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<b>Citation</b>	Moran, M.S. et al. "Fostering applications opportunities for the NASA Soil Moisture Active Passive (SMAP) Mission." Geoscience and Remote Sensing Symposium (IGARSS), 2010 IEEE International. 2010. 2571-2574. Copyright © 2010, IEEE
<b>As Published</b>	<a href="http://dx.doi.org/10.1109/IGARSS.2010.5652647">http://dx.doi.org/10.1109/IGARSS.2010.5652647</a>
<b>Publisher</b>	Institute of Electrical and Electronics Engineers
<b>Version</b>	Final published version
<b>Citable link</b>	<a href="http://hdl.handle.net/1721.1/66195">http://hdl.handle.net/1721.1/66195</a>
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# FOSTERING APPLICATIONS OPPORTUNITIES FOR THE NASA SOIL MOISTURE ACTIVE PASSIVE (SMAP) MISSION

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## ABSTRACT

The NASA Soil Moisture Active Passive (SMAP) Mission will provide global observations of soil moisture and freeze/thaw state from space. We outline how priority applications contributed to the SMAP mission measurement requirements and how the SMAP mission plans to foster applications and applied science.

**Index Terms**— Soil moisture, freeze/thaw, applied science, Earth land surface

## 1. INTRODUCTION

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 (NRC's) Decadal Survey, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* [1]. SMAP will make global measurements of the soil moisture present at the Earth's land surface and will distinguish frozen from thawed land surfaces [2]. Direct observations of soil moisture and freeze/thaw state from space will allow significantly improved estimates of water, energy and carbon transfers between the land and atmosphere.

In this paper we outline how applications and applied science were developed for SMAP and how the science drivers and priority applications contributed to the overall mission measurement requirements. The requirements are diverse and convergence on a common set of values entailed some challenges. Nevertheless the way forward was found and the challenge for the

mission now is how to foster and engage the applications community. The project has formed a SMAP Applications Working Group which now has over 150 members (see <http://smap.jpl.nasa.gov/science/applicWG>). This paper concludes with a plan for fostering applications through engagement with the applications community.

## 2. DERIVATION OF MEASUREMENT REQUIREMENTS

The Decadal Survey was composed of six disciplinary panels. Five of the six panels cited applications and applied science uses for SMAP data (Table 1). The broad and multi-disciplinary call for soil moisture and freeze/thaw data resulted in the placing of SMAP in the first tier of priority Earth science missions. An equally important factor was the maturity and technological readiness of SMAP due to its heritage in the cancelled Hydros Earth System Science Pathfinder mission.

The SMAP Science Definition Team (SDT) defined five major science goals for driving the mission measurement requirements: 1) Estimation of global water and energy fluxes at the land surface; 2) Extend weather forecast skill; 3) Develop flood and drought predictions; 4) Quantify net carbon flux in boreal landscapes; and 5) Link terrestrial water, energy and carbon cycle processes. Alongside these science drivers there are applications that should also be major components of the mission. The SMAP SDT derived a set of common measurement requirements based on the driving science and the priority application goals for the project.

The SMAP SDT next attempted to identify the spatial scales, data refresh and accuracy requirements associated with each general area of application in Table 1. For each application-area, the specific

decision-support systems or models that are used to support them were identified (second column of Table 2).

**Table 1:** NRC Decadal Survey Panel Citation of SMAP Applications.

Decadal Survey Panels	Cited SMAP Applications
Water Resources and Hydrological Cycle	<ol style="list-style-type: none"> <li>1. Floods and Drought Forecasts</li> <li>2. Available Water Resources Assessment</li> <li>3. Link Terrestrial Water, Energy and Carbon Cycles</li> </ol>
Climate Variability and Change	<ol style="list-style-type: none"> <li>4. Longer-Term and More Reliable Atmospheric Forecasts</li> </ol>
Weather Science and Applications	<ol style="list-style-type: none"> <li>5. Longer-Term and More Reliable Atmospheric Forecasts</li> </ol>
Human Health and Security	<ol style="list-style-type: none"> <li>6. Heat Stress and Drought</li> <li>7. Vector-Borne and Water-Borne Infectious Disease</li> </ol>
Land-Use, Ecosystems, and Biodiversity	<ol style="list-style-type: none"> <li>8. Ecosystem Response (Variability and Change)</li> <li>9. Agricultural and Ecosystem Productivity</li> <li>10. Wild-Fires</li> <li>11. Mineral Dust Production</li> </ol>

**Table 2:** Summary of Soil Moisture Information Requirement.

Topic	Application Model	Soil Moisture Requirement
Weather	Initialization of Numerical Weather Prediction (NWP)	Hydrometeorology
Climate	Boundary/Initial Conditions for Seasonal Prediction	Hydroclimatology
	Testing Land Surface Models in Climate Models	Hydroclimateology
Drought and Agriculture	Seasonal Precipitation Prediction	Hydroclimatology
	Regional Drought Monitoring	Hydroclimatology
	Crop Outlook	Hydroclimatology
Floods	River Forecast Model Initialization	Hydrometeorology
	Flash Flood Guidance (FFG)	Hydrometeorology
	NWP Initialization for Precipitation Forecast	Hydrometeorology
Human Health	Seasonal Heat Stress Outlook	Hydroclimatology
	Near-Term Air Temperature and Heat Stress Forecast	Hydrometeorology
	Disease Vector Seasonal Outlook	Hydroclimatology
	Disease Vector Near-Term Forecast	Hydrometeorology

