SYNTHESIZING SMOS ZERO-BASELINES WITH AQUARIUS BRIGHTNESS TEMPERATURE SIMULATOR

A. Colliander[1], E. Dinnat[2], D. Le Vine[3], J. Kainulainen[4]

1)Jet Propulsion Laboratory, California Institute of Technology,
4800 Oak Grove Drive, Pasadena, CA91109, USA
2) Chapman University, NASA-GSFC, Greenbelt Rd, Greenbelt, MD20771
3) NASA-GSFC, Greenbelt Rd, Greenbelt, MD20771
4)Department of Radio Science and Engineering, Aalto University School of Electrical Engineering,
P.O.BOX 13000, FI-00076 AALTO, Finland

ABSTRACT

The antenna pattern and observation geometry of the SMOS zero-baseline radiometer, which is used as a reference for the SMOS brightness temperature calibration, was applied to Aquarius simulator, which is used as a reference for the Aquarius brightness temperature calibration. In the preliminary analysis, simulations carried out over a three month period show remarkable agreement between the measurements and simulations. This fundamental agreement would indicate that the brightness temperature products of the two missions should be well correlated. Some discrepancies were also found, cause of which seems to be consistent with findings of other studies and can be corrected for.

Index Terms— SMOS, Aquarius

1. INTRODUCTION

SMOS [1] and Aquarius [2] are ESA and NASA missions, respectively, to make L-band measurements from the Low Earth Orbit. SMOS makes passive measurements whereas Aquarius measures both passive and active. SMOS was launched in November 2009 and Aquarius in June 2011. The scientific objectives of the missions are overlapping: both missions aim at mapping the global Sea Surface Salinity (SSS). Additionally, SMOS mission produces soil moisture product (however, Aquarius data will eventually be used for retrieving soil moisture too). The consistency of the brightness temperature observations made by the two instruments is essential for long-term studies of SSS and soil moisture.

For resolving the consistency, the calibration of the instruments is the key. The basis of the absolute level of the SMOS brightness temperature level is the measurements performed with the so-called zero-baselines [3]: SMOS employs an interferometric measurement technique which forms a brightness temperature image from several baselines constructed by combination of multiple receivers in an array; zero-length baseline defines the overall brightness temperature level. The basis of the Aquarius brightness temperature level is resolved from the brightness temperature simulator combined with ancillary data such as antenna patterns and environmental models [4]. Consistency between the SMOS zero-baseline measurements and the simulator output would provide a robust basis for establishing the overall comparability of the missions.

In this study the SMOS zero-baselines are synthesized with the Aquarius simulator by applying the antenna patterns of the zero-baseline antennas and geometry of the observation to the simulator engine. The ancillary data are acquired similarly as for simulations for Aquarius beams.

2. METHODS AND MATERIALS

The footprints of the SMOS zero-baseline and the beams of the Aquarius are radically different. This is due to the fact that the SMOS zero-baseline is designed to measure the average brightness temperature of the entire SMOS scene and, therefore, the 3-dB footprint spans over 1000 km in the cross-track direction and includes a piece of sky in the along-track direction, see Figure 1 (note that the resolution of the SMOS brightness temperature product is about 40 km in the boresight direction).

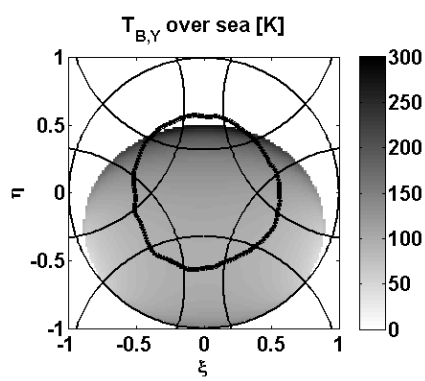

Figure 1. SMOS field of view and the 3-dB footprint of a zero-baseline radiometer marked with black thick line [5].

Aquarius, however, is a real aperture pushbroom system which has footprints of size about 70 km to 150 km on the surface of the Earth.

Although the primary purpose of the Aquarius simulator is to simulate antenna temperature corresponding to Aquarius footprints, it is able to determine the brightness temperature of a wide beam such as that of SMOS zero-baseline, since it includes the simulation of the side and back lobes of the Aquarius antenna for accuracy [4]. Accordingly, the simulator incorporates correction for full view angle and has the capability to simulate brightness temperature emitted by sea, land, atmosphere, cosmic microwave background and celestial objects.

