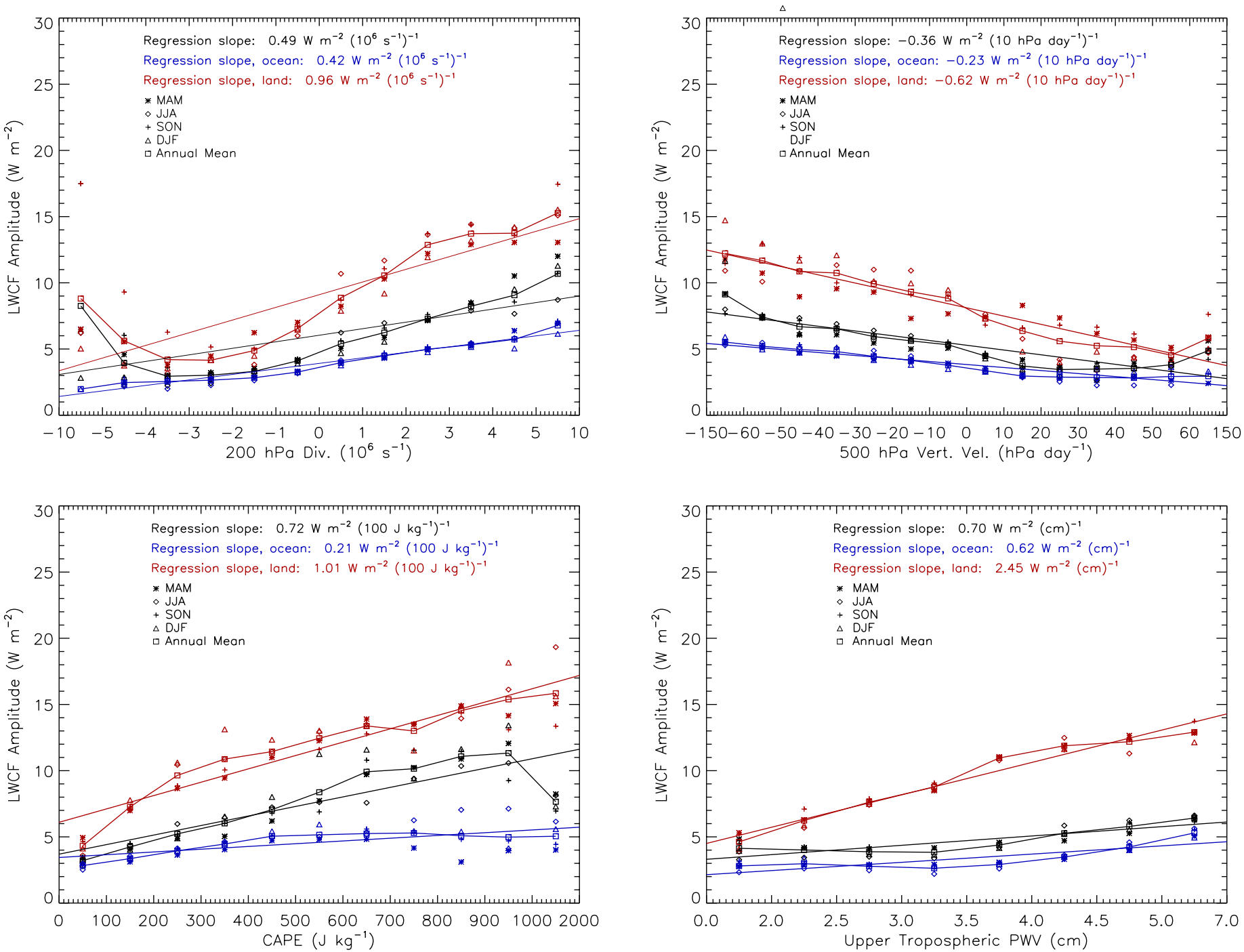
PWV

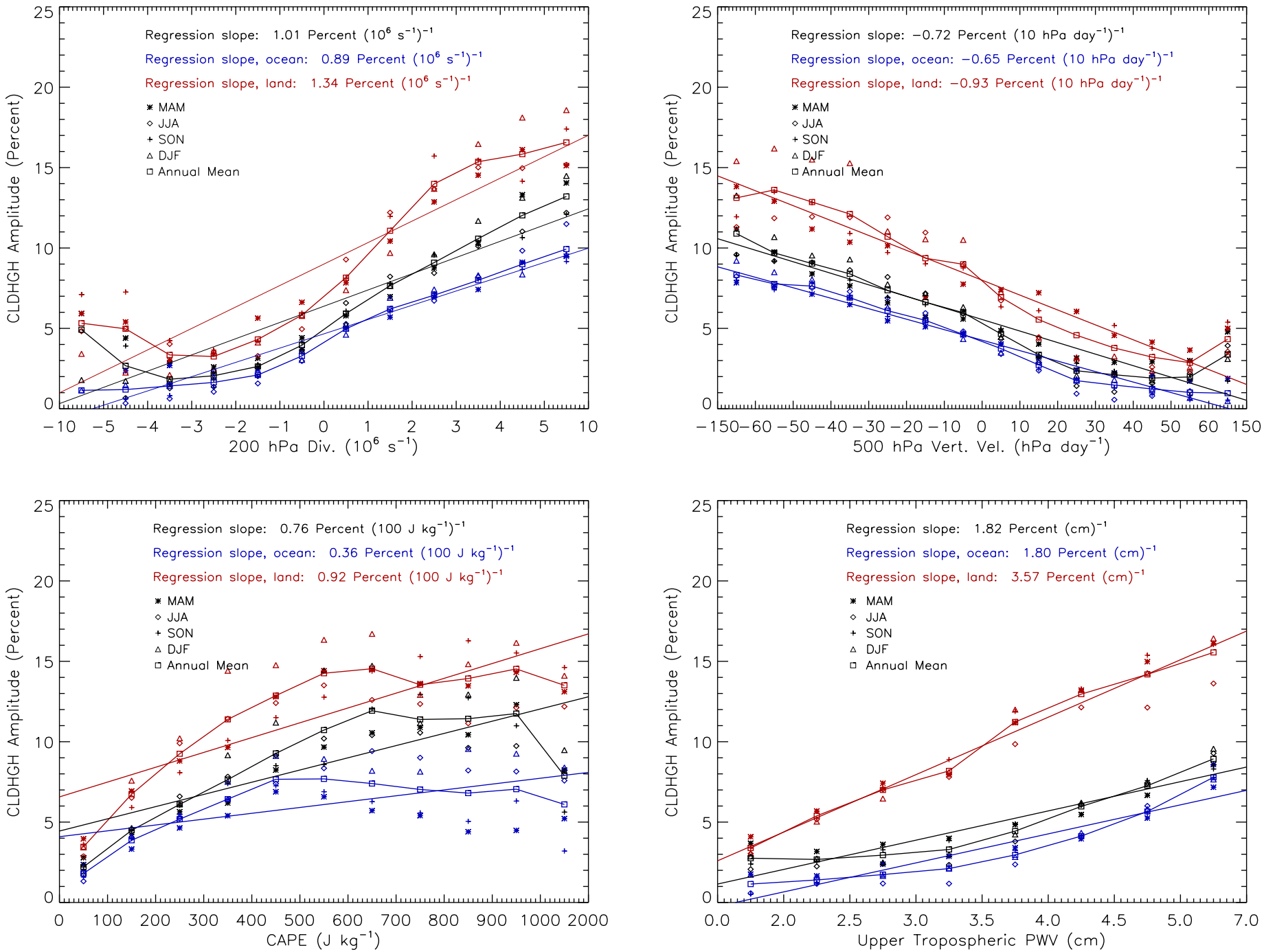
CAPE

500 hPa Vert. Vel

200 hPa Divergence


Regression slope: −0.53 W m^{-2} (10^6 s^{-1})$^{-1}$
Regression slope, ocean: 0.31 W m^{-2} (10^6 s^{-1})$^{-1}$
Regression slope, land: −0.90 W m^{-2} (10^6 s^{-1})$^{-1}$
MAM
JJA
SON
DJF
Annual Mean
OLR Amplitude (W m^{-2})
200 hPa Div. (10^6 s^{-1})
Regression slope: 0.45 W m^{-2} (10 hPa day^{-1})$^{-1}$
Regression slope, ocean: −0.12 W m^{-2} (10 hPa day^{-1})$^{-1}$
Regression slope, land: 0.88 W m^{-2} (10 hPa day^{-1})$^{-1}$
500 hPa Vert. Vel. (hPa day^{-1})
Regression slope: 0.67 W m^{-2} (100 J kg^{-1})$^{-1}$
Regression slope, ocean: 0.20 W m^{-2} (100 J kg^{-1})$^{-1}$
Regression slope, land: 0.08 W m^{-2} (100 J kg^{-1})$^{-1}$
CAPE (J kg^{-1})
Regression slope: −2.52 W m^{-2} (cm)$^{-1}$
Regression slope, ocean: 0.33 W m^{-2} (cm)$^{-1}$
Regression slope, land: −2.81 W m^{-2} (cm)$^{-1}$
Upper Tropospheric PWV (cm)

