Inter-calibration and validation of observations from ATMS and SAPHIR microwave sounders

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Outline

- Radiometric and Geometric Errors
- ATMS and SAPHIR instruments
- Inter-calibrating SAPHIR and ATMS
- Validating SAPHIR and ATMS observations using radiosonde data
- Validating ATMS temperature sounding channels using GPS-RO profiles
- Geolocation Errors
- Conclusion
Radiometric and Geometric Errors

- **Radiometric Errors**
  - Change in Antenna Reflectivity and Emissivity
  - Imperfect Electronics: APC, Oscillators, Amplifiers, ...
  - Radio Frequency Interference (RFI)
  - Uncertainty in Warm Load Temperature
  - Non-linearity in the Calibration
  - Pre- and Post-processing Errors

- **Geometric Errors**
  - Antenna and/or Feedhorn Misalignment
  - Satellite Attitude Offset
  - Satellite Clock Offset and Timing Error
  - Error in Ephemeris Data
  - Anomaly in Scan-drive Motor
  - Error in Sensor Modelling
A Simple Case: Antenna Pattern

Reciprocity = receive and transmit properties of an antenna are identical

FT( ) = sinc Function 3D => Bessel Function
Megha-Tropiques

- A microwave imager (MADRAS) to study precipitation and cloud properties (SSM/I type, with an additional channel at 157 GHz).
- A microwave sounding instrument for the atmospheric water vapor (SAPHIR - 6 channels in the 183 GHz band).
- A radiometer for measuring outgoing radiative fluxes at the top of the atmosphere (ScaRaB).
Inter-calibrating SAPHIR and ATMS
SAPHIR vs. ATMS

\[ \nu \sim 183 \text{ GHz} \]

<table>
<thead>
<tr>
<th>ATMS</th>
<th>SAPHIR</th>
<th>Bias (Obs)</th>
<th>Bias (Sim)</th>
<th>Obs - Sim</th>
</tr>
</thead>
<tbody>
<tr>
<td>183±7.0</td>
<td>183±6.8</td>
<td>-0.68</td>
<td>-0.42</td>
<td>-0.26</td>
</tr>
<tr>
<td>183±4.5</td>
<td>183±4.2</td>
<td>-1.56</td>
<td>-0.91</td>
<td>-0.65</td>
</tr>
<tr>
<td>183±3.0</td>
<td>183±2.8</td>
<td>-1.23</td>
<td>-0.93</td>
<td>-0.30</td>
</tr>
<tr>
<td>183±1.0</td>
<td>183±1.1</td>
<td>+0.42</td>
<td>+0.90</td>
<td>-0.48</td>
</tr>
</tbody>
</table>
**SAPHIR vs. ATMS**

- **F. SAPHIR**: $183.31 \pm 1.1$
- **F. ATMS**: $183.31 \pm 1.0$
- $a = 3.457$, $b = 0.988$
- $B = 0.416$, $U = 0.004$
- $R = 0.985$
- $n = 96981$

- **F. SAPHIR**: $183.31 \pm 1.1$, $a = 3.548$
- **F. ATMS**: $183.31 \pm 1.0$, $b = -0.012$

- **F. SAPHIR**: $183.31 \pm 1.1$
- **F. ATMS**: $183.31 \pm 1.0$
- $a = 5.902$, $b = -0.022$

- **F. SAPHIR**: $183.31 \pm 1.1$
- **F. ATMS**: $183.31 \pm 1.0$
- $a = 0.410$, $b = 0.000$
Validating using radiosonde data
ATMS Weighting Functions

![Graph showing ATMS Weighting Functions with altitude and weight axes. The graph includes lines for different channels labeled 1 to 21, with a shaded area representing Radiosonde data.](image-url)
Cloud and PWV Filters

Cloud Filters

Filter for balloon drift

Surface Contribution [K]

0.001 K

5 kg.m$^{-2}$
Validating Using ARM Data

**SAPHIR vs ARM**

- Bias [K]:
  - TWP-C1
  - TWP-C2
  - TWP-C3

**ATMS vs ARM**

- Channels [#]:
  - Channels 1 to 22

- Bias [K]:
  - SGP-C1
  - TWP-C1
  - TWP-C2
  - TWP-C3

Values:

- SAPHIR vs ARM: 183±0.2
- ATMS vs ARM: 183±11
- SGP-C1: 165.5
- TWP-C1, TWP-C2, TWP-C3: 54, 57, 183±1
Error in IGRA humidity profiles

Isaac Moradi, ESSIC, University of Maryland

Inter-calibrating MW Sensors

Moradi et al., JGR, 2013
Validating using GPS-RO data
GPS Radio Occultation Data

- Radio signals transmitted by Global Positioning System (GPS) satellites are received by a receiver on a LEO satellite.

