FORWARD SIMULATIONS OF PASSIVE MICROWAVE OBSERVATIONS FOR THE SOIL MOISTURE ACTIVE/PASSIVE (SMAP) MISSION

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1. INTRODUCTION

The Soil Moisture Active/Passive (SMAP) mission was recommended in the recent NRC Earth Science Decadal Survey as a first-tier mission designed to address a broad range of science and societal applications [1]. Scheduled for launch in 2015, SMAP will use a combined L-band synthetic aperture radar (SAR) and radiometer to measure land surface soil moisture and freeze-thaw state, providing global coverage in 2-3 days. The resulting hydrological measurements will improve our understanding of the physical processes that link water, energy, and carbon cycles, leading to improved forecasts of weather, flood, drought, and agricultural productivity.

For the purpose of testing and development of retrieval algorithms subject to a given set of measurement accuracy requirements, it is necessary to simulate the native observations of the instrument as accurately as possible prior to launch. As a first step, this process should incorporate the instrument's space-time sampling characteristics and include modeling of measurement uncertainties caused by instrument uncertainties, environmental effects, imperfect knowledge of ancillary data, and gridding errors.

In this presentation, we will focus on the simulations of the SMAP passive observations. The simulation of the SMAP active observations follow an equivalent set of procedures and is not discussed here.

2. APPROACH

To initialize the simulations, we begin with a land surface model (LSM) driven and constrained by meteorological and geophysical forcings. For a given geographical domain, the model produces synoptic estimates of soil temperature, soil moisture, and other dynamic geophysical variables at fixed time intervals (typically every 4 hours or 6 hours).

The model output parameters, along with some of the same ancillary data used by the model, are then sampled in space (through latitude/longitude variation) and time (through UTC time variation) based on the combined geometry of SMAP's conical scanning pattern and sun-synchronous 8-day exact repeat orbital pattern. To conform to the current SMAP data product specifications, the sampled quantities are stored and processed one half orbit at a time. Subsequent orbit propagation is achieved by shifting the first orbit incrementally at the Earth's rotation rate. Throughout the instrument sampling process, the impacts of nonlinear spatial aggregation of multi-scale geophysical parameters are explicitly accounted for through three-dimensional antenna pattern integration and radiative transfer modeling within the antenna field of view (FOV).

To simulate the brightness temperatures observed by SMAP, an established microwave land emission forward model is used. The simulated brightness temperatures resulting from this modeling framework are considered ‘clean’, meaning that they do not incorporate the impacts of error sources on the measurement. In reality, these error sources are diverse in nature and some of them are actually significant drivers in the total radiometer error budget. These error sources typically fall into two categories: (1) instrument uncertainties and (2) environmental effects. While the former has to do with errors introduced by thermal noise, calibration bias, antenna sidelobes, and cross-polarization leakage, the latter has to do with errors introduced by Faraday rotation, solar radiation, galactic radiation, cosmic background radiation, and atmospheric absorption. To account for the impacts of these errors correctly, their unique variability characteristics should be observed: some error terms may be modeled as simply as random variables, whereas others may be modeled as biases that vary with latitude/longitude and/or season of the year.

For realistic simulations of the observed brightness temperatures, it is also important to keep track of the fraction of water (relative to land) within the footprint as the instrument samples along and across scans. The information is used in two ways. First, it is used in the forward antenna pattern integration process so that the resulting simulated brightness temperatures represent the correct mix of microwave emission contributions from land and static/transient open water bodies. Second, it is used in the inversion process in which the simulated brightness temperatures are corrected in such a way that only the portion of emission coming from land is used for soil moisture retrieval.

The forward simulations conclude with binning the simulated brightness temperatures at instrument native sampling on an Earth-fixed grid. This binning process is necessary because it facilitates the use of ancillary data, which are often available in some Earth-fixed grid formats, in the retrieval process. Both fore- and aft-looks of passive microwave observations from a given orbit granule (either 6:00 pm ascending pass or 6:00 am descending pass) are combined to produce the brightness temperatures at a given grid cell. At present, a 36-km EASE Grid [2] is adopted for the SMAP radiometer-derived soil moisture data product. The grid is chosen for a few reasons. First, its nominal dimension (36 km) is similar to that of the SMAP radiometer’s FOV. Second, it has a long heritage in satellite passive microwave data holdings acquired from previous and existing spaceborne radiometers (e.g. SMMR, SSM/I, and AMSR-E). This makes the SMAP data products a potential additional dataset that helps extend the existing radiometer-based hydrological data records. Third, the grid is scalable – the same grid transformation procedures can be used to construct a family of EASE Grids. With proper parameterization, an EASE Grid of fine-scale posting can be made to completely “nest” within an EASE Grid of coarse-scale posting. The resulting multi-scale grid system, in the context of SMAP Level 2 & 3 data products, provides a natural way to simultaneously accommodate the coarse-scale radiometer product, the fine-scale radar products, as well as the intermediate-scale radiometer/radar combined product.

Following the above simulation steps, a full year of simulated observations has been generated to enable evaluation of retrieval algorithms subject to the natural dynamic range of geophysical conditions.

3. CONCLUSION

In this presentation we describe our attempt to perform realistic simulations of SMAP passive microwave observations. The procedure takes into account such factors as orbital sampling, instrument uncertainties, environmental effects, and imperfect knowledge of ancillary data. An annual cycle of simulated observations has been generated as a baseline testing dataset on which the performance of multiple retrieval algorithms is to be evaluated.

4. REFERENCE

[1] The National Research Council, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*, National Academy Press, Washington, D.C., 2007.

[2] The National Snow and Ice Data Center, "EASE-Grid Data." [Online] Available: http://nsidc.org/data/ease/. [Accessed: Dec 10, 2009].