THE NASA SOIL MOISTURE ACTIVE PASSIVE (SMAP) MISSION: OVERVIEW

Peggy O'Neill[1], Dara Entekhabi[2], Eni Njoku[3], and Kent Kellogg[3]

[1]Hydrological Sciences Branch / Code 614.3, NASA Goddard Space Flight Center, Greenbelt, MD 20771 USA
tel: 1-301-614-5773, fax: 1-301-614-5808, Peggy.E.ONeill@nasa.gov

[2] Dept. of Civil & Environmental Engineering, Massachusetts Institute of Technology
Cambridge, MA 02139 USA, tel: 1-617-253-9698 darae@mit.edu

[3]Jet Propulsion Laboratory, 4800 Oak Grove Drive,
Pasadena, CA 91109 USA, tel: 1-818-354-3693, Eni.G.Njoku@jpl.nasa.gov,
tel: 1-818-354-5386, kkellogg@jpl.nasa.gov

ABSTRACT

The Soil Moisture Active Passive (SMAP) mission is one of the first Earth observation satellites being developed by NASA in response to the National Research Council's Decadal Survey [1]. Its mission design consists of L-band radiometer and radar instruments sharing a rotating 6-m mesh reflector antenna to provide high-resolution and high-accuracy global maps of soil moisture and freeze/thaw state every 2-3 days. The combined active/passive microwave soil moisture product will have a spatial resolution of 10 km and a mean latency of 24 hours. In addition, the SMAP surface observations will be combined with advanced modeling and data assimilation to provide deeper root zone soil moisture and net ecosystem exchange of carbon. SMAP is expected to launch in the late 2014 – early 2015 time frame.

Keywords (Index Terms) *-- soil moisture, microwave radiometry, radar, freeze/thaw.*

1. INTRODUCTION

The National Research Council's (NRC) Decadal Survey, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*, was released in 2007 after a two-year study commissioned by NASA, NOAA, and USGS to provide consensus recommendations to guide the agencies' space-based Earth observation programs in the coming decade [1]. Many factors involving engineering maturity, scientific advances, and societal benefits of potential missions were considered as part of the NRC evaluation process. Five of the six NRC Earth science discipline panels (water resources & the hydrologic cycle; climate; weather; human health & security; and land use, ecosystems, & biodiversity) cited numerous science and applications needs that could be wholly or partially met by a mission devoted to measuring surface soil moisture and its freeze/thaw state. Based on the NRC recommendations and on its own evaluation of technical readiness, NASA selected the Soil Moisture Active Passive (SMAP) mission to be the first of the Decadal Survey missions to be developed, with a launch date now in the 2014-2015 time frame. This mission will be a joint effort of NASA's Jet Propulsion Laboratory (JPL) and Goddard Space Flight Center (GSFC), with project management responsibilities at JPL.

2. SMAP SCIENCE

Soil moisture and its freeze/thaw state are key variables that impact the water, energy, and carbon fluxes at the land-atmosphere interface. This interface is highly complex, and new data are required at finer space-time scales to advance understanding of the processes driving the Earth's water, energy, and carbon cycles. The primary science objectives of the SMAP mission are to provide high-resolution global mapping of soil moisture and its freeze/thaw state in order to: (1) estimate global water and energy fluxes at the Earth's surface, (2) improve weather and climate forecast skill, (3) develop more accurate flood and drought predictions, (4) quantify carbon fluxes in boreal landscapes, and (5) help link together terrestrial water, energy, and carbon cycle processes. SMAP also enables a large number of other science research areas and applications of benefit to society, including the potential to provide JPSS / DWSS - era soil moisture measurements, vegetation growth and agricultural productivity estimates, and information relevant to heat stress, human health, and national security.

