Spectral signatures of climate variability and change diagnosed from LW observations-progress update

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with thanks to: Jacqui Russell, Jon Murray, Claudio Belotti, Christopher Dancel, John Harries, Xu Liu and Xianglei Huang
Can we use current/past instruments to get us part way there?

<table>
<thead>
<tr>
<th>Instrument</th>
<th>IRIS</th>
<th>IMG</th>
<th>AIRS</th>
<th>IASI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite</td>
<td>Nimbus 4</td>
<td>ADEOS</td>
<td>AQUA</td>
<td>METOP-A</td>
</tr>
<tr>
<td>Spectrometer type</td>
<td>FTS</td>
<td>FTS</td>
<td>grating spectrometer</td>
<td>FTS</td>
</tr>
<tr>
<td>Spectral coverage (cm(^{-1}))</td>
<td>400 – 1600 cm(^{-1}) continuous</td>
<td>715 – 3030 cm(^{-1}) 3 bands</td>
<td>650 – 2700 cm(^{-1}) 2378 bands</td>
<td>645 – 2760 cm(^{-1}) 3 bands</td>
</tr>
<tr>
<td>Spectral resolution</td>
<td>2.8 cm(^{-1})</td>
<td>0.1 cm(^{-1})</td>
<td>0.4–1.0 cm(^{-1})</td>
<td>0.5 cm(^{-1})</td>
</tr>
<tr>
<td>Footprint (nadir)</td>
<td>95 km diameter</td>
<td>8km x 8km</td>
<td>13 km diameter</td>
<td>12 km diameter</td>
</tr>
</tbody>
</table>

Clear-sky only, no account of variability

Harries et al., 2001
Griggs and Harries, 2007
IASI and IRIS?
IASI and IMG?
Major Questions

• What is the short-term variability seen in observed radiance spectra?
• How do these signals compare to those seen in model simulations and what can this tell us about the representation of the processes driving variability/change?
• Are observed long-term change signals robust?
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Ensure measurements are as consistent as possible

**Spatial consistency:**
average 16 IASI IFOV footprints

- **Direction of flight**

5 years of IASI L1c data: ~ 50 Tb
~ 160 million spectra
(nowarchiving 2013-2014)

**Spectral consistency**

**IRIS**
Pad each spectrum to 0-2000 cm\(^{-1}\) at original sampling interval
- FT padded spectrum
- FT and output at 0.1 cm\(^{-1}\) sampling interval (~ 2.8 cm\(^{-1}\) resolution)

**IASI**
Pad and truncate average spectra to 0-2000 cm\(^{-1}\) at original sampling interval
- FT, remove IASI apodisation function & apply varying length Hamming window
- FT output at 0.1 cm\(^{-1}\) sampling interval (~ 2.8 cm\(^{-1}\) resolution)
- Apply remaining FOV correction factor
Short-term spectral variability

Standard deviation in 10° latitude band annual means

1 K ~ 1 mW m⁻² (cm⁻¹)⁻¹ sr⁻¹
Short-term spectral variability

Deviation from overall global annual mean for each year

Multivariate ENSO Index (NOAA ESRL) [black]
CERES OLR [blue and red]
Short-term spectral variability

Standard deviation in 10° latitude band annual means

Standard deviation in global annual means

Note change in scale and change in shape
Short-term spectral variability

Huang and Ramaswamy, (2009)
AIRS: 2002-2007
GFDL, CM2
Consistency with broadband measurements?

Employ observations from CERES: broadband and window fluxes.
Different measurement scales so use coefficient of variation, \( CV \)

\[
CV = \frac{\sigma}{\mu} \quad \text{and note that} \quad \sigma_{BB} = [\sigma_{\text{win}}^2 + \sigma_{\text{nonwin}}^2 + 2\text{cov}_{\text{win,nonwin}}]^{1/2}
\]
• Window inter-annual variability reduces most rapidly with increasing scale
• Results in non-window variability becoming dominant at global scale
• Difference between IASI BB and CERES BB behaviour suggests an important role for the far infra-red in determining all-sky inter-annual variability at the global scale
• Spectrally, global inter-annual variability < 0.17 K, < 0.05 K across window
Major Questions

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Consistency with Reanalyses?

