Using ARM data to provide atmospheric state best estimates for satellite retrieval validation

Lori Borg, David Tobin, Michelle Feltz, Robert Knuteson, Tony Reale, Quanhua (Mark) Liu, Donna Holdridge, Jim Mather

Cooperative Institute for Meteorological Satellite Studies Space Science and Engineering Center
University of Wisconsin-Madison, USA
• ARM & GRUAN can help the satellite community
• The satellite community can help ARM & GRUAN

Needs: sonde processing validation

Needs: T & WV retrieval validation

Comparisons between observed satellite radiances and radiances computed from coincident in situ profile data can be used to validate the accuracy of the radiative transfer. Similarly, these comparisons can be used to identify issues with sonde calibration.
Validation of the AIRS Radiative Transfer Algorithm

- significant differences in the RS-90 biases between day and night
S-NPP Validation: Sonde Launches

**Sonde Launch Efforts**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Site</th>
<th>Start</th>
<th>Stop</th>
<th>nOverPasses</th>
<th>nSingle</th>
<th>nDual</th>
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</table>

Table 1 CrIMSS EDR sonde launch efforts: Phase-1 through Phase-4, July 2012 – March 2016.
S-NPP Validation: RS-92 Launch Strategies

- Single Launch: 15 minutes prior to overpass
- Dual Launch: 45 & 5 minutes prior to overpass
While the collection sites are limited in number, the profiles consist of highly accurate measurements of a wide range of climatic conditions.
Differences between sonde pairs are shown
mean (dashed) & RMS (solid) differences shown in red for 1km (temp) & 2km (h2o) layers
The variability in temperature that occurs within ~40 minutes is 3/4°K
The water vapor RMS percent differences range from 5-30%
• 1km layer differences shown for each ARM site for ALLSky conditions
• mean (dashed) & RMS (solid) differences shown

S-NPP Validation: Validation of NUCAPS Temperature Retrievals
• Radiosondes often not best suited in measuring UTLS temperatures
• GPS RO offers potential produce climate quality measurements with SI traceability

• RO Background
  • Measurements are very stable
  • Profiles are pseudo-random in time and space
  • Temperature derived from GPS signals occulted by Earth’s atmosphere
    • Dry Temp product stated to have high accuracy in UTLS (~200-10 hPa)
      • Below, water vapor contamination causes cold bias
      • Above ionospheric contribution noise causes errors to increase with height
    • Low horizontal resolution: ~200km along raypath
    • High vertical resolution: 0.1-1km from trop. to strat.
Basic Message:
• 1970-1995: stratospheric cooling due to decrease in ozone and increase in CO2
• 1995-2015: zero trend due to the rebound (increase) ozone causes a warming that appears to be cancelling the cooling caused by increasing CO2
• Lack of reference-quality observations a major problem
• GPS RO & GRUAN can help resolve trends & ambiguities in stratospheric temperature
S-NPP Validation: COSMIC Matchups w/Dedicated Launches

Matchup Criteria:
- 300km/3hr
- 100km/1hr

courtesy of Michelle Feltz
This is an example showing benefit of RO & sonde over IR sounder
• RO & sonde pick up coldest layer at tropopause
• NUCAPS captures general structure well, but not able to pick up finer vertical structures

Matchup Criteria:
• 100km/1hr
S-NPP Validation: COSMIC Matchups w/Routine Launches at NSA

- May 2012 thru April 2015
- Criteria: 3hrs, 300km
- Small sample numbers
- Average over all seasons

LEGEND:
- Solid: bias
- Dashed: RMS
- Dotted: bias +/- 2*(bias uncertainty)

- NUCAPS has a ~1K cold/warm bias at ~150hPa/250hPa respectively
- Bias btwn RO and sonde less than 0.5K where there’s more samples and no water vapor contamination. Also true at SGP (not shown).
Comparisons of:

- COSMIC2013 vs. EUMETSAT IASI B v6 1 yr: May 2013-April 2014
- COSMIC2013 vs. AIRS v6 3 yr: May 2012-April 2015
- COSMIC2013 vs. NUCAPS 3 yrs: May 2012-April 2015

Updated COSMIC version 2013.3520 (climate and post processed versions) is used.

