Inter-Comparison of Aquarius and SMOS Brightness Temperature Observations

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

Nov 6, 2013

Overview

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

Introduction

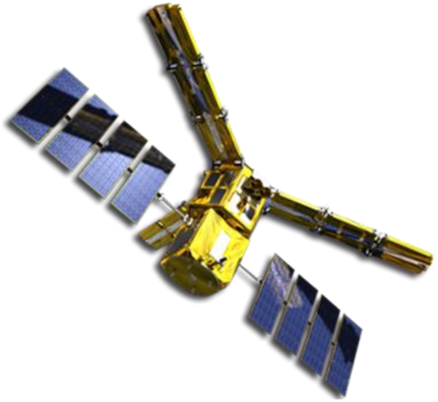
- Verifying the calibration of the L-band radiometer data (SMOS, Aquarius, SMAP) over the entire dynamic range is necessary.
- Land brightness temperatures over land fall in a completely different range of response and it is prudent to verify that the primary calibration extends to these levels.
- It 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

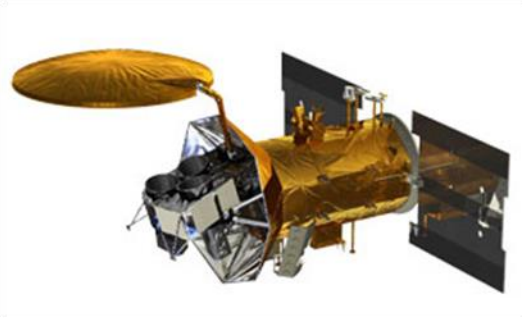
SMOS

- Launched Nov 2009
- 2D-synthetic aperture
  - Multiple incidence angles at every location [0^o-65^o]
- 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^o, 38.49^o, 46.29^o
- 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