The comparisons of this study will be made over ocean where the primary brightness temperature contribution comes from the sea with partial effect from the sky. The surface emission models from the sea surface are more accurate than models from land surfaces and, therefore, a region over Pacific Ocean is chosen as a test area. For this area the surface conditions (temperature, winds, precipitation) do not go through large rapid changes climatologically, the full field of view is as free as possible from the effect of land, and the interference from galaxy and the sun is low and predictable. The test area is limited between 25°S and 5°N latitude and between -140°W and -130°W longitude (see Figure 4a) for the boresight location. In the long-term analysis between June and October, 2010 the measurements are compared against simulations over this region. The mean values over the test are used to analyze the differences over time. The version of the SMOS zero-baseline brightness temperature is 3.42, which does not include the updated antenna model presented in [5].

3. RESULTS

Figure 2 shows measurements and corresponding simulations of two orbits crossing Antarctica and advancing over the southern Pacific. The measurements over the ocean test region have been marked in red.

The results show that when crossing Antarctica the simulator predicts the brightness temperature level well, in particularly for the southern hemisphere fall (Figure 2b), and (Figure 2c). However, this is not the primary objective of the simulator; for the ocean part the match between the measurements and simulations is excellent. Figure 2d and Figure 2e show the zoom of the first orbit for the vertical polarization. No adjustments to either the measurement or the simulations were made in the processing of these results (other than reduction of noise from the measurements with sliding window averaging). The about 1-K changes in the brightness temperature level when crossing the Pacific are replicated very well. The offset between the results is 2 K at the maximum.

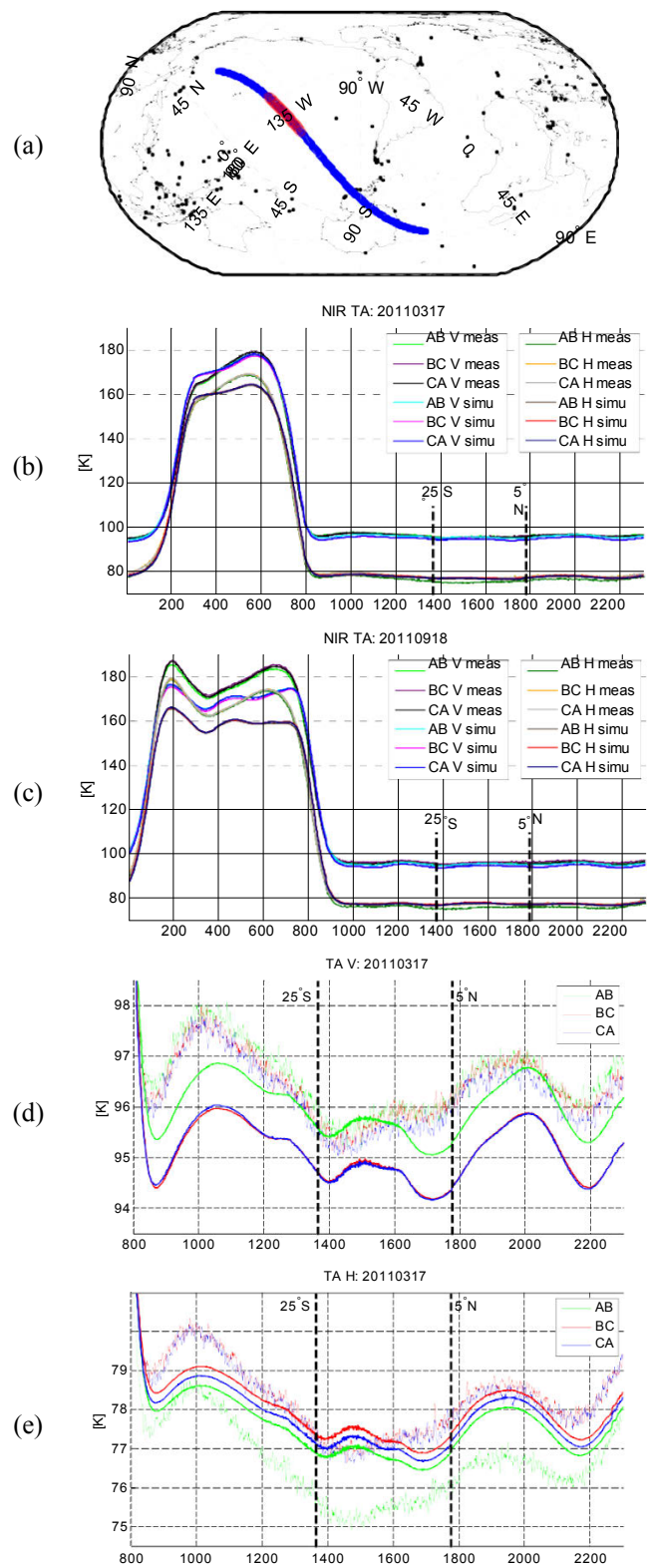

Figure 2. Measured (SMOS data ver. 3.42) and simulated zero-baseline brightness temperature: (a) ground track of the selected part of the orbit; (b) and (c) the values for the entire period on March 17, 2011 and September 18, 2011; (d) and (e) the values for the ocean part on March 17, 2011 for vertical and horizontal polarization, respectively.