- Temperature and water vapor profiles are derived from bending angles using a-priori profiles and inversion techniques.

- Raw GPS-RO data (time delay) have very high accuracy in the upper troposphere and lower stratosphere (500 hPa to 40 km) but different.

- Errors and uncertainties are introduced during inversion to the atmospheric state variables.
Drift in GPS Profiles

From 400 hPa to 100 hPa

From ground To 400 hPa

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Inter-calibrating MW Sensors
Application of Microwave Satellite Data Inter-calibrating MW Sensors

ATMS vs. GPS RO

Uncertainty = STD / SQRT(N)

50 km, 30 min

100 km, 30 min

100 km, 60 min
Application of Microwave Satellite Data
Inter-calibrating MW Sensors

<table>
<thead>
<tr>
<th>Channel 10</th>
<th>Channel 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 hr, 50 km</td>
<td>0.5 hr, 100 km</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Channel 11</th>
<th>Channel 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 hr, 50 km</td>
<td>1 hr, 100 km</td>
</tr>
</tbody>
</table>
Geolocation Error
Characterization: Asc - Des

ATMS: Original Data

ATMS: 15-km along-track error

NOAA-15 AMSU-A Channel 1, 1-1-2003 to 1-31-2003

Moradi et al., TGRS 2013
Effect of Geo Error on Obs

ATMS Chan 3: Geolocation Error

Effect of 15-km along-track error on Channel 18

Effect of 15-km along-track error on Channel 18

Effect of 15-km along-track error on Channel 15

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Inter-calibrating MW Sensors
Conclusions

- SAPHIR and ATMS observations show very good consistency.
- SAPHIR provides a great opportunity for inter-calibrating MW WV channels on POES satellites or to transfer the calibration among the POES satellites.
- There is still a lack of reference datasets for validating MW satellite observations.
- Radiosonde data can only be used to evaluate the overall bias in the WV channels and cannot precisely detect the magnitude of the bias.
- GPS-RO data provide a good opportunity for validating observations from upper troposphere and lower stratosphere but the difference between GPS-RO and satellite observations cannot be translated as absolute bias in the satellite data.
- The window channels cannot still be validated because of uncertainty in the surface emissivity.
- The accuracy of geolocation data is very important for many of the MW channels including surface sensitive, water vapor and stratospheric channels.
Thanks for your attention

Sunrise in Northern Sweden after a two-month long polar-night

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ARM Stations

Moradi et al., JGR, 2010, DOI: 10.1029/2010JD013962
ATMS (AMSU+MHS)

- ATMS: Advanced Technology Microwave Sounder
- 22 channels, almost all AMSU-A and MHS plus a few additional channels

© NASA
SAPHIR/ATMS WF

Solid: ATMS WV
Dashed: SAPHIR

Altitude [km]

Weight

A ±165.5, S ±11.0
A ±7.0, S ±6.8
A ±4.5, S ±4.2
A ±3.0, S ±2.8
A ±1.8, S ±1.1
A ±1.0, S ±0.2

Isaac Moradi, ESSIC, University of Maryland
Inter-calibrating MW Sensors
SAPHIR Specifications

Megha-Tropiques Orbital Characteristics ©CNES

<table>
<thead>
<tr>
<th>Orbit</th>
<th>Altitude</th>
<th>Inclination</th>
<th>Period</th>
<th>#rev/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circular</td>
<td>867 km</td>
<td>20°</td>
<td>102.16 min</td>
<td>14</td>
</tr>
</tbody>
</table>

Saphir Instrument Characteristics

| S1       | 183.31 ± 0.20 | 200 | 1.82 K | H |
| S2       | 183.31 ± 1.10 | 350 | 1.01 K | H |
| S3       | 183.31 ± 2.70 | 500 | 0.93 K | H |
| S4       | 183.31 ± 4.00 | 700 | 0.88 K | H |
| S5       | 183.31 ± 6.60 | 1200| 0.81 K | H |
| S6       | 183.31 ±11.00 | 2000| 0.73 K | H |