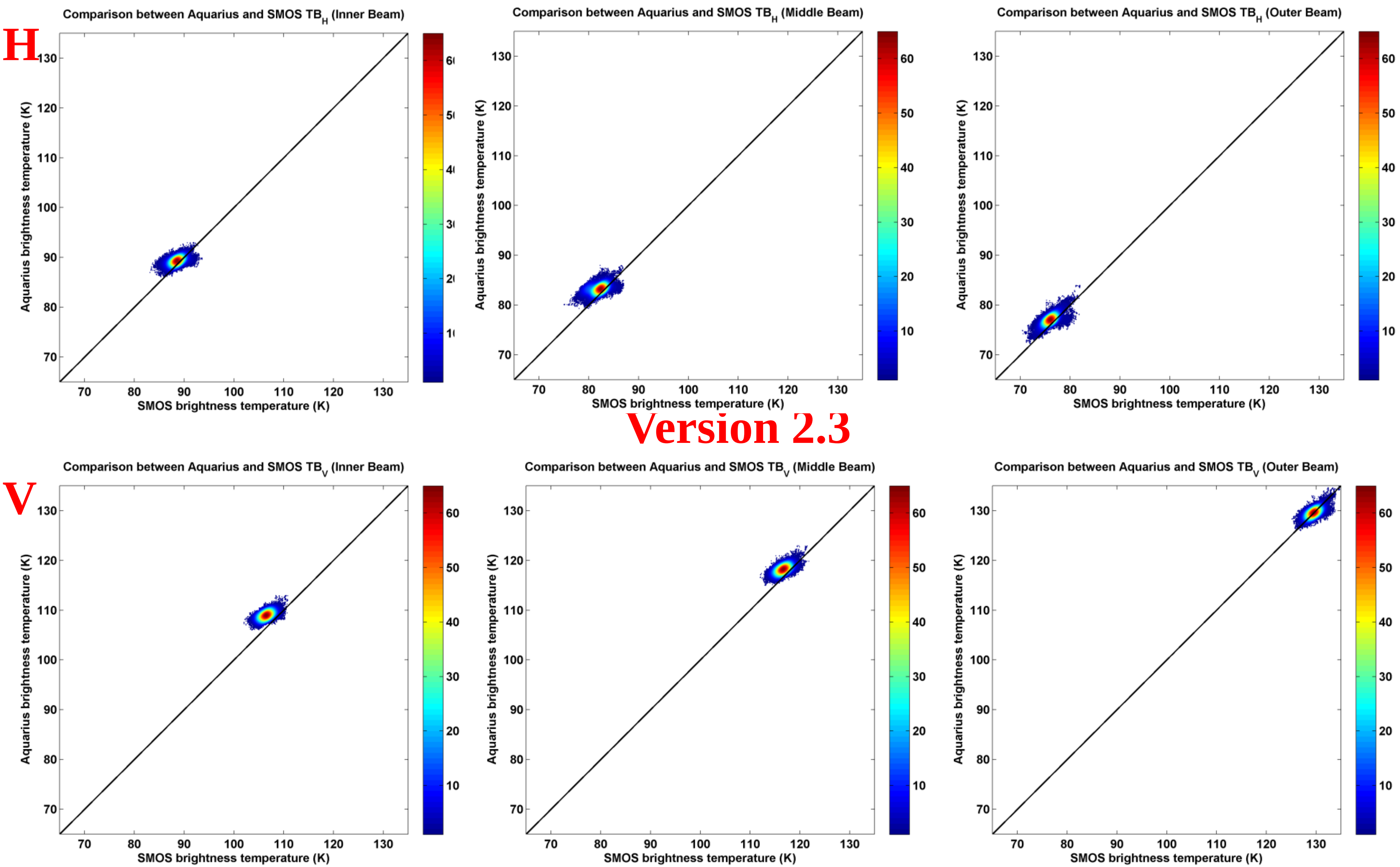
SMAP

- Launch Nov 2014
- Conically Scanning Real aperture
  - Constant incidence angle of 40^o
- 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
  - Period of record : August 25, 2011 – July 31, 2013
  - 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)



Comparison between Aquarius and SMOS over Ocean

Summary Statistics

		RMSD (K)	Bias [Aq-SMOS] (K)
H pol	Inner (29.36^o)	1.22	0.77
	Middle (38.49^o)	1.73	1.24
	Outer (46.29^o)	1.33	1.08
V pol	Inner (29.36^o)	2.67	2.51
	Middle (38.49^o)	1.83	1.61
	Outer (46.29^o)	0.78	0.09

Version 2.3

Comparison between Aquarius and SMOS over Ocean

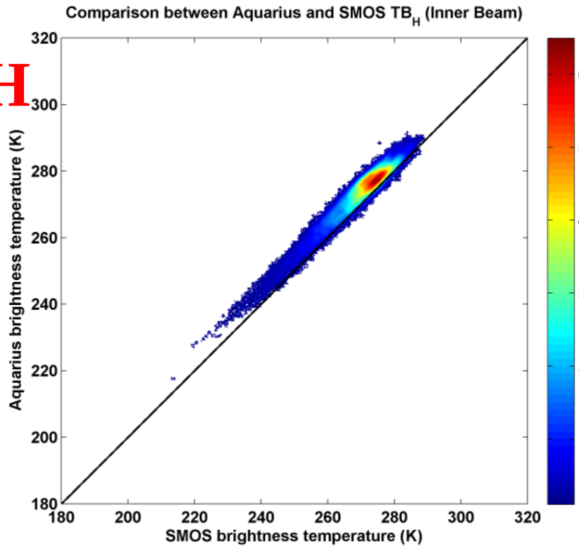
Summary Statistics

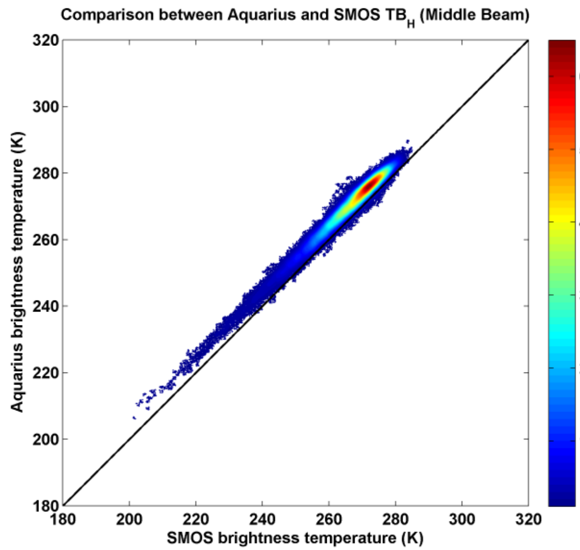
		RMSD (K)	Bias [Aq-SMOS] (K)
H pol	Inner (29.36°)	1.22 (1.29)	0.77 (0.76)
	Middle (38.49°)	1.73 (1.77)	1.24 (1.20)
	Outer (46.29°)	1.33 (1.35)	1.08 (0.98)
V pol	Inner (29.36°)	2.67 (2.71)	2.51 (2.50)
	Middle (38.49°)	1.83 (1.82)	1.61 (1.53)
	Outer (46.29°)	0.78 (0.90)	0.09 (-0.08)