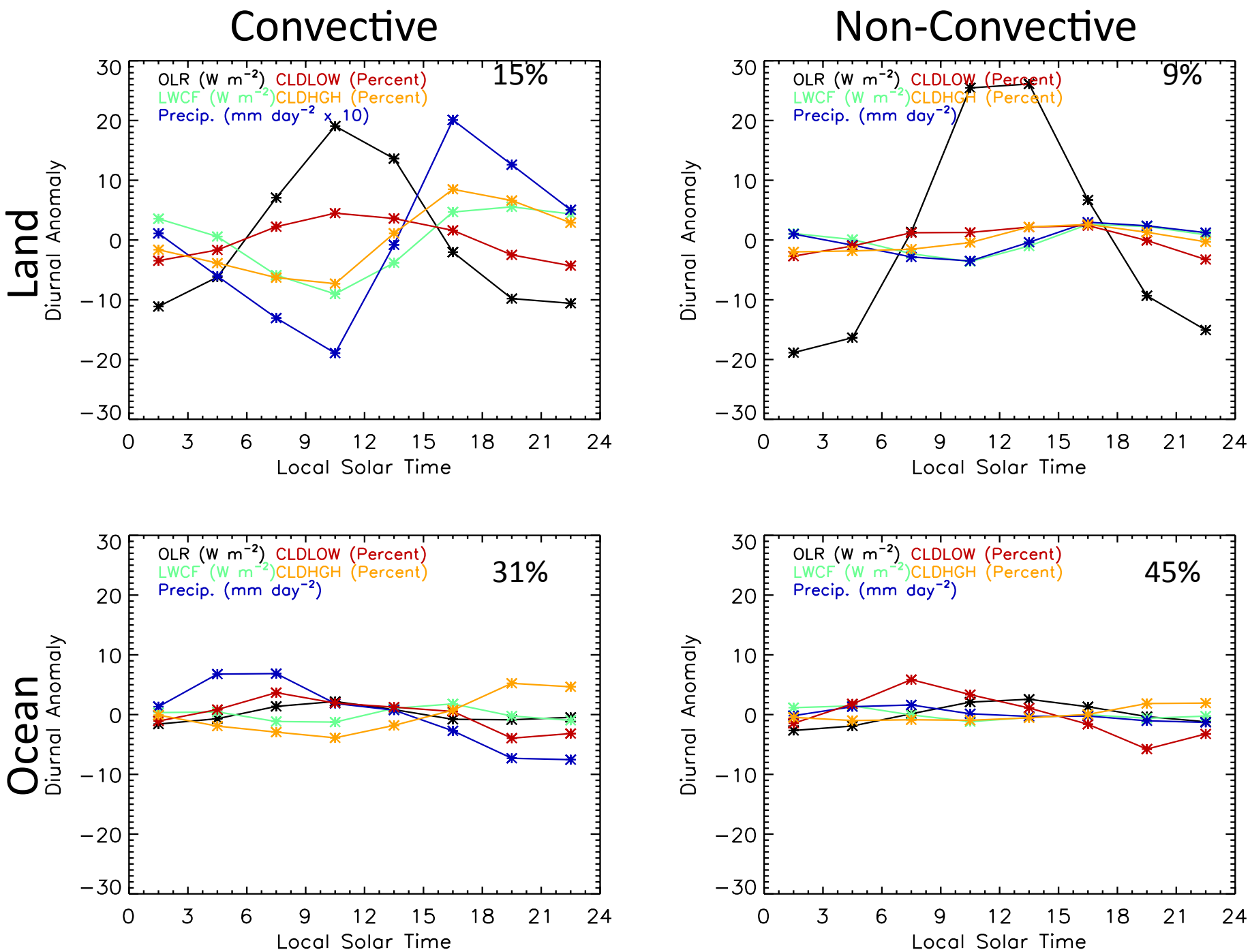

Regression slope: 0.49 W m^{-2} (10^6 s^{-1})$^{-1}$
Regression slope, ocean: 0.42 W m^{-2} (10^6 s^{-1})$^{-1}$
Regression slope, land: 0.96 W m^{-2} (10^6 s^{-1})$^{-1}$
MAM
JJA
SON
DJF
Annual Mean
LWCF Amplitude (W m^{-2})
200 hPa Div. (10^6 s^{-1})
Regression slope: −0.36 W m^{-2} (10 hPa day^{-1})$^{-1}$
Regression slope, ocean: −0.23 W m^{-2} (10 hPa day^{-1})$^{-1}$
Regression slope, land: −0.62 W m^{-2} (10 hPa day^{-1})$^{-1}$
500 hPa Vert. Vel. (hPa day^{-1})
Regression slope: 0.72 W m^{-2} (100 J kg^{-1})$^{-1}$
Regression slope, ocean: 0.21 W m^{-2} (100 J kg^{-1})$^{-1}$
Regression slope, land: 1.01 W m^{-2} (100 J kg^{-1})$^{-1}$
CAPE (J kg^{-1})
Regression slope: 0.70 W m^{-2} (cm)$^{-1}$
Regression slope, ocean: 0.62 W m^{-2} (cm)$^{-1}$
Regression slope, land: 2.45 W m^{-2} (cm)$^{-1}$
Upper Tropospheric PWV (cm)

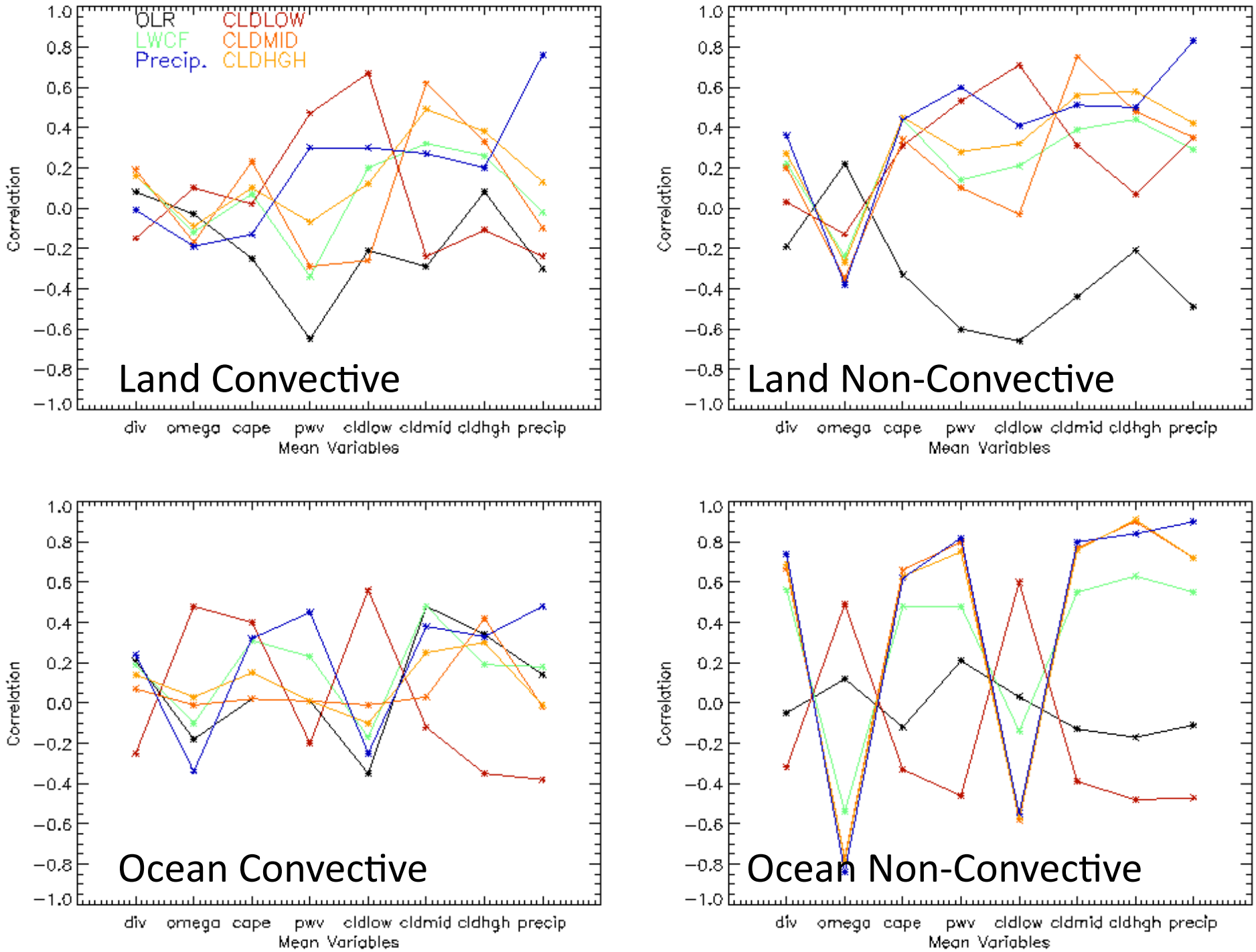

Regression slope: 1.01 Percent (10^6 s^-1)^-1
Regression slope, ocean: 0.89 Percent (10^6 s^-1)^-1
Regression slope, land: 1.34 Percent (10^6 s^-1)^-1
MAM
JJA
SON
DJF
Annual Mean
CLDHGH Amplitude (Percent)
200 hPa Div. (10^6 s^-1)
Regression slope: −0.72 Percent (10 hPa day^-1)^-1
Regression slope, ocean: −0.65 Percent (10 hPa day^-1)^-1
Regression slope, land: −0.93 Percent (10 hPa day^-1)^-1
500 hPa Vert. Vel. (hPa day^-1)
Regression slope: 0.76 Percent (100 J kg^-1)^-1
Regression slope, ocean: 0.36 Percent (100 J kg^-1)^-1
Regression slope, land: 0.92 Percent (100 J kg^-1)^-1
CAPE (J kg^-1)
Regression slope: 1.82 Percent (cm)^-1
Regression slope, ocean: 1.80 Percent (cm)^-1
Regression slope, land: 3.57 Percent (cm)^-1
Upper Tropospheric PWV (cm)

