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
- Validation versus radiosonde data
- Validation versus 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 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

Weighting Functions

\( \nu \sim 183 \text{ GHz} \)

<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. SAPH: 183.31 ± 1.1
F. ATMS: 183.31 ± 1.0
a = 3.457, b = 0.988
B = 0.416, U = 0.004
R = 0.985
n = 96981

F. SAPH: 183.31 ± 1.1, a = 3.548
F. ATMS: 183.31 ± 1.0, b = -0.012

F. SAPH: 183.31 ± 1.1
F. ATMS: 183.31 ± 1.0
a = 5.902, b = -0.022

F. SAPH: 183.31 ± 1.1
F. ATMS: 183.31 ± 1.0
a = 0.410, b = 0.000

**Isaac Moradi, ESSIC, University of Maryland**

Application of Microwave Satellite Data

Inter-calibrating MW Sensors

SAPHIR

vs.

ATMS
Validating using radiosonde data
ATMS Weighting Functions

![Graph showing ATMS weighting functions with altitude on the y-axis and weight on the x-axis. The graph includes lines for different indices, with a shaded area representing radiosonde data.](image)
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

ATMS vs ARM

183±0.2 → 183±11

54 57 165.5 183±1
Error in IGRA humidity profiles

Moradi et al., JGR, 2013

Isaac Moradi, ESSIC, University of Maryland

Inter-calibrating MW Sensors
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.

© NCAR
Drift in GPS Profiles

From 400 hPa to 100 hPa

From ground To 400 hPa
ATMS vs. GPS RO

Uncertainty = \frac{\text{STD}}{\sqrt{\text{N}}}

- 50 km, 30 min
- 100 km, 30 min
- 100 km, 60 min
ATMS vs. GPS RO

- **Channel 10**
  - 0.5 hr, 50 km
  - 0.5 hr, 100 km

- **Channel 11**
  - 1 hr, 50 km
  - 1 hr, 100 km
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 (identical measurements in terms of physical quantity and geometry) 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.
Thanks for your attention

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

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University of Maryland
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Paper under revision at IEEE TGRS
Moradi, I., Ferraro, R., Eriksson, P., Weng, F., Inter-calibration and validation of observations from ATMS and SAPHIR microwave sounders
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 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>
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<tbody>
<tr>
<td>Circular</td>
<td>867 km</td>
<td>20°</td>
<td>102.16 min</td>
<td>14</td>
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Saphir Channels

<table>
<thead>
<tr>
<th>Channel No.</th>
<th>Central frequencies (GHz)</th>
<th>Bandwidth (MHz)</th>
<th>Radiometric sensitivity (estimated by calculation)</th>
<th>Polarisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>183.31 ± 0.20</td>
<td>200</td>
<td>1.82 K</td>
<td>H</td>
</tr>
<tr>
<td>S2</td>
<td>183.31 ± 1.10</td>
<td>350</td>
<td>1.01 K</td>
<td>H</td>
</tr>
<tr>
<td>S3</td>
<td>183.31 ± 2.70</td>
<td>500</td>
<td>0.93 K</td>
<td>H</td>
</tr>
<tr>
<td>S4</td>
<td>183.31 ± 4.00</td>
<td>700</td>
<td>0.88 K</td>
<td>H</td>
</tr>
<tr>
<td>S5</td>
<td>183.31 ± 6.60</td>
<td>1200</td>
<td>0.81 K</td>
<td>H</td>
</tr>
<tr>
<td>S6</td>
<td>183.31 ± 11.00</td>
<td>2000</td>
<td>0.73 K</td>
<td>H</td>
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</table>

Saphir Instrument Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Pixel interval /y (nadir)</td>
<td>10 km</td>
</tr>
<tr>
<td>Earth pixel Number of pixels (Earth)</td>
<td>128</td>
</tr>
<tr>
<td>Incidence angle (ground)</td>
<td>&lt;50°  deg</td>
</tr>
<tr>
<td>Swath</td>
<td>1661 km</td>
</tr>
<tr>
<td>Extreme pixel size /x</td>
<td>21.96 km</td>
</tr>
<tr>
<td>Extreme pixel size /y</td>
<td>14.29 km</td>
</tr>
<tr>
<td>Average pixel size /x</td>
<td>13.3 km</td>
</tr>
<tr>
<td>Average pixel size /y</td>
<td>11.3 km</td>
</tr>
<tr>
<td>Average pixel size</td>
<td>12.3 km</td>
</tr>
<tr>
<td>Scan interval (/x)</td>
<td>10 km</td>
</tr>
<tr>
<td>Rotation period</td>
<td>1.639 s</td>
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<tr>
<td>Rotation frequency</td>
<td>0.61 Hz</td>
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