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

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- 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

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S-NPP Validation: ARM Sites

S-NPP Validation: Sonde Launches

Sonde Launch Efforts						
Phase	**Site**	**Start**	**Stop**	**nOverPasses**	**nSingle**	**nDual**
1	NSA	Jul12	Dec12	90	--	90
	SGP		Jan13	89	--	89
	TWP		Jun13	94	94	--
2	NSA	Jun13	Sep14	124	68	56
	SGP		Sep14	129	31	98
	TWP		May14	79	79	--
3	ENA	Feb15	Sep15	38	38	--
	NSA			46	23	23
	SGP			53	23	30
4	ENA	Oct15	ongoing	37	37	--
	NSA			41	28	13
	SGP			33	17	16

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

Single Launch

Dual Launch (NSA & SGP)

S-NPP Validation: Temperature & WV Profile Distributions

- While the collection sites are limited in number, the profiles consist of highly accurate measurements of a wide range of climatic conditions

ENA

Temperature (K)

NSA

Temperature (K)

SGP

Temperature (K)

TWP

Temperature (K)

H2O (g/kg)

H2O (g/kg)

H2O (g/kg)

H2O (g/kg)

S-NPP Validation: Short Term Variability at NSA & SGP

- 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%

NSA

SGP

Temperature (K) **H2O (%)**

S-NPP Validation: Validation of NUCAPS Temperature Retrievals

- 1km layer differences shown for each ARM site for ALLSky conditions
- mean (dashed) & RMS (solid) differences shown

ENA

Temperature (K)

NSA

Temperature (K)

SGP

Temperature (K)

TWP

Temperature (K)

S-NPP Validation: UTLS Temperature Validation using RO

- 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.

GRAS RO Measurement Depiction
Courtesy EUMETSAT

Stratospheric Temperature Trends

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**

S-NPP Validation: COSMIC Case Study at NSA

Matchup Criteria:

- **100km/1hr**

Oscillation (blue line) is seen in NUCAPS statistics

- 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

courtesy of Michelle Feltz

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)

All

Day

Night

- 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).

COSMIC/Operational Sounders Matchups (next 4 slides)

- **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)**

courtesy of Michelle Feltz

COSMIC/Operational Sounders Matchups: Arctic

courtesy of Michelle Feltz

COSMIC/Operational Sounders Matchups: NH-Midlat

courtesy of Michelle Feltz

COSMIC/Operational Sounders Matchups: Tropics

courtesy of Michelle Feltz

COSMIC/Operational Sounders Matchups: SH-Midlat

courtesy of Michelle Feltz

COSMIC/Operational Sounders Matchups: Antarctic

courtesy of Michelle Feltz

COSMIC/Operational Sounders Matchups:

- **Daily Mean Lowess Filter (AK smoothed temp biases)**

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 btwn RO and IR sounders

Polar zones reveal larger differences and some seasonal dependences of bias

Polar-Orbiting Hyperspectral Sounding Instruments

Instrument	AIRS	IASI	CrIS
Satellite (operating agency)	EOS Aqua (NASA)	Metop-A, Metop-B (EUMETSAT)	Suomi-NPP (NOAA)
Type	Grating Spectrometer	Michelson Interferometer	Michelson Interferometer
Spectral resolution	0.5 – 2 cm^{-1}	0.25 cm^{-1}	0.625 (LW), 1.25 (MW), 2.5 cm^{-1} (SW)
Spectral range	650 – 2670 cm^{-1} (15.4 – 3.7 µm)	645 – 2760 cm^{-1} (15.5 – 3.62 µm)	650 – 2550 cm^{-1} (15.4 – 3.9 µm)
Number of detectors/channels	4756 / 2378	12 / 8461	27 / 1305
NEDT range	0.05 - 0.5 K	0.1 – 0.75 K	0.05 – 0.5 K
Spatial resolution (at nadir)	13.5 km	12 km	14 km
Launched	May 2002	Oct 2006, Sept 2012	Oct 2011

courtesy of Elisabeth Weisz

Bering Sea Storm (7/8 November 2014) - 1

NWS-OPC November 8 2014

Overpasses 11-07-2014

Overpasses 11-08-2014

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)

Field Campaign: S-NPP Arctic Validation Mission

- Goal: Asses 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)

courtesy of David Tobin

Raob Vs.SHIS & CrIS DR Retrieval Summit Greenland (March 19, 2015)

courtesy of Bill Smith

Radiosonde Vs. DR Retrievals*
Summit Greenland (March 23, 2015)

* 25-km Average Retrieval Closest to the Summit Radiosonde Location

courtesy of Bill Smith

Raob Vs.SHIS & NAST & CrIS DR Retrieval

Summit Greenland (March 28, 2015)

courtesy of Bill Smith

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?