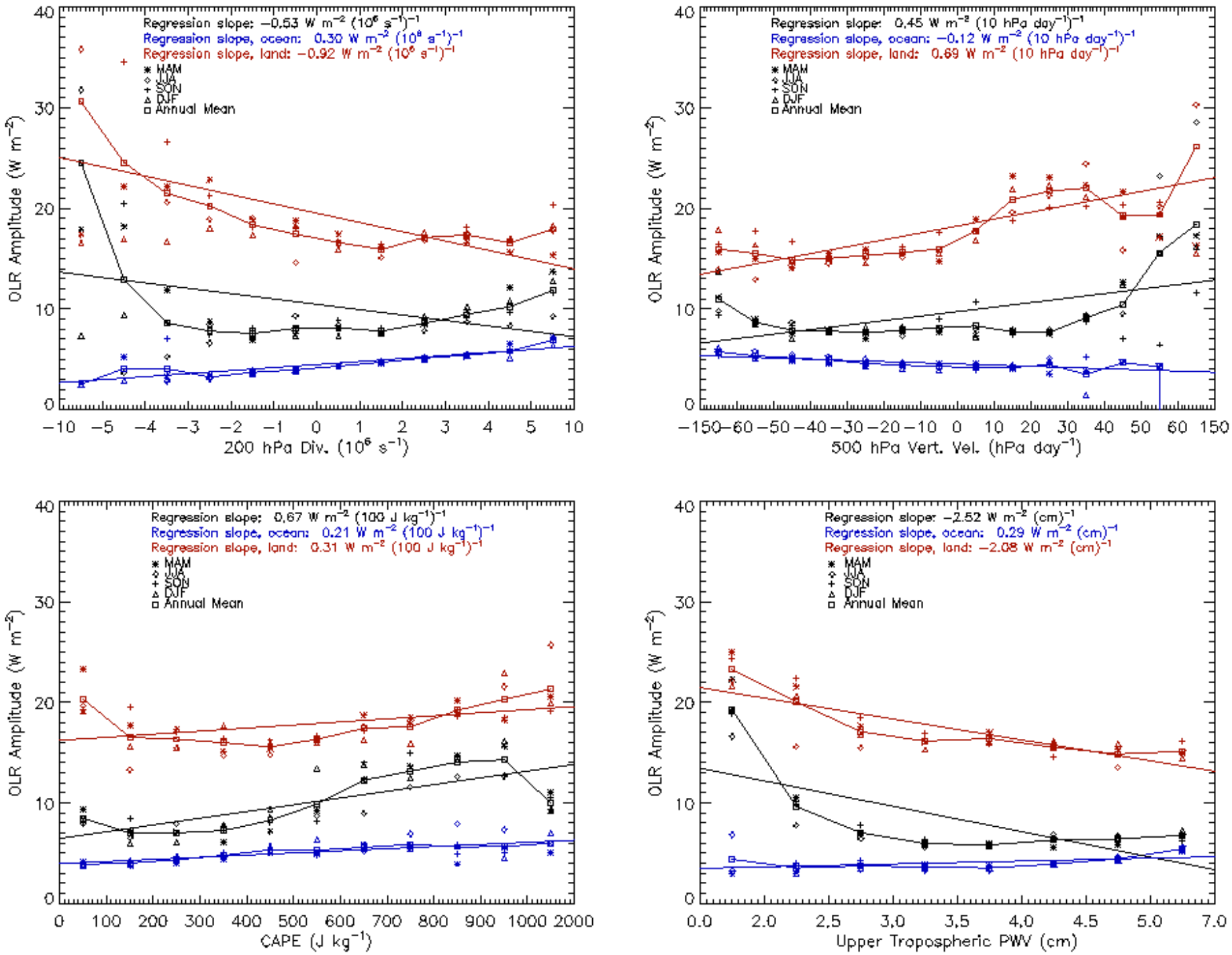
Conclusions

- Mean fields to correlate well with diurnal cycle amplitude spatial distribution.
- Strong LWCF diurnal cycle amplitudes occur in regions of large mean high cloud fraction and precipitation over land and ocean.
- The diurnal cycle amplitudes exhibit stronger spatial sensitivities to dynamic variables than to CAPE.
- It seems that the annual mean state is setting up cloud types distributions that exhibit a robust diurnal cycle.

Questions?


Convective
Non-Convective
Land
Ocean
Diurnal Anomaly
Local Solar Time
OLR (W m^{-2})
CLDLOW (Percent)
LWCF (W m^{-2})
CLDHGH (Percent)
Precip. (mm day^{-2} x 10)
Precip. (mm day^{-2})
15%
9%
31%
45%
30
20
10
0
−10
−20
−30
0
3
6
9
12
15
18
21
24


OLR
LWCF
Precip.
CLDLOW
CLDMID
CLDHGH
Land Convective
Land Non-Convective
Ocean Convective
Ocean Non-Convective
Correlation
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
div
omega
cape
pwv
cldlow
cldmid
cldhgh
precip
Mean Variables


Regression slope: −0.53 W m^{-2} (10^{6} s^{-1})$^{-1}$
Regression slope, ocean: 0.30 W m^{-2} (10^{6} s^{-1})$^{-1}$
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MAM
JJA
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Annual Mean
OLR Amplitude (W m^{-2})
200 hPa Div. (10^{6} s^{-1})
Regression slope: 0.45 W m^{-2} (10 hPa day^{-1})$^{-1}$
Regression slope, ocean: −0.12 W m^{-2} (10 hPa day^{-1})$^{-1}$
Regression slope, land: 0.69 W m^{-2} (10 hPa day^{-1})$^{-1}$
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Annual Mean
OLR Amplitude (W m^{-2})
500 hPa Vert. Vel. (hPa day^{-1})
Regression slope: 0.67 W m^{-2} (100 J kg^{-1})$^{-1}$
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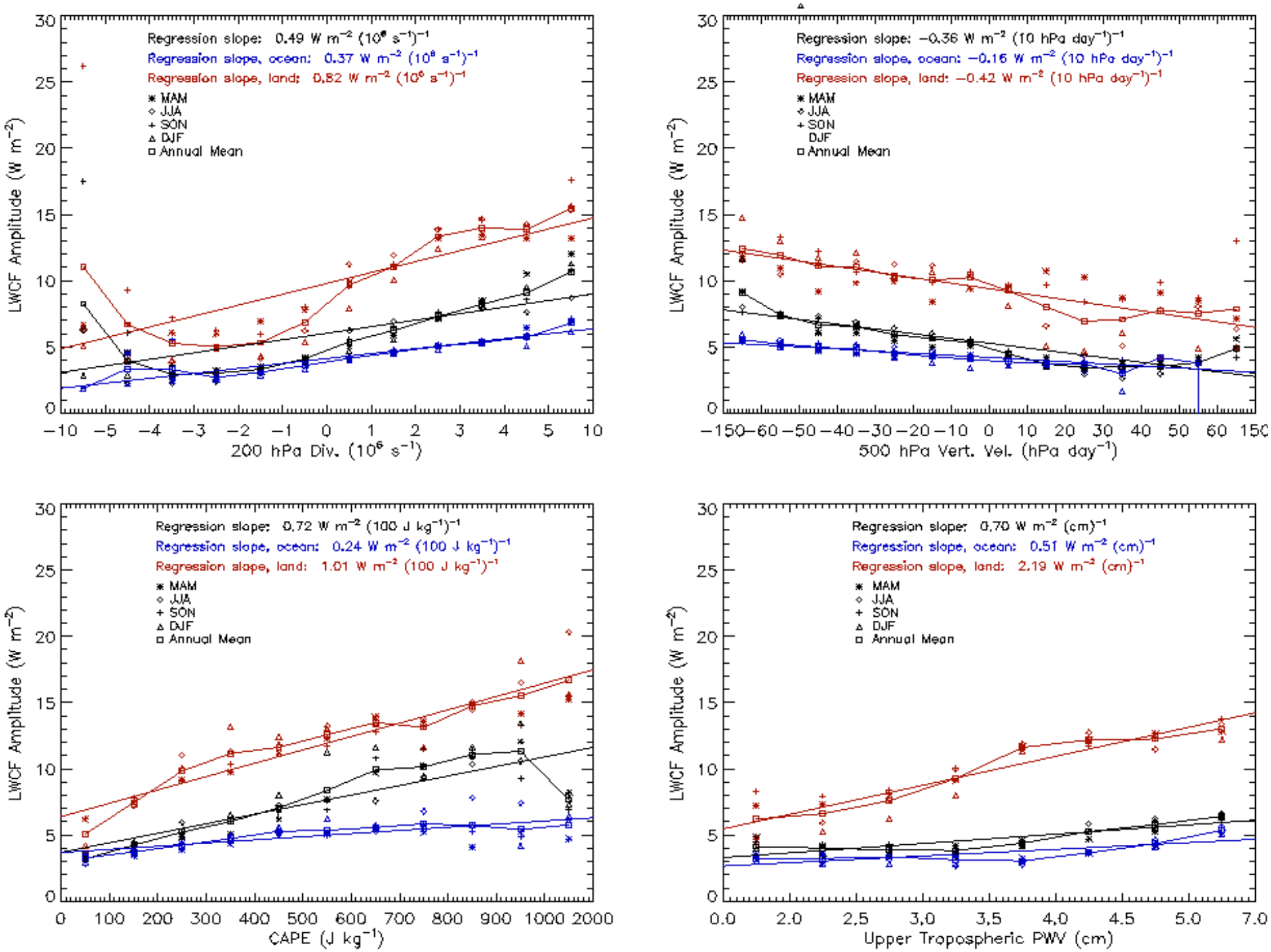
Regression slope, land: 0.31 W m^{-2} (100 J kg^{-1})$^{-1}$
MAM
JJA
SON
DJF
Annual Mean
OLR Amplitude (W m^{-2})
CAPE (J kg^{-1})
Regression slope: −2.52 W m^{-2} (cm)$^{-1}$
Regression slope, ocean: 0.29 W m^{-2} (cm)$^{-1}$
Regression slope, land: −2.08 W m^{-2} (cm)$^{-1}$
MAM
JJA
SON
DJF
Annual Mean
OLR Amplitude (W m^{-2})
Upper Tropospheric PWV (cm)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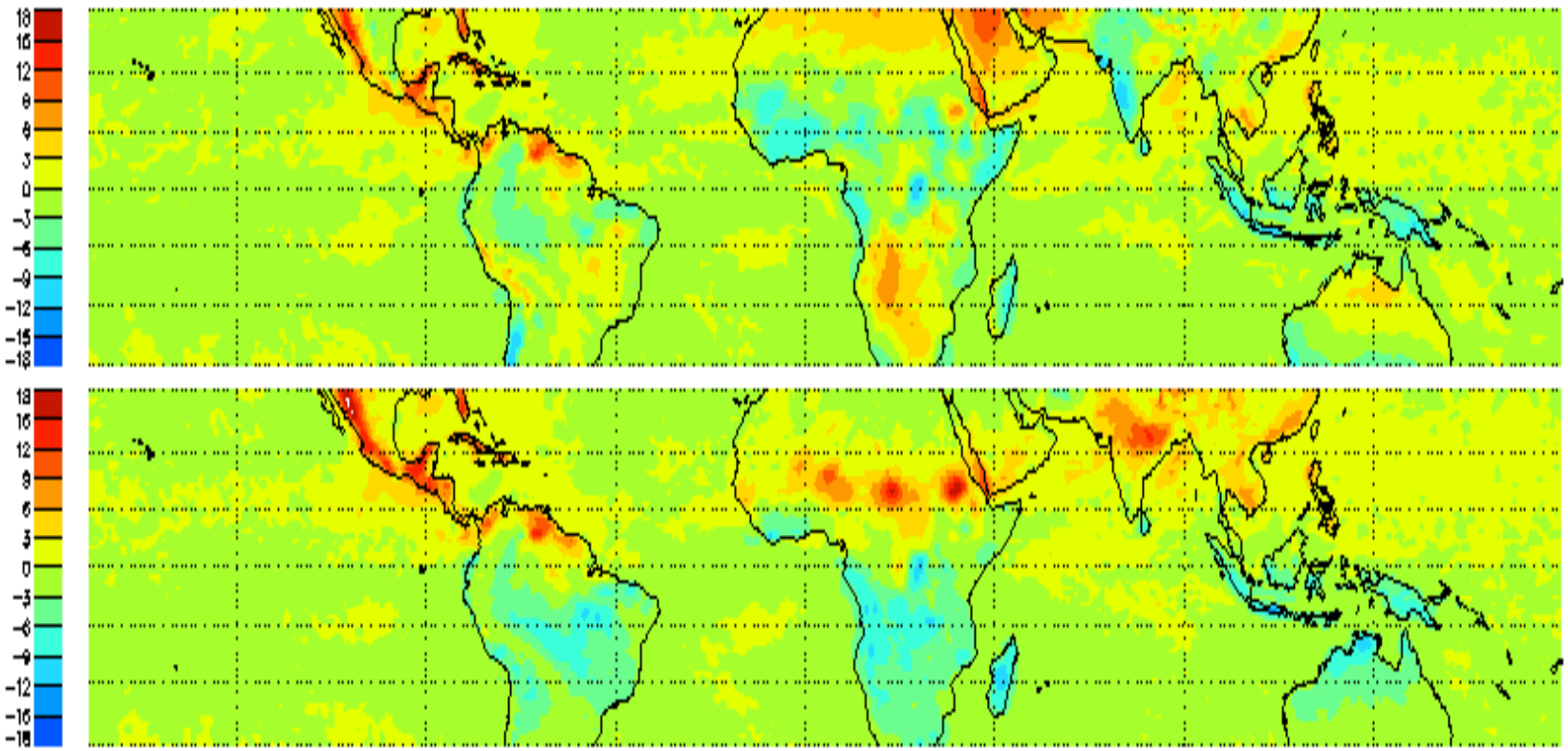
Regression slope, land: 0.82 W m^{-2} (10^6 s^{-1})$^{-1}$
MAM
JJA
SON
DJF
Annual Mean
LWCF Amplitude (W m^{-2})
200 hPa Div. (10^6 s^{-1})
Regression slope: −0.36 W m^{-2} (10 hPa day^{-1})$^{-1}$
Regression slope, ocean: −0.16 W m^{-2} (10 hPa day^{-1})$^{-1}$
Regression slope, land: −0.42 W m^{-2} (10 hPa day^{-1})$^{-1}$
500 hPa Vert. Vel. (hPa day^{-1})
Regression slope: 0.72 W m^{-2} (100 J kg^{-1})$^{-1}$
Regression slope, ocean: 0.24 W m^{-2} (100 J kg^{-1})$^{-1}$
Regression slope, land: 1.01 W m^{-2} (100 J kg^{-1})$^{-1}$
CAPE (J kg^{-1})
Regression slope: 0.70 W m^{-2} (cm)$^{-1}$
Regression slope, ocean: 0.51 W m^{-2} (cm)$^{-1}$
Regression slope, land: 2.19 W m^{-2} (cm)$^{-1}$
Upper Tropospheric PWV (cm)

