NASA's Soil Moisture Active Passive (SMAP) Mission and Opportunities For Applications Users

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Water in the soil, both its amount (soil moisture) and its state (freeze/thaw), plays a key role in water and energy cycles, in weather and climate, and in the carbon cycle. Additionally, soil moisture touches upon human lives in a number of ways—from the ravages of flooding to the needs for monitoring agricultural and hydrologic droughts. Because of their relevance to weather, climate, science, and society, accurate and timely measurements of soil moisture and freeze/thaw state with global coverage are critically important.

To address this need, NASA has initiated the Soil Moisture Active Passive (SMAP) satellite mission, as recommended by the National Research Council in their 2007 report, "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond." Set to launch in October 2014, SMAP will use a combination of an active radar and a passive radiometer to provide global measurements of surface soil moisture and soil freeze/thaw state (Figure 1). The synergy of active and passive microwave observations, combined with SMAP's wide swath, enables measurements of soil moisture and freeze/thaw state with high resolution, and adequate sensitivity, area coverage, and revisit frequency. This design will address many scientific problems in hydrology, meteorology, and ecology, as well as provide information to science applications such as flood forecasting, drought monitoring, and numerical weather prediction.

The 2007 report tasked NASA with ensuring that "emerging scientific knowledge is actively applied to obtain societal benefits," and emphasized the importance of early and sustained interaction of the Earth science community with a broad range of organizations and individuals. From its inception, SMAP has been committed to a strong, integrated program of engagement with potential data users in applied and operational domains, the first NASA mission to have such a program before the satellite is launched. The SMAP Applications program is designed to first increase and then sustain the interaction between application users and scientists involved in mission development. The SMAP project has sponsored several applications meetings and workshops. To better reach the applications users, some of these have been held at user locations such as the U.S. Department of Agriculture (USDA), U.S. Geological Survey (USGS), and NOAA headquarters among others. Feedback from user communities is formally and actively reported to mission scientists to broaden and facilitate eventual SMAP data access and enhance opportunities to use mission data to address societal needs. For example, collaboration between the SMAP mission and the USDA's Foreign Agriculture Service (FAS) has elicited the requirements of yield forecasting and familiarized analysts to soil moisture data. Another example pertains to the Emergency Response and Operational users, who have worked with the SMAP mission to plan for providing data in friendly formats (kmz and geotiffs) for a more rapid ingestion of soil moisture data into decision-making environments.

The SMAP Applications program is ground-breaking and serves as an example for other NASA missions to expand their focus to include user communities' needs in the early phases of mission development. Through a team that includes an applications lead on the Science Definition Team (SDT), leadership from the mission, and an applications coordinator, the applications program works to characterize the community of mission data users through workshops and applied research. We have also initiated a program of Early Adopters to promote application research in the pre-launch stages of the mission, in order to provide a better understanding of how SMAP data products can be scaled and integrated onto organizations' policy, business, and management activities. These efforts will expand the use of the data after launch, and increase the societal benefit of the mission.

The overall strategy for the SMAP Applications program is to develop a community of end users and decision makers who are interested in using SMAP products in their applications by providing opportunities to learn about SMAP's unique capabilities and scientific objectives. The SMAP science objectives are to acquire space-based hydrosphere state measurements to (1) understand processes that link the terrestrial water, energy, and carbon cycles; (2) estimate global water and energy fluxes at the land surface; (3) quantify net carbon flux in boreal landscapes; (4) enhance weather and climate forecast abilities; and (5) develop improved flood prediction and drought monitoring capabilities. To meet its scientific goals, SMAP will fly a dedicated satellite in a near-polar, sun synchronous orbit, crossing the equator at 6 a.m. and 6 p.m. local time. The satellite will carry an L-band (1.26 GHz) radar and an L-band (1.4 GHz) radiometer that share a deployable light-weight mesh parabolic reflector, which provides a conically scanning antenna beam with a constant surface incidence angle of approximately 40° and will measure a swath approximately 1000 kilometers wide. The combined observations from the two sensors will allow accurate estimation of soil moisture and freeze/thaw states at spatial scales valuable for both hydro-meteorological (10 km) and hydro-climatological (40 km) studies.

After launch, the satellite's instruments will be calibrated, (an expected time period of 3 months). Once calibrated, the SMAP mission will deliver estimates of soil moisture in the top 5 cm of soil with an accuracy of 0.04 cm^3/cm^3 volumetric soil moisture, at 10 km resolution, with 3-day average intervals (Table 1). Global maps will also be available of landscape freeze/thaw state derived from L-band radar at 3 km spatial resolution with a 2-day refresh rate for the high northern latitudes (i.e., latitudes above 45 degrees north). Measurements will be made over the global land area, excluding regions of snow and ice, mountainous topography, open water, and areas of extremely dense vegetation such as tropical forests (See smap.jpl.nasa.gov for latency, resolution, and other details).