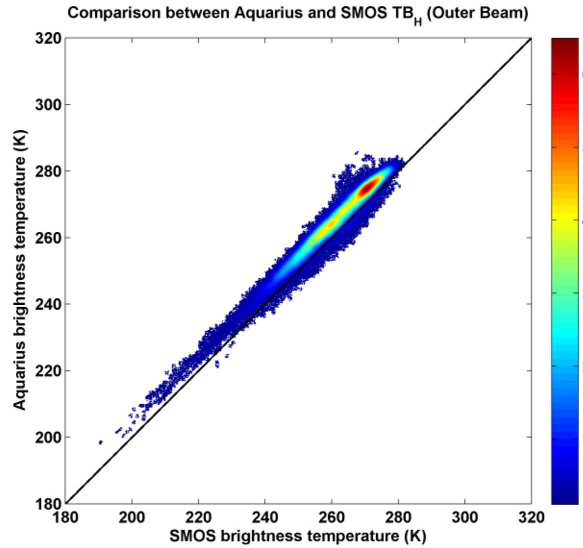
Version 2.3 **Version 2.0**

Comparison between Aquarius and SMOS (land)

H

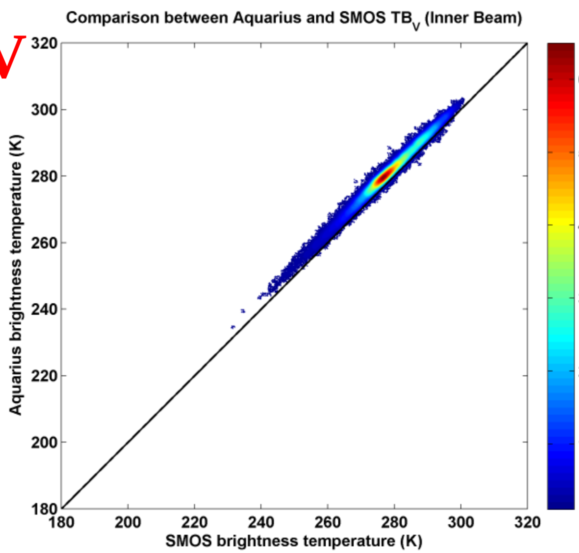


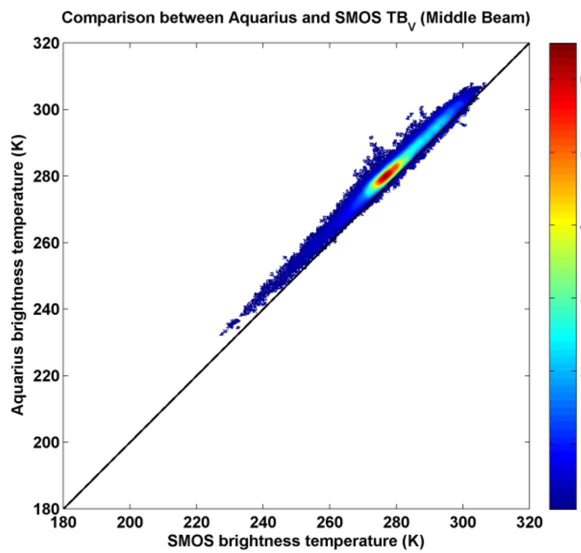


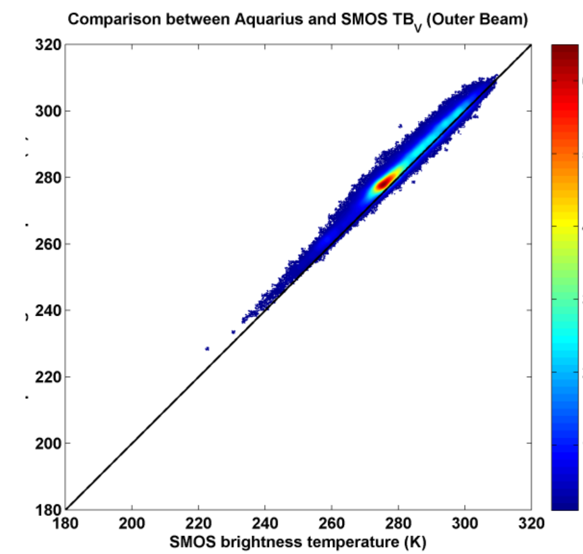


Version 2.3

V







Comparison between Aquarius and SMOS over Land

Summary Statistics

		RMSD (K)	R	Bias [Aq-SMOS] (K)
H pol	Inner (29.36^o)	4.35	0.9703	3.67
	Middle (38.49^o)	4.28	0.9858	3.89
	Outer (46.29^o)	4.51	0.9786	3.78
V pol	Inner (29.36^o)	3.10	0.9897	2.78
	Middle (38.49^o)	3.80	0.9850	3.31
	Outer (46.29^o)	3.10	0.9861	2.36

