Global Calibration of the GEOS-5 L-band Microwave Radiative Transfer Model over Non-Frozen Land Using SMOS Observations

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Assimilating low-frequency (1-10 GHz) passive microwave observations into land surface models should improve estimates of land surface conditions and hence weather and climate predictions. Global observations of brightness temperatures (Tb) are available from the L-band Soil Moisture Ocean Salinity (SMOS), and similarly low frequency Tb observations are expected from the future NASA Soil Moisture Active Passive (SMAP) mission. In this study, a microwave radiative transfer model (RTM) is coupled to the Goddard Earth Observing System, Version-5 (GEOS-5) Catchment land surface model in preparation for the assimilation of global Tb observations from SMOS and SMAP as part of a radiance-based soil moisture analysis.

Figure 1 shows differences between climatological mean SMOS Tb observations and Tb forecasts using three different literature-based sets of RTM-parameters:

- "Lit1" refers to RTM parameters that are proposed for the future SMAP L2/3 radiometer retrieval products,
- "Lit2" refers to RTM parameters collected from literature studies using the L-band Microwave Emission of the Biosphere Model (L-MEB), the Land Surface Microwave Emission Model (LSMEM), or the Community Microwave Emission Modelling Platform (CMEM), and
- "Lit3" parameters are identical to the Lit2 parameters except for the microwave roughness *h*, which is set to values used for SMOS monitoring at the European Center for Medium-Range Weather Forecasts (ECMWF).

All three sets of literature-based RTM parameters lead to substantial biases when used in the GEOS-5 system, with Lit1 being too cold by up to 50 K and Lit3 being too warm all over the globe. Even though Lit2 estimates are nearly

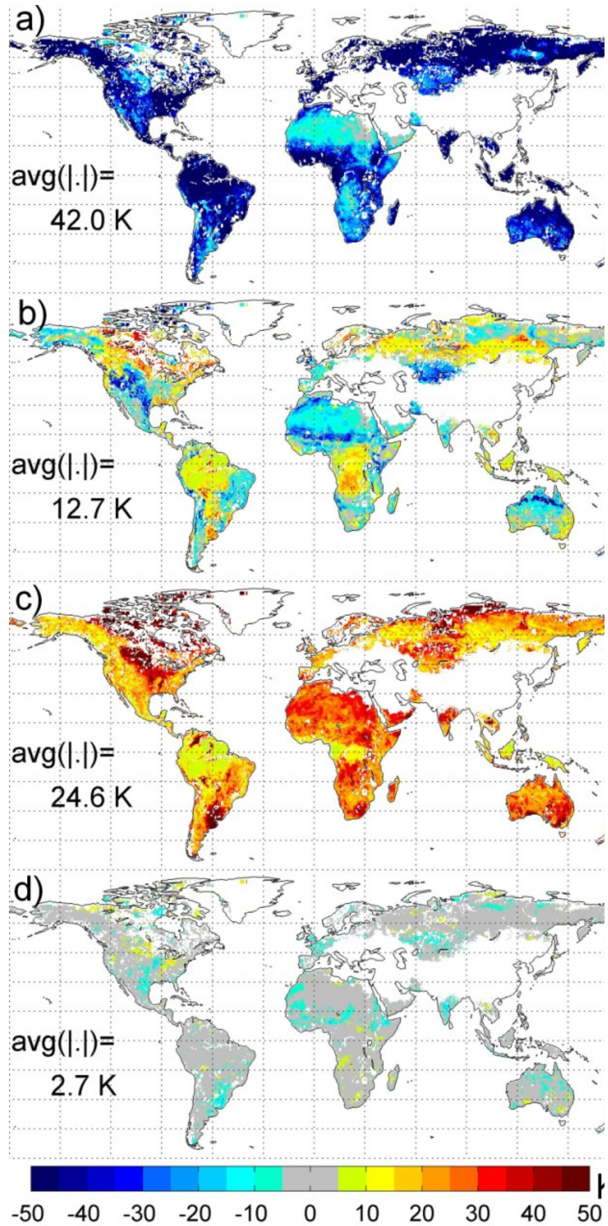

Figure 1: Difference in Kelvin between one-year (1 July 2010 – 1 July 2011) mean values of horizontally polarized Tb at 42.5° incidence angle from GEOS-5 and SMOS observations for (a) Lit1, (b) Lit2, (c) Lit3, and (d) calibrated parameters. Within each subplot, "avg(|.|)" indicates the average absolute difference across the globe (excluding regions impacted by open water or radio-frequency interference that are shown in white).

