Inter-Comparison of Aquarius and SMOS Brightness Temperature Observations

Rajat Bindlish, Thomas Jackson, Tianjie Zhao, Gary Lagerloef, David Le Vine, Simon Yueh, Yann Kerr

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Overview

• Introduction
• Objectives
• Methodology
• Comparison results for areas with concurrent Aquarius and SMOS observations
• Vicarious targets
Introduction

• Verifying the calibration of the L-band radiometer data (SMOS, Aquarius, SMAP) over the entire dynamic range is necessary.

• Land brightness temperatures over land fall in a completely different range of response and it is prudent to verify that the primary calibration extends to these levels.

• It is a challenge to validate TB over land using models because there are more factors that contribute to TB and the footprints are more heterogeneous than the oceans.

• Inter-comparison with other L-band radiometers can use used as a cal/val tool for radiometer L1 calibration
Approach

• Use SMOS as a tool in assessing the calibration of the Aquarius radiometer over land
• On orbit inter-comparison of two L-band radiometers
• Need for consistent observations:
  – Aquarius and SMOS provide an opportunity to check each others calibration
  – Critical to develop a long-term climatic data record of L-band brightness temperature observations
  – A physical algorithm for development of a long term environmental data record that spans multiple L-band missions requires consistent input observations
  – It is prudent that all L-band radiometers (SMOS, Aquarius and SMAP) have a consistent calibration
SMOS
- Launched Nov 2009
- 2D-synthetic aperture
  - Multiple incidence angles at every location [0°-65°]
- Sun Synchronous orbit with an ascending orbit of 6:00 AM
- Spatial resolution 40 km
- Swath – 1400 km
- 3 day global coverage

Aquarius
- Launched June 2011
- Real aperture
  - Three incidence angles of 29.36°, 38.49°, 46.29°
- Sun Synchronous orbit with an descending orbit of 6:00 AM
- Spatial resolution 100 km
- Swath – 350 km
- 7 day global coverage
- 7 day exact repeat

SMAP
- Launch Nov 2014
- Conically Scanning Real aperture
  - Constant incidence angle of 40°
- Sun Synchronous orbit with an descending orbit of 6:00 AM
- Spatial resolution 40 km
- Swath – 1050 km
- 3 day global coverage
- 8 day exact repeat
Aquarius and SMOS inter-comparison methodology

• Approach: Inter-compare the TOA TB observed by SMOS and Aquarius

• Concurrent observations in both time (within 30 min → eliminates effect of change in physical temperature) and space (same location)

• Aquarius and SMOS inter-comparison notes
  – Aquarius evaluation Version 2.3
  – SMOS Version 5.05
  – Land and ocean
  – Concurrent SMOS and Aquarius observations within 30 min
  – Same incidence angle (after re-processing SMOS data)
  – Only alias free portions of SMOS observations
  – Multiple SMOS DGG locations within a single Aquarius footprint
  – Min number of SMOS observations per Aquarius footprint required: 20 (to minimize partial Aquarius footprint coverage)
  – Std. Dev. of SMOS data averaged < 5 K (land) and 1 K (ocean) (to minimize footprint variability; also results in screening RFI)
  – Differences in azimuth angle and orientation of the footprints ignored
Comparison between Aquarius and SMOS (ocean)

Version 2.3
## Comparison between Aquarius and SMOS over Ocean
### Summary Statistics

<table>
<thead>
<tr>
<th></th>
<th>RMSD (K)</th>
<th>Bias [Aq-SMOS] (K)</th>
</tr>
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<tbody>
<tr>
<td><strong>H pol</strong></td>
<td></td>
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<tr>
<td>Inner (29.36°)</td>
<td>1.22</td>
<td>0.77</td>
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<td>Middle (38.49°)</td>
<td>1.73</td>
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<td>Outer (46.29°)</td>
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<td><strong>V pol</strong></td>
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<tr>
<td>Inner (29.36°)</td>
<td>2.67</td>
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<tr>
<td>Middle (38.49°)</td>
<td>1.83</td>
<td>1.61</td>
</tr>
<tr>
<td>Outer (46.29°)</td>
<td>0.78</td>
<td>0.09</td>
</tr>
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<tr>
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<tr>
<td>Inner (29.36°)</td>
<td>1.22 (1.29)</td>
<td>0.77 (0.76)</td>
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<tr>
<td>Middle (38.49°)</td>
<td>1.73 (1.77)</td>
<td>1.24 (1.20)</td>
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<tr>
<td>Outer (46.29°)</td>
<td>1.33 (1.35)</td>
<td>1.08 (0.98)</td>
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<td>Inner (29.36°)</td>
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<td>Middle (38.49°)</td>
<td>1.83 (1.82)</td>
<td>1.61 (1.53)</td>
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<tr>
<td>Outer (46.29°)</td>
<td>0.78 (0.90)</td>
<td>0.09 (-0.08)</td>
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**Version 2.3**  **Version 2.0**
Comparison between Aquarius and SMOS (land)

Version 2.3
# Comparison between Aquarius and SMOS over Land

## Summary Statistics

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<tr>
<th>H pol</th>
<th>RMSD (K)</th>
<th>R</th>
<th>Bias [Aq-SMOS] (K)</th>
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<tr>
<td>Inner (29.36°)</td>
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<td>Middle (38.49°)</td>
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<td>Outer (46.29°)</td>
<td>4.51</td>
<td>0.9786</td>
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<tr>
<th>V pol</th>
<th>RMSD (K)</th>
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<th>Bias [Aq-SMOS] (K)</th>
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<tbody>
<tr>
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<tr>
<td>Middle (38.49°)</td>
<td>3.80</td>
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<tr>
<td>Outer (46.29°)</td>
<td>3.10</td>
<td>0.9861</td>
<td>2.36</td>
</tr>
</tbody>
</table>

