Relationship of regional radiation anomalies with environmental conditions

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Introduction

- **Short-Term Variations and Feedbacks**
  - climate states vary & drive radiation changes
  - variations in radiation fields: lead climate state changes
  - simulations & observations focus on radiation & clouds
  - difficulties: no clear signals <<<< non-linear, chaotic
  - climate variations in different time scales

- **Clouds and Radiation**
  - clouds are the direct factor affecting radiation fields
  - predictions of clouds >>>>>>> radiation
    \[ \Delta R = -\Delta c R_{clr} + (1-c)\Delta R_{clr} + \Delta c R_{cld} + c \Delta R_{cld} + \ldots. \]
  - clouds: also hard to resolve

Do not use clouds as one of the predictors or analysis variables
radiation anomaly

cld+clr combined

\[ \Delta R \approx -\Delta c \, R_{clr} + (1-c) \Delta R_{clr} + \Delta c R_{cld} + c \, \Delta R_{cld} \]
Observed radiation variations

- climate tendency: maintain its base state, especially LW
- processes: radiation, dynamics, & thermodynamics
- previous studies for global and tropical means
  very good results
Tropical Mean Analysis

Observed anomalies Estimates: meteorological variables

Corr. 0.867

Corr. 0.804

Corr. 0.832

time (yr)
Introduction (conti.)

- Current work on regional scales: tropics (±23°N)

What kinds of variables?

Subtropical
23° ~ 40° latitudes

Tropical Eastern Pacific
5° N ~ 5° S
90° ~ 150° W
Observation radiation variations

- climate tendency: maintain its base state, especially LW
- processes: radiation, dynamics, & thermodynamics
- previous studies for global and tropical means: very good results
- extended to regional analysis for the tropics
- anomalies of key parameters and variables for radiation:
  \( T, CWV, W, \nabla \cdot W, \Delta T_{LAT}, \Delta T_{LON}, O_3 \)

  higher-order terms: e.g. \( CWV \times W, T \nabla \cdot W, \Delta T_{LON} O_3 \)

  total 35 variables/parameters compound terms

and, Blackbody emission due to \( T \):

\[ \Delta LW_{BB} \approx -3.3\frac{W}{K} \text{ globally} \]

remove this term from CERES LW & Net first
Approaches

- **10-years CERES data: 2001 ~ 2010**
  - TOA radiation fields & changes
  - variations in T and other variables
  - 10 years ‘climatologies’

- **Data Processing**
  - tropical 23°S to 23°N zonal band
  - deseasonalized anomalies >>> perturbation/linearization
  - SSF1DEG monthly $1° \times 1°$ grid boxes
Approaches (conti.)

- **Radiation Change**

  \[ R = (1-c)R_{clr} + cR_{cld} \]

  \[ \Delta R = -\Delta c \cdot R_{clr} + (1-c)\Delta R_{clr} + \Delta cR_{cld} + c \Delta R_{cld} + \ldots \]

  \[ = \sum_i \left( \frac{\partial R}{\partial v_i} \right) \Delta v_i + \sum_{ij} \frac{\partial^2 R}{(\partial v_i \partial v_j)} \Delta v_i \Delta v_j + \text{other terms} \]

  after removing the \( \Delta LW_{BB} \) term in LW and Net

- multivariable linear regression

  eliminating statistically insignificant terms,

  until all terms are statistically meaningful

  empirically explain the anomalies in radiation fields

Thus, this analysis emphasizes on individual variable's influences on radiation
Results: environmental anomalies

Skin temperature

- 2002 Moderate El Nino
- 2009 Moderate El Nino
- 2007 Moderate La Nina
- 2010 Strong La Nina

Wind speed

- 2002 Moderate El Nino
- 2009 Moderate El Nino
- 2007 Moderate La Nina
- 2010 Strong La Nina

Anomaly for El Nino and La Nina years
Results: environmental anomalies

CWV

2002 Moderate El Nino

2009 Moderate El Nino

2007 Moderate La Nina

2010 Strong La Nina

O3

2002 Moderate El Nino

2009 Moderate El Nino

2007 Moderate La Nina

2010 Strong La Nina

Anomaly for El Nino and La Nina years
Results: environmental anomalies

\[ \Delta T_{LAT} \]

2002 Moderate El Nino

2009 Moderate El Nino

2007 Moderate La Nina

2010 Strong La Nina

\[ \Delta T_{LON} \]

