Assessment of NUCAPS S-NPP CrIS/ATMS Sounding Products Using Reference and Conventional Radiosondes

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Outline

• The NOAA Products Validation System (NPROVS) & its expansion (NPROVS+)

• Discussion on uncertainty arising from
  – Time/space mismatch in radiosonde and satellite observations
  – Radiosonde measurement accuracy
  – Radiosonde and satellite vertical resolution differences

• Analysis of S-NPP CrIS/ATMS temperature and water vapor retrievals (IR+MW) based on collocations with Reference (3-yr) and conventional RAOBs (6 mons).
  – Global
  – Individual sites
Typical NPROVS Global Collocations (1000 per day)

Vaisala RS92 (28%), Vaisala RS41 (6%)
Global Climate Observing System (GCOS)
Reference Upper Air Network (GRUAN)

JPSS Funded Dedicated RAOB
- DOE ARM (SGP, NSA, ENA)
  ✓ SSEC/Madison …
  ✓ (2) per week
  ✓ dual vs single, etc

- AEROSE
- CALWATER
- El Nino Rapid Response
  - GRUAN processed

Ongoing coordination with “other” field experiments particularly if synchronized with S-NPP
- Sterling Test Site
- ARM Mobile Sites
- CIRA/CSU
GRUAN and JPSS funded Dedicated (S-NPP) RAOB Sites

Of 23,600 RAOBs, 5,600 are synchronized (1373 via JPSS/ARM) since Jan 2013 thru Jun 2016
### GRUAN/Dedicated radiosonde sites and date ranges

**January 2013 to mid-July 2016 (01)**

<table>
<thead>
<tr>
<th>RAOB Site</th>
<th>Date Range &amp; Number of Launches</th>
<th>Active</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascension Island ARM site (ASCENS, 80)</td>
<td>2016-04-29 to (175)</td>
<td>yes</td>
</tr>
<tr>
<td>CI RA/ CSU (CI RA, 114)</td>
<td>2016-05-06 to 2016-06-28 (18)</td>
<td>No</td>
</tr>
<tr>
<td>AWARE Antarctic ARM site (AWARE, 80)</td>
<td>2015-12-04 to 2016-01-18 (169)</td>
<td>No</td>
</tr>
<tr>
<td>Barrow, AK ARM site (70027, 272, 81, 80)</td>
<td>2013-07-01 to (2579)</td>
<td>Yes</td>
</tr>
<tr>
<td>Beltsville, MD (BELTSV, 114, 80, 272)</td>
<td>2013-07-01 to (178)</td>
<td>Yes</td>
</tr>
<tr>
<td>Boulder, CO (BOULDE, 272)</td>
<td>2013-07-09 to (147)</td>
<td>Yes</td>
</tr>
<tr>
<td>Cabauw, Netherlands (06260, 272)</td>
<td>2013-07-01 to (1201)</td>
<td>Yes</td>
</tr>
<tr>
<td>Kritimati Island ENRR (CXENRR, 80)</td>
<td>2016-01-26 to 2016-03-13 (96)</td>
<td>No</td>
</tr>
<tr>
<td>Darwin, Australia ARM site (94120, 80)</td>
<td>2014-04-01 to 2015-01-14 (714)</td>
<td>No</td>
</tr>
<tr>
<td>Eastern North Atlantic Azores ARM site (GRACI O, 80)</td>
<td>2013-09-28 to (2086)</td>
<td>Yes</td>
</tr>
<tr>
<td>Lauder, New Zealand (LAUDER, 123)</td>
<td>2013-07-03 to (234)</td>
<td>Yes</td>
</tr>
<tr>
<td>Lindenberg, Germany (10393, 272)</td>
<td>2013-07-01 to (4357)</td>
<td>Yes</td>
</tr>
<tr>
<td>Manus Island, Papua New Guinea ARM site (92036, 272, 80)</td>
<td>2013-07-01 to 2014-07-06 (110)</td>
<td>No</td>
</tr>
<tr>
<td>McMurdo, Antarctica ARM site (89664, 80)</td>
<td>2015-11-30 to 2016-03-31 (364)</td>
<td>No</td>
</tr>
</tbody>
</table>
# GRUAN/Dedicated radiosonde sites and date ranges

