

The Soil Moisture Active Passive (SMAP) Applications Activity

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Abstract— The Soil Moisture Active Passive (SMAP) mission is one of the first-tier satellite missions recommended by the U.S. National Research Council Committee on Earth Science and Applications from Space. The SMAP mission¹ is under development by NASA and is scheduled for launch late in 2014. The SMAP measurements will allow global and high-resolution mapping of soil moisture and its freeze/thaw state at resolutions from 3-40 km. These measurements will have high value for a wide range of environmental applications that underpin many weather-related decisions including drought and flood guidance, agricultural productivity estimation, weather forecasting, climate predictions, and human health risk. In 2007, NASA was tasked by The National Academies to ensure that “emerging scientific knowledge is actively applied to obtain societal benefits” by broadening community participation and improving means for use of information. SMAP is one of the first missions to come out of this new charge, and its Applications Plan forms the basis for ensuring its commitment to its users. The purpose of this paper is to outline the methods and approaches of the SMAP applications activity, which is designed to increase and sustain the interaction between users and scientists involved in mission development.

Keywords— Soil moisture, freeze/thaw, applications, weather

¹ The SMAP mission has not been formally approved by NASA. The decision to proceed with the mission will not occur until the completion of the National Environmental Policy Act (NEPA) process. Discussions in this paper related to SMAP are being made available for information purposes only.

I. INTRODUCTION

The Soil Moisture Active Passive (SMAP) mission is one of four first-tier missions recommended by the National Research Council's Committee on Earth Science and Applications from Space [1]. Set to launch in 2014, SMAP soil moisture and freeze/thaw measurements will have an accuracy, resolution, and global coverage required to address many scientific problems in hydrology, meteorology and ecology as well as many applications such as flood forecasting, drought monitoring, and Numerical Weather Prediction. The SMAP concept was born out of a decade of community organizing through which a clear need for global, satellite-based estimates of soil moisture was articulated, thus the application of soil moisture to scientific and operational processes has been a focus of the mission from its inception.

The purpose of this paper is to outline the methods and approaches of the SMAP applications activity, which is designed to increase and sustain the interaction between users and scientists involved in mission development. As part of the NASA applied science activity, the SMAP mission is one of the first NASA Earth science missions to develop a specific programmatic approach to integrate users into NASA mission development and pre-launch activities. The objective of the activity is to enable increased collaboration between earth scientists and researchers in multiple disciplines and to improve the pace at which new measurements are incorporated into systems and processes used in decision-making throughout the country. The paper will first describe

the SMAP mission, outline the methods and approaches the applications activity is taking to involve users in the mission, and describe the seven Early Adopters of SMAP data in the scientific and modelling communities.

II. THE SMAP MISSION

On Feb 2, 2008, the Earth Science Division (ESD) of the Science Mission Directorate (SMD) at NASA Headquarters determined that SMAP would be implemented as a directed mission within the NASA Earth Systematic Mission (ESM) Program managed by Goddard Space Flight Center (GSFC). The Jet Propulsion Laboratory (JPL) is assigned responsibility for the overall success of the SMAP project [2].

The SMAP observatory employs a dedicated spacecraft with an instrument suite that will be launched on an expendable launch vehicle into a 680-km near-polar, sun-synchronous orbit, with equator crossings at 6 am and 6 pm local time. The SMAP instrument architecture incorporates an L-band radar and an L-band radiometer that share a deployable parabolic mesh reflector. The reflector is offset from nadir and rotates about the nadir axis at 14.6 rpm, providing a conically scanning antenna beam with a surface incidence angle of approximately 40° (Figure 1). The combined observations from the two sensors will allow accurate estimation of soil moisture at spatial scales that are valuable for hydrometeorological (10 km²) and hydroclimatological (40 km²) studies. The wide-swath (1000 km) measurements will allow global mapping of soil moisture and freeze/thaw state with a 2-3 day revisit frequency [3].

To obtain the desired high spatial resolution the radar employs range and Doppler discrimination. The radar data is processed to yield 1-3 km spatial resolution over 70% of the swath. Freeze/thaw in boreal latitudes will be mapped using the radar at 3 km resolution with a 1-2 day revisit frequency. The synergy of active and passive observations enables measurements of soil moisture and freeze/thaw state with unprecedented resolution, sensitivity, area coverage and revisit frequency.

Following launch, in 2014, the SMAP mission will deliver global maps of soil moisture content and surface freeze/thaw state (Table 1) at various resolutions and latencies. The primary requirement of the SMAP mission is to provide estimates of soil moisture in the top 5 cm of soil with an accuracy of 0.04 cm³/cm³ volumetric soil moisture, at 10 km resolution, with 3-day average intervals over the global land area excluding regions of snow and ice, mountainous topography, open water and vegetation with total water content greater than 5kg/m³ [3]. By merging the active radar measurements with the passive radiometer observations taken by the SMAP instrument, we will be able to provide a 9km soil moisture product that meets these requirements. Measurements are planned during the official mission life of three years, though the observatory may last much longer. A comprehensive validation program will be carried out after launch to assess the accuracies of the soil moisture and freeze/thaw estimates. Data products from the SMAP mission

will be made available through a NASA-designated data center.

