JPL Publication 10-05

Report of the 1st SMAP Applications Workshop
Silver Spring, Maryland
September 9–10, 2009

S. Moran
D. Entekhabi
E. Njoku
P. O'Neill

National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

March 2010

This publication was prepared by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. It contains results of research and planning performed by a number of government and contractor facilities provided with funding by the National Aeronautics and Space Administration Headquarters.

Interaction at the 1st SMAP Applications Workshop at National Oceanic and Atmospheric Administration (NOAA) Science Center, Silver Spring, MD September 9–10, 2009

Table of Contents

Executive Summary

The NASA Soil Moisture Active and Passive (SMAP) mission aims to provide global soil moisture and freeze-thaw measurements from space using a combination of low-frequency microwave (L-band) radar and radiometry. The high accuracy, spatial resolution, and global coverage of the planned soil moisture and freeze/thaw products from SMAP will be invaluable across many science and applications disciplines, including water cycle science, carbon cycle science, climate science, and ecology.

With regard to applications, the primary goal of the SMAP mission is to engage SMAP end users and build broad support for SMAP applications through a transparent and inclusive process. Toward this goal, the SMAP mission formed an open-community SMAP Applications Working Group (ApplWG) and held the first SMAP Applications Workshop on September 9–10, 2009, at the National Oceanic and Atmospheric Administration (NOAA) in Silver Spring, Maryland. Presentations and discussions at the workshop provide a basis for developing a SMAP Applications Plan, including an implementation roadmap and a preliminary list of likely and potential mission applications.

Implementation of the SMAP Applications Plan will be based on how the SMAP mission can *assist* the ApplWG and, conversely, what the SMAP mission *expects* from the ApplWG. For the former, the SMAP mission is taking a number of steps to increase collaboration with the broadest possible applications community and enable product leveraging by making SMAP data products easily accessible. These steps include implementing open access to SMAP data products, making SMAP products available with the shortest possible latencies (within budgetary constraints), establishing a group of applications early adopters, cooperating on NASA Applied Sciences Program (ASP) solicitations, engaging end users in pre- and post-launch calibration and validation activities, and making value-added products generated during pre-launch observing system experiments available for application development. The SMAP mission has in-kind expectations for the ApplWG related to SMAP application development and feedback to the SMAP mission.

The engagement of the ApplWG at the SMAP Applications Workshop produced the first detailed summary of SMAP applications and a compilation of the SMAP practicing and potential end users, early adopters, and the broad science community that can be tapped to build support for SMAP applications. This led to dozens of follow-up contacts that should be made in the short term and a prioritization of SMAP Applications Plan implementation tasks. In addition to tasks already underway (related to data access and latencies), high priority tasks for SMAP are to appoint a SMAP applications coordinator and implement a process for determining and engaging SMAP early adopters. Other tasks include working with the SMAP community of support to target more international applications and making a concerted effort to promote "potential" applications to the list of "likely" applications.

At the workshop, the ApplWG emphasized the benefits of coordinating the applications plans of all NASA Decadal Survey missions. It was suggested that NASA Headquarters promote Applications Readiness Levels (ARL; similar to existing Technology Readiness Levels [TRL]) and help develop metrics for application success across all Decadal Survey missions.

The SMAP mission is committed to the dual role—science and applications—defined by the NRC Decadal Survey. Through this first and through the successive Applications Workshops, the SMAP mission has and will continue to be listening, learning, and striving to be of maximum value to applications. A second Applications Workshop is planned for September 2010 to report progress on development of the Applications Plan, expand the applications community, and receive feedback on how best to engage and promote SMAP applications.