2002 Moderate El Nino

2009 Moderate El Nino

2007 Moderate La Nina

2010 Strong La Nina

Anomaly for El Nino and La Nina years
Estimations

SW comparison

2002 Mod El Nino

2009 Mod El Nino

2007 Mod La Nina

2010 Strong La Nina

CERES

Estimate
Estimations

LW comparison

<table>
<thead>
<tr>
<th>Year</th>
<th>Type of Event</th>
<th>CERES Map</th>
<th>Estimate Map</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>Mod El Nino</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>2009</td>
<td>Mod El Nino</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>2007</td>
<td>Mod La Nina</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>2010</td>
<td>Strong La Nina</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
</tbody>
</table>
Estimations

CERES

Net radiation comparison Estimate

2002 Mod El Nino

2009 Mod El Nino

2007 Mod La Nina

2010 Strong La Nina
CERES - Estimate

LW

2002 Mod El Nino

2009 Mod El Nino

2007 Mod La Nina

2010 Strong La Nina

SW

2002 Mod El Nino

2009 Mod El Nino

2007 Mod La Nina

2010 Strong La Nina

[Color scale from -5 to 5]
Variability

- Very similar patterns for both SW and LW
- Large variability over convergent zones
- Minimal in tropical southeastern Pacific
Radiation from Individual Variables: SW

\[ \Delta R (v_i = 1\sigma) \]
Radiation from Individual Variables: LW

- skin: (-10, 10)
- CWV: (-20, 0)
- wind: (-10, 10)
- Div: (-10, 10)
- 03: (-10, 10)
- Tdiff°lat: (-10, 10)
- Tdiff°lon: (-10, 10)
Relation to Environments

Relationship with individual variables: SW Corr
## Relation to Environments

### Relationship with individual variables: LW Corr

<table>
<thead>
<tr>
<th>Variable</th>
<th>Correlation Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>skin</td>
<td>$(-1, 0)$</td>
</tr>
<tr>
<td>CWV</td>
<td>$(-1, 0)$</td>
</tr>
<tr>
<td>wind</td>
<td>$(-0.5, 0.5)$</td>
</tr>
<tr>
<td>Div</td>
<td>$(-1, 1)$</td>
</tr>
<tr>
<td>03</td>
<td>$(-0.5, 0.5)$</td>
</tr>
<tr>
<td>Tdiff°lat</td>
<td>$(-1, 0)$</td>
</tr>
<tr>
<td>Tdiff°lon</td>
<td>$(-1, 1)$</td>
</tr>
<tr>
<td>Total corr</td>
<td>$(0, 1)$</td>
</tr>
</tbody>
</table>

The images depict spatial distributions of the correlation coefficients for each variable, with color bars indicating the range of values from $-1$ to $1$. The color scale ranges from blue (-1) to red (1), with intermediate shades representing different magnitudes of correlation.
Relation to Environments

Relationship with individual variables: SW Corr

- skin$^2$ (-0.5, 0.5)
- CWV$^2$ (-0.5, 0.5)
- wind$^2$ (-0.5, 0.5)
- div$^2$ (-0.5, 0.5)
- Tdiff$^\circ$lat$^2$ (-0.5, 0.5)
- Tdiff$^\circ$lon$^2$ (-0.5, 0.5)
- skin*cwv (-0.5, 0.5)
- skin*wind (-0.5, 0.5)
- skin*div (-0.5, 0.5)
Summary

• Climate system has different characteristics in different time scale. This study analyzes radiative variations in short-time scales (within few years).

• TOA radiation variations are strongly related to basic meteorological state variables such as column water vapor, wind speed, divergence, O₃, and temperature gradient.

• The strongest contribution of surface temperature is from the blackbody emission.

• Wind and column water vapor dominant radiation variations, representing dynamic/thermodynamic impacts.
Summary (conti.)

• Surface temperature gradients along east-west directions clearly show certain general patterns, but not for those along meridional directions, which may indicate concentrated areas for Walker cells and wide spread Hadley circulation.

• These environmental variables could explain changes of regional radiation fields very well. (~70% variability explained)

• The use of the radiative relationships here as climate feedbacks should be with caution due to its short-term response nature as indicated by many dynamic and thermodynamic terms.

• Additional variables such as aerosols on radiation anomalies still need to be investigated.
Acknowledgement

Many people, especially Norm Loeb, Seiji Kato, Don Garber, and Gary Gibson, have significant supports for this study.