SOIL MOISTURE ACTIVE/PASSIVE (SMAP) FORWARD BRIGHTNESS TEMPERATURE SIMULATOR

[1,2]Jinzheng Peng, [2]Jeffrey Peipmeier, [2]Edward Kim

[1] Morgan State University, MD, USA

[2] NASA Goddard Space Flight Center, Greenbelt, USA

Abstract

The SMAP is one of four first-tier missions recommended by the US National Research Council's Committee on Earth Science and Applications from Space (Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond, Space Studies Board, National Academies Press, 2007) [1]. It is to measure the global soil moisture and freeze/thaw from space. One of the spaceborne instruments is an L-band radiometer with a shared single feedhorn and parabolic mesh reflector. While the radiometer measures the emission over a footprint of interest, unwanted emissions are also received by the antenna through the antenna sidelobes from the cosmic background and other error sources such as the Sun, the Moon and the galaxy. Their effects need to be considered accurately, and the analysis of the overall performance of the radiometer requires end-to-end performance simulation from Earth emission to antenna brightness temperature, such as the global simulation of L-band brightness temperature simulation over land and sea [2]. To assist with the SMAP radiometer level 1B algorithm development, the SMAP forward brightness temperature simulator is developed by adapting the Aquarius simulator [2] with necessary modifications. This poster presents the current status of the SMAP forward brightness simulator's development including incorporating the land microwave emission model and its input datasets, and a simplified atmospheric radiative transfer model. The latest simulation results are also presented to demonstrate the ability of supporting the SMAP L1B algorithm development.

Simulator Development

The SMAP forward brightness temperature simulator is developed from the Aquarius simulator by incorporating SMAP specifications. All the error sources in Figure 1 and their effects are addressed. Here lists a summary of main further development in the SMAP simulator.

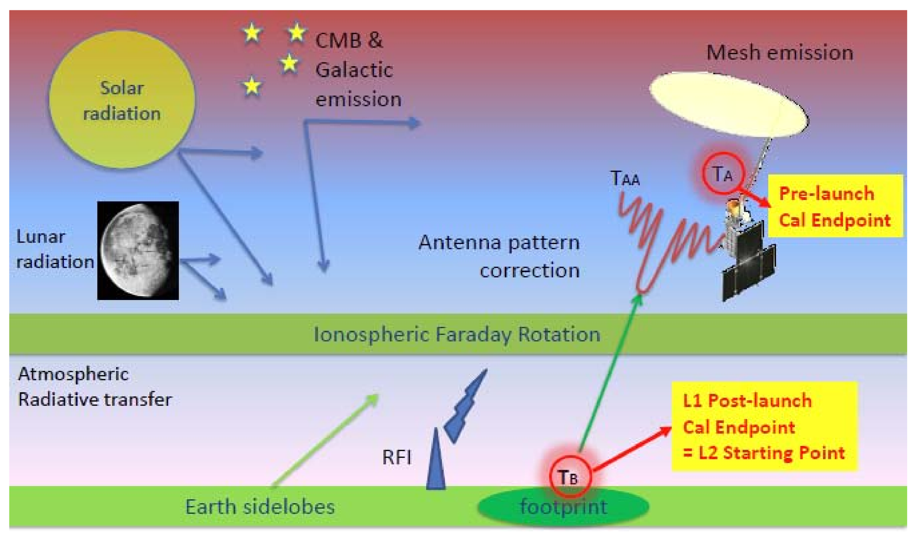

Figure 1. Sources and effects considered in the simulator

1) Conical Scan

SMAP employs a conical scan at 40 degrees EIA vs. Aquarius' 3 fixed beams. Primarily as a result of adding the additional footprints associated with the conical scan, the computational efficiency of the SMAP L1B simulator becomes critical. Much effort is being devoted to speed up execution.

2) Antenna pattern

SMAP's 6 m antenna has a considerably narrower beam than Aquarius' 2 m antenna. The actual pattern from the SMAP antenna design is used in the simulator. To balance the spatial resolution over a footprint and simulation speed, hybrid-resolution antenna pattern is used in the orbit simulator. Within the first null-to-null beamwidth which is defined as 2.5 times 3-dB beamwidth, the resolution of the antenna pattern is 0.1°, while beyond the region, it is 0.5°.

