THE NASA SOIL MOISTURE ACTIVE PASSIVE (SMAP) MISSION FORMULATION

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ABSTRACT

The Soil Moisture Active Passive (SMAP) mission is one of the first-tier projects recommended by the U.S. National Research Council Committee on Earth Science and Applications from Space. The SMAP mission is in formulation phase and it is scheduled for launch in 2014. The SMAP mission is designed to produce high-resolution and accurate global mapping of soil moisture and its freeze/thaw state using an instrument architecture that incorporates an L-band (1.26 GHz) radar and an L-band (1.41 GHz) radiometer. The simultaneous radar and radiometer measurements will be combined to derive global soil moisture mapping at 9 [km] resolution with a 2 to 3 days revisit and 0.04 [cm^3 cm^{-3}] (1 sigma) soil water content accuracy. The radar measurements also allow the binary detection of surface freeze/thaw state. The project science goals address in water, energy and carbon cycle science as well as provide improved capabilities in natural hazards applications.

***Index Terms*—** Soil Moisture, Freeze/Thaw, Water Cycle, Microwave, Decadal Survey.

1. SCIENCE GOALS

The Soil Moisture Active Passive (SMAP) Mission[1] is one of the first Earth observation satellites being formulated by NASA in response to the 2007 National Research Council's Earth Science Decadal Survey[1] SMAP will make high-resolution global measurements of near-surface soil moisture and its freeze-thaw state. These measurements will allow significantly improved estimates of water, energy and carbon transfers between the land and atmosphere. The soil moisture control of these fluxes is a key factor in the performance of atmospheric models used for weather forecasts and climate projections. Soil moisture measurements are also of great importance in assessing flooding and monitoring drought.

SMAP measurements will also yield high resolution spatial and temporal mapping of the frozen or thawed condition of the surface soil and vegetation. The observations of soil moisture and freeze/thaw timing over the boreal latitudes will contribute to reducing a major uncertainty in quantifying the global carbon balance and help resolve an apparent missing carbon sink over land.

In summary SMAP hydrosphere state measurements will yield a critical data set that will enable science and applications users to:

- Understand processes that link the terrestrial water, energy and carbon cycles;
- Estimate global water and energy fluxes at the land surface;
- Quantify net carbon flux in boreal landscapes;
- Enhance weather and climate forecast skill;

JPL Disclaimer: *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.*

- Develop improved flood prediction and drought monitoring capability.

