The SMAP Science Data System Algorithm and Application Simulation Testbed

Wade T. Crow - USDA-ARS Hydrology and Remote Sensing Laboratory
Eni G. Njoku, R. Scott Dunbar, Steven K. Chan - Jet Propulsion Laboratory, California Institute of Technology

1. Introduction

Slated for launch in 2015, the NASA Soil Moisture Active/Passive mission represents a significant advance in our ability to globally observe time and space variations in surface soil moisture fields. The SMAP mission concept is based on the integrated use of L-band active radar and passive radiometry measurements to optimize both the accuracy and resolution of remotely-sensed surface soil moisture estimates. In order to facilitate the pre-launch development of science algorithms, the SMAP mission has established a SMAP Science Data System (SDS) Testbed. This presentation will discuss the SDS Testbed and describe its potential use as the basis for SMAP application development studies.

2. SDS Testbed Background and Description

The SDS Testbed consists of three major architectural components, each with distinct functions:

(1) The Science Processing Prototype (SPP) code forms the core of the Testbed, incorporating all essential functionality required to process data from lower-level sensor data (Level 1) to higher-level geophysical products (Level 3). The design of the SPP is driven by the detailed contents of the input and output data products and the algorithm functions, including ancillary tables and geophysical model data. The algorithm processors will implement the baseline and optional algorithms under consideration for SMAP. The SPP will be used to design, test and optimize the processing sequence, and to select among competing algorithms.

(2) The Science Simulation (SciSim) is a model of the SMAP measurement system. The SciSim combines detailed knowledge of the mission instrument and spacecraft design to realistically sample an input geophysical field. Using forward radiative transfer and scattering models, SciSim generates high-fidelity simulated radiometer and radar sensor data from simulated "truth", for algorithm experiments.

(3) Observational Data from SMAP-specific field campaigns and other satellite missions will be the other major source of input data for the SPP. Simulation is useful for testing the overall self-consistency of the processing model, but real data are indispensible for pre-launch algorithm tuning and validation. Observational data from appropriate satellite, airborne, and ground-based sensors that can mimic the SMAP sensor observational configuration (active and passive L-band at 40° incidence) will be used to test the algorithms prior to launch.

Figure 1 describes the typical implementation of the system in a science experiment. Similar designs have been previously applied to simulate soil moisture retrieval products from earlier missions [1, 2]. The experiments starts with a truth simulation based on a land surface model (LSM) and available ancillary data to generate geophysical parameter fields used as inputs for the observing system simulations. A forward microwave model is used to translate the simulated geophysical fields and ancillary data to computed L-band brightness temperatures (T_b) and backscatter cross-sections (σ_o) fields. These fields are then fed into an orbit simulation which applies sampling to the geophysical fields in a manner consistent with SMAP's orbital and instrument sampling patterns and thus simulates the generation of SMAP Level 1 products. Such products can subsequently be feed into various retrieval processing algorithms to generate higher-order SMAP data products.

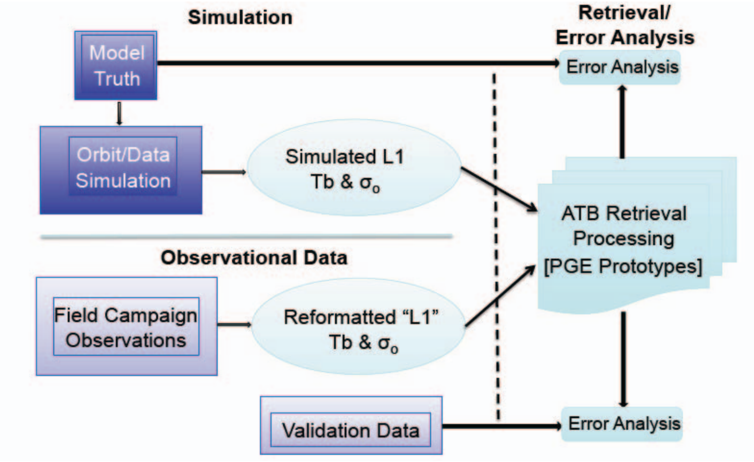

Figure 1. Top-level Architecture of the SMAP SDS Testbed.

The Testbed is designed to capture various sources of errors in products including environment impacts (e.g. Faraday rotation or cosmic background and galactic radiation) on T_b and σ_o observed at the antenna aperture, instrument effects covering the non-ideal aspects of the measurement system, and retrieval parameter error effects (e.g. ancillary surface temperature or roughness data required by the retrievals algorithms). The error analysis component of the Testbed quantifies the aggregate impact of these error sources by comparing simulated retrievals back to analogous products acquired directly from the truth model simulation (see Figure 1).