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

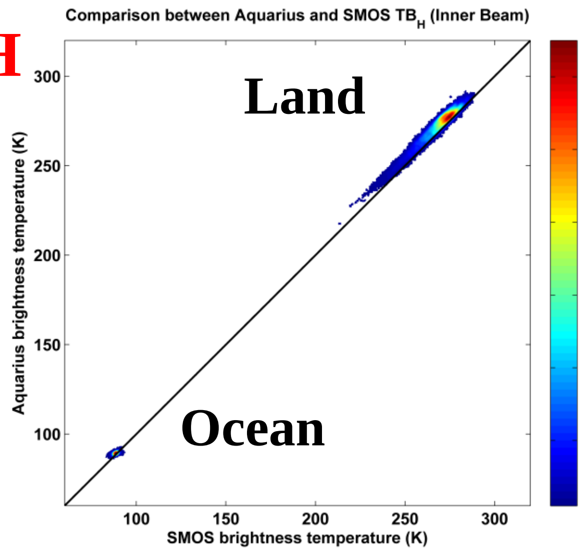
Summary Statistics

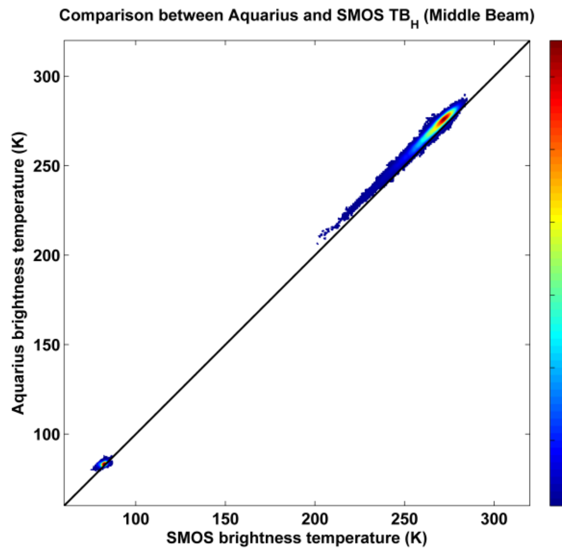
		RMSD (K)	R	Bias [Aq-SMOS] (K)
H pol	Inner (29.36º)	4.35 (8.60)	0.9703 (0.9687)	3.67 (8.34)
	Middle (38.49º)	4.28 (8.49)	0.9858 (0.9860)	3.89 (8.35)
	Outer (46.29º)	4.51 (8.12)	0.9786 (0.9830)	3.78 (7.88)
V pol	Inner (29.36º)	3.10 (6.27)	0.9897 (0.9892)	2.78 (6.15)
	Middle (38.49º)	3.80 (7.37)	0.9850 (0.9854)	3.31 (7.20)
	Outer (46.29º)	3.10 (6.53)	0.9861 (0.9882)	2.36 (6.29)