III. SMAP APPLICATIONS WORKING GROUP

The SMAP Applications Working Group (AppWG) is an inclusive group that functions as one of four working groups sponsored by the SMAP Science Definition Team (SDT). The AppWG accepts members through registration on the SMAP website and through networking and invitation. Two key roles for members of the AppWG are: (1) application development, and (2) feedback to the SMAP mission. The AppWG can achieve these goals through partnering with SMAP Science Definition Team (SDT) members and communicating with the SMAP Applications Coordinator.

TABLE I
SMAP MISSION PRODUCTS

Data Product	Description	Resolution	Latency *
L1B_S0_LoRes	Low Resolution Radar σ_o in Time Order	5x30 km (10 slices)	12 hrs
L1C_S0_HiRes	High Resolution Radar σ_o on Swath Grid	1x1 km to 1x30 km	12 hrs
L1B_TB	Radiometer T_B in Time Order	36x47 km	12 hrs
L1C_TB	Radiometer T_B	40 km	12 hrs
L2_SM_A	Radar Soil Moisture*	1-3 km	24 hrs
L2_SM_P	Radiometer Soil Moisture	40 km	24 hrs
L2_SM_A/P	Active-Passive Soil Moisture	9 km	24 hrs
L3_F/T_A	Daily Global Composite Freeze/Thaw State	1-3 km	50 hrs
L3_SM_A	Daily Global Composite Radar Soil Moisture	1-3 km	50 hrs
L3_SM_P	Daily Global Composite Radiometer Soil Moisture	40 km	50 hrs
L3_SM_A/P	Daily Global Composite Active-Passive Soil Moisture	9 km	50 hrs
L4_SM	Surface and Root Zone Soil Moisture	9 km	7 days
L4_C	Carbon Net Ecosystem Exchange	9 km	14 days

* Mean latency under normal operating conditions. Latency defined as time from data acquisition by instrument to availability to designated data archive. The SMAP project will make a best effort to reduce these latencies.

The objectives of the AppWG are to:

- Assess current applications benefits and requirements for SMAP products;
- Develop a community of end-users that understand SMAP capabilities and are interested in using SMAP products in their application;
- Foster Early Adopters who can work with the SMAP project during the pre-launch period, particularly to assess impacts on their applications;
- Provide information about the SMAP mission and its products to the broad user and science community; and
- Provide guidance to future solicitation processes.

The relationship between the Science Definition Team and members of the AppWG is a collaborative one. The SDT will benefit enormously from understanding the concrete challenges that are faced in using SMAP data. The interaction will help them prioritize their work, focus on areas of analysis

that will have the biggest reward in the long term, and provide clear examples of the benefits of the mission even before it is launched. The SMAP AppWG will assist the SMAP mission in conducting the preliminary scientific research required to promote the use of SMAP data products in previously identified applications and demonstrate the potential use of the products in new applications. Applied research conducted in the context of the AppWG has the goal of refining our current understanding of science and application requirements for SMAP data products and feeding this information back to the SMAP mission.

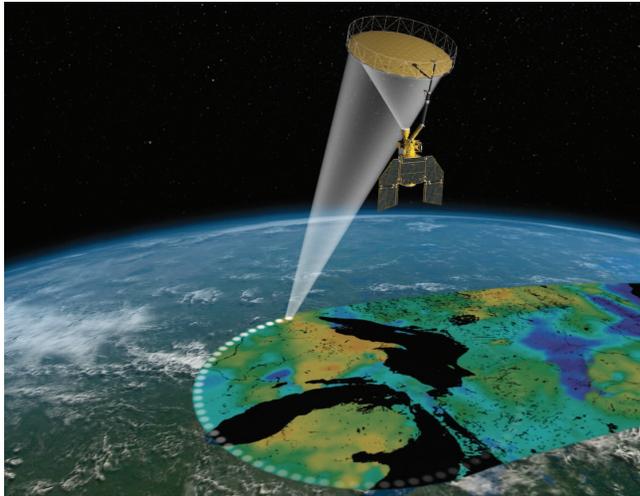


Fig. 1 Artist's rendering of SMAP satellite with example soil moisture.

IV. APPLICATIONS PLAN AND IMPLEMENTATION

The strategy that the SDT will use to engage the user follows a pathway from simple knowledge of the SMAP data configuration and availability to active use of the data in the user system or process. Users will learn about the SMAP mission in a variety of ways, and will be ready to use SMAP data when they engage in analysis, demonstration and have an understanding of the impact of the data on their own processes. It is not expected that all users will achieve readiness to integrate SMAP data before launch, but those that do will be powerful examples for others to follow.