1. Introduction

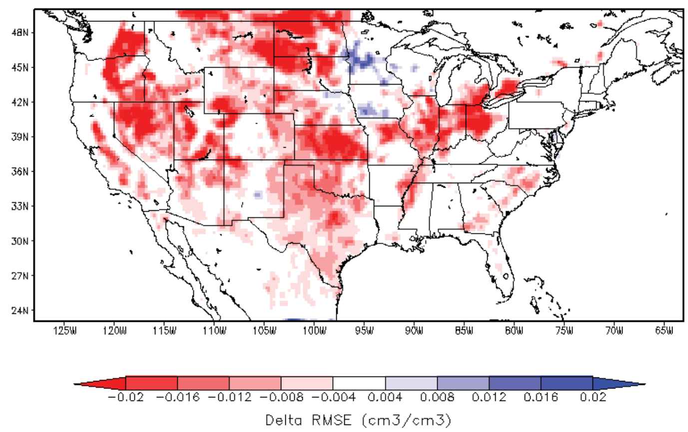
The NASA Earth Science Division has made a commitment to "discover and demonstrate applications that inform resource management, policy development and decision making" (NASA Earth Science Division Applied Sciences Program, Program Strategy, 2010–2015). The NASA mission teams have the opportunity to take a lead role in meeting this challenge. A primary goal of the SMAP mission is to engage SMAP end users and build broad support for SMAP applications through a transparent and inclusive process.

Toward this goal, the SMAP mission formed an open-community SMAP Applications Working Group (ApplWG) with over 150 members (http://smap.jpl.nasa.gov/science/applicWG). The ApplWG held the first SMAP Applications Workshop on September 9–10, 2009, at the National Oceanic and Atmospheric Administration (NOAA) in Silver Spring, Maryland. Workshop attendees represented state and federal agencies, operational centers focused on natural hazards and disasters, international organizations, and academia. Introductory speakers from NOAA, US Geological Survey (USGS), US Department of Agriculture (USDA), Environment Canada, and US Department of Defense (DoD) addressed applications that included floods and droughts, early famine warning, crop assessments, human health, and defense. Examples of these applications are shown in Figure 1. The rest of the workshop was dedicated to breakout groups tasked with generating the basis for development of a SMAP Applications Plan. Presentations and posters from the workshop can be accessed at http://smap.jpl.nasa.gov/science/workshops.

The SMAP Applications Plan will be designed to:

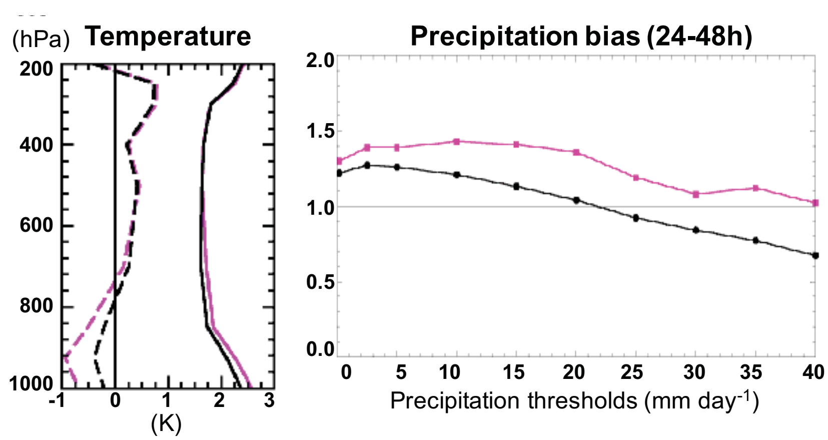
1) Develop a community of end users and decision makers that understand SMAP capabilities and are interested in using SMAP products in their applications (termed SMAP community of practice);
2) Identify from within the SMAP community of practice several early adopters who will partner with the SMAP data producers to optimize applications usage of SMAP products, including during the pre-launch phase as part of SMAP algorithm testbed activities and calibration/validation planning (termed SMAP community of early adopters);
3) Reach out to end users who are unfamiliar with SMAP capabilities but have the potential to benefit from SMAP products in their applications (termed SMAP community of potential);
4) Provide information about SMAP applications to the broad science community to build support for SMAP applications (termed SMAP community of support); and
5) Facilitate feedback between these SMAP application communities, the SMAP science definition team (SDT), and the SMAP project office (termed SMAP mission).

The SMAP Applications Plan will be a living document that will be updated regularly in the context of SMAP science requirements and input from the SMAP Applications Working Group. This Report of the 1st SMAP Applications Workshop is organized as follows: The background for defining SMAP applications and designing SMAP products is presented in Section 2. An implementation approach for identifying and engaging the SMAP communities of practice, potential, and support is presented in Section 3. Section 4 provides a summary of the workshop discussions, with an extensive list of applications and contacts (see also Appendices II and III). The report concludes with short-term actions needed to expand and accelerate SMAP applications and long-term ideas for coordination of such efforts across all Decadal Survey missions (Section 5). Acronyms are defined in Appendix IV.