3) Land focus

Whereas Aquarius' focus is naturally the ocean, SMAP's focus is land areas (plus selected ocean and ice sheet targets for calibration). The land T_B model in the Aquarius simulator is upgraded with significantly more realistic detail regarding land cover types, and other factors to yield more realistic land T_B at a spatial resolution sufficient to use the simulator to analyze effects requiring sub-pixel resolution such as geolocation.

The land microwave emission is computed using the microwave emission model [3] which requires the specification of the soil, such as sand and clay fractions and the soil moisture content besides land surface temperature. To consider the effects of surface scattering and vegetation on land, a semiempirical two-parameter roughness model [4] is used and vegetation is modeled as a single-scattering layer above its rough soil in the land microwave emission model.

The effect of the fresh water body on continent is considered in the simulator by using the parameter of open water fraction which is relative to land for a given footprint.

4) Atmosphere model

The Aquarius simulator employed an atmosphere model that was simplified for L-band. It was found that adding the conical scan also multiplied the number of iterations needed for the atmosphere routine. In fact, the atmosphere routine could dominate the computation time. A simplified atmosphere model was developed and validated against almost 10^6 soundings in the NCDC radiosondes database [5]. The up-/down-welling brightness and the total loss factor of the atmosphere are modeled as polynomial functions of pressure, temperature, water vapor density near Earth surface and incidence angle. At incidence angle 40°, the atmospheric upwelling brightness and loss factor are modeled as

$$\hat{T}_{up} = 2.3058 - 3.2735\times10^{-3} T_{surf} + 4.2330\times10^{-3} P_{900} + 1.4472\times10^{-3} V$$

$$\hat{L} = 1.0094 - 2.9626\times10^{-5} T_{surf} + 1.6521\times10^{-5} P_{900} + 1.0712\times10^{-5} V$$

where T_{surf} is near surface air temperature in degrees Celsius. P_{900} (= P – 900, where P is near surface pressure in millibars) is a biased surface pressure in millibars. V is water vapor density near the surface in grams per cubic meter.

The atmospheric upwelling TB (unit: Kelvin) and loss factor of the atmosphere on 01/01/2001 are shown in Figure 2.