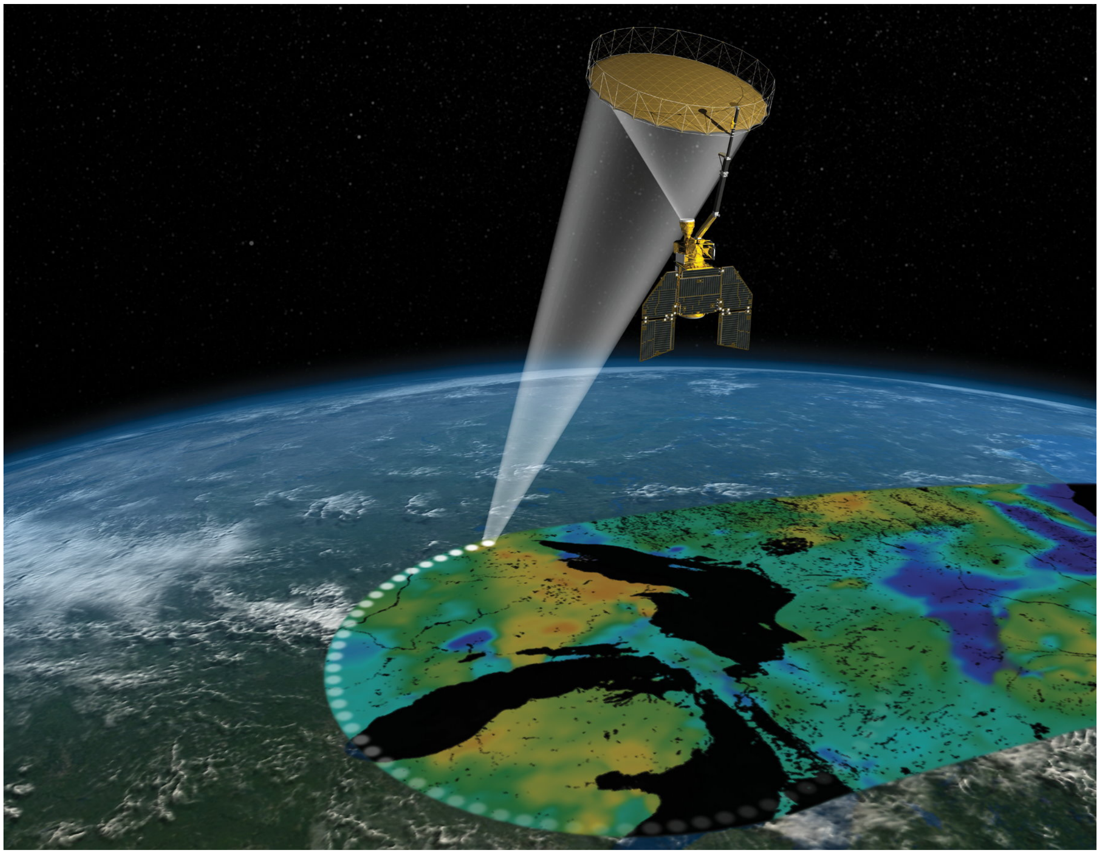

Figure 1: The SMAP Observatory includes a light-weight deployable mesh reflector and the radar and radiometer instruments share a common feed.

2. MEASUREMENT APPROACH AND DATA PRODUCTS

The SMAP mission will utilize an L-band radar and radiometer sharing a rotating 6 [m] mesh reflector antenna (see Figure 1). The radar (HH, VV and HV polarizations) and radiometer (H, V, U and third and fourth Stokes parameters) instruments will be carried onboard a 3-axis stabilized spacecraft in a 680 [km] polar orbit with an 8 [days] repeating ground track [2]. Because the effects of vegetation and surface roughness are dependent on incidence angle, the SMAP mission adopted a conical scan, constant incidence angle approach. This reduces the retrieval complexity and also facilitates the use of time-series retrieval algorithms.

The SMAP planned data products are listed in Table 1. Level 1B and 1C instrument data products are calibrated and geolocated measurements of surface radar backscatter cross-section and brightness temperatures derived from antenna temperatures. Level 2 products are geophysical retrievals of soil moisture on a fixed Earth grid based on Level 1 products and ancillary information (primarily surface physical temperature, land cover type and wet and dry biomass, inland water bodies locations, and exclusion flags for urban areas, rugged terrain and excessive snow cover and precipitation presence). Level 2 products are geophysical retrievals on half-orbit basis. Level 3 products are daily composites of Level 2 surface soil moisture and freeze/thaw state data. Level 4 products are data assimilation value-added data products that support key SMAP applications and more directly address the science goals listed above.

