CrIS Trace Gas Data Users Workshop: Goals and Agenda

Matthew J. Alvarado
Atmospheric and Environmental Research

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Why are we here?

• Trace gas retrievals from thermal infrared (TIR) sounders (e.g., TES, AIRS, MOPITT, IASI) are used extensively by scientists studying:
  – Atmospheric Chemistry
  – Air Quality
  – The Carbon and Nitrogen Cycles
  – Climate Change

• All of the NASA EOS TIR sounders (TES, AIRS, and MOPITT) are past their design lifetimes, and there are no current plans at NASA to replace these instruments.
3.3 CrIMSS EDRs

temperature shows a discontinuous increase in difference across a $\chi^2$ value of 1 and the tropical saturated upper troposphere where $\chi^2$ is greater than 50. At most levels the difference either independent of $\chi$ or weakly dependent on it. For these reasons, we believe $\chi^2$ is a poor Q/C detector and recommend high registered error obtained by propagating radiance residual or error covariance to a product error estimate.

3.3.2 Ozone IP

Ozone is an important AIRS/CrIS product and could supplement the Ozone Mapper and Profiler Suite (OMPS) products on NPP by providing nighttime ozone, polar winter ozone, and some measure of tropospheric ozone. CrIS should easily be able to continue this product, possibly with improvements due to the far lower CrIS noise levels in the long-wave $O_3$ channels (compared to AIRS). Ozone is an intermediate product for the CrIMSS algorithm; but as yet the quality of this product has not been investigated by the NPP Sounder Team. We provide here in Fig. 26 a comparison done by the NOAA STAR Team (led by Larry Flynn) from the CrIMSS Provisional Review at NOAA, showing OMPS total ozone and the CrIS derived total ozone for Oct. 16, 2012. This figure at least shows good qualitative agreement, rigorous validation remains to be done. We do note that the impact of the excellent signal-to-noise of CrIS (relative to AIRS, for example) in the $O_3$ sounding region has yet to be explored. Synergy between the OMPS total column $O_3$ and CrIS derived $O_3$ should also be explored.

Figure 26: Left: OMPS, Right: CrIS total ozone, Larry Flynn, NOAA/NESDIS

3.3.3 EDR Validation Issues

At the time of this report (Spring 2013), the CrIMSS EDR products are in transition from "beta" to "provisional" status. The results presented here are a high level summary of results by the NPP science team members, some of whom are also JPSS Cal/Val team members. The top level conclusion is that the CrIMSS product has seen rapid improvements since launch in the very capable hands of the JPSS EDR Cal/Val team lead (Chris Barnet) at NOAA NESDIS working closely with the original CrIMSS algorithm innovator (Xiu Lu) at NASA LaRC. The result is that Mx 6.4 (Oct. 15, 2012 to current) is much improved in both bias, RMS, and yield (1% to 25% in MW+IR) over the previous version Mx6.3 and offline evaluations of Mx7 suggest further improvements in yield (about 50% in MW+IR) will be obtained in the next IDPS version update (approx. Feb. 2013). Performance results are summarized in Fig. 31 in the Appendix of this report.

One possible criticism of the NOAA validation approach is over reliance on an NWP analysis field (in this case ECMWF) for the "truth" field. To mitigate this concern; the team members will be making assessments of the CrIMSS product against "independent" measurements. (Note, since many data types, including satellite data, are assimilated into NWP models and because NWP model fields are used in retrieval regression training, the term "independent" is used here in a qualitative sense only.) The independent measurements being used to assess the CrIMSS product for climate quality include:

- Fourier Transform Infrared (FTIR) Spectrometer aboard Suomi-NPP
- NOAA is planning to launch future versions on JPSS-1 (2017), JPSS-2 (2022), …
- NOAA NUCAPS produces retrievals of $O_3$, CO, CO$_2$, CH$_4$, N$_2$O, HNO$_3$, and SO$_2$
- AER prototype retrieves NH$_3$
- But the current products are not extensively used by the science communities and they need to be further evaluated.
# CrIS versus other TIR sounders

<table>
<thead>
<tr>
<th></th>
<th>MOPITT</th>
<th>AIRS</th>
<th>TES</th>
<th>IASI</th>
<th>CrIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite</td>
<td>EOS-Terra</td>
<td>EOS-Aqua</td>
<td>EOS-Aura</td>
<td>MetOp-A/B</td>
<td>Suomi-NPP</td>
</tr>
<tr>
<td>Technique</td>
<td>Gas-cell Correlation Radiometry</td>
<td>Grating Spectrometer</td>
<td>FTIR Spectrometer</td>
<td>FTIR Spectrometer</td>
<td>FTIR Spectrometer</td>
</tr>
<tr>
<td>Resolution</td>
<td>0.04 cm(^{-1}) (eff. res.)</td>
<td>0.5-2.3 cm(^{-1}) ((\lambda/\Delta\lambda=1200))</td>
<td>0.10 cm(^{-1}) apodized</td>
<td>0.50 cm(^{-1}) apodized</td>
<td>0.625 cm(^{-1}) (potential)</td>
</tr>
<tr>
<td>Footprint</td>
<td>22x22km</td>
<td>45x45km (cloud-cleared)</td>
<td>5x8 km</td>
<td>12 km circle (2x2 array)</td>
<td>14 km circle (3x3 array)</td>
</tr>
<tr>
<td>Swath</td>
<td>640 km</td>
<td>1650 km</td>
<td>N/A</td>
<td>2200 km</td>
<td>2200 km</td>
</tr>
<tr>
<td>Global Coverage</td>
<td>3 days</td>
<td>Twice Daily</td>
<td>16 days</td>
<td>Twice Daily</td>
<td>Twice Daily</td>
</tr>
<tr>
<td>Eq. crossing (am/pm)</td>
<td>~10:20</td>
<td>~1:15</td>
<td>~1:40</td>
<td>~8:45/9:30</td>
<td>~1:30</td>
</tr>
</tbody>
</table>
CrIS Noise Remarkably Low!