In addition to the instrument measurements and derived products for the surface layer, SMAP will also provide Level 4 data assimilation products by ingesting active and passive observations into land surface models to provide root zone soil moisture (to a depth of ~100 cm). A net ecosystem exchange product will also be developed that integrates freeze/thaw measurements into a carbon model to provide ecosystem exchange at 9km resolution. As these two products are intended to serve a broad community, there is an opportunity for user engagement now to optimize the design of these products so that they can ultimately satisfy user requirements.

The SMAP Applications program facilitates applied research to provide a fundamental understanding of how SMAP data products can be scaled and integrated into a user's decision-making process to improve policy, business, and management activities. By working with relevant users and early adopters before the satellite is launched, SMAP hopes to improve the pace of incorporation of the new measurements in decision making during the life of the mission, which is expected to be at least 3 years. To join the SMAP Applications Working Group, which is dedicated to enabling scientists and others interested in SMAP to engage with the SMAP Science Definition Team, readers are encouraged to go to the following website: (http://smap.jpl.nasa.gov/science/wgroups/applicWG/).

ACKNOWLEDGMENTS

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FOR FURTHER READING

National Research Council , 2007, Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond., National Acadmey of Science Press.

Entekhabi, D.; Njoku, E.G.; O'Neill, P.E.; Kellogg, K.H.; Crow, W.T.; Edelstein, W.N.; Entin, J.K.; Goodman, S.D.; Jackson, T.J.; Johnson, J.; Kimball, J.; Piepmeier, J.R.; Koster, R.D.; Martin, N.; McDonald, K.C.; Moghaddam, M.; Moran, S.; Reichle, R.; Shi, J.C.; Spencer, M.W.; Thurman, S.W.; Leung Tsang; Van Zyl, J., 2010: The Soil Moisture Active Passive (SMAP) Mission, Proceedings of the IEEE, Volume: 98 , Issue: 5, Pages 704-716. 10.1109/JPROC.2010.2043918

"SMAP Applications Plan" document available at smap.jpl.nasa.gov

Table 1. Anticipated SMAP Mission products

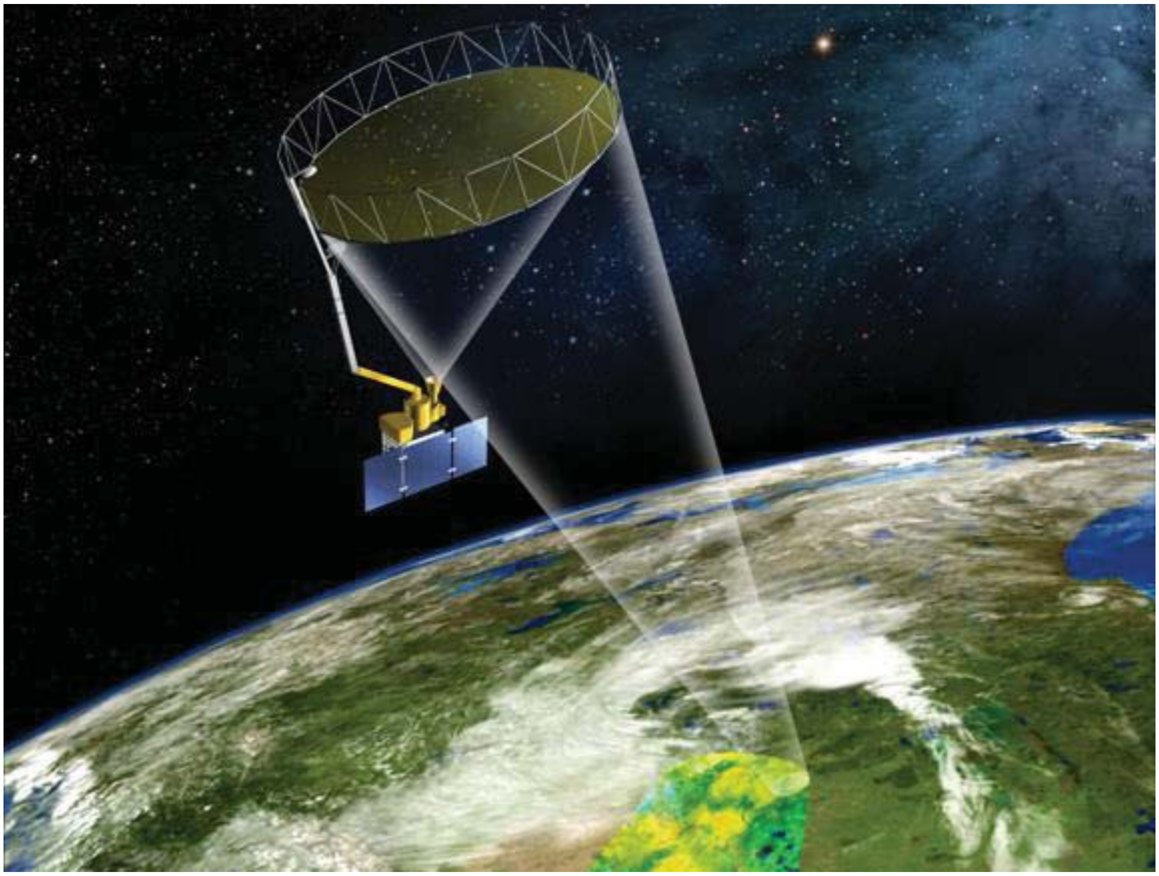
Product	Description	Gridding (Resolution)	Latency*	
L1A_Radiometer	Radiometer Data in Time-Order	-	12 hrs	**Instrument Data**
L1A_Radar	Radar Data in Time-Order	-	12 hrs	
L1B_TB	Radiometer TB in Time-Order	(36x47 km)	12 hrs	
L1B_S0_LoRes	Low Resolution Radar σo in Time-Order	(5x30 km)	12 hrs	
L1C_S0_HiRes	High Resolution Radar σo in Half-Orbits	1 km (1-3 km)**	12 hrs	
L1C_TB	Radiometer TB in Half-Orbits	36 km	12 hrs	
L2_SM_A	Soil Moisture (Radar)	3 km	24 hrs	**Science Data (Half-Orbit)**
L2_SM_P	Soil Moisture (Radiometer)	36 km	24 hrs	
L2_SM_AP	Soil Moisture (Radar + Radiometer)	9 km	24 hrs	
L3_FT_A	Freeze/Thaw State (Radar)	3 km	50 hrs	**Science Data (Daily Composite)**
L3_SM_A	Soil Moisture (Radar)	3 km	50 hrs	
L3_SM_P	Soil Moisture (Radiometer)	36 km	50 hrs	
L3_SM_AP	Soil Moisture (Radar + Radiometer)	9 km	50 hrs	