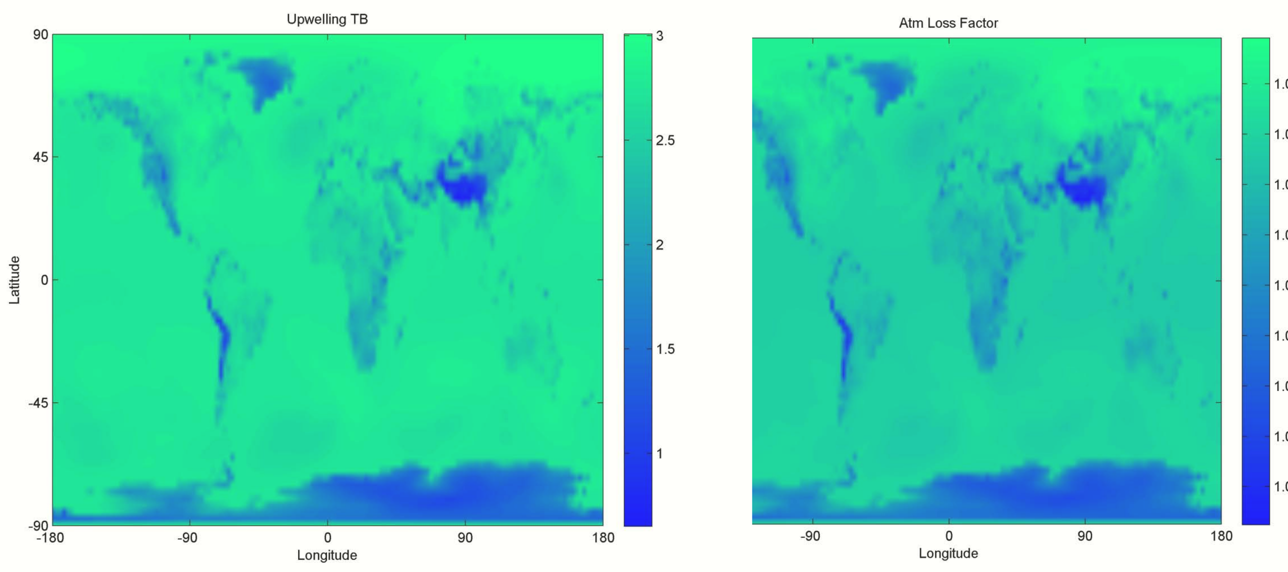

Figure 2 Atmospheric upwelling TB and loss factor

5) Ancillary data

As a result of the upgrades to the land and atmosphere modules, the input and ancillary data needs for the SMAP simulator are different vs. the Aquarius simulator. The ancillary data requirements are listed in Table 1.

Table 1. Ancillary Datasets for SMAP Orbit Simulator

Name	Spatial Resolution	Temporal Resolution	Note
SSS	0.1° x 0.1°	6 hours	
SST	0.1° x 0.1°	6 hours	
WS	0.1° x 0.1°	6 hours	
Mask	0.1° x 0.1°	6 hours	Water, land, ice.
Vegetation Water Content (VWC)	0.1° x 0.1°	1 day	
Land Roughness Map	0.1° x 0.1°	static	
Land Surface Temp	0.1° x 0.1°	1 hour	
Land Soil Moisture	0.1° x 0.1°	1 hour	
Sand Fraction Map	0.1° x 0.1°	static	
Clay Fraction Map	0.1° x 0.1°	static	
Open Water Fraction	0.1° x 0.1°	static	
Near Surface Air Temp	2.5° x 2.5°	6 hours	
Near Surface Pressure	2.5° x 2.5°	6 hours	
Near Surface Water Vapor Density	2.5° x 2.5°	6 hours	
Solar Flux		1 day	
Sun Spot Number		1 day	
Galactic TB Map	0.5° x 0.5°	static	

Simulation Result

Simulation of the first few days in 2001 has been performed in a local workstation. Part of the simulation results are shown in Figure 3. For v polarization channel, the emission from the galaxy directly entering the radiometer antenna backlobe is varied from 0.48 K to 0.68 K. The variation from the Sun directly is also 0.2 K.

The brightness difference between vertical and horizontal polarization components are shown in Figure 3(c). While the brightness temperature of the vertical polarization component is larger than that of horizontal polarization component over ocean, it is not always the case over land. The difference (T_h – T_v) could be up to 17 K over land in the latitude range [-59.6, 83.4].

The simulation results will be used to support SMAP radiometer L1B algorithm development. For example, the simulated antenna sidelobe contribution from the Earth is shown in Figure 3(d). For a footprint over ocean, the Earth sidelobe contribution has less variation. While for a footprint over land, it could be high to 5.8 K. The SMAP Antenna Pattern Correction (APC) algorithm is under development based on the simulation result. Initial APC correction result is that the residual errors are 0.31 K (V) and 0.33 (H) over land, and 0.21 K (V) and 0.22 K over ocean.