Tropical Diurnal Cycle Seasonality

OLR



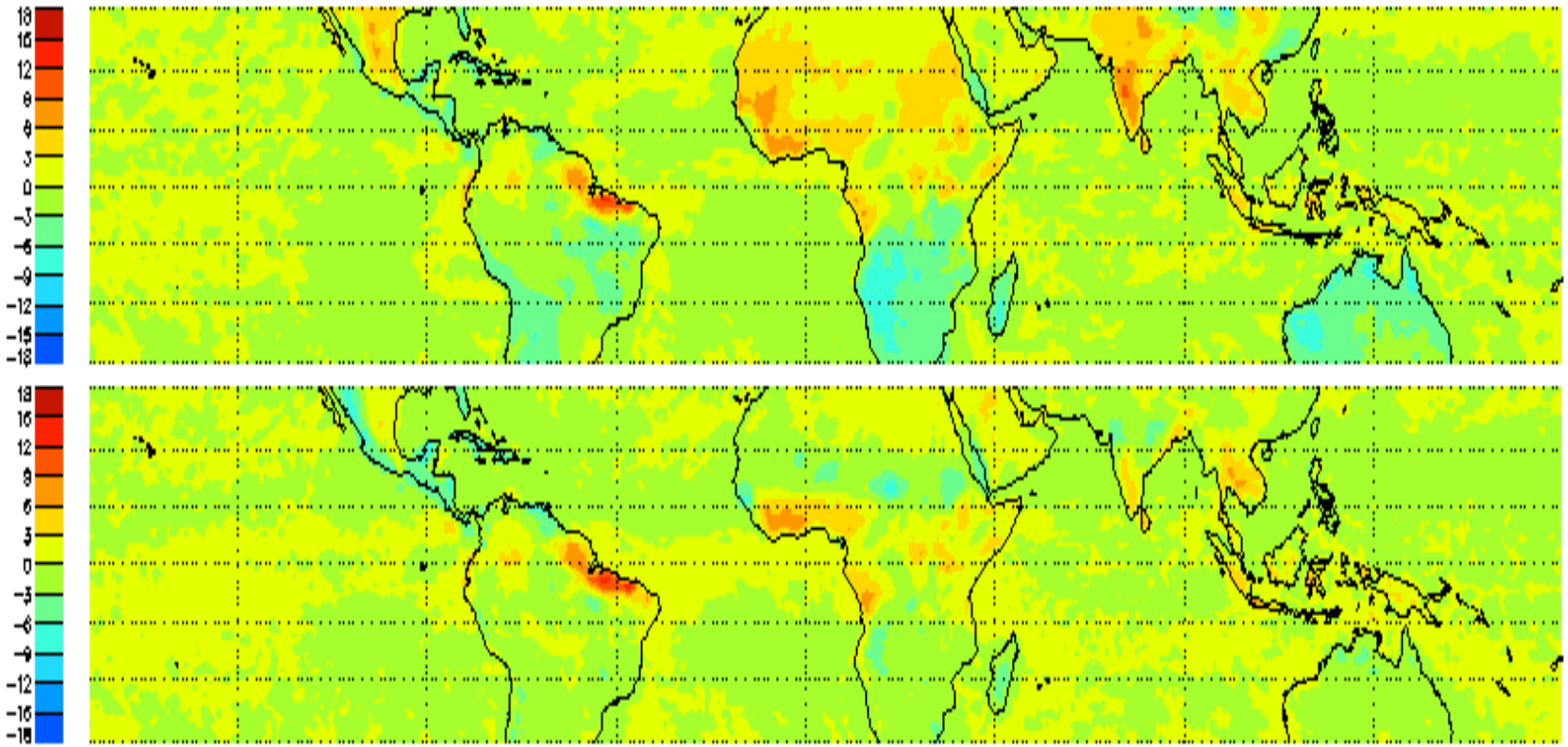
LWCF

SQ: What does the seasonality look like? It is explained completely by solar insolation?