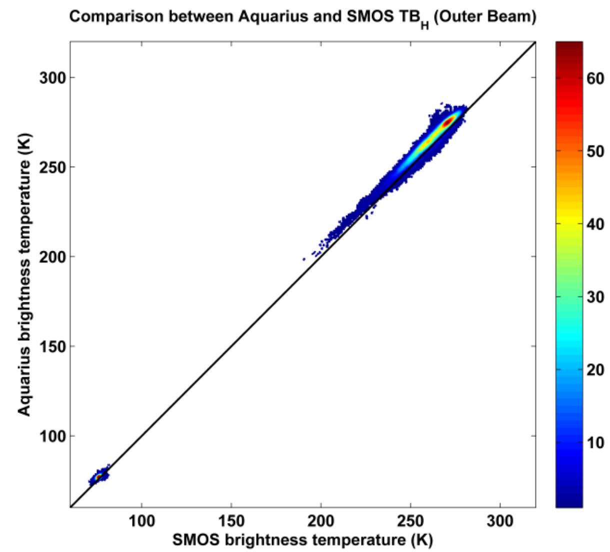
Version 2.3 **Version 2.0**

Comparison between Aquarius and SMOS

H

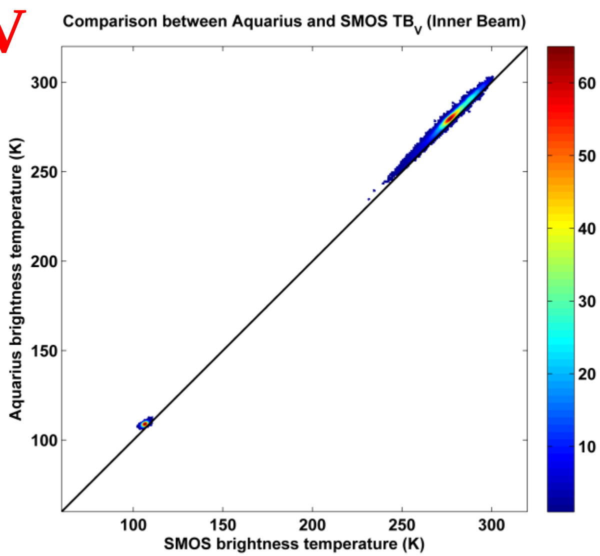


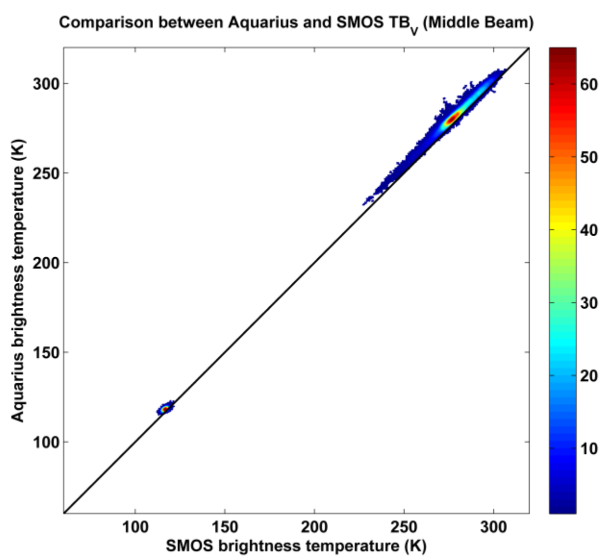


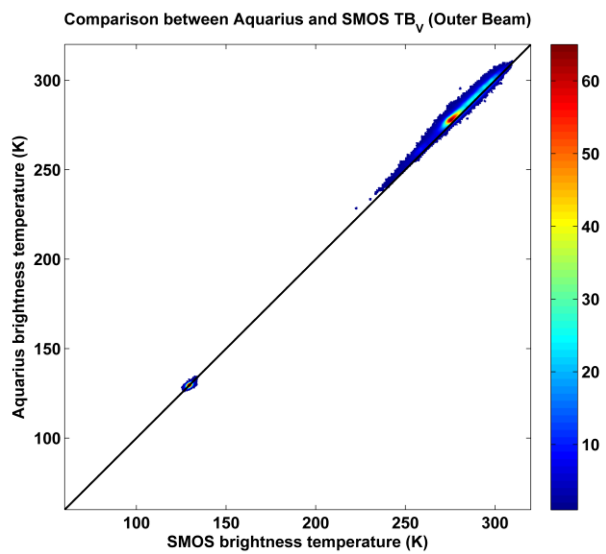


Version 2.3

V







Comparison between Aquarius and SMOS

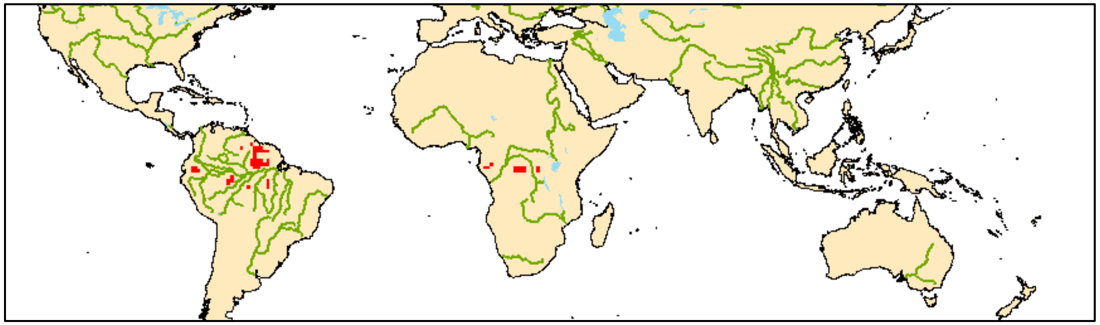
- Scatter possibly due to:
  - RFI (possible RFI in SMOS/Aquarius)
  - Heterogeneous footprint
  - Different azimuth angles
  - Noise in SMOS and Aquarius data
- Intercomparison results:
  - Very high correlation between SMOS and Aquarius observations
  - Systematic difference in gain and offset for 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

