Improving Land Surface Microwave Emissivity Simulation to Support GPM Precipitation Retrievals

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Abstract – Accurate representation of land surface microwave radiometric properties is critical to physical precipitation retrieval algorithms over land for GPM. It is well known that microwave emission, particularly over the range of frequencies to be included in GPM, is sensitive to land surface states, including soil properties, vegetation type and states, soil moisture, surface temperature, and snow cover, density, and grain size. We performed extensive studies with NASA Land Information System (LIS) coupled with radiative transfer models (RTM) such as CRTM. Our results show that the interplay of soil moisture content (SMC) and leaf area index (LAI) is the most critical driver for the dynamics of land surface emissivity. We constructed an SMC-LAI regime diagram to depict the nonlinear dependencies of emissivity on these two land surface variables. Our model tests indicate SMC-LAI can capture most of the variability and serve as an accurate predictor of emissivity.

1.Introduction

Recent evaluations of TRMM-era multi-sensor precipitation products have helped raise the priority of developing improved over-land retrieval algorithms in preparation for the GPM era. An example of recent work evaluating TRMM-era multi-sensor precipitation products (Tian and Peters-Lidard, 2007) has documented systematic biases in overland retrievals related to land surface states—in this case the presence of inland water bodies. Physical precipitation retrievals rely on accurate characterization of the microwave radiometric properties of the land surface. Therefore it is critical to understand how the land surface states can affect these properties, and how we can accurately model these properties, specifically, surface microwave emissivity at various frequencies.

2. Land Surface Emissivity Forward Modeling Framework

Land surface emissivity is simulated with NASA's Land Information System (LIS) coupled to various radiative transfer models, including the Community Radiative Transfer Model (CRTM, ver.1 and ver. 2, Weng, et al. 2001) developed at the U.S. Joint Center for Satellite Data Assimilation, and the Community Microwave Emission Model (CMEM, ver. 3, Holmes et al. 2008) by ECMWF. LIS is run with various land surface models to generate a wide range of land surface variables, including soil moisture content, soil temperature, land surface temperature, and snow depth, that are used to drive CRTM or CMEM to produce land surface emissivity values at various frequencies.

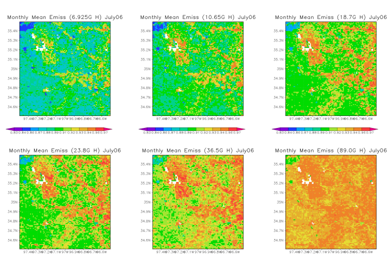

Figure 1. Monthly mean land surface emissivity at AMSR-E frequencies simulated by LIS-CRTM over Southern Great Plains (SGP), at 1x1-km resolution, for July 2006.

3. Land Surface Emissivity Dynamics

LIS generates a wide array of land surface states, including soil moisture and vegetation, from meteorological forcing and remote sensing data. Our modeling studies reveal that land surface emissivity dynamics is mainly driven by the interplay of soil moisture and vegetation (except for snow cover and frozen soil). Representing vegetation with the leaf area index (LAI) and soil moisture with volumetric soil moisture content (SMC), our results show that SMC-LAI can be used to predict fairly accurately the emissivity for various frequencies, and can explain most of the variability.

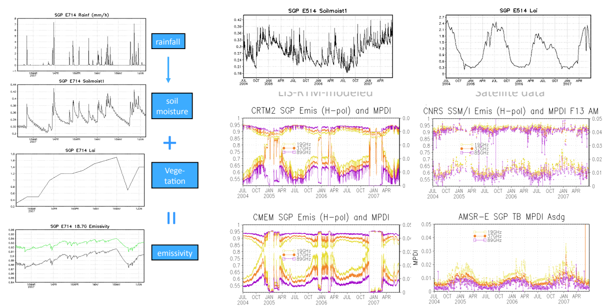

Figure 2. Left) Taking meteorological forcing (precipitation, wind speed, radiation, etc.) as input, LIS can generate land surface states, such as soil moisture and LAI, which drive the variability of emissivity. Right) Long-term simulation of LIS-CRTM and LIS-CMEM over SGP, compared with retrieved SSM/I emissivity (Prigent et al. 1997, 2006) and AMSR-E brightness temperature data.

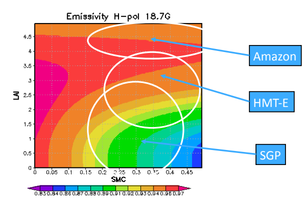

Figure 3. An SMC-LAI regime diagram. The combination of SMC and LAI represents well the nonlinear dependencies of emissivity on the two land surface variables, and captures most of the variability (see side bar on right). Different geographic regions/climate regimes occupy different areas of the diagram.

4.Summary

- The integrated LIS/RTM framework can generate both realistic land surface hydrologic status and radiometric signatures.
- Our modeling studies identified that SMC-LAI combined can serve as a good predictor for land surface emissivity.
- The SMC-LAI regime diagram gives us a unified paradigm to understand the nonlinear interplay of soil and vegetation.
- More reference data are needed to verify, validate and calibrate model results.

The Regime Diagram: Capturing Emissivity Dynamics

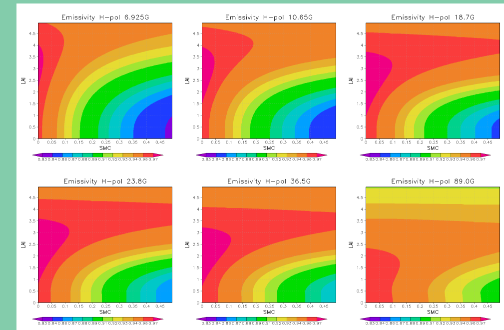

Figure A. Land surface emissivity as a function of SMC and LAI, produced by CRTM offline for SGP.

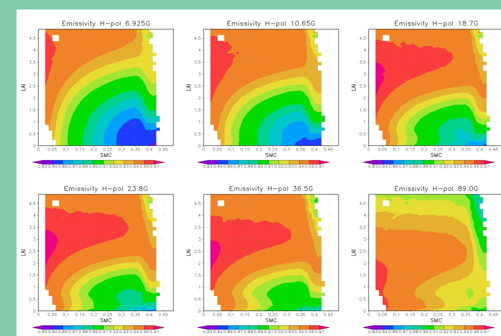

Figure B. Average land surface emissivity as a function of SMC and LAI, produced by LIS-CRTM online runs for SGP at 1x1-km resolution, for the 3-year period of Jul. 2004 – Jun. 2007.

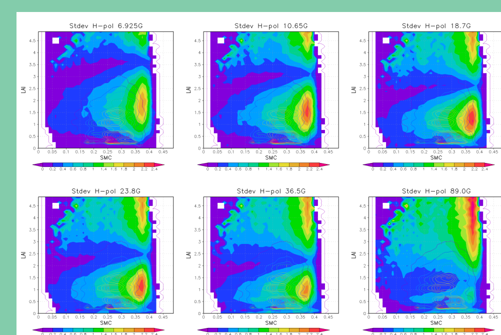

Figure C. Standard deviation from average land surface emissivity show in Fig. B, as a function of SMC and LAI, produced by LIS-CRTM online runs for SGP at 1x1-km resolution, for the 3-year period of Jul. 2004 – Jun. 2007.