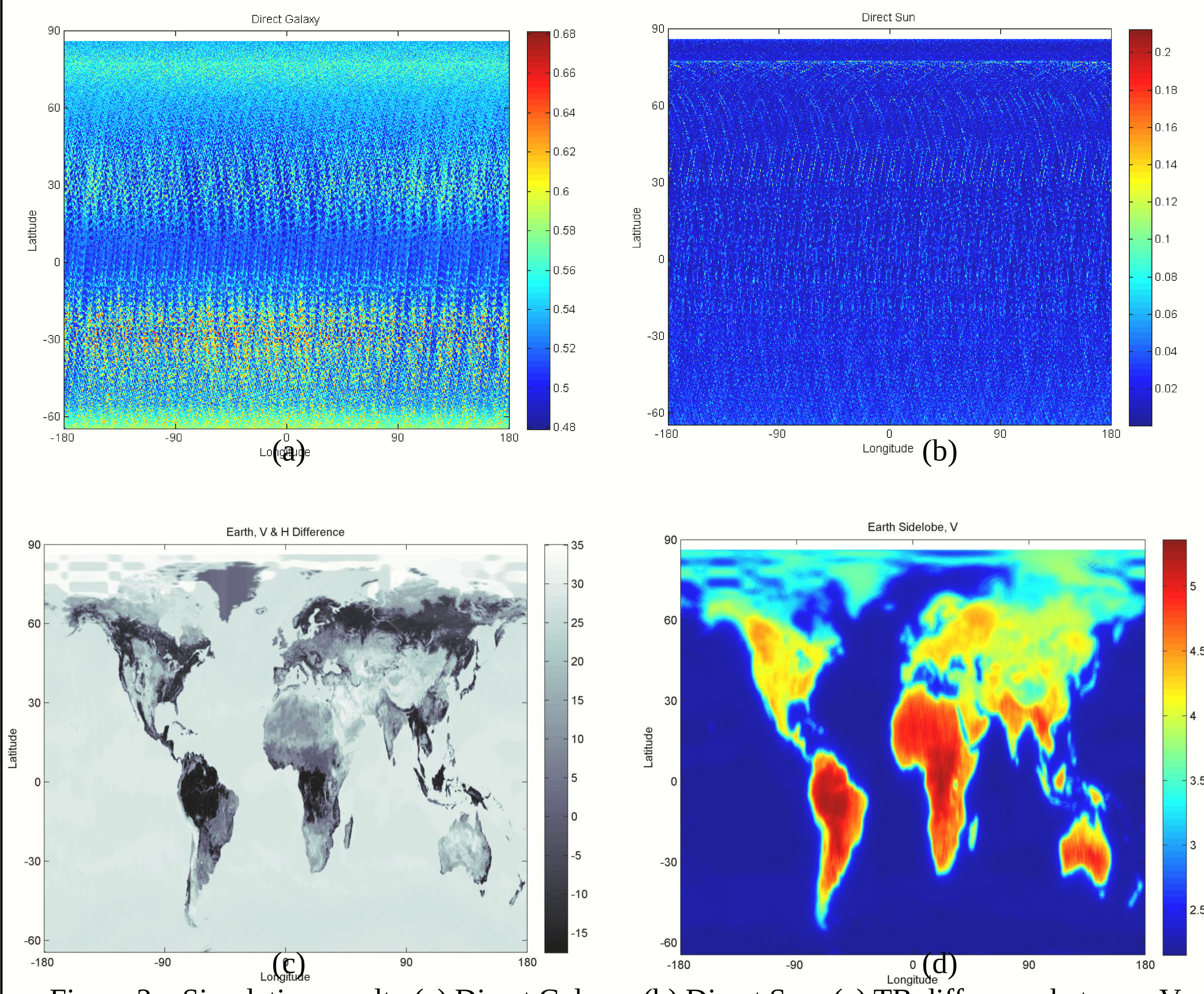

Figure 3. Simulation result (a) Direct Galaxy; (b) Direct Sun; (c) TB difference between V and H pols. (d) Earth sidelobe contribution

Conclusion

The SMAP level 1B forward brightness temperature simulator is developed by incorporating a land microwave emission model, a simplified atmospheric radiative transfer model, and other necessary modification for SMAP specifications and to speed-up execution. Simulation results demonstrate the ability of the SMAP simulator to support the SMAP level 1B algorithm development.

References

[1] Entekhabi, et al., "The Soil Moisture Active Passive (SMAP) Mission," *Proceedings of the IEEE*, Vol. 98, No. 5, pp. 704-716, May 2010.

[2] Le Vine, D.M. Dinnat, E.P. Abraham, S. de Matthaeis, P. Wentz, F.J. "The Aquarius Simulator and Cold-Sky Calibration", *IEEE Trans. Geosci. Remote Sens.*, 49(9), doi:10.1109/TGRS.2011.2161481, 2011

[3] Njoku, E.G., Li Li, "Retrieval of land surface parameters using passive microwave measurements at 6-18 GHz", *IEEE Trans. Geosci. Remote Sens.*, 37(1), doi:10.1109/36.739125, 1999

[4] J. R. Wang and B. J. Choudhury, "Remote sensing of soil moisture content over bare fields at 1.4 GHz frequency," *J. Geophys. Res.*, vol. 86, pp. 5277–5282, 1981.

[5] J. Peng, E. Kim, J. Piepmeier, "Global Simplified Atmospheric Radiative Transfer Model at L-band", *IEEE Geoscience and Remote Sensing Letters*, in press.