A Look at Intra-season to Inter-annual Variability in 12 years of AIRS Nadir-view Radiances and AIRS-CERES Spectral Fluxes

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Roadmap

• Motivation and Background Information
  – Archiving AIRS nadir-view radiance
  – Spectral fluxes estimated from the collocated AIRS and CERES observations
  – Spectral EOF (PCA) analysis

• Standard deviations of global-mean spectral radiances and fluxes
  – Comparison with published IASI results

• Spectral EOF analysis results (working in progress)
  – Global mean
  – Hemispheric mean
  – Zonal mean

What 12 years of AIRS data can tell us about spectral variability over different time scales?
Motivation and Background Information

• AIRS radiances (Sep 2002 to present)
  – L1B nadir-view radiances archived in nearly real time
    • Follow Huang & Yung (2005, JGR) procedures
    • Quality control of each AIRS spectrum
      – Bad channel detections (2081 out of 2378 channels used)
  • Average onto 2.5 lat by 2.0 lon grids; 16-day average for the uniform samplings
  • Ascending and descending nodes are processed separately then are averaged with equal weight
  • Using detrended data up to Dec 2014 in this analysis
Number of qualified nadir-view AIRS spectra in 2004
Motivation and Background Information

• The full LW spectral flux based on collocated AIRS and CERES observations
  – Leverage on the sophisticated scene type information from CERES SSF data set
  – Invert spectral flux using the pre-constructed spectral ADMs
  – Estimate spectral flux not covered by the AIRS instrument with a PCA-based regression scheme
  – Detrended spectral flux at 10 cm\(^{-1}\) interval from 10 to 2000 cm\(^{-1}\) (Sep 2002 to Nov 2014)

Ref: Huang et al. (2008; 2010; 2014), Chen et al. (2013)
Global OLR\textsubscript{AIRS\_Huang} - OLR\textsubscript{CERES}: annual means and year to year changes
Global mean spectral flux with 10 cm$^{-1}$ spectral interval

2008-2012 average

![Graph showing global mean spectral flux with 10 cm$^{-1}$ spectral interval for the years 2008-2012. The graph plots mean flux (W m$^{-2}$ 5 cm$^{-1}$) against wavenumber (cm$^{-1}$).]
Number of collocated observations used in averages for 2004
Spectral EOF

• Similar to the EOF approach widely used in climate data analysis

• Coherent Spectral patterns persistent from time to time (or from location to location)

Observation anomaly \( A = (I_1(\nu), I_2(\nu), \ldots I_n(\nu)) \)

\[
C = AA^T, \quad C\phi_i = \lambda_i \phi_i \quad \text{where} \quad \lambda_i \geq \lambda_{i+1}
\]

Principal Component \( \text{PC}^{(i)} = \sqrt{\lambda_i} \phi_i \)

Normalized Expansion Coefficient (time series, or spatial pattern)

\[
\text{EC}^{(i)}(t) = \left< \frac{\text{PC}^{(i)}}{\lambda_i}, A \right>
\]

PC has the same dimension as radiance

EC is normalized (std = 1)
Spectral EOF: the interpretation

- Always start from the PC1
- Forced linear orthogonality can complicate the physical interpretation

(Huang & Yung, 2005)
Standard deviations of annual global-mean spectra

2008-2012 IASI results

Brindley et al., J. Climate, 2015
AIRS2CERES Spectral flux

AIRS
All 5-year segments: AIRS
All 5-year segments: Spectral flux

Change of orders: far IR vs. mid IR

$\sigma_F (\text{Wm}^2/5\text{cm}^{-1})$

Wavenumber (cm$^{-1}$)
Spectral EOF analysis
Global-mean spectral flux: PCs

PC01 (96.65%)

PC02 (2.55%)

PC03 (0.36%)

PC04 (0.18%)
Global-mean spectral flux: Power spectra of PC time series

12 mon EC01 (96.65%)  2 mon

EC02 (2.55%)

6mon

EC03 (0.36%)

EC04 (0.18%)
Why is seasonal cycle still so dominant?

- Thermal contrast: Many channels are sensitive to boundary emission (surface or thick cloud top), more than anything else.

- Seasonality in global-mean surface temperature
  - Land-sea contrast: NH vs. SH
  - Eccentricity
Global-mean AIRS nadir radiances: PCs

PC 1 0.947

PC 2 0.031

PC 3 0.005

PC 4 0.004
Results after de-seasonalization
Results after de-seasonalization

EC 1 0.517

EC 2 0.159

EC 3 0.084

EC 4 0.072
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<td>96%</td>
<td>59%</td>
<td>87%</td>
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<td>Negligibly flat</td>
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Only detrended

SH mean radiances

Detrended and deseasonalized
Only detrended

SH mean radiances

Detrended and deseasonalized
Southern Hemisphere: spectral flux (deseasonalized)

PC01 (72.75%)  
PC02 (12.94%)

EC01 (72.75%)  
EC02 (12.94%)

EC03 (8.83%)  
EC04 (1.71%)
A Comparison of results based on detrended and deseasonlized spectra flux over different regions
Conclusion

• Depending on which 5 consecutive years are used, standard deviations of annual global-mean spectra can change considerably.

• Seasonal and semi-seasonal cycle dominates the PCs if data is not deseasonalized. Physical causes of the PCs can also change.
  – SH is a good example

• PCA analysis can help identify bad channels of AIRS to some extent

• Near-term work plan
  – Linear inverse modeling of spectral flux and radiances
  – How to “map” spectral variability back to geophysical dimension: spectral radiative kernel approach
Thank You!

Both AIRS radiances and spectral flux data can be provided upon request