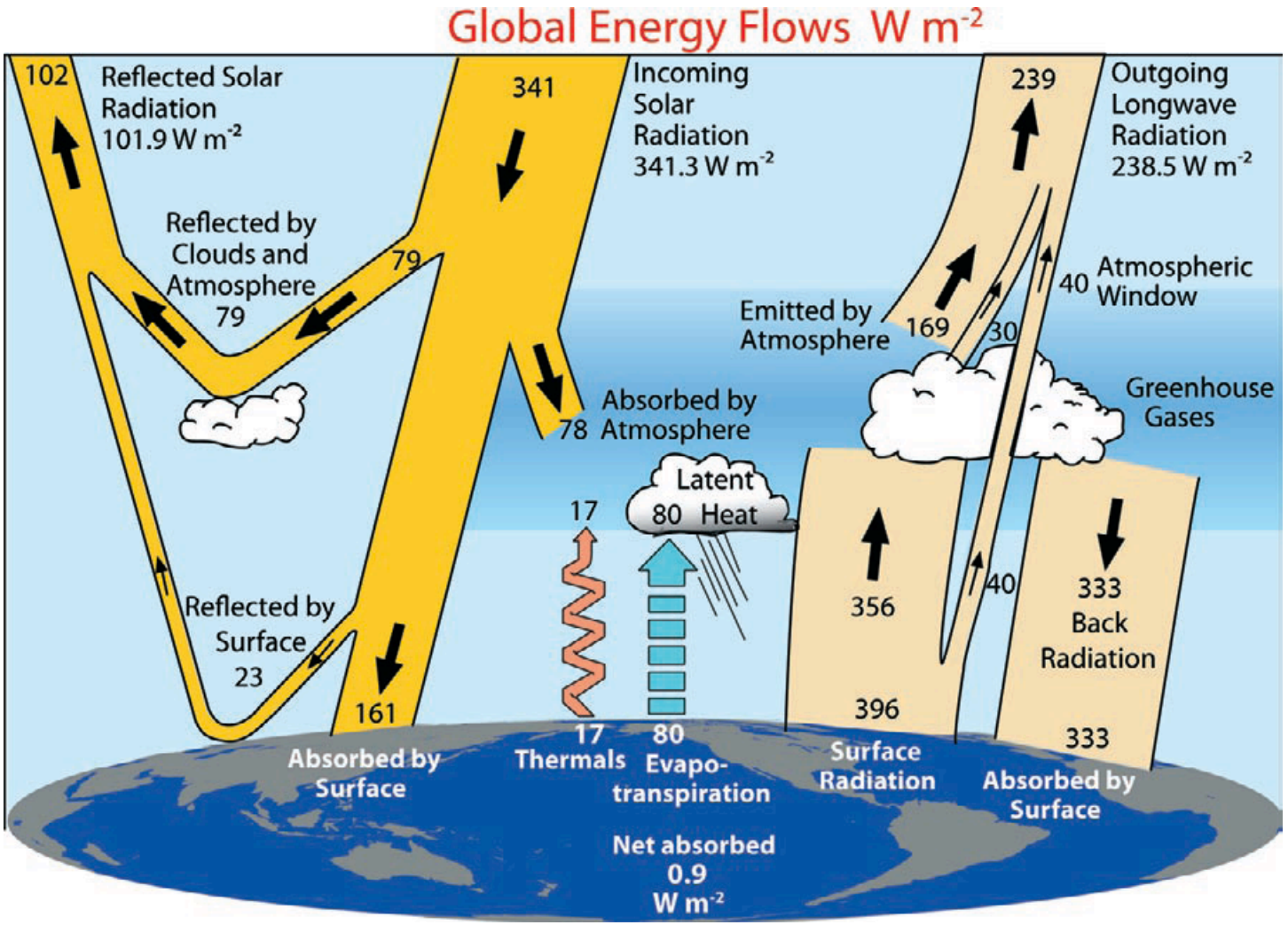
-Show spatial plots that indicate seasonality structure and magnitude
-show zonal mean plots: say that the solar insolation has a correlation here
-To remove the solar zenith angle signal in the seasonality, lets look at the MAM minus SON difference since the solar declination angle is the same. The correlations with the seasonality of dynamics and thermodynamics show low correlations.
-Show the zonal mean difference: this suggest memory in the diurnal cycle.