EXAMPLE: AGRICULTURAL DROUGHT

Agricultural drought represents a major source of inter-annual variability in regional agricultural productivity. Currently, drought impacts on productivity trends are captured via soil water balance models forced with available global precipitation data products. Unfortunately, such products are prone to errors, which frequently degrade the quality of modeled soil moisture products. Using a data denial framework, Bolten et al. [2009] examined the potential of currently available, remotely sensed soil moisture data products to enhance root-zone (top 1 meter) soil moisture products obtained by forcing a water balance model with real-time, satellite-based precipitation information. Their evaluation strategy was based on three separate model runs for the contiguous United States: a "truth" simulation forced with a high-quality respective precipitation data set obtained from a rain gauge analysis; an "open loop" run obtained using a real-time satellite-based precipitation product; and a "data assimilation" run in which surface soil moisture retrievals were assimilated into the open loop run. Results in the figure indicate the relative improvement (measured via the root-mean-square-error fit to the truth simulation) in root-zone soil moisture retrievals between the "open loop" and "data assimilation" runs. As seen in the figure, the inclusion of soil moisture information has a consistently positive impact on the characterization of root-zone soil moisture variations. Given the substantial improvement in both resolution and accuracy expected, relative to the currently available products used here, even larger amounts of added value are expected to accompany the assimilation of SMAP data products.



EXAMPLE: NUMERICAL WEATHER PREDICTION

Soil moisture is a very important variable in numerical weather prediction systems. Because of its influence on evaporation and on the partition of available energy at the surface, soil moisture is one of the factors controlling the evolution of the daytime atmospheric boundary layer. For drier soils, cooling caused by evaporation is generally limited, leading to increased warming and mixing in the atmospheric boundary layer (and vice-versa for humid soils). This directly affects near-surface air characteristics (i.e., air temperature and humidity) as well as pollutant concentration near the surface. Through this impact on the boundary layer, soil moisture plays a major role in the production of clouds and precipitation.

This figure illustrates an objective evaluation of the impact of improved surface fluxes on numerical weather predictions, obtained in the context of a 2001 operational implementation of a new land surface scheme with improved soil moisture initial conditions in the Canadian Meteorological Centre short-range regional forecasting system (Bélair et al. 2003). Root-mean-square errors (solid) and biases (dash) for 48-h predictions of air temperature are shown in the left panel. Biases for 24-48h precipitation accumulations are shown in the right panel. The control (magenta lines) and the new system with improved land surface scheme and soil moisture initial conditions (black lines) are compared against radiosondes (for air temperature) and surface observations (for precipitation), for a series of 48 cases.

Figure 1. Representative examples of data-denial experiments conducted by early adopters, illustrating the added value of remotely sensed soil moisture for specific applications.

2. Background

2.1. NRC Decadal Survey for Earth Science and Applications from Space

The report of 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. Over one hundred mission concepts with associated scientific justifications were submitted by the Earth science community and considered within the NRC panels. Many factors involving scientific advances and societal benefits were considered in the process. In the end, fifteen missions were ranked as top priority and presented in three tiers corresponding to different time periods in the coming decade. SMAP was in the top tier and was selected by NASA for development in 2008.

The Decadal Survey report underscores a desire for a stronger connection between Earth science missions and applications user communities. Specifically, it states "…addressing the environmental challenges will not be possible without increased collaboration between Earth scientists and researchers in other disciplines including the social, behavioral, and economic sciences, and policy experts. It is necessary now to build on the paradigm of Earth system science and strengthen its dual role—science and applications. This duality has always been an element of Earth science, but it must be leveraged more effectively than in the past.…"

NASA recognizes that planned SMAP data products have high applications value as well as high science value. The high accuracy, spatial resolution, and global coverage of the planned soil moisture and freeze/thaw products from SMAP will be invaluable across many science and applications disciplines, including water cycle science, carbon cycle science, climate science and ecology.