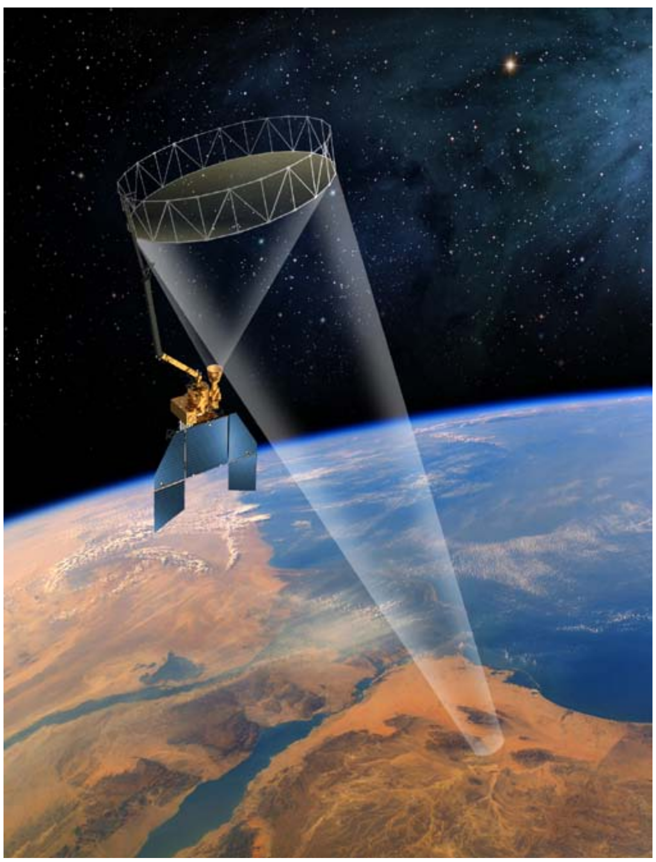

Figure 1. The SMAP mission concept consists of an L-band radar and radiometer sharing a single spinning 6-m mesh antenna in a sun-synchronous dawn/dusk orbit.

3. SMAP MISSION DESIGN

The SMAP mission design is driven by the temporal and spatial resolution requirements of the hydrometeorology, hydroclimatology, and carbon cycle communities [2]. SMAP will consist of a polarimetric 1.4 GHz radiometer and a 1.26 GHz (HH, VV, HV pol) radar sharing a single L-band feed and a 6-meter spinning deployable mesh reflector antenna. The antenna rotates about the nadir axis at 14.6 rpm, producing a conically scanned antenna beam with a surface incidence angle of ~ 40° (Figure 1). SMAP will be launched into a sun-synchronous dawn-dusk orbit, and its wide swath of 1000 km will enable global mapping of surface soil moisture and freeze/thaw every 2-3 days. The SMAP radiometer will produce calibrated brightness temperatures at a coarse spatial resolution of 40 km, while the SMAP radar will produce calibrated backscatter at 1-3 km resolution over the outer 70% of the swath (radar resolution degrades to 30 km at center of swath). By combining the high soil moisture retrieval accuracy but coarse resolution radiometer data with the high resolution but lower accuracy radar data, an intermediate resolution 10 km soil moisture product will be generated. Baseline mission duration is three years in order to capture positive and negative seasonal anomalies in the water, energy, and carbon cycles across environmentally diverse regions of the globe.

4. SMAP GEOPHYSICAL DATA PRODUCTS

The planned SMAP data products are listed in Table 1. Level 1B and 1C data products are calibrated and geolocated instrument measurements of radar backscatter and brightness temperature. Level 2 products are geophysical retrievals of soil moisture on a fixed Earth grid based on Level 1 products and ancillary information; the Level 2 products are output on a half-orbit basis. Level 3 products are daily composites of Level 2 surface soil moisture and freeze/thaw state. Retrieval algorithms for these geophysical products are currently being refined and tested, and vetted in open community

Table 1. SMAP DATA PRODUCTS

Data Product Short Name	Short Description	Spatial Resolution	Grid Spacing	Latency*
L1A_Radar	Radar raw data in time order	NA	NA	12 hours
L1A_Radiometer	Radiometer raw data in time order	NA	NA	12 hours
L1B_S0_LoRes	Low resolution radar σ_o in time order	5x30 km	NA	12 hours
L1B_TB	Radiometer T_B in time order	40 km	NA	12 hours
L1C_S0_HiRes	High resolution radar σ_o (half orbit, gridded)	1x1 km to 1x30 km	1 km	12 hours
L1C_TB	Radiometer T_B (half orbit, gridded)	40 km	36 km	12 hours
L2_SM_P	Soil moisture (radiometer, half orbit)	40 km	36 km	24 hours
L2_SM_A/P	Soil moisture (radar/radiometer, half orbit)	9 km	9 km	24 hours
L3_F/T_A	Freeze/thaw state (radar, daily composite)	3 km	3 km	48 hours
L3_SM_P	Soil moisture (radiometer, daily composite)	40 km	36 km	48 hours
L3_SM_A/P	Soil moisture (radar/radiometer, daily composite)	9 km	9 km	48 hours
L4_SM	Soil moisture (surface & root zone)	9 km	9 km	7 days
L4_C	Carbon net ecosystem exchange (NEE)	9 km	1 km	14 days

