Comparison of Climate Variables from AIRS, IASI, and CrIS - CLARREO Implications

W. L. Smith, N. Smith, E. Weisz, and H.E. Revercomb
# Ultra-spectral Measurement Characteristics

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Instrument</th>
<th>Spatial resolution</th>
<th>Spectral resolution</th>
<th>Spectral Range</th>
<th>Spatial Sampling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aqua (1330 LST)</td>
<td>AIRS (2002 -)</td>
<td>3x3 13.5-km (50 km)</td>
<td>~1200 resolving power</td>
<td>645-2700 cm⁻¹</td>
<td>Contiguous Cross-track scan</td>
</tr>
<tr>
<td>Metop-A/B (0900/0930 LST)</td>
<td>IASI (2006 -)</td>
<td>2x2 12.0-km (50 km)</td>
<td>0.25 cm⁻¹</td>
<td>645-2760 cm⁻¹</td>
<td>Contiguous Cross-track Scan</td>
</tr>
<tr>
<td>SNPP (1330 LST)</td>
<td>CrIS (2011 -)</td>
<td>3 x 3 13-km (50 km)</td>
<td>0.6 cm⁻¹</td>
<td>645-2700 cm⁻¹</td>
<td>Contiguous Cross-track Scan</td>
</tr>
<tr>
<td>CLARREO Polar (All LST)</td>
<td>IR-SW/MW</td>
<td>25 to 100-km (TBD km)</td>
<td>0.5 cm⁻¹</td>
<td>200-2700 cm⁻¹</td>
<td>Nadir</td>
</tr>
</tbody>
</table>
Desirable Features of a Climate Variable Retrieval Algorithm*:

- **Linear dependence on radiance spectra**
  - Variation depends only on radiance (i.e., no other input variables)
- **All sky**
  - clear and cloudy (0 - 100%)
- **Independent of Field-of-View (FOV) size**
  - Can be applied to different instruments
- **Retrieval Variables**
  - **Surface**: temperature & spectral emissivity
  - **Atmosphere**: T, H$_2$O, and O$_3$ profiles & CO$_2$ ppm
  - **Cloud**: height and optical thickness

“Dual-Regression” Retrieval Algorithm Overview

Theoretical Statistics

Radiance Observations

Global clear soundings
Radiances (clear FM)
Clear-trained regression coefficients

Global cloudy soundings
Radiances (cloudy FM)
Cloud height classes
Cloud-trained regression coefficients

Clear-trained EOF regression retrieval

Cloud-trained EOF regression retrieval

Cloud Top Altitude
Level where $T_{\text{cloudy}} > T_{\text{clear}}$ for $p > p_{\text{cl}}$

Final Profile
from cloudy and/or clear retrievals

Temperature, Humidity and Ozone profiles, Surface and Cloud parameter at single FOV (15-km) resolution

500-hPa (5-km) Temperature AIRS Vs. GDAS
7-yr (2003-2009) Mean & Annual Trend (Feb+Aug)
AIRS Vs. GDAS 2003 – 2009 Climate Statistics

**Temperature**
- **AIRS > GDAS**
- **AIRS < GDAS**

**Relative Humidity**
- **AIRS > GDAS**

**AIRS is Reasonable:**
- Warming Troposphere
- Cooling Stratosphere

2003-2009 Global Mean Temperature Difference

2003-2009 Global Mean Relative Humidity
Comparing AIRS, IASI, and CrIS 2012 Annual Means*

Annual Average Cloud Height and Deviations from AIRS+IASI+CrIS (2012)

- **AIRS** – \((\text{AIRS}+\text{IASI}+\text{CrIS})/3\)
- **IASI** – \((\text{AIRS}+\text{IASI}+\text{CrIS})/3\)
- **CrIS** – \((\text{AIRS}+\text{IASI}+\text{CrIS})/3\)

- **CrIS (land) and AIRS (ocean) have smallest differences with respect 3 Instrument Mean**
- **IASI and CrIS Opposite Sign Over West Coastal Stratus Regions (diurnal dependence ?)**

- **Annual mean is defined as the average of the months of February, May, August, and November.**
- **The gridding was performed using the technique described by Smith, N, W.P Menzel, E. Weisz, A. Heidinger and B.A. Baum, 2013, “A uniform space-time gridding algorithm comparison of satellite data products: Characterization and sensitivity studies” JCAM, 52: 255–268)**
Comparing AIRS, IASI, and CrIS 2012 Annual Means
Annual Average Cloud Optical Depth and Deviations from AIRS+IASI+CrIS (2012)

IASI has smallest differences with respect to Mean of the Three Instruments AIRS and CrIS of Opposite Sign (i.e., no diurnal dependence)
Comparing AIRS, IASI, and CrIS 2012 Annual Means

Annual Average 850 hPa T and Deviations from AIRS+IASI+CrIS (2012)

(AIRS+IASI+CrIS)/3

AIRS – (AIRS+IASI+CrIS)/3

IASI – (AIRS+IASI+CrIS)/3

CrIS – (AIRS+IASI+CrIS)/3

CrIS has smallest T differences with respect to Mean of the Three Instruments
CrIS and AIRS in Agreement in their Difference wrt IASI (i.e., diurnal dependence ?)
Comparing AIRS, IASI, and CrIS 2012 Annual Means

Annual Average 850 hPa RH and Deviations from AIRS+IASI+CrIS (2012)

(AIRS+IASI+CrIS)/3

AIRS – (AIRS+IASI+CrIS)/3

IASI – (AIRS+IASI+CrIS)/3

CrIS – (AIRS+IASI+CrIS)/3

AIRS has smallest T differences with respect to Mean of the Three Instruments CrIS and AIRS of Opposite Sign (instrument dependence ?)
Comparing AIRS, IASI, and CrIS 2012 Annual Means

Annual Average 500 hPa T and Deviations from AIRS+IASI+CrIS (2012)

CrIS has smallest RH differences with respect to Mean of the Three Instruments
CrIS and AIRS Opposite Sign Over North Africa (instrument dependence ?)
Comparing AIRS, IASI, and CrIS 2012 Annual Means

Annual Average 500 hPa RH and Deviations from AIRS+IASI+CrIS (2012)

(AIRS+IASI+CrIS)/3

(AIRS+IASI+CrIS)/3

IASI – (AIRS+IASI+CrIS)/3

CrIS – (AIRS+IASI+CrIS)/3

AIRS (water) & CrIS (land) Have Smallest RH Differences wrt 3 Instrument Mean
Comparing AIRS, IASI, and CrIS Annual Means

Annual Average 850 hPa T & RH Deviation From GDAS for AIRS, IASI, and CrIS (2012)

13:30 PM

09:30 AM

13:30 PM

All Three Instrument “Agree” In Their Differences With Respect to GDAS
Comparing AIRS, IASI, and CrIS Annual Means

Annual Average 500 hPa T & RH Deviation From GDAS for AIRS, IASI, and CrIS (2012)

All Three Instrument “Agree” In Their Differences With Respect to GDAS
Summary and Conclusion

1. Deviations of AIRS, IASI, and CrIS from the mean of the three instruments:
   – Cloud heights from all three instruments are in excellent agreement
   – Cloud optical depth differences can be as large as 2
   – Regional temperature differences can be as large as 3 degrees
   – Regional relative humidity differences can be as large as 15 %

2. Differences appear to be more instrument related rather than being diurnal sampling related

3. The three instruments (AIRS, CrIS, and IASI) agree in their deviations from analyses of operational data (i.e., GDAS)

4. These preliminary results support the need for a common absolute reference in orbit (e.g., CLARREO)