SMAP aims to provide soil moisture and freeze-thaw measurements globally from space. Using a combination of low frequency microwave (L-band) radar and radiometry, SMAP will provide soil moisture and surface freeze-thaw measurements with unprecedented spatial resolution and accuracy. A primary objective of SMAP is to demonstrate this measurement capability on a research and operational demonstration basis so that it can be used for a future operational monitoring system. However, first-of-a-kind measurements such as these entail a degree of developmental and operational risk. For these reasons, and consistent with NASA's agency role, SMAP is a developmental mission, not an operational mission.

2.2. SMAP Measurement Objectives and Requirements

The NRC committee on Earth Science and Applications from Space was composed of six panels. Each panel provided an individual report as well as contributions to the common sections. The panels were organized by discipline and charged with identifying priority science and applications within their disciplines. Of the six panels, five explicitly cited applications within their discipline areas that would benefit from SMAP data. Table 1 lists these five discipline panels and the priority applications cited that would utilize SMAP data products. The sixth panel was Solid Earth.

The SMAP Science Definition Team (SDT) developed five objectives for the mission that span the primary science and applications of soil moisture and freeze/thaw measurements. The five objectives are:

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 skill; and
5) Develop improved flood prediction and drought monitoring capability.

In order to define the measurement approach and requirements for SMAP (spatial resolution, refresh rate, accuracy, latency, etc.), the SDT further refined these objectives and identified specific applications (e.g., models, decision-support systems, etc.) for each of them. These are listed in Table 2 and link to the Decadal Survey priority applications areas of Table 1.

The specific applications listed in Table 2 have different sets of requirements for resolution, refresh rate, accuracy, and other attributes. In order to derive an overall set of requirements for the SMAP mission and instrument design, the applications were grouped into three requirements categories:
(1) Hydrometeorology and (2) Hydroclimatology, driven primarily by soil moisture; and (3) Boreal Carbon Cycle, driven primarily by freeze/thaw. A well-defined set of requirements can be derived for each of the three categories. The requirements for each category either meet or exceed the individual requirements of its constitutive applications.

The spatial resolution requirement for the hydrometeorology soil moisture data product is determined primarily by: (1) scales at which the surface and atmosphere interact through surface fluxes and the planetary boundary layer, (2) anticipated grid scales of numerical weather prediction (NWP) models during the SMAP time-horizon, and (3) grid scales for hydrologic forecast models for streamflow and flash flood forecasting. The remaining applications are implicitly included in each of these considerations.

Table 1. Decadal Survey Applications by Panel Cited for SMAP

Decadal Survey Panels	Cited SMAP Applications
1. Water Resources and Hydrological Cycle	• Floods and Drought Forecasts • Available Water Resources Assessment • Link Terrestrial Water, Energy and Carbon Cycles
2. Climate and 3. Weather	• Longer-Term and More Reliable Atmospheric Forecasts
4. Human Health and Security	• Heat Stress and Drought • Vector-borne and Water-Borne Infectious Disease
5. Land-Use, Ecosystems, and Biodiversity	• Ecosystem Response (Variability and Change) • Agricultural and Ecosystem Productivity • Wild-Fires • Mineral Dust Production

Table 2. Applications Associated with Decadal Survey Priorities for SMAP Data

Decadal Survey Objective	Specific Application	Science Requirement
Weather Forecast	Initialization of Numerical Weather Prediction (NWP)	Hydrometeorology
Climate Prediction	Boundary and Initial Conditions for Seasonal Climate Prediction Models	Hydroclimatology
	Testing Land Surface Models in General Circulation Models	
Drought and Agriculture Monitoring	Seasonal Precipitation Prediction	Hydroclimatology
	Regional Drought Monitoring	
	Crop Outlook	
Flood Forecast	River Forecast Model Initialization	Hydrometeorology
	Flash Flood Guidance (FFG)	
	NWP Initialization for Precipitation Forecast	
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 (NWP)	Hydrometeorology
Boreal Carbon	Freeze/Thaw Date	Carbon Cycle

The spatial resolution requirement for the hydrometeorology soil moisture data product is determined primarily by: (1) scales at which the surface and atmosphere interact through surface fluxes and the planetary boundary layer, (2) anticipated grid scales of numerical weather prediction (NWP) models during the SMAP time-horizon, and (3) grid scales for hydrologic forecast models for streamflow and flash flood forecasting. The remaining applications are implicitly included in each of these considerations.