unbiased in the global average, there are still significant regional biases in the simulated Tbs. Such biases would hamper the assimilation of Tb from SMOS or SMAP. Therefore, we calibrated the relevant RTMparameters to obtain climatologically unbiased Tb estimates. After calibration, the Tb simulations show a global absolute bias of 2.7 K, as shown in Figure 1d. It should be emphasized that an RMSE of approximately 10 K remains, due to seasonal biases and short-term errors, which will be addressed in the Tb data assimilation system.

The calibration minimized the difference between modelled and observed climatological means and standard deviations, as well as the deviation of the optimized parameters from prior guesses (Lit1, Lit2, and Lit3), at each individual location. Through a number of experiments, we determined that it is best to simultaneously calibrate (i) the microwave roughness h, (ii) the vegetation opacity τ and (iii) the scattering albedo ω.

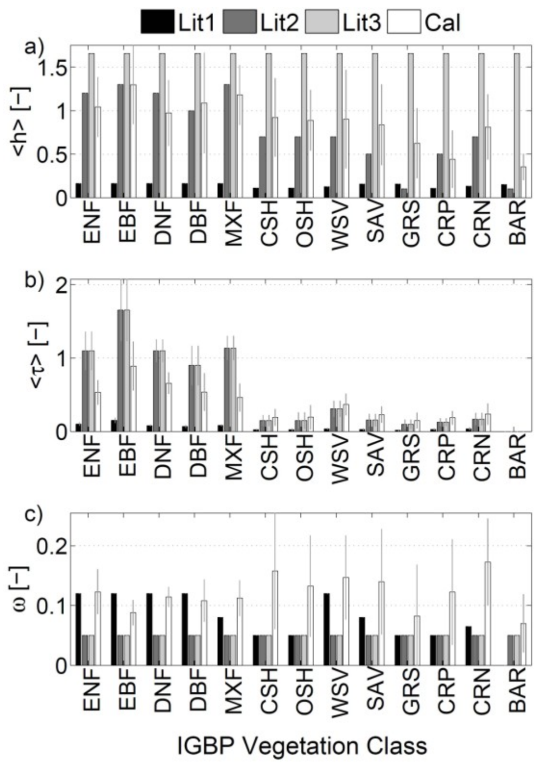

Figure 2: (a) Time-mean <h> (1 July 2010 – 1 July 2011), (b) time-mean <τ>, and (c) time-invariant ω; (Lit1, Lit2 and Lit3) before calibration, and (Cal) after calibration, spatially averaged by vegetation class. International Geosphere-Biosphere Programme (IGBP) vegetation classes are (ENF) Evergreen Needleleaf Forest, (EBF) Evergreen Broadleaf Forest, (DNF) Deciduous Needleleaf Forest, (DBF) Deciduous Broadleaf Forest, (MXF) Mixed Forest, (CSH) Closed Shrublands, (OSH) Open Shrublands, (WSV) Woody Savannas, (SAV) Savannas, (GRS) Grasslands, (CRP) Croplands, (CRN) Cropland and Natural Vegetation, and (BAR) Barren or Sparsely Vegetated. Thin gray lines for Cal indicate the spatial standard deviation within each vegetation class.

Figure 2 shows the prior guesses (Lit1, Lit2, and Lit3) for the RTM parameters along with the optimized parameter values after calibration, averaged by vegetation class. Both the microwave soil roughness h and vegetation opacity τ are time dependent (because h depends on soil moisture and τ depends on the leaf area index) and are therefore presented as temporal averages (denoted with <.>). The figure suggests that the h is too low in Lit1 and too high in Lit3. After calibration, h values are closest to Lit2. The τ estimates distinguish clearly between high and low vegetation. Finally, ω is increased over low vegetation to reduce the vegetation effect in the simulated Tb.

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