Matchup Method

- IR raypath technique accounts for estimated RO horizontal resolution & geometry
- 1 hr time criterion

Averaging Kernel (AK) Calculation

- AKs calculated for each matchup case for 15um region channels

Results:

- Largest biases occur in the polar zones
- IASI in general has smaller biases then AIRS & NUCAPS
- For all zones the AK smoothed differences are within ~1K except for the JJA Antarctic
- RO and IR sounders on zonal scales are agreeing to within 1K. In some zones (e.g. Mid-lats) this agreement is even better (within ~0.5K)
COSMIC/Operational Sounders Matchups: NH-Midlat

courtesy of Michelle Feltz
COSMIC/Operational Sounders Matchups: SH-Midlat

courtesy of Michelle Feltz

DJF

MAM

JJA

SON

19/29
COSMIC/Operational Sounders Matchups: Antarctic

courtesy of Michelle Feltz
COSMIC is known to have a warm bias in polar winters, but nucaps is often warmer than cosmic in those locations.

Global and tropical panels show good (less than 0.3K?) agreement between RO and IR sounders.

Polar zones reveal larger differences and some seasonal dependences of bias.
# Polar-Orbiting Hyperspectral Sounding Instruments

<table>
<thead>
<tr>
<th>Instrument</th>
<th>AIRS</th>
<th>IASI</th>
<th>CrIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite (operating agency)</td>
<td>EOS Aqua (NASA)</td>
<td>Metop-A, Metop-B (EUMETSAT)</td>
<td>Suomi-NPP (NOAA)</td>
</tr>
<tr>
<td>Type</td>
<td>Grating Spectrometer</td>
<td>Michelson Interferometer</td>
<td>Michelson Interferometer</td>
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<tr>
<td>Spectral resolution</td>
<td>0.5 – 2 cm(^{-1})</td>
<td>0.25 cm(^{-1})</td>
<td>0.625 (LW), 1.25 (MW), 2.5 cm(^{-1}) (SW)</td>
</tr>
<tr>
<td>Spectral range</td>
<td>650 – 2670 cm(^{-1}) (15.4 – 3.7 μm)</td>
<td>645 – 2760 cm(^{-1}) (15.5 – 3.62 μm)</td>
<td>650 – 2550 cm(^{-1}) (15.4 – 3.9 μm)</td>
</tr>
<tr>
<td>Number of detectors/channels</td>
<td>4756 / 2378</td>
<td>12 / 8461</td>
<td>27 / 1305</td>
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<tr>
<td>NEDT range</td>
<td>0.05 - 0.5 K</td>
<td>0.1 – 0.75 K</td>
<td>0.05 – 0.5 K</td>
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<tr>
<td>Spatial resolution (at nadir)</td>
<td>13.5 km</td>
<td>12 km</td>
<td>14 km</td>
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</tbody>
</table>

courtesy of Elisabeth Weisz
Bering Sea Storm (7/8 November 2014) - 2

Overpasses 11-07-2014

Overpasses 11-08-2014

Cloud Top Temperature [°C] Animation (7/8 Nov 2014)

Aqua
Metop-A
S-NPP
Metop-B

courtesy of Elisabeth Weisz
Field Campaign: S-NPP Arctic Validation Mission

- Goal: Assess CrIS, AIRS, IASI (A&B) relative and absolute performance observing very cold scenes
- Flights timed to underfly multiple satellites and pass over Greenland Summit Station where RS-92 sondes launched

Instruments:
- NAST-I (NASA Langley)
- NAST-M (MIT-LL)
- S-HIS (UW)
- MASTER (NASA)
Raob Vs. SHIS & CrIS DR Retrieval Summit Greenland (March 19, 2015)
Radiosonde Vs. DR Retrievals*
Summit Greenland (March 23, 2015)

* 25-km Average Retrieval Closest to the Summit Radiosonde Location
Raob Vs. SHIS & NAST & CrIS DR Retrieval
Summit Greenland (March 28, 2015)
Conclusions

- ARM & GRUAN can help the satellite community
- The satellite community can help ARM & GRUAN

Any possibility GRUAN site could change sonde launch time periodically to launch coincident with satellite overpasses?

GRUAN may consider partnering with field campaigns?