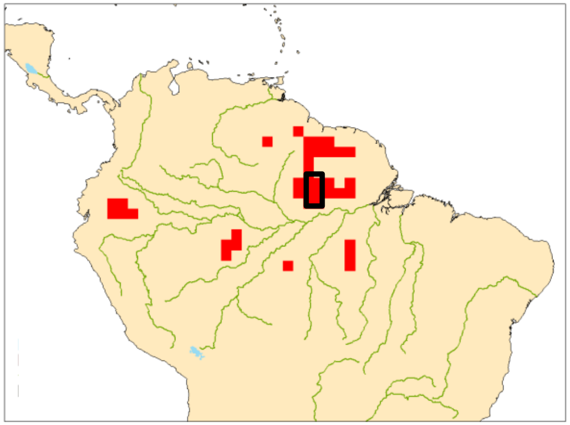
Vicarious Calibration Targets

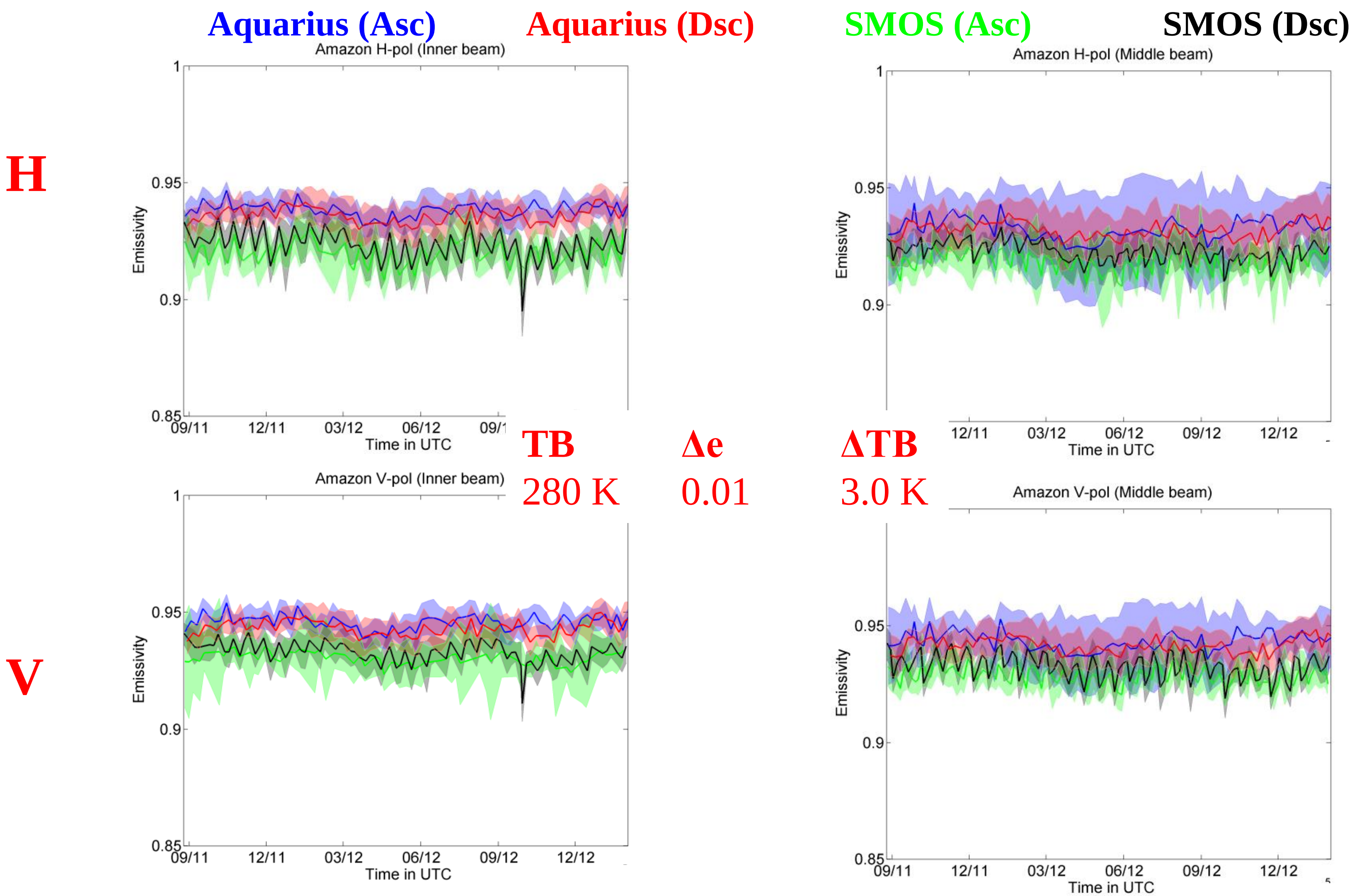
- Amazon
  - Hot target
- Dome-C
  - Stable cold target in Antarctica
    - ESA has done extensive studies over this location.
    - Multi-year field experiment with a ground based radiometer (RADOMEX)

