Integration (and Assessment) of Uncertainty in Satellite Profile Cal/Val (NPROVS)

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GRUAN ICM-9
June 12-16, 2017
Helsinki, Finland
NPROVS/NPROVS+ Data Management Schematic

**Inputs**
- Conv Radiosondes
- GFS 6-hr NWP
  - NOAA
- MIRS: S-NPP NOAA-18,19 MetOP-A,B
  - DMSP F16,18
  - NOAA
- AIRS v.6
  - Aqua-EOS
  - NASA
- IASI: MetOp-A, MetOp-B
  - EUMETSAT
- ATOVS
  - NOAA-18,19 MetOp-A,B
  - NOAA
- GOES
  - NOAA
- GRAS
  - MetOp-A,B
  - EUMETSAT
- COSMIC
  - UCAR
- NWP ANAL
  - ECMWF
- GRUAN JPSS DOE/ARM etc Radiosondes

**Processing**
- 3 day delay
- 14 day delay

**Visualization Tools:**
- ODS
- PDISP
- NARCS

**Outputs**
- FTP
- NPROVS Collocation Archive
- NPROVS+ Collocation Archive
- Algorithm Development
- FTP
- VALAR

**Algorithm Development**
Observations can be used to “test’ the uncertainties… ?

from Immler:

$$\left|m_1 - m_2\right| < k\sqrt{\sigma^2 + u_1^2 + u_2^2}$$

for k.le.2, in more than 95% of cases, the uncertainties are likely to be smaller than estimated …

likewise, if k.gt. 2, the uncertainties are likely to be larger than estimated …

If k< 1 …
Approach

1) \[ \text{ABS} (m1 - m2) > k (\sigma^2 + u1^2 + u2^2)^{1/2} \]

2) “k” = \[ \frac{\text{ABS} (m1 - m2)}{u2} \]
   
   \text{for } k=2 \ldots \text{agreement:}

3) \[ \sigma^2 + u1^2 = \left(\frac{“k”}{2}\right)^2 - 1 \right) (u2)^2 \]

4) \[ u1 = \left(\frac{“k”}{2}\right)^2 - 1 \right)^{1/2} (u2) \]

… given \( u2 \), quantify the \( \left(\sigma^2 + u1^2 \right) \) required for consistent observations … or worst case estimate of \( u1 \)

……… given \( u2 \), quantify the \( \left(\sigma^2 + u1^2 \right) \) required for consistent observations … or worst case estimate of \( u1 \)

for moisture:

1) \[ u2 = u2 (\text{RH}) \times \text{Saturation} (\text{MR} @T) \]

2) \[ \text{MR ( % )} = \frac{\text{SAT} (\text{MR}) - \text{minus-GRUAN (MR))}}{\text{GRUAN (MR)}} \]
Tropical Sea

Non-tropical, land

GEWEX Water Vapor Assessment … GVAP-5 … Schroder et.al
Figure 6: Mean “k” vertical profile using equation (3) for collocated GRUAN radiosonde, HIRS from Metop-A (green), Aqua AIRS v.5 which passed QC (purple) and the ECMWF Analysis (orange) over tropical sea (left) and non-tropical land (right) with GRUAN mean MR uncertainty along inside left and sample size along right axes; black line denotes $k=2$

GEWEX Water Vapor Assessment ... GVAP-5 Final Report, Schroder et.al
## Uncertainty summary table (tropic sea)