Currently, numerical weather prediction within the US National Weather Service (NWS), the primary target user, employs a 12-km model grid in its highest-resolution mode over the contiguous United States (CONUS). It is anticipated that in the coming decade a 4-km model grid will be implemented over CONUS. The National Weather Service (NWS) River Forecast System for streamflow is implemented at several thousand forecast locations, depending on how proximity to stage gauges and development of semi-distributed hydrologic modeling are counted. Over CONUS, this leads to an average resolution scale of between 40 and 80 km for predictions made by a specific forecast location. NWS Flash Flood Guidance (FFG) products are produced on a county by county basis. Given that there are 3077 counties in CONUS, the average entry in the current FFG corresponds to a 50-km resolution scale. To provide added value to hydrologic applications, remotely sensed soil moisture information should resolve land surface heterogeneity at length scales finer than current model-based forecasting.

Grouping together the above spatial scale considerations for hydrometeorology, the 10-km scale emerges as a soil moisture spatial resolution requirement that satisfies most of the applications. This requirement is unique for SMAP in that it is an improvement on current and forthcoming capabilities defined for the AMSR-E, SMOS, and MIS sensors, as well as others planned for operation prior to the anticipated launch of SMAP. These sensors provide relatively coarse resolution soil moisture (40 to 60 km) and do not enable the hydrometeorology applications cited here. In order to enable the hydrometeorology applications, and to provide value above other current and planned missions, the 10-km requirement must be met by SMAP for both its baseline and minimum missions.

The second important attribute for hydrometeorology applications is the temporal revisit, or data refresh rate. The requirement for this attribute is controlled by the arrival rate of individual storm events and the dry-down rate of surface soil moisture. To adequately capture the temporal variability of soil moisture under most circumstances, a three-day refresh rate is required. To account for seasonal and geographical differences in precipitation patterns, a two- to three-day refresh rate is ideal.

The soil moisture spatial resolution and temporal refresh rate requirements for hydroclimatology applications are derived from the data requirements of climate models used for seasonal prediction and global change studies. The spatial resolution requirement is driven by the resolution of these models. The models are commonly implemented on grid scales of about 2 degrees latitude and longitude (lat-lon), although some limited higher resolution cases do exist. With enhanced computational capabilities, this resolution could increase to 0.5 degrees lat-lon (corresponding to two orders of magnitude more computational demand) prior to the SMAP launch. In mid-latitudes, 0.5 degrees longitude corresponds to about 50 km. This anticipated high-resolution climate requirement can be considered the baseline. A minimum spatial resolution requirement can be considered to be the grid scale of current high-resolution climate models, or about 100 km.

The temporal refresh rate requirement of soil moisture information for hydroclimatology applications is not governed by storms as it is for hydrometeorology applications. It is governed primarily by the time scale of climate anomalies that can persist for weeks to months. Since the revisit requirement for hydrometeorology is more rigorous, the hydroclimatology soil moisture requirement does not drive the SMAP orbit and swath design.

The spatial resolution of SMAP freeze/thaw measurements should be sufficient to capture the freeze/thaw constraints on boreal-arctic carbon fluxes and allow characterization of surface processes at a scale commensurate with the measurement footprint of stand-level tower eddy covariance based carbon flux measurements. Spatial heterogeneity in freeze/thaw transitions has been assessed from a resolution degradation exercise using an ERS C-band-radar-backscatter-based freeze/thaw classification time series. Classification error increases rapidly as the resolution approaches the scale of landscape freeze/thaw spatial heterogeneity. The results show maximum classification error of approximately 20% at 3-km resolution, which degrades to ~30% at 10-km resolution. The freeze/thaw temporal refresh requirement is defined relative to an assumed 100-day growing season representative of boreal and tundra ecosystems. An estimated two-day temporal accuracy of the freeze/thaw measurement is sufficient to resolve temporal variations in NPP and net CO2 exchange to within 3% (of annual NPP) or 5 g C m^{-2}.