3. Application Simulation Studies

In addition to improving our understanding of various error sources in algorithm retrievals, products generated from the SDS Testbed can also be used as the basis for algorithm studies to articulate the added value to a particular application derived from the assimilation of SMAP data products. These studies are typically referred to as Observing System Simulation Experiments (OSSE). The goal of an OSSE is identifying the added impact of a particular simulated product (i.e. output from the SDS Testbed described above) on a particular application. Based on research described in [3], Figure 2 describes results from one such experiment. The OSSE consists of a suite of synthetic data assimilation experiments that are based on integrations of two distinct land models, one representing "truth" and the other representing our flawed ability to model the truth (referred to as the "open loop"). Output from the SDS Testbed can be assimilated in the open loop model to evaluate its potential value in terms of correcting model output back to the truth.

Figure 2 describes net skill improvement realized by the assimilation of Testbed soil moisture products. Here, net skill improvement is defined as the correlation-based skill of the assimilation product minus the correlated-based skill of the open loop model estimates (without assimilation). The amount of improvement is dependent on both the accuracy of the Testbed-simulated soil moisture products (see x-axis) and the skill of the open loop model (see y-axis). Therefore Figure 2 illustrates for a given level of accuracy in the stand-alone model product, how much information can be added to the soil moisture products through the assimilation of satellite retrievals of surface soil moisture with a given uncertainty. Quantifying such added value is critical for the development of viable applications for SMAP data products.

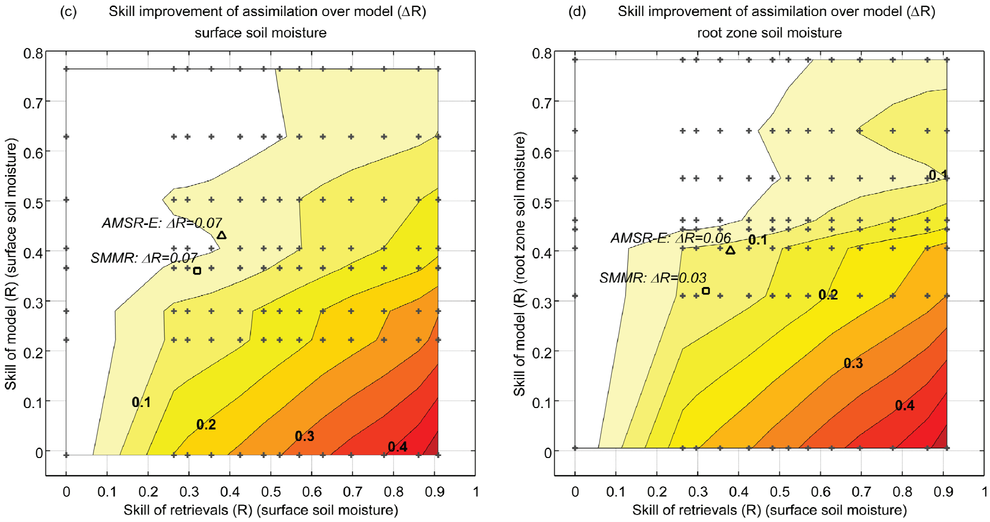

Figure 2. The net skill improvement in model surface and root-zone soil moisture predictions realized upon assimilation of simulated products from the SMAP SDS Testbed.

5. Discussion and Conclusions

Prior to the 2015 launch of the SMAP mission, the SMAP Science Data System (SDS) Testbed will provide the basis for evaluating SMAP algorithm and instrument design issues on SMAP product accuracy. Simulated SDS Testbed data products can also be used as the basis for OSSE experiments design to articulate and optimize the added value of SMAP data products on key applications. This presentation will describe the SMAP SDS Testbed in detail and provide further examples of potential follow-on OSSE activities aimed at developing SMAP applications.

6. Bibliography

[1] W.T. Crow, M. Drusch and E.F. Wood, "An observation system simulation experiment for the impact of land surface heterogeneity on AMSR-E soil moisture retrieval," *IEEE Transactions on Geoscience and Remote Sensing*, 39(8), 1622-1632, 2001.

[2] W.T. Crow, T. Chen, D. Entekhabi, P. Houser, A. Hsu, T. Jackson, E. Njoku, P. O'Neill, J. Shi and X. Zhan, "An observing system simulation experiment for Hydros radiometer-only soil moisture products," *IEEE Transactions on Geoscience and Remote Sensing*, 43(6), 1289-1303, 2005.

[3] R.H. Reichle, W.T. Crow, R. D. Koster, H. Sharif and S. Mahanama, "Contribution of soil moisture retrievals to land data assimilation products," *Geophysical Research Letters,*35, L01404, doi:10.1029/2007GL031986, 2008.