Seasonality: MAM minus SON

OLR

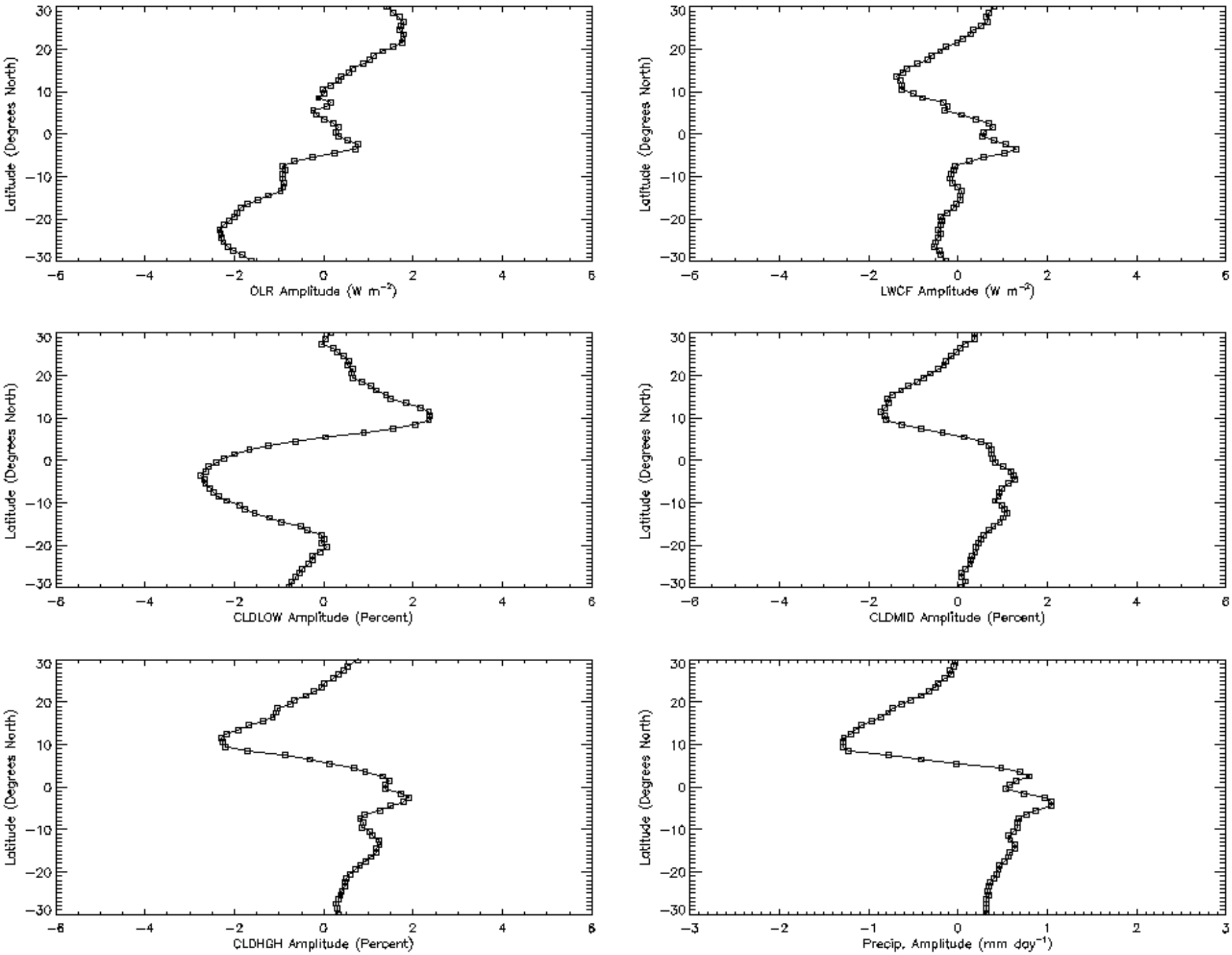


LWCF

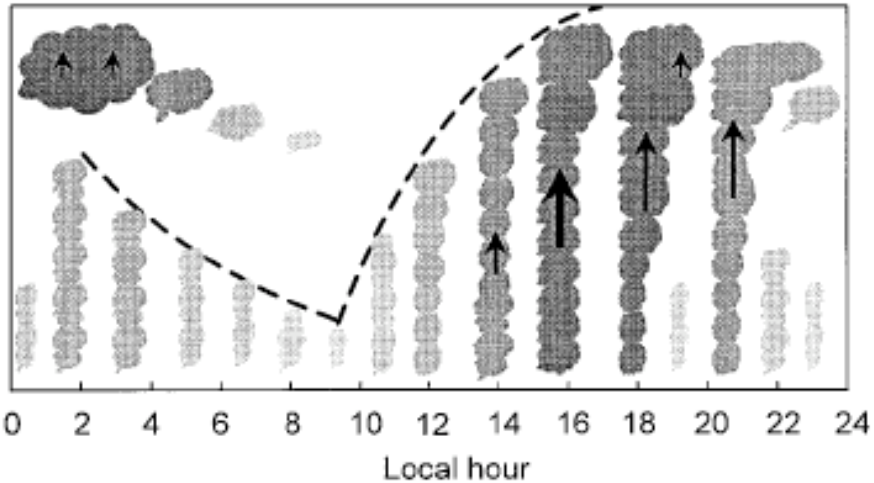


Trenberth et al. 2007

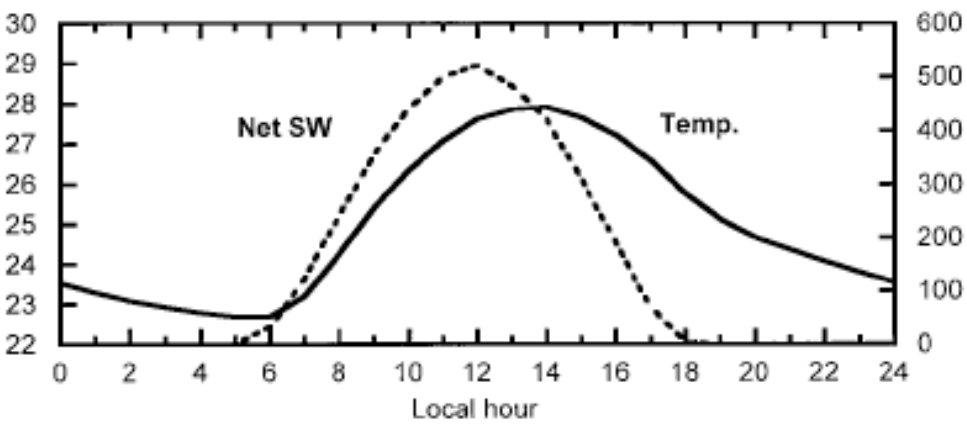
Seasonality MAM minus SON correlations

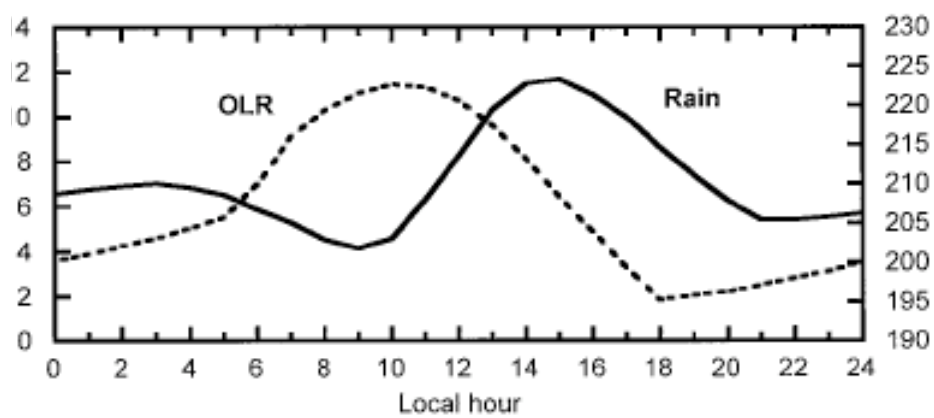

Latitude (Degrees North)
OLR Amplitude (W m^{-2})
LWCF Amplitude (W m^{-2})
CLDLOW Amplitude (Percent)
CLDMID Amplitude (Percent)
CLDHGH Amplitude (Percent)
Precip. Amplitude (mm day^{-1})

Diurnal Cycle Schematic



Lin et al. 2000





SQ: Why do we see these patterns?

Show lwcf vs. cldhgh d.c.

What drives lwcf d.c.?

-Show maps of div-200, omega-500, cape, and pwv (GEOS-4)

-Then discuss correlations

-State: it seems that everything is well correlated although CAPE shows a larger correlation over land and dynamics stronger over ocean

-Next show binned curves: interesting that CAPE seems to asymptote at relatively low values and mean diurnal cycle becomes insensitive to larger CAPE values. General monotonic increases, although non-linear, occur in the dynamic variables.

-To get a better idea of what is causing the spatial distribution let look at what I called diurnal cycle "regimes." The diurnal cycle has previously (e.g. Bergman and Salby 1996) been separated into four types: land and ocean convective and non-convective.

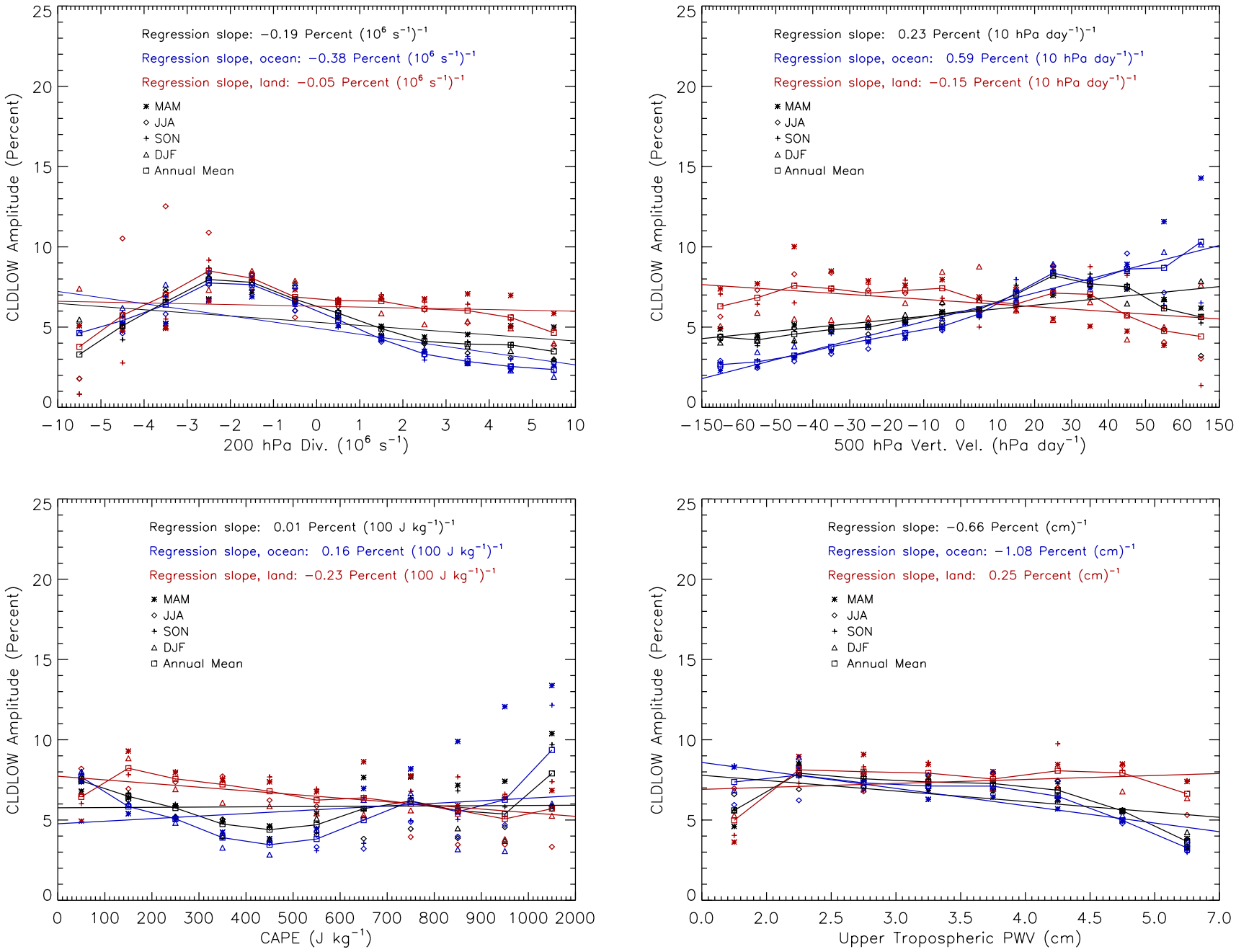
-Show composite.

-Show a few correlations

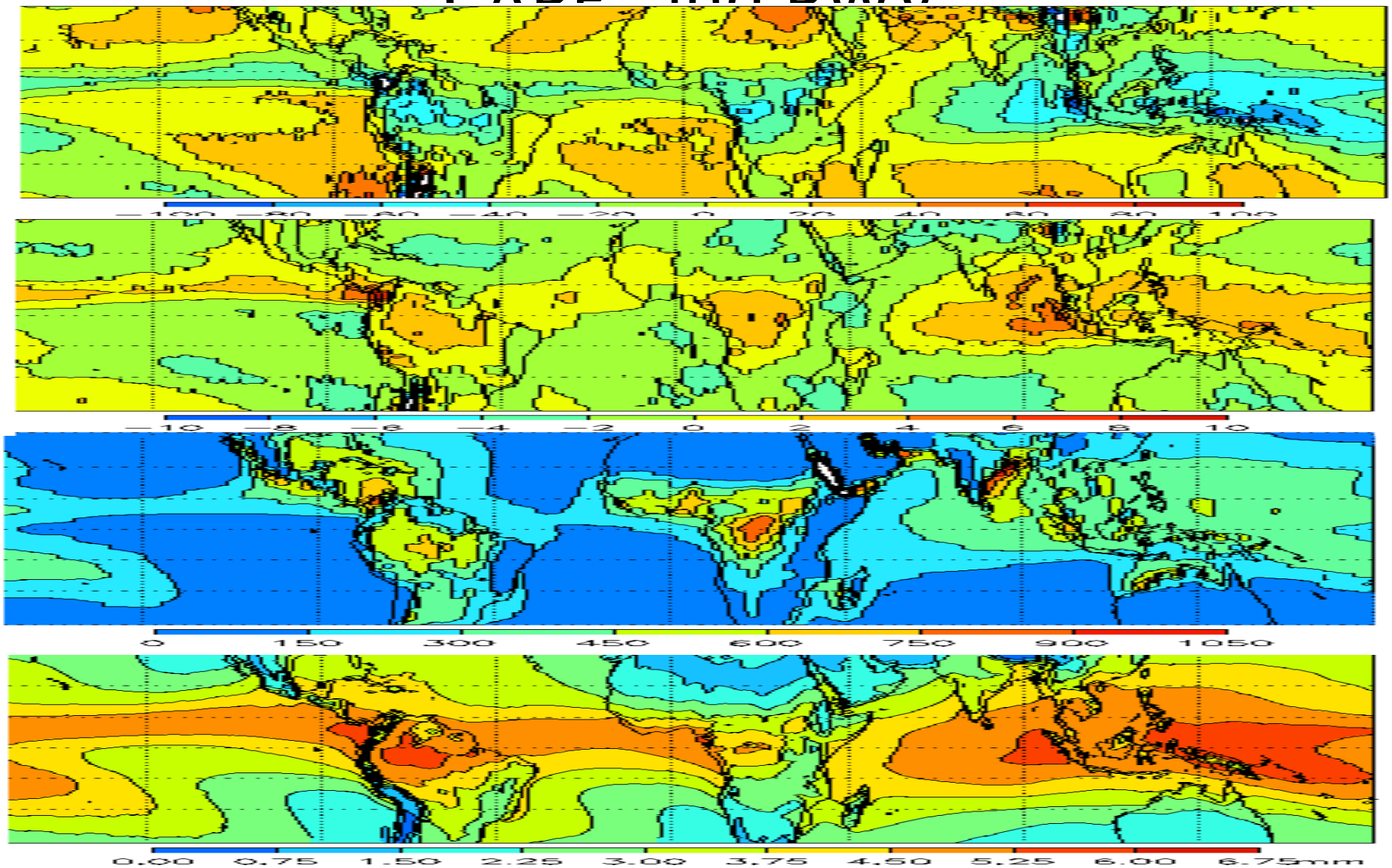
-Show binned curves.