Based on the hydrometeorology, hydroclimatology, and carbon cycle science and applications requirements, the SMAP baseline and minimum mission requirements have been defined (Table 3). The baseline mission requirements are the starting point for the Science Traceability Matrix (STM), shown in Table 4, which provides the flow down to the SMAP instrument and mission functional requirements. In the first column of the STM, the major science application areas are listed. These constitute the five science objectives of SMAP. The second column consists of the science measurement requirements derived from these objectives. The instrument and mission functional requirements to achieve the science requirements are summarized in the last two columns of the SMAP STM.

Table 3. SMAP Baseline and Minimum Mission Requirements

	Baseline Mission	Minimum Mission
Soil Moisture Measurement	Provide estimates of soil moisture in the top 5 cm of soil with an accuracy of 4% volumetric at 10 km resolution and 3-day average intervals	Provide estimates of soil moisture in the top 5 cm of soil with an accuracy of 6% volumetric at 10 km resolution and 3-day average intervals
Freeze/Thaw Measurement	Provide estimates of surface binary transitions in the region north of 45N with a classification accuracy of 80% at 3 km resolution and 2-day average intervals	Provide estimates of surface binary transitions in region north of 45N with a classification accuracy of 70% at 10 km resolution and 3-day average intervals
Mission Duration	At least 3 years	At least 2 years

Table 4. SMAP Science Traceability Matrix

<table>
<tr><th>Science Objectives</th><th>Scientific Measurement Requirements</th><th>Instrument Functional Requirements</th><th>Mission Functional Requirements</th></tr>
<tr><td rowspan="4">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.

Develop improved flood prediction and drought monitoring capability.</td><td>Soil Moisture
~4% volumetric accuracy in top 5 cm for vegetation water content < 5 kg m^{-2};
Hydrometeorology at 10 km;
Hydroclimatology at 40 km</td><td>L-Band Radiometer
Polarization: V, H, U;
Resolution: 40 km;
Relative accuracy*: 1.5 K
L-Band Radar
Polarization: VV, HH, HV;
Resolution: 10 km;
Relative accuracy*: 0.5 dB for VV and HH
Constant incidence angle† between 35° and 50°</td><td rowspan="2">DAAC data archiving and distribution

Field validation program

Integration of data products into multisource land data assimilation</td></tr>
<tr><td>Freeze/Thaw State
Capture freeze/thaw state transitions in the integrated vegetation-soil continuum with two-day precision, at the spatial scale of landscape variability (3 km).</td><td>L-Band Radar
Polarization: HH;
Resolution: 3 km;
Relative accuracy*: 0.7 dB (1 dB per channel if 2 channels are used);
Constant incidence angle† between 35° and 50°</td></tr>
<tr><td>Sample diurnal cycle at consistent time of day
Global, 3–4 day revisit;
Boreal, 2 day revisit</td><td>Swath Width: 1000 km
Minimize Faraday rotation (degradation factor at L-band)</td><td>Orbit 680 km, circular, polar, sun-synchronous, ~6 am/pm equator crossing</td></tr>
<tr><td>Observation over a minimum of three annual cycles</td><td>Minimum three-year mission life</td><td>Three-year baseline mission‡</td></tr>
</table>

* Includes precision and calibration stability and antenna effects
† Defined without regard to local topographic variation
‡ Starting from completion of a 90-day post-launch observatory check-out

2.3. SMAP Data Products

SMAP data products are designed to meet the science and applications objectives and requirements of the mission. The baseline SMAP data products and their average latencies as committed to by the project are listed in Table 5. Average latencies are defined as mean times (averaged over the mission) under normal operating conditions, from time of acquisition on board the spacecraft to availability for access by users. The average latencies include significant margins to accommodate missed passes, transmission and processing problems, and other anomalous operating conditions. The SMAP project will make a best effort (within resources allocated by NASA) to reduce the average data latencies beyond those shown in Table 5. Nominal expected upper- and lower-bound latencies are discussed later in this section and shown in Table 6.

The definitions of data levels used by SMAP are consistent with NASA Earth Observing System (EOS) conventions. Level 1 products are swath instrument data. Level 2 products are retrieved geophysical data stored as half-orbit granules. Level 3 products are geophysical data composited daily onto global grids, separately for ascending and descending passes. The SMAP mission will also provide Level 4 products generated by land data assimilation systems that integrate the Level 1, 2, or 3 data with models to produce value-added products.