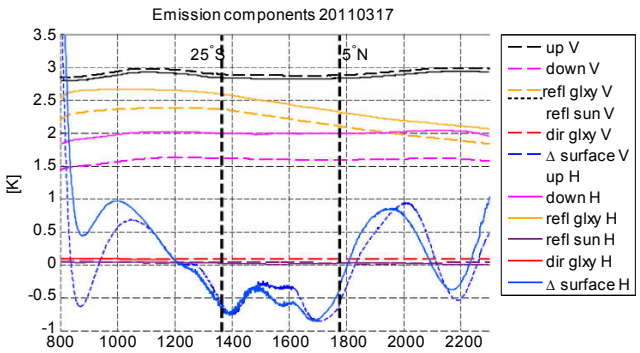

Figure 3. Emission components of the simulator over the ocean part of the orbit in Figure 2 ("up" means upwelling radiation, "down" means downwelling radiation, "refl glxy" means reflected radiation from the galaxy, "dir glxy" means direct radiation from the galaxy, "refl sun" means reflected radiation from the Sun, and "Δsurface" is the deviation of the surface emission component from the mean).

Furthermore, the results show that there are gradients in the brightness temperature over the test area as well, and the profiles of the time series of measurements and simulations depart from each other. The reason for this is under investigation. Figure 3 shows, however, that atmospheric effects or celestial sources do not seem to be the cause for this kind of changes in the simulation.

The results in Figure 2e also show that the output of the unit designated as AB deviates from the other two. Issues regarding unit AB have been reported in [5] and therefore the results obtained from this unit will not be discussed in the further analysis below.

Figure 4 shows the results obtained over the test area between June and October, 2010. Figure 4b and Figure 4c show the zero-baseline measurements over the test area for ascending and descending orbits for vertical and horizontal polarization of units BC and CA, respectively. As shown in Figure 2 the brightness temperature level experiences and gradient over the test area, which causes the large dispersion for each overpass. The mean values of the overpasses have been plotted on top of the individual measurements. The mean values show a trend where measurements obtained on ascending and descending orbits depart by 1 K at each polarization from each other at around day of year of 220. This result alone does not give indication whether this is an orbital effect on the instrument or true change in the antenna temperature due to seasonal changes in the contributing sources.

Figure 4d and Figure 4e show the difference of the test area means between the measurement and simulation for ascending and descending orbits for vertical and horizontal polarization of units BC and CA, respectively. The vertical polarization shows slight trends for increasing difference for descending orbits and decreasing difference for ascending orbits, which would indicate that there is an orbit dependent drift affecting the measurements. Overall the measurement gives values of about 1.2 K higher than the simulation.