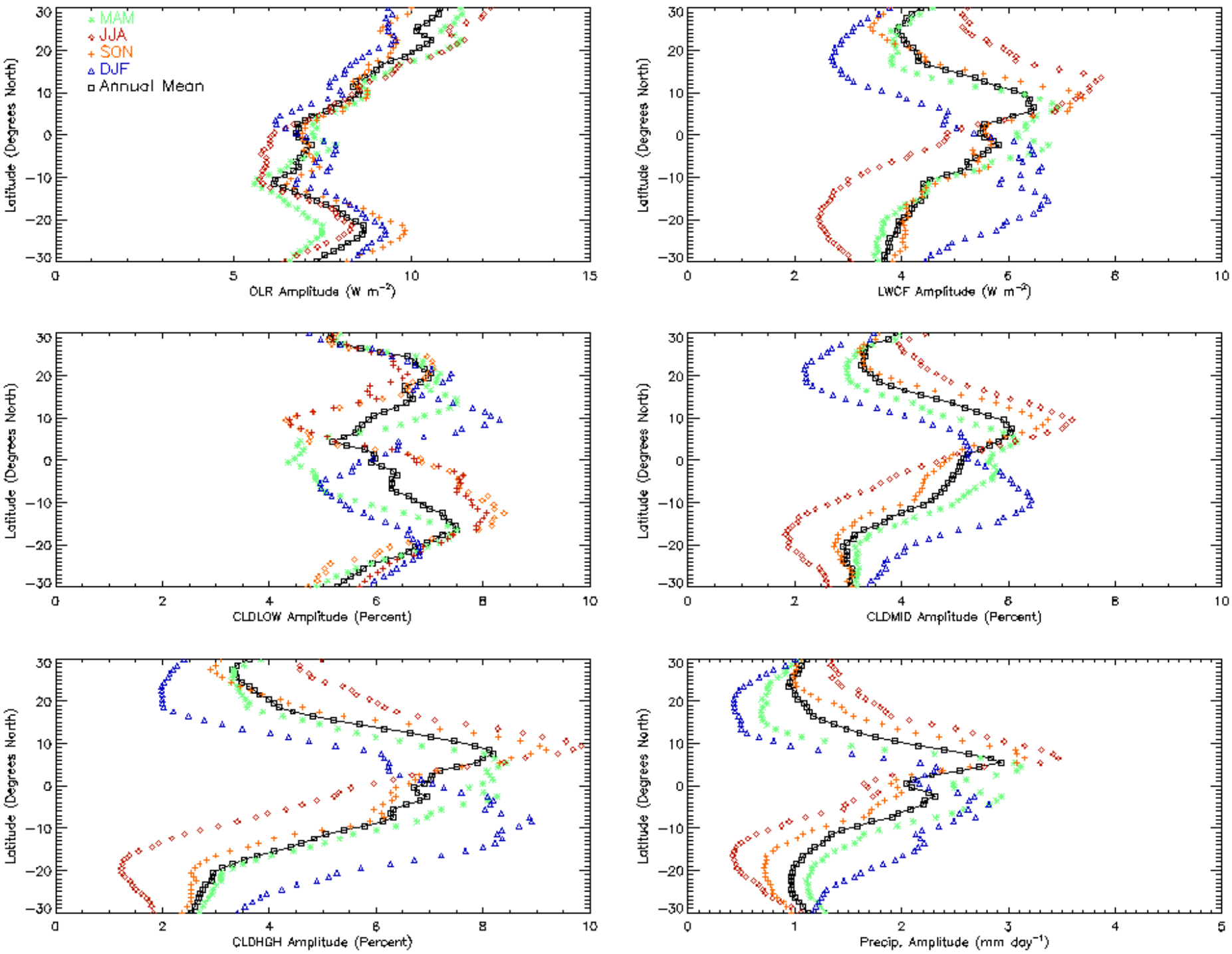
-Conclusions: The binned curves suggest that the slope of the regressions decrease when diurnal cycle regimes are considered, suggesting that the mean diurnal cycle amplitude distribution is determined by climatological cloud type and may be insensitive to the mean distribution of dynamical and thermodynamic variables.