### January 2013 to mid-July 2016 (02)

<table>
<thead>
<tr>
<th>RAOB Site</th>
<th>Date Range &amp; Number of launches</th>
<th>Active</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nauru Island ARM site (91532, 272)</td>
<td>2013-07-01 to 2013-08-26 (717)</td>
<td>No</td>
</tr>
<tr>
<td>Ny-Ålesund, Norway (01004, 272)</td>
<td>2013-07-01 to (1270)</td>
<td>Yes</td>
</tr>
<tr>
<td>Oliktok Point, AK ARM site (OLKTO, 80)</td>
<td>2013-09-10 to (944)</td>
<td>Yes</td>
</tr>
<tr>
<td>Payerne, Switzerland (06610, 272)</td>
<td>2013-07-02 to (106)</td>
<td>Yes</td>
</tr>
<tr>
<td>Potenza, Italy (16300, 272)</td>
<td>2013-12-19 to (73)</td>
<td>Yes</td>
</tr>
<tr>
<td>La Reunion Island, France ARM site (REUNIO, 272) Indian ocean away from Africa</td>
<td>2015-05-05 to 2016-05-28 (19)</td>
<td>No</td>
</tr>
<tr>
<td>San Cristobal Island, Ecuador (84008, 272) sea terrain</td>
<td>2013-07-26 to 2015-01-26 (142)</td>
<td>No</td>
</tr>
<tr>
<td>Southern Great Plains, OK ARM site (74646, 272, 80)</td>
<td>2013-07-01 to (4740)</td>
<td>Yes</td>
</tr>
<tr>
<td>Juan Santamaria, Costa Rica (78762, 272)</td>
<td>2013-07-11 to 2014-02-21 (39)</td>
<td>No</td>
</tr>
<tr>
<td>Sodankyla, Finland (02836, 272)</td>
<td>2013-07-03 to (2250)</td>
<td>Yes</td>
</tr>
<tr>
<td>Sterling, VA 71000 (81) 72403 (182) 72000 (152)</td>
<td>2015-10-28 to (724)</td>
<td>Yes</td>
</tr>
<tr>
<td>Tateno, Japan (47646, 272)</td>
<td>2013-07-01 to (296)</td>
<td>Yes</td>
</tr>
<tr>
<td>Table Mountain Facility, CA (TMFJPL, 272)</td>
<td>2014-12-05 to (27)</td>
<td>Yes</td>
</tr>
<tr>
<td>Pacific Missile Range Facility, HI (91162, 80)</td>
<td>2014-04-11 to 2014-04-26 (23)</td>
<td>No</td>
</tr>
</tbody>
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### GRUAN/Dedicated radiosonde sites and date ranges
January 2013 to mid-July 2016 (03)

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<th>RAOB Site</th>
<th>Date Range &amp; Number of launches</th>
<th>Active</th>
</tr>
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<tr>
<td>Eureka, Northwestern territory of Canada (71917, 272)</td>
<td>2013-01-10 to 2013-02-13 (17)</td>
<td>No</td>
</tr>
<tr>
<td>AEROSE Jan-Feb 2013</td>
<td>2013-01-09 to 2013-02-13 (109)</td>
<td>No</td>
</tr>
<tr>
<td>AEROSE Nov-DEC 2013</td>
<td>2013-11-12 to 2013-12-07 (96)</td>
<td>No</td>
</tr>
<tr>
<td>AEROSE Jan-Feb 2015</td>
<td>2015-11-17 to 2015-12-13 (90)</td>
<td>No</td>
</tr>
<tr>
<td>Cal Water/ACAPEX Jan-Feb 2015</td>
<td>2015-01-12 to 2015-02-10 (171)</td>
<td>No</td>
</tr>
<tr>
<td>ENRR Feb-Mar 2016</td>
<td>2016-02-16 to 2016-03-16 (166)</td>
<td>No</td>
</tr>
</tbody>
</table>
Roles of NPROVS in sounding EDR cal/val

- Routine product monitoring (e.g., anomaly/outlier detection and long-term stability).
- Characterize product performance in a variety of meteorological conditions.
- Identify problem areas in retrieval algorithm in support of algorithm development.
- Provide independent oversight for operational product implementation.
- Provide support to AWIPS for NUCAPS applications in severe weather detection and prediction.
Outline

• The NOAA Products Validation System (NPROVS) & its expansion (NPROVS+)

• Discussion on uncertainty arising from
  – Time/space mismatch in radiosonde and satellite observations
  – Radiosonde measurement accuracy
  – Radiosonde and satellite vertical resolution differences

• Analysis of S-NPP CrIS/ATMS temperature and water vapor retrievals (qc-accepted IR+MW)
  – Global collocations
  – Individual sites
Satellite-RAOB Time Mismatch Impact

RMS error changes with time mismatch

- Based on the analysis of 3-yr global IASI-RAOB collocations (506,354)
Satellite-RAOBD Distance Mismatch Impact

RMS error changes with distance mismatch

• Based on the analysis of 3-yr global IASI-RAOB collocations (506,354)
Radiosonde temperature radiation bias impact

- Radiosondes tend to have a radiation induced warm bias in the UTLS during daytime.
- The RAOB T bias at 10-70 hPa is 0.18 K for all-the –day and 0.39 K for daytime (Sun et al., JGR 2013)

NUCAPS S-NPP IR+MW - minus - RAOB

Sample:
- All Data (202,00)
- Night (101,00)
- Day (6,200)

0.3 K “cooler” for Day than Night
Most radiosondes tend to have a dry bias in the UTLS particularly daytime.

The RAOB RH bias at 300 hPa is ~7% for Day and ~3% (Sun et al., JGR 2011)
RS41 Improvement over RS92