L4_SM	Soil Moisture (Surface and Root Zone)	9 km	7 days	**Science Value-Added**
L4_C	Carbon Net Ecosystem Exchange (NEE)	9 km	14 days	

* Mean latency under normal operating conditions. Latency is defined as the time from data acquisition by the instrument to its availability in a designated data archive. The SMAP project will make a best effort to reduce these latencies.
** Over outer 70% of swath.

Figure Caption:

Figure 1. The SMAP L-band radar and radiometer share a common feed and reflector antenna system. The instruments conically scan across a wide swath allowing global mapping with frequent revisit.



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Reviewer/Editor Comments included in this letter (all those pertinent to your revision have either been made in the edited article or have been embedded in comments in the edited article):

Reviewer #1: BAMS 11-00049.

General:
This is a short synopsis on NASA's soil moisture sensor. Given the importance of the parameter and the upcoming launch, this is appropriate for a nowcast article.

Specific:
(there are no line numbers to reference)

Page 1.
"NASA has funded" sounds like NASA funded this out-of-hide. I would think the taxpayers funded it. Suggest verbs such as: started/procured/launched.
If it's launched in October of 2014 - when we users get calibrated data to use? This is date should be included.
"enables measurements of soil moisture and freeze/thaw state with high resolution" Need to state that this is referred to spatial resolution; even better, state the value (10-40 km). Meanings of the words like 'high resolution' vary greatly over sensor, instrument, field, etc.

WE HAVE MADE BOTH THESE CHANGES.

Page 2.
"of its data" is wordy.
WE HAVE AMENDED THIS SENTENCE.

Page 3.
"Following launch" is wordy.
WE HAVE AMENDED THIS SENTENCE.

Page 4.
What format is the exchange product?
How long is the missing lifetime?
WE HAVE ADDED BOTH THESE PIECES OF INFORMATION.

Page 5. http://smap.jpl.nasa.gov/science/ might be a better link for the BAMS reader, rather than jumping into the Working Group level. [EDITOR'S NOTE: I disagree with this recommendation -- the link you have here is the proper one.]

WE HAVE LEFT THE URL AS STATED.

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Reviewer #2: SMAP information will reach an excellent audience within BAMS and will benefit many readers.
THANK YOU.

Authors should add appropriate references and websites that explain more details about the SMAP mission and sensor attributes. [EDITOR'S NOTE: the short Nowcast article format does not allow the inclusion of citations; you are welcome to add any material readers might be interested in to the section at the end of the article labeled FOR FURTHER READING.] In the process, they should add details on product data latency since the draft currently is unclear on age of data, though it does address what products will be made and at what resolution.

WE HAVE ADDED LATENCY INFORMATION, AND HAVE AMENDED THE ‘FOR FURTHER READING’ SECTION.

Figure 1

Click here to download Non-Rendered Figure: SMAP_BeautyShot4_Landscape(3).jpg