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

workshops [3]. The SMAP Project is also generating two model-derived value-added Level 4 data products (root zone soil moisture and net ecosystem exchange of carbon) that support key SMAP applications and more directly address driving science questions. The baseline mission requirements are to provide estimates of soil moisture in the top 5 cm of soil with an error no greater than 0.04 cm^3/cm^3 volumetric (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}), and a binary freeze/thaw classification accuracy of 80%. These levels of performance will enable SMAP to meet the needs of the hydroclimatology and hydrometeorology applications identified in the NRC report [1], and to provide the new global data sets necessary to tackle hydrologically-relevant societal issues.

The latency of SMAP mission products is important to a variety of end users. As a non-operational research mission, SMAP is constrained by budget and other logistical issues, and will make mission data available to the public archive (to be selected by NASA HQ) as quickly as possible on a best-effort basis. Mean latencies for the standard mission products are listed in Table 1. These products will be verified during an extended calibration/validation period during the first year SMAP is in orbit. Calibration/validation activities will include comparisons of SMAP products with data from *in situ* instrument networks, dedicated field campaigns, aircraft underflights, models, and other missions.

5. SMAP APPLICATIONS OUTREACH

A key challenge for SMAP as the first of NASA's Earth Science Decadal Survey missions is to foster applications and applied sciences given (1) budget constraints, (2) long development horizons, and (3) the primacy of science over applications in driving the mission measurement requirements. A primary goal of the SMAP Mission is to engage SMAP end users early in the pre-launch phase and begin to prepare them to take advantage of SMAP data as soon as SMAP is launched. Broad support for SMAP applications is sought through a transparent and inclusive process. Toward this goal, the SMAP Project has formed a SMAP Applications Working Group, which is open to all interested members of the community (register at http://smap.jpl.nasa.gov/science/applicWG). [Information about other SMAP working groups on Algorithms, RFI, and Calibration/Validation can be found at http://smap.jpl.nasa.gov/science/wgroups/.]

The first SMAP Applications Workshop was held at NOAA (National Oceanographic and Atmospheric Administration) facilities in Silver Spring, MD on September 9-10, 2009 [4]. Discussions during this meeting formed the basis for the SMAP Applications Plan, currently in draft form.

Figure 2. 1st SMAP Applications Workshop, Silver Spring, MD, September, 2009.

6. SUMMARY

SMAP is scheduled to be the first of NASA's Earth Science Decadal Survey missions, with a launch date in the late 2014 – early 2015 time frame. It will provide high resolution and frequent revisit global mapping of soil moisture and freeze/thaw state, utilizing enhanced Radio Frequency Interference (RFI) mitigation approaches to collect new measurements of the hydrological condition of the Earth's surface. These observations will (1) improve our understanding of linkages between the Earth's water, energy, and carbon cycles, (2) benefit many application areas including numerical weather and climate prediction, flood and drought monitoring, agricultural productivity, human health, and national security, (3) help to address priority questions on climate change, and (4) potentially provide continuity with brightness temperature and soil moisture measurements from ESA's SMOS (Soil Moisture Ocean Salinity) and NASA's Aquarius missions.

REFERENCES

[1] National Research Council, "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond," pp. 400, 2007.

[2] Entekhabi, D., E, Njoku, P. O'Neill, K. Kellogg, plus 19 others, "The Soil Moisture Active Passive (SMAP) Mission," Proceedings of the IEEE, Vol. 98, No. 5, May, 2010.

[3] O'Neill, P., M. Moghaddam, and T. Jackson, "SMAP Algorithms and Calibration / Validation Workshop," *The Earth Observer*, NASA, 21 (5), October, 2009, pp. 40-43, 49.

[4] Moran, S., P. O'Neill, D. Entekhabi, E. Njoku, and K. Kellogg, "Fostering Applications Opportunities for the NASA Soil Moisture Active Passive (SMAP) Mission," *Proceedings of IGARSS'10*, Honolulu, HI, July 25-30, 2010.