Low noise may make it possible to retrieve species difficult to see with AIRS, IASI, or TES (HCN, C₂H₂, etc.).

[Zavyalov et al., 2013]
Spectrum Comparison

<table>
<thead>
<tr>
<th>Band</th>
<th>Spectral range [cm⁻¹]</th>
<th>Spectral range [µm]</th>
<th>Band width [cm⁻¹]</th>
<th>Resolution Δσ [cm⁻¹]</th>
<th>MPD [cm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>LW</td>
<td>650 – 1095</td>
<td>15.4 – 9.1</td>
<td>445</td>
<td>0.625</td>
<td>0.8</td>
</tr>
<tr>
<td>MW</td>
<td>1210 – 1750</td>
<td>8.3 – 5.7</td>
<td>540</td>
<td>1.25</td>
<td>0.4</td>
</tr>
<tr>
<td>SW</td>
<td>2155 – 2550</td>
<td>4.6 – 3.9</td>
<td>395</td>
<td>2.5</td>
<td>0.2</td>
</tr>
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</table>

Not an instrument limitation – 0.625 cm⁻¹ data for these bands coming soon!

Simulated CrIS spectrum overlaid with IASI and AIRS spectra

*Image from Y. Han and D. Tremblay (NOAA) 2012 AMS Talk*
Need For Full Resolution CrIS Data

Simulated NUCAPS CO Retrieval

[0.625 cm\(^{-1}\)]

[2.5 cm\(^{-1}\)]

[Gambacorta et al., 2014]
Spectrum Comparison

Not an instrument limitation – 0.625 cm\(^{-1}\) data for these bands coming soon!

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<th>Spectral range [(\mu)m]</th>
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<th>Resolution (\Delta\sigma) [cm(^{-1})]</th>
<th>MPD [cm]</th>
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Spectral gap cuts out HCOOH and PAN signal!

Image from Y. Han and D. Tremblay (NOAA) 2012 AMS Talk
Need an “Observation Operator” to compare models with satellites (and sats w/ other obs!)

- L. Schiferl and C. Heald are investigating Intrannual variability in NH$_3$ using IASI and AMoN
- Challenge: new IASI ammonia product does not include averaging kernels [Van Damme et al., 2014]

Figures from Luke Schiferl and Colette Heald, MIT
What is needed to increase use of CrIS trace gas products?

• Demonstrate that:
  – The scientific community needs these products
  – Operational users (e.g., AQ and chemical weather forecasters) within and outside NOAA need these products
• More communication between retrieval, science, and operational end user teams
• Validation of products
• Improvement of current products based on validation
• Development of new products
• Get full spectral resolution from CrIS
  – Should be available by end of 2014

• Assess the products that can be retrieved from CrIS and their potential accuracy compared to other sounders
  – Much work has been done on retrieving gases from CrIS
  – But further validation needed and additional products may be possible

• Use multi-spectral approaches to obtain near-surface trace gas data
  – Lots of work done with MOPITT NIR/TIR, TES/OMI, AIRS/OMI, and CrIS/OMPS for CO and O₃, but much more work to do!
  – Combine at retrieval or assimilation level?
Agenda

• Today:
  – JPSS Overview
  – CrIS Trace Gas Retrievals
  – Use of TIR Retrievals in Atmospheric Chemistry and Climate Studies
  – Poster Session and Reception

• Tomorrow
  – Breakout Sessions
    • Greenhouse Gases (e.g., CH₄, CO₂, N₂O)
    • Air Quality (e.g. CO, O₃, NH₃)
  – Discussion
  – Assign Action Items
After the Workshop

- Keep talking!
- Community report on what needs to be done to use CrIS for atmospheric chemistry
- Op. Ed. In EOS or other forums
- Coordinate with field campaigns for validation activities
Logistics

- UM Shuttle
  - Back to Holiday Inn at 7:30 PM Thursday
  - From Holiday Inn at 7:30 AM Friday
  - Back to Holiday Inn at 5 PM Friday

- Meals
  - Reception at poster session tonight
  - Breakfast at 8 AM Friday
  - Box Lunch at 12 PM Friday