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 [Mean(e_i) - Mean(e_j) <0.02]





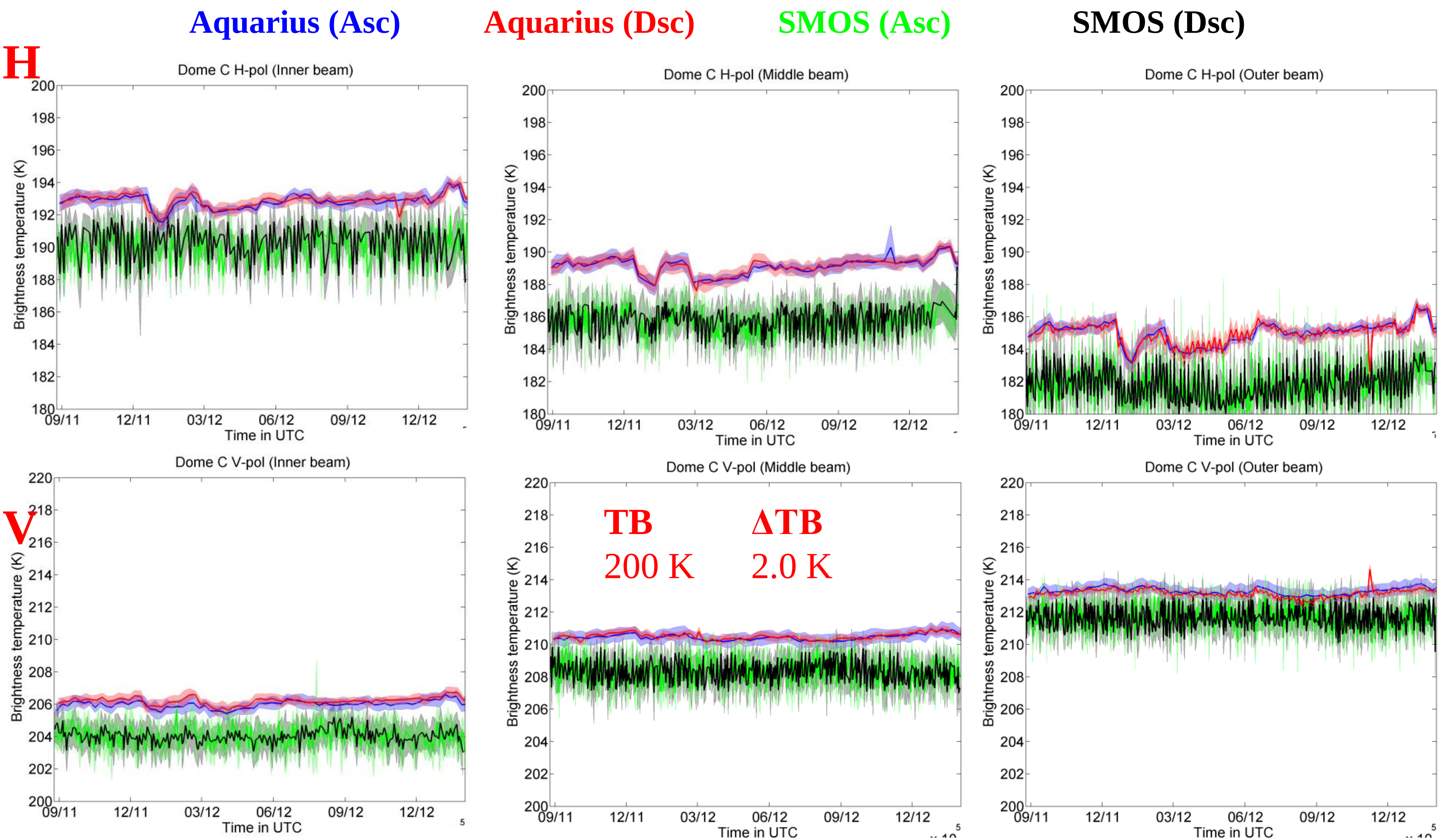


- Surface temperature effects eliminated by the use of land surface emissivity (NCEP surface temperature)
- Very little difference in Asc and Dsc observations over Amazon
- H and V pol observations are similar
- TB and emissivity does not change with incidence angle for both h- and v-pol
- Variability – Aquarius has higher stability (lower St. Dev.)
- Consistent difference between Aquarius and SMOS observations

Amazon