<table>
<thead>
<tr>
<th>Tropical, Sea</th>
<th>HIRS</th>
<th>IASI / HIRS</th>
<th>AIRS / HIRS / ECMWF</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 hPa</td>
<td>0.061</td>
<td>0.051 / 0.061</td>
<td>0.025 / 0.052 / 0.028</td>
</tr>
<tr>
<td></td>
<td>0.175</td>
<td>0.172</td>
<td>0.166</td>
</tr>
<tr>
<td></td>
<td>0.014</td>
<td>0.013</td>
<td>0.013</td>
</tr>
<tr>
<td></td>
<td>9.0</td>
<td>8.1 / 9.6</td>
<td>4.4 / 8.3 / 4.8</td>
</tr>
<tr>
<td>500 hpa</td>
<td>0.23</td>
<td>0.18 / 0.23</td>
<td>0.18 / 0.20 / 0.09</td>
</tr>
<tr>
<td></td>
<td>1.87</td>
<td>1.68</td>
<td>1.59</td>
</tr>
<tr>
<td></td>
<td>0.115</td>
<td>0.113</td>
<td>0.107</td>
</tr>
<tr>
<td></td>
<td>4.5</td>
<td>3.8 / 4.5</td>
<td>3.9 / 4.4 / 2.3</td>
</tr>
<tr>
<td>700 hpa</td>
<td>0.59</td>
<td>0.46 / 0.56</td>
<td>0.46 / 0.53 / 0.16</td>
</tr>
<tr>
<td></td>
<td>5.51</td>
<td>5.52</td>
<td>5.63</td>
</tr>
<tr>
<td></td>
<td>0.272</td>
<td>0.268</td>
<td>0.273</td>
</tr>
<tr>
<td></td>
<td>4.8</td>
<td>4.0 / 4.6</td>
<td>3.9 / 4.4 / 2.3</td>
</tr>
<tr>
<td>1000 hPa</td>
<td>---</td>
<td>--- / 0.49</td>
<td>0.20 / --- / ---</td>
</tr>
<tr>
<td></td>
<td>16.6</td>
<td>12.9</td>
<td>16.0</td>
</tr>
<tr>
<td></td>
<td>0.651</td>
<td>0.537</td>
<td>0.626</td>
</tr>
<tr>
<td></td>
<td>1.9</td>
<td>1.6 / 2.7</td>
<td>2.1 / 1.7 / 1.0</td>
</tr>
</tbody>
</table>

**Table 1:** Each element (box) includes four sets of mean values for:
- Satellite (and ECMWF) MR uncertainties using (6),
- GRUAN MR (g/kg),
- GRUAN MR uncertainty
- “k” value

GEWEX Water Vapor Assessment ... *GVAP-5 Final Report, Schroder et.al*
ECMWF Uncertainty Assessments using NPROVS+

NOAA Products Validation System (NPROVS)

<table>
<thead>
<tr>
<th>Coast</th>
<th>Land</th>
<th>Island (Coast)</th>
<th>Island (Inland)</th>
<th>Ship</th>
<th>Dropsonde</th>
</tr>
</thead>
</table>

Number of collocations: 30951 (40 unique locations)

2013 to 2017

NOAA Products Validation System (NPROVS)

<table>
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<tr>
<th>Coast</th>
<th>Land</th>
<th>Island (Coast)</th>
<th>Island (Inland)</th>
<th>Ship</th>
<th>Dropsonde</th>
</tr>
</thead>
</table>

Number of collocations: 16613 (19 unique locations)

2013 to 2017

ECMWF Uncertainty Assessments using NPROVS+

GRUAN and ECMWF +/- 2 hrs

All
GRUAN and ECMWF +/- 2 hrs; Day

GRUAN and ECMWF +/- 2 hrs; Night

ECMWF Uncertainty Assessments using NPROVS+)}
ECMWF Uncertainty Assessments using NPROVS+}

NWP-RAOB

Temp

0.3 $u_2$

“k”

0.5 $u_2$

2.6 $u_2$

Baseline: Radiosonde

Baseline: Radiosonde

ECMWF

ECMWF
ECMWF Uncertainty Assessments using NPROVS+)}
ECMWF Uncertainty Assessments using NPROVS+)
NWP-RAOB H2O Vapor

Night

“k” H2O Vapor

3.2 $u_2$

0.0 $u_2$

ECMWF Uncertainty Assessments using NPROVS+)
"σ" term for RAOB vs satellite platforms can be significant even if observations timely
GRUAN collocations with COSMIC GPSRO (or GRAS)
GRUAN collocations with COSMIC GPSRO (or GRAS)
GRUAN collocations with COSMIC GPSRO (or GRAS)
GSICS/GRUAN Actions from March 2017 Annual GSICS Meeting

Action: GMW.2017.6f.2: Tony Reale (NOAA) to provide a draft of uncertainty analysis examples to monitor satellite microwave instruments using GRUAN observations (radiosonde) – by the next annual meeting
Cheng-zhi Zou, Bomin Sun, Isaac Moraldi, Viju John, Vinia Mattioli, Mark Liu, Ralph Peterson …

Action: GIR.2017.7d.1: Tony Reale (NOAA) to provide a draft of uncertainty analysis examples to monitor satellite infra-red instruments using GRUAN observations (radiosonde) – by the next annual meeting
Xavier Calbet, Bomin Sun, Isaac Moraldi, Tim Hewison, Nick Nalli …