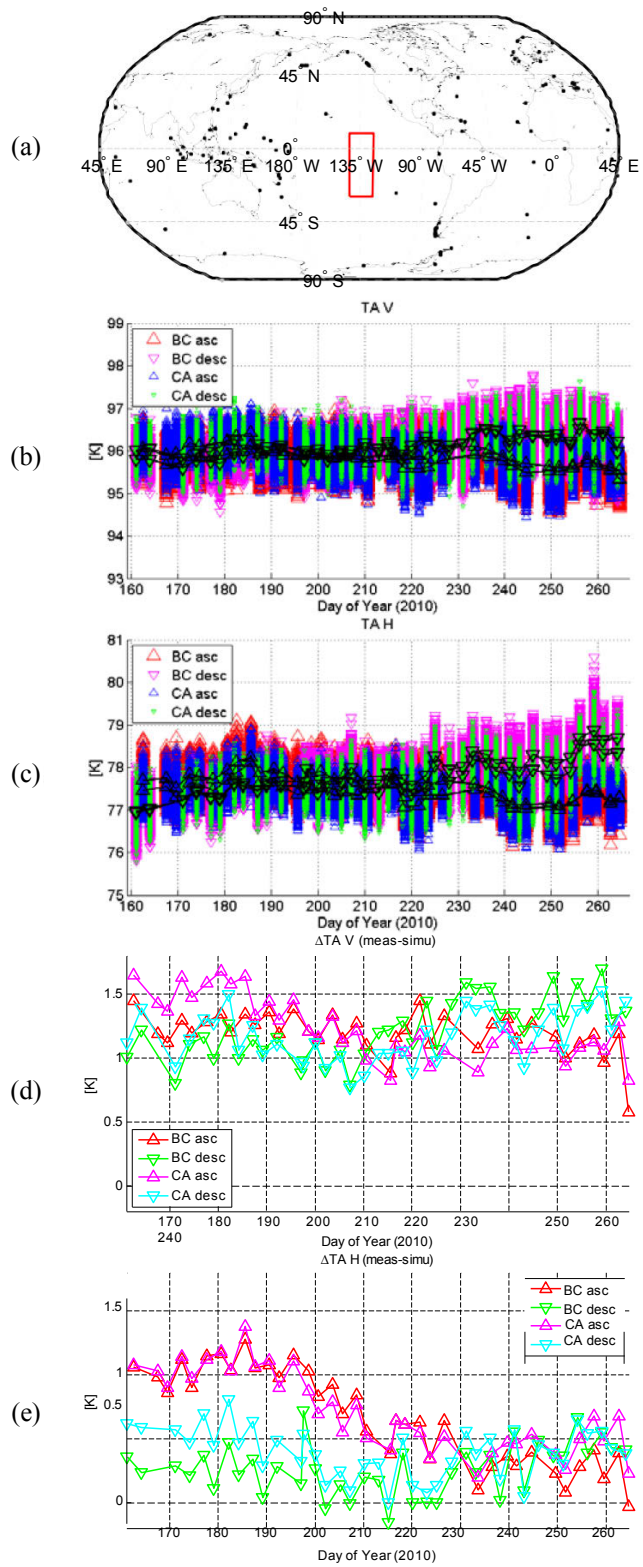

Figure 4. Long-term comparison of measurements (SMOS data ver. 3.42) and simulations for the period between June and October, 2010: (a) the test area; (b) and (c) measurements with all samples and mean for vertical and horizontal polarization, respectively; (d) and (e) the difference of the measurements and simulations

The horizontal polarization show decreasing trend for ascending orbits but does not show any observable trend for the descending orbits. The overall offset for descending orbits is about 0.3 K so the measured increasing trend for descending orbits in Figure 4c is likely real seasonal trend based on these results.

The ascending/descending bias have been addressed with the updated antenna model of the zero-baseline presented in [5] and the results will be reanalyzed against the reprocessed brightness temperatures.

4. CONCLUSIONS

The calibration references of SMOS and Aquarius were compared. Although the comparison is not done at the retrieval resolution of geophysical parameters, the results will give important direction where corrections are potentially required for increasing the consistency between the brightness temperature products of the two missions. The results show remarkable agreement between the measurements and simulations. This fundamental agreement would indicate that the brightness temperature products of the two missions should be well correlated. Some discrepancies were also found, cause of which seems to be consistent with findings of other studies and can be corrected for. The observed ascending/descending bias have been addressed with the new antenna model of the zero-baseline presented in [5]. Next steps of the investigation will include simulation of full time series of measurements of the latest reprocessed data (which includes the updated antenna model) and derivation of parameters for matching the results.

REFERENCES

[1] Y. Kerr et al., The SMOS Mission: New Tool for Monitoring Key Elements of the Global Water Cycle, *Proc. of IEEE*, Vol. 98, No. 5, May 2010.

[2] D. Levine, G. Lagerloef, S. Torrusio, Aquarius and Remote Sensing of Sea Surface Salinity from Space, *Proc. of IEEE*, Vol. 98, No. 5, May 2010.

[3] A. Colliander, L. Ruokokoski, J. Suomela, K. Veijola,J. Kettunen, V. Kangas, A. Aalto, M. Levander, H. Greus, M. Hallikainen, J. Lahtinen, Development and Calibration of SMOS Reference Radiometer, *IEEE Trans. Geosci. Rem. Sens.*, Vol. 45, No. 7, July 2007.

[4] D. Le Vine, E. Dinnat, S. Abraham, P. de Matthaeis, F. Wentz, The Aquarius Simulator and Cold-Sky Calibration, *IEEE Trans. Gesci. Rem. Sens.*, Vol. 49, No. 9, September 2011.

[5] J. Kainulainen, A. Colliander, J. Closa, M. Martin-Neira, R. Oliva, G. Buenadicha, P. Rubiales, A. Hakkarainen, M. Hallikainen, Radiometric Performance of the SMOS Reference Radiometers – Assessment after One Year of Operation, *IEEE Trans. Geosci. Rem. Sens.*, Vol. 50, No. 5, May 2012.

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