Then the data attributes (resolution, revisit, and accuracy) were assembled for each application. These requirements were subsequently grouped under either Hydrometeorology or Hydroclimatology to make the problem tractable. Each grouping (Hydrometeorology and Hydroclimatology) has its own resolution requirement, but they share revisit and accuracy

requirements (Table 3). Separately, there is a Carbon cycle requirement that drives the freeze/thaw classification uses for the data. Finally, a baseline mission set of measurement requirements (last two columns in Table 3) were derived as a recommendation for the mission design.

**Table 3:** Soil Moisture Measurement Requirement.

Requirement	Hydro-Meteorology	Hydro-Climatology	Carbon Cycle	Baseline Mission	
				Soil Moisture	Freeze/Thaw
Resolution	4–15 km	50–100 km	1–10 km	10 km	3 km
Revisit	2–3 days	3–4 days	2–3 days	3 days	2 days (>45N)
Accuracy	4–6% Error (1 $\sigma$ )	4–6% Error	80–70% Accuracy (Binary Classification)	4% Error	80% Accuracy

### 3. FOSTERING THE APPLICATIONS

A key challenge for the SMAP project is to foster applications and applied science given: 1) the limited budget, 2) long development horizons, and 3) the primacy of science over applications in driving measurement requirements for NASA-funded projects. We do not believe that science and applications are competing with one another as much as they used to. Advances in computation and data transfer, the maturation of applications, and the increased emphasis of Earth scientists on transferring their discoveries to applications expediently has led to significant overlaps between science- and application-derived requirements for data. The SMAP project is working with the SMAP Applications Working Group to expand this area of overlap and develop data products that bring significant value to applications.

For this purpose, the SMAP Project sponsored the first in a series of workshops on the topic. During 9-10

September 2009, an open meeting with 125 persons in attendance was held at NOAA Silver Spring, MD (<http://smap.jpl.nasa.gov/science/applicWG/>). This meeting formed the basis for the SMAP Applications Plan.

The SMAP Applications Workshop produced the following tangible results:

1. The first detailed summary of SMAP applications;
2. A compilation of SMAP practicing and potential end-users, including early adopters;
3. A review of the broad science community that can build support for SMAP applications;
4. Dozens of contacts that should be made in the short-term; and
5. Prioritization of SMAP Applications Plan implementation tasks, where high priority items include hiring a SMAP Applications Coordinator and implementing the process to determine and engage SMAP Early-Adopters.

Following the meeting, a set of mutual expectations between the SMAP project and the SMAP Applications Working Group was developed. For the SMAP Applications Working Group, the Mission plans to:

1. Implement open access to planned SMAP data products;
2. Make available SMAP products with moderate latencies of 12 and 24 hours [the SMAP project will make a best effort to reduce these latencies];
3. Establish a Community of Early-Adopters;
4. Steer end-users to NASA Applied Sciences Program (ASP) solicitations with potential opportunities for SMAP product application;
5. Engage end-users in SMAP pre- and post-launch cal/val activities;
6. Create access to simulated SMAP data products generated pre-launch by algorithm and observing system simulation experiments; and
7. Use the SMAP testbed to develop value-added products in the simulation environment for general distribution.

In turn, the Mission expects the SMAP Applications Working Group to:

1. Partner with SMAP SDT members;
2. Communicate with the SMAP Applications Coordinator;
3. Conduct preliminary scientific research to promote use of SMAP products;
4. Refine our current understanding of SMAP products;
5. Feed information back to the SMAP Mission; and
6. Participate in SMAP calibration and validation activities.

These mutual expectations form the basis for the engagement between the SMAP project and the applications community. A 2<sup>nd</sup> Applications Workshop is planned for 2011 to be held at the location of a to-be-determined SMAP Early Adopter. In preparation, the SMAP SDT is working with the Community of Support to include more international applications and working with the NASA Applied Sciences Program to determine performance metrics to list in the SMAP Applications Plan.

Coordination of applications needs with other Decadal Survey Missions was discussed at the 1<sup>st</sup> SMAP Applications Workshop. The questions that arose included: Is it possible to develop Applications Readiness Levels (ARL) across missions? If so, how would NASA Headquarters implement ARL to take advantage of Mission products from Day 1? Alternatively, will NASA Headquarters develop metrics for applications success across all Decadal Survey Missions? These unanswered questions should stimulate a multi-Mission dialogue led by the NASA Applied Sciences Program.

#### 4. REFERENCES

- [1] National Research Council (NRC), "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond", available at <http://www.nap.edu>, *National Academies Press*, 400 pages, 2007.
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