Volunteers from GRUAN community solicited
UPDATE on: Consistency for water vapour of GRUAN, LBLRTM and IASI

Xavier Calbet (xcalbeta@aemet.es)
Radiation Uncertainties
Radiation Bias: Final Result Day-time
Radiation Bias: Final Result Day-time + 2.5% RH
**WP3**

**Full name:**
WP3 - Comparison error budget closure - Quantifying metrology related uncertainties of data comparisons

This workpackage is concerned with improving our quantification of irreducible uncertainties that arise from inevitable non-coincidence of satellite and non-satellite measurements. The measurements may occur at slightly different times or locations or measure different volumes. Because the atmosphere is a dynamic fluid system any mismatch will lead to a difference that arises from changes in the atmospheric state. These differences must be accounted for in any meaningful comparison between the satellite and non-satellite measurements if reliable inferences are to be made. The workpackage shall:

- Characterise the uncertainties arising for single instruments (Task 3.1).
- Characterise the uncertainties arising for more spatially comprehensive network comparisons (Task 3.2).

**WP5**

**Full name:**
WP5 - Creation of a 'Virtual Observatory' visualization and data access facility

This workpackage is concerned with enabling user access to and use of satellite to non-satellite data comparisons through a 'Virtual Observatory' facility. A range of visualisation and analysis tools will be developed to enable users to explore, analyse, and interact with the data. The Virtual Observatory shall be built to showcase potential methods by which the underlying scientific advances in workpackages 1 through 4 can be realised. It will be built in such a way that it could subsequently become an operational service, but within this project shall only serve as a proof-of-concept facility. The workpackage shall:

- Create a collocation database of reference-quality non-satellite measurements and satellite measurements (Task 5.1).
- Build a graphical user interface and user tools (Task 5.2).
Objective: Can GRUAN help verify the “accuracy/uncertainty” of GSICS adjustments?
Summary

NPROVS+ and the integration of GRUAN uncertainty (Immler) leading to satellite product and NWP “worst-case” uncertainty estimates … *is the approach appropriate?*

This is a robust addition to routine satellite product cal/val

Results suggest possible cases of suspicious GRUAN uncertainty estimates associated with cases of high moisture content and daytime radiation corrected observations … *Tom Gardiner talk Thursday*

Suspictions (for radiation correction) appear confirmed using collocations of GRUAN and GPSRO

GSICS action items initiated to test whether GRUAN (and uncertainty) can be used to assess/monitor satellite IR and MW sensors (and associated GSICS uncertainty estimates) … *propagation to the radiance space*
Extras
ECMWF collocations with Conventional RAOB ... NPROVS
NWP characterization using NPROVS)

Temperature (sat - baseline) deg K
May 22, 2017 to June 1, 2017

Pressure (hPa)
-1  0  0.5  1  1.5  2

Bias / RMS

SONDE
SONDE GFS 6 Hour
ECMWF

NON-GUAN

Water Vapor (sat - baseline) % error
May 22, 2017 to June 1, 2017

Pressure (hPa)

Sample Size

Baseline: SONDE

SONDE GFS 6 Hour
ECMWF

NWP characterization using NPROVS)
NWP characterization using NPROVS

Baseline: SONDE

SONDE GFS 6 Hour

ECMWF

NWP characterization using NPROVS)
NWP characterization using NPROVS

GUAN Night

May 22, 2017 to June 1, 2017

Temperature (sat - baseline) deg K

Pressure (hPa)

Sample Size

Baseline: SONDE

SONDE GFS 6 Hour

ECMWF

NWP characterization using NPROVS
ECMWF Uncertainty Assessments using NPROVS+)}
NWP characterization using NPROVS

GUAN Day

Temperature (sat - baseline) deg K

May 22, 2017 to June 1, 2017

Pressure (hPa)

Bias / RMS

Sample Size

Baseline: SONDE

SONDE GFS 6 Hour

ECMWF

NWP characterization using NPROVS
ECMWF Uncertainty Assessments using NPROVS+)}
GUAN  Night

Temperature (sat - baseline) deg K
May 22, 2017 to June 1, 2017

Pressure (hPa)

Bias / RMS

Sample Size

Baseline: SONDE

SONDE GFS 6 Hour  ECMWF

NWP characterization using NPROVS)
Temperature K Statistics
January 8, 2013 to April 24, 2017

Baseline: Radiosonde

ECMWF
GRAS
GRAS Raw Dry