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

Dome-C

Summary

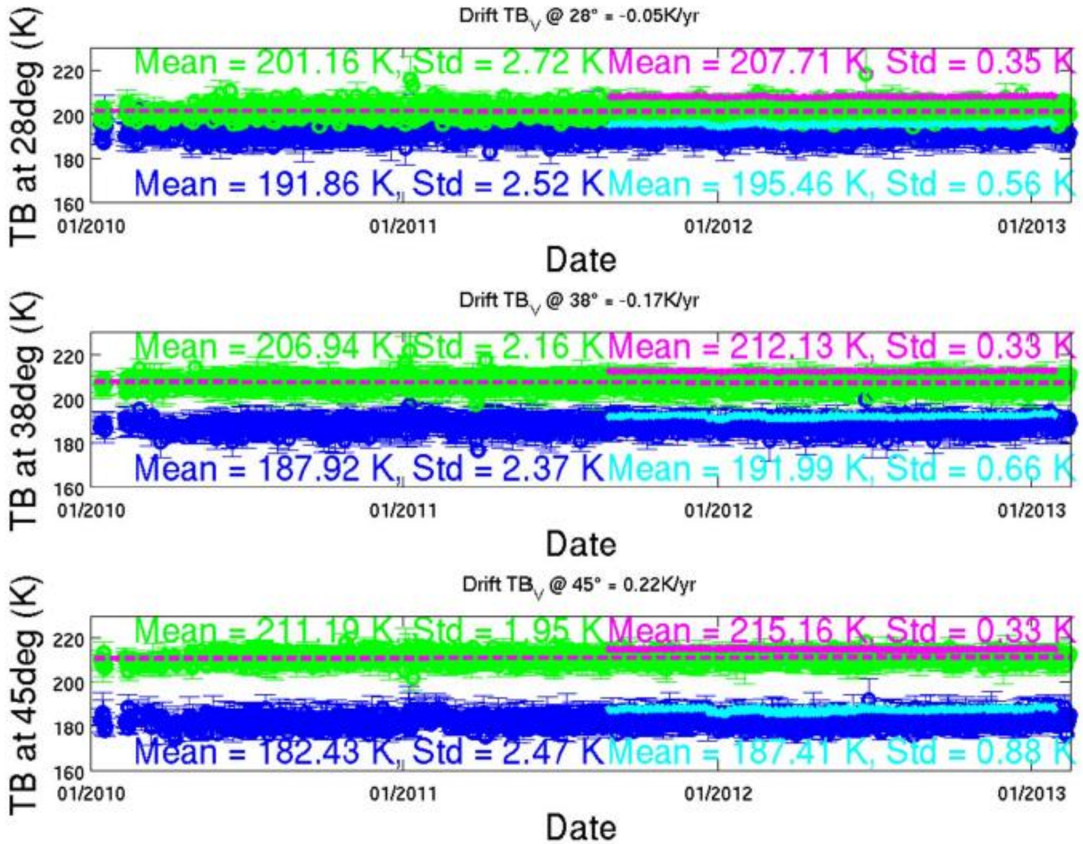
- Results similar between v2.0 and v2.3 for ocean observations
- The bias is reduced by about 4K (reduced by half) to 3-4 K in version 2.3
- The general trends for the inter-comparison same as earlier
  - Very high correlation between SMOS and Aquarius observations
  - Systematic difference in gain and 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

	H	V
inner	6.11	5.54
middle	5.12	3.40
outer	5.54	3.99



Francois Cabot, Yann Kerr