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

Patrick Taylor and Norman Loeb
NASA Langley Research Center
Climate Sciences Branch
CERES Science Team Meeting
3 May 2012
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

- **CERES Synoptic Data**
  - 3-hourly CERES-Geo merged data product.

- **Fourier Analysis** is used to compute diurnal harmonics.

\[ X'(t) = A \cos \left( \frac{2\pi t}{24 \text{ hrs}} - \phi \right) \]
CERES Climatology

Amplitude: W m\(^{-2}\)

Phase: Local Solar Time

Taylor (2012, Submitted)
Does OLR Diurnal Cycle Vary?
Diurnal Cycle Amplitude
Monthly Variability: 1°x1°

Units: W m⁻²
OLR Diurnal Cycle Amplitude Monthly Variability: 10°x10°

Units: W m⁻²

Taylor and Loeb (In prep.)
Diurnal Cycle Phase
Monthly Variability: 1°×1°

Units: Hours
Diurnal Cycle Phase
Monthly Variability: 10°x10°

Units: Hours

Taylor and Loeb (In prep.)
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. $OLR'$

10°x10°

Units: W m$^{-2}$
Quantifying diurnal shape contributions to OLR’

$$\text{OLR}_{\text{model}}(t) = \text{OLR}_{\text{clim}}(t) + \delta \text{OLR}_{\text{shift}}$$

$$\delta \text{OLR}_{dc} = \text{OLR}_{\text{obs}}(t) - \text{OLR}_{\text{model}}(t)$$

Local Time (Hours)

OLR (W m$^{-2}$)

OLR mean: 204.36
OLR$_{dc}$: −4.86
OLR$_{\text{Shift}}$: 1.59
OLR$_{\text{Anomaly}}$: −3.26
Contribution to Monthly OLR variability: $1^\circ \times 1^\circ$

Units: % Variance Explained

\[
\text{OLR}^2 = \delta \text{OLR}_{\text{shift}}^2 + \delta \text{OLR}_{dc}^2 + \text{cov}(\delta \text{OLR}_{\text{shift}}, \delta \text{OLR}_{dc})
\]

Taylor and Loeb (In prep.)
Contributions to Monthly OLR variability: 10° x 10°

Units: % Variance Explained

Taylor and Loeb (In prep.)
Implications for sun-synchronous sampling of OLR variability
What are the implications for satellite sampling of the ERB?

- AM-only
- PM-only
- AM+PM
- Full DC

[Graph showing OLR (W m\(^{-2}\)) over months for different sampling scenarios.]
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

Units: W m\(^{-2}\) yr\(^{-1}\)
# 68-month Tropical Mean OLR Trends

<table>
<thead>
<tr>
<th></th>
<th>Full DC</th>
<th>AM-Only</th>
<th>PM-Only</th>
<th>AM+PM</th>
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</thead>
<tbody>
<tr>
<td>Slope (W m(^{-2}) yr(^{-1}))</td>
<td>0.16</td>
<td>0.07</td>
<td>0.29</td>
<td>0.18</td>
</tr>
<tr>
<td>2-sigma conf.</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
<td>0.11</td>
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<tr>
<td>T-stat</td>
<td>2.7</td>
<td>1.2</td>
<td>4.7</td>
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<table>
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<tr>
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<th>AM+PM</th>
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</thead>
<tbody>
<tr>
<td>Slope (W m(^{-2}) yr(^{-1}))</td>
<td>-0.10</td>
<td>0.13</td>
<td>0.02</td>
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<tr>
<td>2-sigma conf.</td>
<td>0.06</td>
<td>0.04</td>
<td>0.02</td>
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<tr>
<td>T-stat</td>
<td>3.3</td>
<td>6.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Stdev</td>
<td>0.42</td>
<td>0.38</td>
<td>0.15</td>
</tr>
<tr>
<td>(f^2)</td>
<td>0.27</td>
<td>0.22</td>
<td>0.03</td>
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Leroy et al. (2008)
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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%
$A'(\pm 1\sigma)-A'(\mp 1\sigma)$

Units: W m$^{-2}$
OLR Diurnal Cycle Amplitude Sensitivity to 500 hPa Omega

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

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

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<td>1.8</td>
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<td>T-stat</td>
<td>6.9</td>
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<tr>
<td>Stdev</td>
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</tr>
<tr>
<td>f(^2)</td>
<td>0.01</td>
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How can $A'$ and $OLR'$ be related?
PDF of OLRMAX and OLRMIN