**TB**

- 240-280 K
- 260-300 K

**ΔTB**

- 4 K (H)
- 3-4 K (V)

**Version 2.3**
Comparison between Aquarius and SMOS over Land
Summary Statistics

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</tr>
<tr>
<td>Inner (29.36°)</td>
<td>4.35 (8.60)</td>
<td>0.9703 (0.9687)</td>
<td>3.67 (8.34)</td>
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<tr>
<td>Middle (38.49°)</td>
<td>4.28 (8.49)</td>
<td>0.9858 (0.9860)</td>
<td>3.89 (8.35)</td>
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<tr>
<td>Outer (46.29°)</td>
<td>4.51 (8.12)</td>
<td>0.9786 (0.9830)</td>
<td>3.78 (7.88)</td>
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<tr>
<td><strong>V pol</strong></td>
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<tr>
<td>Inner (29.36°)</td>
<td>3.10 (6.27)</td>
<td>0.9897 (0.9892)</td>
<td>2.78 (6.15)</td>
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<tr>
<td>Middle (38.49°)</td>
<td>3.80 (7.37)</td>
<td>0.9850 (0.9854)</td>
<td>3.31 (7.20)</td>
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<tr>
<td>Outer (46.29°)</td>
<td>3.10 (6.53)</td>
<td>0.9861 (0.9882)</td>
<td>2.36 (6.29)</td>
</tr>
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Version 2.3  Version 2.0
Comparison between Aquarius and SMOS

Comparison between Aquarius and SMOS $T_{B_H}$ (Inner Beam)

Comparison between Aquarius and SMOS $T_{B_H}$ (Middle Beam)

Comparison between Aquarius and SMOS $T_{B_H}$ (Outer Beam)

Comparison between Aquarius and SMOS $T_{B_V}$ (Inner Beam)

Comparison between Aquarius and SMOS $T_{B_V}$ (Middle Beam)

Comparison between Aquarius and SMOS $T_{B_V}$ (Outer Beam)

Version 2.3

Land

Ocean
Comparison between Aquarius and SMOS

• Scatter possibly due to:
  – RFI (possible RFI in SMOS/Aquarius)
  – Heterogeneous footprint
  – Different azimuth angles
  – Noise in SMOS and Aquarius data

• Intercomparison results:
  – Very high correlation between SMOS and Aquarius observations
  – Systematic difference in gain and offset for all channels
  – H-pol bias greater than V-pol bias for all beams
  – Expecting improvements in future versions

• Results similar between v2.0 and v2.3 for ocean observations
• The bias is reduced by about 4K (reduced by half) to 3-4 K in version 2.3
• The general trends for the inter-comparison same as earlier
Vicarious Calibration Targets

• Amazon
  – Hot target

• Dome-C
  – Stable cold target in Antarctica
    • ESA has done extensive studies over this location.
    • Multi-year field experiment with a ground based radiometer (RADOMEX)
Amazon

• Max e (emissivity)
• e is independent of incidence angle and polarization (can be investigated using SMOS)
• Low St Dev of e (signal is almost saturated and surface effects are minimal)
  • SMOS observations at 10 different incidence angles ranging from 20-50 degrees used to identify candidate areas
  • St. Dev. less than 0.02 for all angles
  • Difference in mean for all angles and polarizations less than 0.02 [\(\text{Mean}(e_i) - \text{Mean}(e_j) < 0.02\)]
• Surface temperature effects eliminated by the use of land surface emissivity (NCEP surface temperature)
• Very little difference in Asc and Dsc observations over Amazon
• H and V pol observations are similar
• TB and emissivity does not change with incidence angle for both h- and v-pol
• Variability – Aquarius has higher stability (lower St. Dev.)
• Consistent difference between Aquarius and SMOS observations
Vicarious Targets

• **Amazon**
  – Hot target

• **Dome-C**
  – Stable cold target in Antarctica
    • ESA has done extensive studies over this location.
    • Multi-year field experiment with a ground based radiometer (RADOMEX)
Very little difference in Asc and Dsc observations over Dome-C
Variability – Aquarius has higher stability (lower St. Dev.)
V pol observations higher than h pol for both satellites
TB increases with incidence angle for v-pol and vice versa for h-pol
Bias between Aquarius and SMOS observations
Summary

• Results similar between v2.0 and v2.3 for ocean observations
• The bias is reduced by about 4K (reduced by half) to 3-4 K in version 2.3
• The general trends for the inter-comparison same as earlier
  – Very high correlation between SMOS and Aquarius observations
  – Systematic difference in gain and offset for all channels
  – H-pol bias greater than V-pol bias for all beams
• Aquarius observations compare well with SMOS observations over oceans (smaller differences of 1-2 K). How these TB differences translate to differences in SSS is not clear. SMOS does additional TB processing (OTT) before estimating SSS.
• Aquarius observations very stable over Dome-C
• SMOS observations lower than Aquarius observations for all channels over land (3-4 K difference between SMOS and Aquarius)
• Possibly due to Aquarius radiometer calibration (spill-over ratio)
• Anticipated to be fixed in future versions of Aquarius data
• Important to develop a consistent calibration across all L-band mission SMOS, Aquarius and SMAP
Version 2.0
Long term stability over Antarctica

Both instruments show good long term stability
Difference in sensitivity clearly evidenced
Summer surface changes induce noisier behavior at V polarization

Mean biases

<table>
<thead>
<tr>
<th></th>
<th>H</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
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<tr>
<td>outer</td>
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Francois Cabot, Yann Kerr