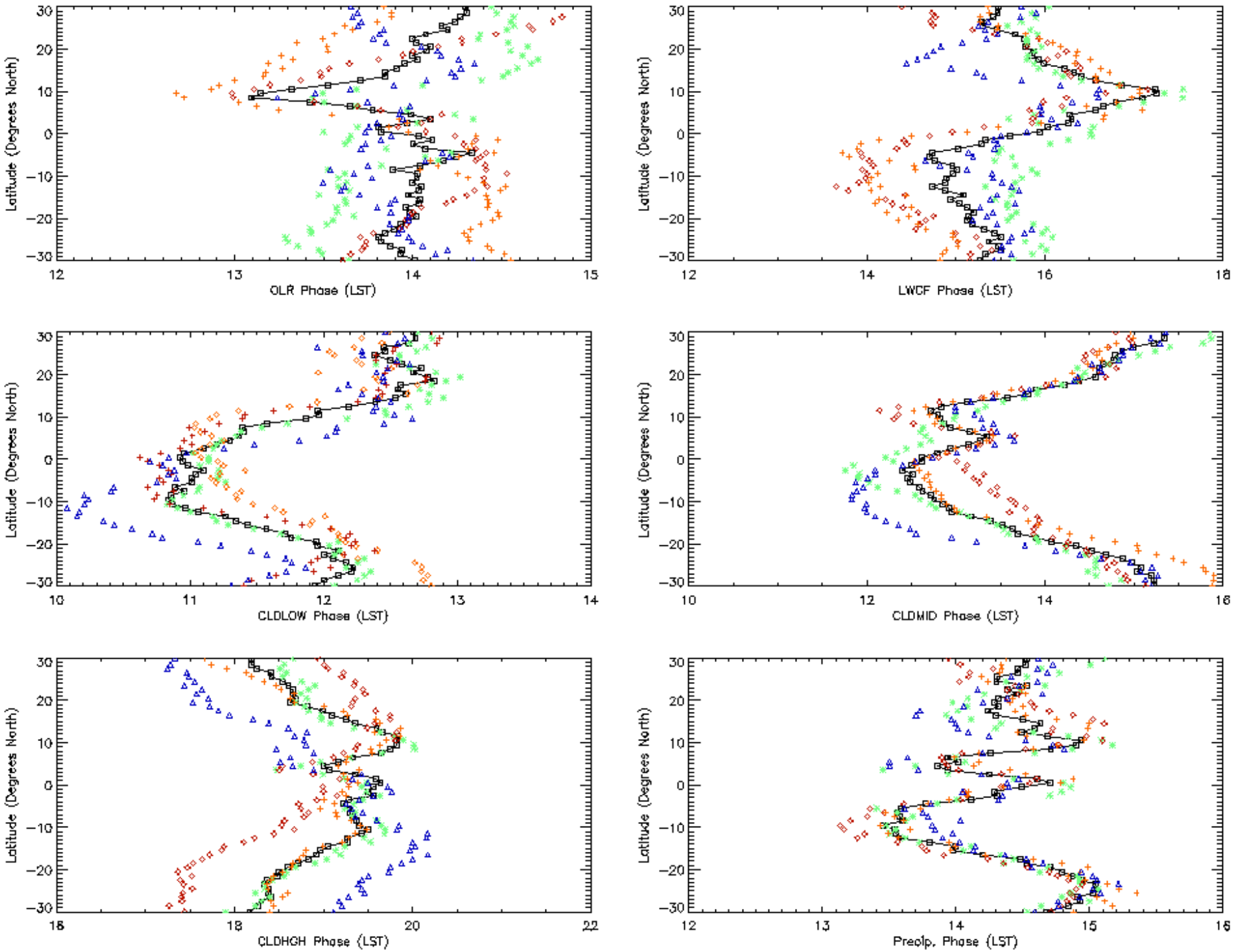
CLDLOW

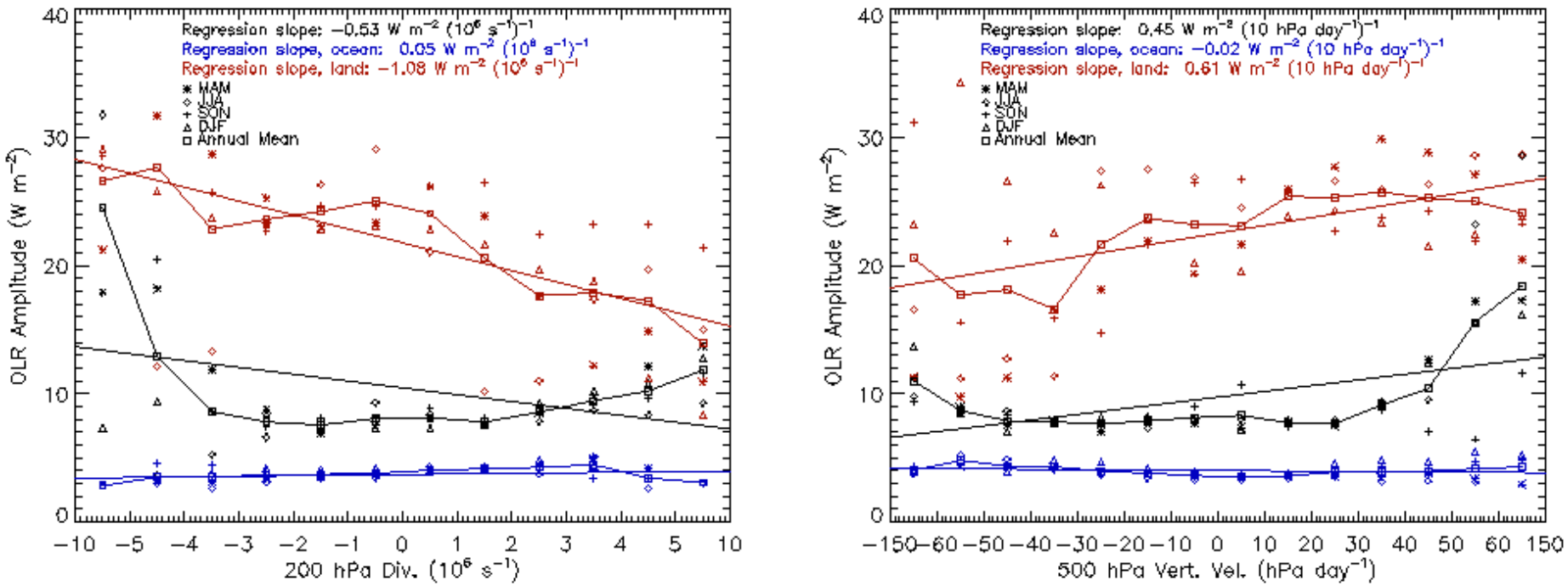

Regression slope: −0.19 Percent (10^6 s^−1)^−1
Regression slope, ocean: −0.38 Percent (10^6 s^−1)^−1
Regression slope, land: −0.05 Percent (10^6 s^−1)^−1
MAM
JJA
SON
DJF
Annual Mean
CLDLOW Amplitude (Percent)
200 hPa Div. (10^6 s^−1)
Regression slope: 0.23 Percent (10 hPa day^−1)^−1
Regression slope, ocean: 0.59 Percent (10 hPa day^−1)^−1
Regression slope, land: −0.15 Percent (10 hPa day^−1)^−1
500 hPa Vert. Vel. (hPa day^−1)
Regression slope: 0.01 Percent (100 J kg^−1)^−1
Regression slope, ocean: 0.16 Percent (100 J kg^−1)^−1
Regression slope, land: −0.23 Percent (100 J kg^−1)^−1
CAPE (J kg^−1)
Regression slope: −0.66 Percent (cm)^−1
Regression slope, ocean: −1.08 Percent (cm)^−1
Regression slope, land: 0.25 Percent (cm)^−1
Upper Tropospheric PWV (cm)

Annual Mean Div-200, Omega-500, CAPE, and PWV

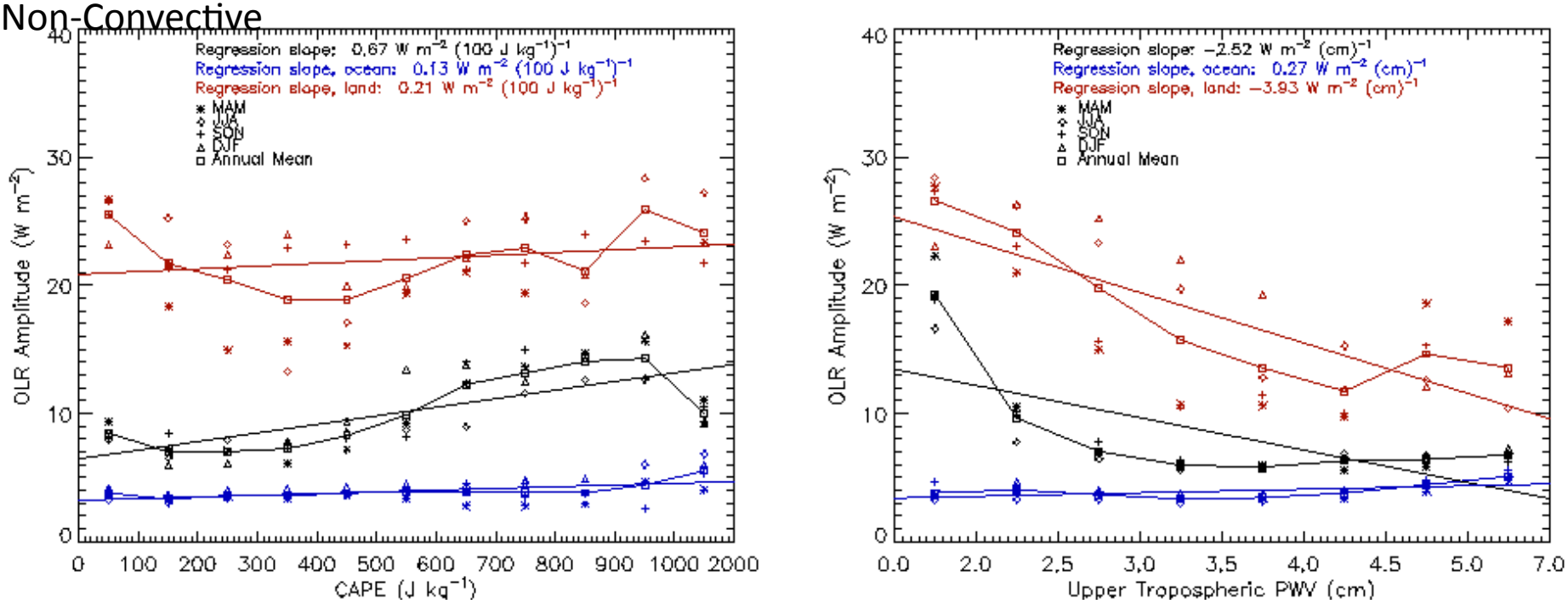


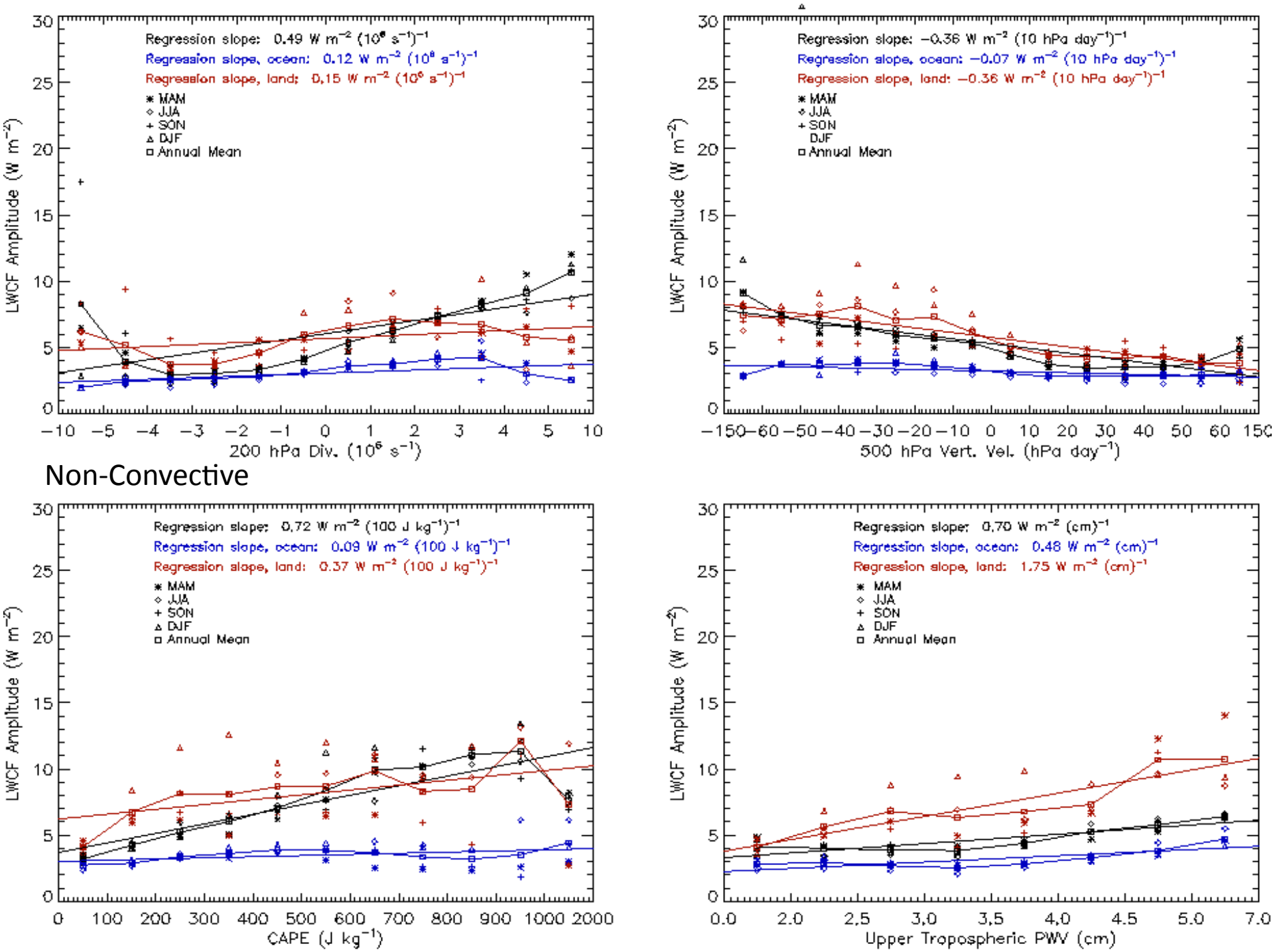

MAM
JJA
SON
DJF
Annual Mean
Latitude (Degrees North)
OLR Amplitude (W m^{-2})
LWCF Amplitude (W m^{-2})
CLDLOW Amplitude (Percent)
CLDMID Amplitude (Percent)
CLDHGH Amplitude (Percent)
Precip. Amplitude (mm day^{-1})


Latitude (Degrees North)
OLR Phase (LST)
LWCF Phase (LST)
CLDLOW Phase (LST)
CLDMID Phase (LST)
CLDHGH Phase (LST)
Precip. Phase (LST)



Non-Convective





Non-Convective