PCRTM
Liu et al., 2006

\[ Y_i = \sum_{j=1}^{N_{\text{EOF}}} \alpha_j R^{\text{mon}}(j) \]

EOF Transformation
\[ \vec{R}^{\text{EOF}} = \sum_{i=1}^{N_{\text{EOF}}} y_i \vec{U}_i \]

Next Profile

Generate predictors by performing monochromatic RT calculations

Data

Input PCRTM Parameters (OD, PCs, cloud parameters, etc.)

No

Channel Radiance?

Yes

\[ \sim 10 \text{ million matched IRIS-like IASI spectra} \]
(in 10 days!)

X. Huang, University of Michigan

ECMWF ERA—Interim Reanalysis

Annual 1979–2011 Average

Temperature at 2 meters (deg C)
Consistency with Reanalyses?

OBSERVATIONS

SIMULATIONS

10° bands

Northern Hemisphere

Southern Hemisphere
Consistency with Reanalyses?

**OBSERVATIONS**

**SIMULATIONS**

Global
Consistency with Reanalyses?

- Window inter-annual variability reduces most rapidly with increasing scale
  
  *Simulations show the same behaviour but reduction in window is not as rapid. Non-window variability exceeds broadband at all scales and seems to show a faster rate of change with scale than observations*

- Results in non-window variability becoming dominant at global scale
  
  *Window variability still dominates at global scale*

- Spectrally, global inter-annual variability $< 0.17 \text{ K}$, $< 0.05 \text{ K}$ across window
  
  *Variability $< 0.15 \text{ K}$ but up to $0.08 \text{ K}$ within window*
Major Questions

• What is the short-term variability seen in observed radiance spectra?
• How do these signals compare to those seen in model simulations and what can this tell us about the representation of the processes driving variability/change?
• Are observed long-term change signals robust?
Ocean only scenes, 220 K < \( T_{B_{1126}} \) < 250 K, IRR & IRIS
Ocean only scenes, $290 \text{ K} < T_{B1126} < 310 \text{ K}$, IRR & IRIS
Ocean only scenes, $290 \, \text{K} < T_{B1126} < 310 \, \text{K}$, IRR & PCRTM
Global Mean AMJ $T_B$ difference spectra

**IRR-IRIS**

**IMG (97)-IRIS (70)**

**IRR-IMG**
Summary

• Used IASI data to probe how the emission to space varies spectrally on short timescales. While variability reduces with increasing spatial scale across the spectrum, the rate of change varies with wavenumber. Hence a more marked reduction is seen in window variability compared to that seen in regions sensitive to the upper troposphere.

• These findings are in agreement with observations from CERES over the same period and imply that at the largest spatial scales fluctuations in mid-upper tropospheric temperatures and water vapour, and not surface temperature or cloud, play the dominant role in determining the level of inter-annual all-sky OLR variability. (Brindley et al., *J. Clim*, in review)

• Although simulations from reanalysis show an encouraging level of agreement in general, they do not replicate this scaling behaviour.

• To diagnose longer term spectral changes confidence in instrument calibration and stability is key.
TRUTHS/NCEO status

• New Minister for Universities and Science from July 2014 (Greg Clark): national/bilateral mission opportunities unlikely before UK general election.

• Presentations made to Mark Walport (Government Chief Scientific Advisor), Ian Boyd (Chief Scientific Advisor at DEFRA), Outgoing DECC Chief Scientist. DECC Climate Minister visiting NPL in November.

• Joint bid with Airbus-DS for TRUTHS related funding in latest CEOI round (£1M budget). [Note that Imperial has also submitted a bid for FIR instrument development to same call].

• Formal letter of support for TRUTHS from NASA HQ?

• Ongoing CASE PhD studentship with Imperial to strengthen science case.

• Studies supporting CLARREO funded until at least April 2015 via NCEO (new director: John Remedios; HB now joint head of Earth Observation Data and Model evaluation division). Should be opportunities for continued funding for TRUTHS/CLARREO science support.