RS41-minus-RS92 MR %

20 dual launches of RS92 & RS41 at SGP

RS41 is wetter/better

S-NPP IR+MW - minus - RAOB MR (%)

Sample:
RS92 (6641)
RS41: (1810)
Radiosonde vs. Satellite Vertical Sensitivity Impact
(example of Temp inversion)

- RMS error for the low layer:
  - Weak inv (13,500): 2.2 K
  - Strong inv (10,500): 3.0 K

Sample:
- Strong inv (13,500)
- Weak inv (10,500)
Datasets used for S-NPP NUCAPS retrieval analysis

- **NUCAPS-RAOB collocation data**
  - Time mismatch: <1 hr
  - Distance mismatch: < 50 km

- **Sonde types**
  - Vaisala RS92 and RS41 (conventional)
  - Vaisala RS92 (Reference)

- **Conventional RAOBs (NPROVS, 6 mons)**
  - 14,000 (global), 255 (sea)

- **Reference RAOBs (NPROVS+, 3 yrs)**
  - 4,200 (global), 167 (sea)
S-NPP NUCAPS IR+MW Temperature Statistics (K)

Relative to **Conventional** RAOBs

<table>
<thead>
<tr>
<th>Pressure (hPa)</th>
<th>Bias</th>
<th>RMS</th>
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<tr>
<td>NUCAPS-minus-RAOB T mean diff (K)</td>
<td>Global</td>
<td>Sea</td>
</tr>
<tr>
<td>1000</td>
<td>-2</td>
<td>10</td>
</tr>
<tr>
<td>930</td>
<td>-1</td>
<td>10</td>
</tr>
<tr>
<td>870</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>825</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>750</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>3074 (global), 167 (sea)</td>
<td></td>
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Relative to **Reference** RAOBs

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S-NPP NUCAPS IR+MW H2O Vapor MR Statistics (%)

Relative to Conventional RAOBs

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<th>Pressure (hPa)</th>
<th>Bias</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>-100</td>
<td>100</td>
</tr>
<tr>
<td>8881</td>
<td>0</td>
<td>0</td>
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<tr>
<td>101</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>3074</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>167</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Relative to Reference RAOBs

8881 (global), 101 (sea)

3074 (global), 167 (sea)
Suomi-NPP NUCAPS IR+MW Temperature Statistics

Bias RMS

Pressure (hPa)

NUCAPS - RAOB T mean diff(K)

NUCAPS - RAOB T RMS diff(K)

Jan-Feb 2013 AEROSE
Nov-Dec 2013 AEROSE
Nov-Dec 2015 AEROSE
Jan-Feb 2015 CALWATER
Feb-Mar 2016 ENRR
NUCAPS IR+ MW vs. ECMWF analysis relative to JPSS funded field campaign ship RAOBs

Water Vapor Mixing Ratio % diff.
Beltsville & Sterling RAOBs for S-NPP Evaluation

Launch Synchronizations Summary

- 8 Sterling synchronized to S-NPP
- 90 Beltsville synchronized to S-NPP
- 4 Sterling / Beltsville synchronized to S-NPP:
  - 10/10/15  7100  1733 Z
  - 3/18/16   7200  1730 Z
  - 4/15/16   7100  1705 Z
  - 4/18/16   7100  0700 Z
ARM RAOBs for S-NPP Evaluation

RAOB Launches synchronized with S-NPP

- 367 at SGP site
- 341 at NSA site
- 73 at ENA
North and South Polar RAOBs for S-NPP Evaluation

RAOB Launches within 1hr/50km of S-NPP

- 30 at AWARE ARM site
- 28 at McMurdo ARM site
- 398 at Ny-Alesund, Norway
IR+MW NUCAPS S-NPP vs. AIRS Retrieval Statistics
(Sea data, relative to Reference sondes)

**Temperature**

Sample: 60 collocations (+/- 1.5 hr & 50 km)

**Water Vapor Mixing Ratio**

Sample: 60 collocations (+/- 1.5 hr & 50 km)
Summary

- NPROVS+ (anchored to Reference RAOBs) and NPROVS (anchored to conventional RAOB) are complementary in support of JPSS atmospheric sounding EDR cal/val.

- Analysis of satellite collocations with conventional (6 months) and with Reference RAOBs (3 yrs), done globally and at individual sites, indicated:
  - NUCAPS IR+MW temperature and water vapor retrievals perform well.

- Uncertainties were discussed in the context of hyperspectral sounder retrieval validation:
  - Time mismatch matters
  - Satellite vs. radiosonde vertical resolution inconsistency
  - Radiosonde accuracy including warm T and dry humidity at the upper levels.
NUCAPS IR+ MW vs. ECMWF analysis relative to NOAA field campaign ship RAOBs
S-NPP NUCAPS IR+MW vs. MW-only Retrieval Statistics

(Sea data; relative to Reference sondes)

Temperature

Water Vapor Mixing Ratio (%)

bias

RMS

IR+MW (122), MW-only (185)