Through a series of pre-launch contacts and workshops, likely and potential SMAP Mission Applications have been identified. For each of these applications, there is a distinct and active science community that is working on improving methods and ingesting satellite remote sensing from a variety of sensors. The SMAP Applications activity will focus on targeting more international efforts and promoting "potential" applications to the list of "likely" applications. In the pre-launch phase when only testbed simulations of soil moisture datasets and data from other sensors are available, the SMAP mission will work with user organizations to move as far along as possible in the cycle of engagement. Through this work we expect to find additional organizations and communities who may be interested in SMAP data.

To facilitate implementation of these steps, the SMAP mission has appointed a SMAP Applications Coordinator, to serve as a liaison between the SMAP mission and the SMAP AppWG, and to assist the SMAP SDT member in charge of the AppWG. The coordinator will engage with agencies to define data attributes that would best facilitate the entrainment of SMAP data products within operational frameworks. We envision that this relationship with relevant agencies will foster case-examples and demonstrations of the operational uses of SMAP data sets. The coordinator will also work with SMAP scientists to refine mission data products in order to best meet application needs.

V. SMAP EARLY ADOPTERS

SMAP is actively recruiting organizations to be Early Adopters, who are defined as those groups and individuals who have a direct or clearly defined need for soil moisture and/or freeze/thaw data, and who are planning to apply their own resources (funding, personnel, facilities, etc) to demonstrate the utility of SMAP data for their particular system or model. Through an un-funded Memorandum of Agreement (MOA) between the Early Adopter and the SMAP Mission, the use of SMAP products produced after launch will be accelerated by providing specific support to Early Adopters who commit to invest in pre-launch research that will enable integration of SMAP data in their applications.

As a result of the MOA, the SMAP Mission agrees to incorporate the Early Adopter contributions into the SMAP Mission Applications Plan; to provide Early Adopters with simulated SMAP data products via the SMAP Science Data System (SDS) Testbed, and to provide Early Adopters with planned pre-launch Calibration and Validation (Cal/Val) data from SMAP field campaigns, modeling, and synergistic studies. In exchange, Early Adopters agree to engage in pre-launch research that will enable integration of SMAP data after launch in the application; complete the project with quantitative metrics prior to launch; join the SMAP Applications Team to participate in discussions of SMAP mission data products related to application needs; and participate in the implementation of the SMAP Mission Applications activity by taking lead roles in applications research, meetings, workshops, and related activities.

Below are the first Early Adopter projects and the institutions and departments that are sponsoring them:

- Assimilation of SMAP active and passive data in the Canadian Land Data Assimilation System (CaLDAS), with the Meteorological Research Division, Environment Canada;
- Soil Moisture Monitoring in Canada, with the Agriculture and Agri-Food Canada, Ottawa, ON Canada;
- Implementation of monitoring of SMAP soil moisture and brightness temperature at ECMWF with the Data Assimilation section, European Centre for Medium-Range Weather Forecasts (ECMWF);
- Transition of NASA SMAP research products to NOAA operational numerical weather and seasonal climate

predictions and research hydrological forecasts, with NOAA National Environmental Satellite, Data and Information Service (NESDIS), Center for Satellite Applications and Research (STAR);

- Estimating and mapping the extent of Saharan dust emissions using SMAP-derived soil moisture data, with the Masdar Institute, United Arab Emirates;
- US National Cropland Soil Moisture Monitoring using SMAP, with the USDA National Agriculture Statistics Service;
- SMAP for Crop Forecasting and Food Security Early Warning Applications, with the International Research Institute for Climate and Society (IRI), The Earth Institute at Columbia University.

Each Early Adopter has its own plan to evaluate results and provide an assessment of the efficiency of estimating surface soil moisture compared to using the SMAP measurement. An evaluation of the potential trade-offs associated with the expected SMAP product spatial resolution and latency may also be conducted. Metrics and evaluations from Early Adopter projects will be organization and context specific, enabling analysis on the use and utility of the SMAP data in the specific projects.

VI. CONCLUSIONS

Opportunities for participants in the SMAP Applications Working Group include:

- Receiving early announcements and news about SMAP mission and its progress;
- Becoming an Early Adopter of SMAP data;
- Attending SMAP applications, calibration/validation and algorithm workshops;
- Using SMAP Soil Moisture Datasets for Applications Research; and
- Learning from other AppWG members in modifying models and analysis to incorporate SMAP data.

The 2nd SMAP Applications Workshop is scheduled for October 12-13, 2011 in Washington, D.C. (see meeting notice posted on the SMAP web page).

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