For both the hydroclimatology (L2_SM_P) and hydrometeorology (L2_SM_A/P) data products, the baseline mission requirement is to provide estimates of soil moisture in the top 5 [cm] of soil with an error of no greater than 0.04 [cm^3 cm^{-3}] (one sigma) volumetric soil water content at 3-day average intervals over the global land area excluding regions of snow and ice, frozen ground, mountainous topography, open water, urban areas, and vegetation with water content greater than 5 [kg m^{-2}] (averaged over the spatial resolution scale). This level of performance will enable SMAP to meet the needs of the hydroclimatology and hydrometeorology applications identified in the NRC report [1].
SMAP is also adopting a number of approaches to identify and mitigate potential terrestrial radio frequency interference (RFI). At L-band, RFI can contaminate both radar and radiometer measurements. Early flight measurements and results from the European Space Agency (ESA) Soil Moisture and Ocean Salinity (SMOS) mission indicate that in some regions RFI is present and detectable. The SMAP radar and radiometer electronics and algorithms have been designed to include novel features to mitigate the effects of RFI. Interference for the SMAP radar comes largely from ground-based surveillance radars that share the spectrum with Earth science radars. To combat this, the SMAP radar utilizes selective filters and an adjustable carrier frequency in order to tune to pre-determined RFI-free portions of the spectrum while on orbit. The radiometer suffers interference primarily from out-of-band and spurious emissions by numerous active services (including radars, communications systems, and others). The SMAP radiometer will implement a combination of time and frequency diversity, and kurtosis detection, to mitigate RFI.

Product	Short Description	Resolution	Latency	
L1A_S0	Radar raw data in time order	–	12 hours	Instrument Data
L1A_TB	Radiometer raw data in time order	–	12 hours	
L1B_S0_LoRes	Low resolution radar σ_o in time order	5x30 km	12 hours	
L1B_TB	Radiometer T_B in time order	36x47 km	12 hours	
L1C_S0_HiRes	High resolution radar σ_o	1-3 km	12 hours	
L1C_TB	Radiometer T_B	36 km	12 hours	
L2_SM_A	Soil moisture (radar)	3 km	24 hours	Science Data (Half-Orbit)
L2_SM_P	Soil moisture (radiometer)	36 km	24 hours	
L2_SM_A/P	Soil moisture (radar/radiometer)	9 km	24 hours	
L3_SM_A	Soil moisture (radar)	3 km	24 hours	Science Data (Daily Composite)
L3_F/T_A	Freeze/thaw state (radar)	3 km	50 hours	
L3_SM_P	Soil moisture (radiometer)	36 km	50 hours	
L3_SM_A/P	Soil moisture (radar/radiometer)	9 km	50 hours	
L4_SM	Soil moisture (surface & root zone)	9 km	7 days	Science Value-Added
L4_C	Carbon net ecosystem exchange (NEE)	9 km	14 days	

Table 1: The suite of SMAP science data products with associated spatial resolution and availability-latency from the time of acquisition.

3. WORKING GROUPS

Four working groups have been established as a means to enable broad science participation in the SMAP mission (Algorithms, Calibration/Validation, Applications, and Radio-Frequency Interference; see http://smap.jpl.nasa.gov/science/wgroups/). The working groups are led by Science Definition Team (SDT) members and provide forums for information exchange on issues related to SMAP science and applications goals and objectives. The working groups communicate via email and at meetings, conference sessions, workshops, and other venues. The SMAP project also includes an international SDT that provides direct links to activities that support SMAP science and applications outside the USA. For example, two airborne field campaigns – one in Canada and another in Australia -- have been conducted in support of testing SMAP algorithms.

4. CURRENT STATUS

The preliminary baseline algorithms are undergoing tests and evaluations using airborne field experiment observations. Additional tests are made using the end-to-end SMAP Algorithm Testbed simulation environment. SMAP has nearly completed its Phase B Mission Concept Study for NASA and it is ready to transition into Phase C. The SMAP radar and radiometer also derive some heritage from the NASA Aquarius/SAC-D mission which is also carries L-band active and passive microwave instruments. As a result elements of the instruments are currently being implemented and tested over bread-board and brass-board platforms. The launch vehicle selection is currently underway at NASA. SMAP is ready and currently on schedule for launch in late 2014.

5. ACKNOWLEDGMENT

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6. REFERENCES

[1] National Research Council, "*Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*," 2007.

[2] Entekhabi, D., E, Njoku, P. O'Neill, K. Kellogg, et al., "The Soil Moisture Active Passive (SMAP) Mission," *Proceedings of the IEEE*, Vol. 98, No. 5, May, 2010.