Consistent with NASA's established Level 1 requirements for the SMAP mission, SMAP's initial implementation plan has the following policy regarding data latency for operational users:

> *The SMAP Project encourages the use of its data products by all scientific, operational and applications communities. Applications development and application-specific data flow provisions (such as near real-time data delivery) that require deviation from capability required to meet the science mission requirements will not be implemented under direct (NASA) Project funds. In the event such capability is required, the Project will work on a cost reimbursable basis to accommodate the additional capability or functionality.*

The timeline for validated SMAP data product availability is shown in Figure 2. Current plans are for the SMAP observatory to complete an in-orbit checkout (IOC) period within 90 days after launch and then operate beyond the end of the IOC for a science mission duration of three years.

Following the IOC period, the project will complete an initial calibration and validation (Cal/Val) of the data products within six months for Level 1 products and twelve months for Levels 2, 3 and 4. When the Cal/Val campaigns are complete, the data acquired during each of these campaigns will be reprocessed to ensure data product consistency. At the conclusion of each product's Cal/Val period, calibrated and validated data from that period will be made available for public release through a NASA-designated archive (DAAC), and newly acquired data products will be released on a routine basis with the latency shown in Table 5. During the Cal/Val period early releases of data products through the DAAC will occur. These will have designations of "beta" or "provisional" to indicate that these products have not yet been fully validated. A final, long-term archival data set, generated using a consistent suite of algorithms, will be delivered to the public archive (DAAC) within six months after the end of the mission.

Science data will be downlinked from the flight system according to ground station visibility and availability. Downlink opportunities will range from once an orbit to once every few orbits. Once data are downlinked to the ground, they will be dispatched to the SMAP Science Data Processing Center, queued for processing, processed (with priority given to oldest data in the queue), and delivered to the DAAC. Data transfer, processing, and delivery to the DAAC are planned to be automated to reduce data latencies.

The SMAP project has committed to deliver data products to the DAAC with average latencies shown in Table 5 during nominal mission operations. However, the project expects that data products will nominally be available with shorter latencies than the aforementioned commitments. Current best-estimate average and high-end latencies are summarized in Table 6. Data flows will be interrupted in the event of an on-orbit or ground-system anomaly. The latencies shown in Table 6 are provisional and will be updated as additional studies are preformed during Phase B of the mission.

Table 5. SMAP Data Products and Average Data Latencies*

Data Product	Description	Spatial Resolution	Average Latency
L1A_Radar	Level 1A Radar Raw Data, time ordered	N/A	12 hours
L1B_S0_LoRes	Level 1B Low Resolution Radar σ^o, time ordered	5x30 km	12 hours
L1C_S0_HiRes	Level 1C High Resolution Radar σ^o, gridded	1-3 km	12 hours
L1A_Radiometer	Level 1A Radiometer Raw Data, time ordered	N/A	12 hours
L1B_TB	Level 1B Radiometer T_B, time ordered	40 km	12 hours
L1C_TB	Level 1C Radiometer T_B, gridded	40 km	12 hours
L2_SM_A†	Level 2 Soil Moisture (active)	3 km	24 hours
L2_SM_P	Level 2 Soil Moisture (passive)	40 km	24 hours
L2_SM_A/P	Level 2 Soil Moisture (active/passive)	10 km	24 hours
L3_F/T_A	Level 3 Freeze/Thaw State (active)	3 km	36 hours
L3_SM_A†	Level 3 Soil Moisture (active)	3 km	36 hours
L3_SM_P	Level 3 Soil Moisture (passive)	40 km	36 hours
L3_SM_A/P	Level 3 Soil Moisture (active/passive)	10 km	36 hours
L4_SM	Level 4 Soil Moisture (surface and root zone)	10 km	7 days
L4_C	Level 4 Carbon Net Ecosystem Exchange	10 km	14 days

*Average latency is defined as the mean time under normal operating conditions between data acquisition on board the spacecraft and availability for access by users

† Research products (not Level 1 science requirement deliverables)

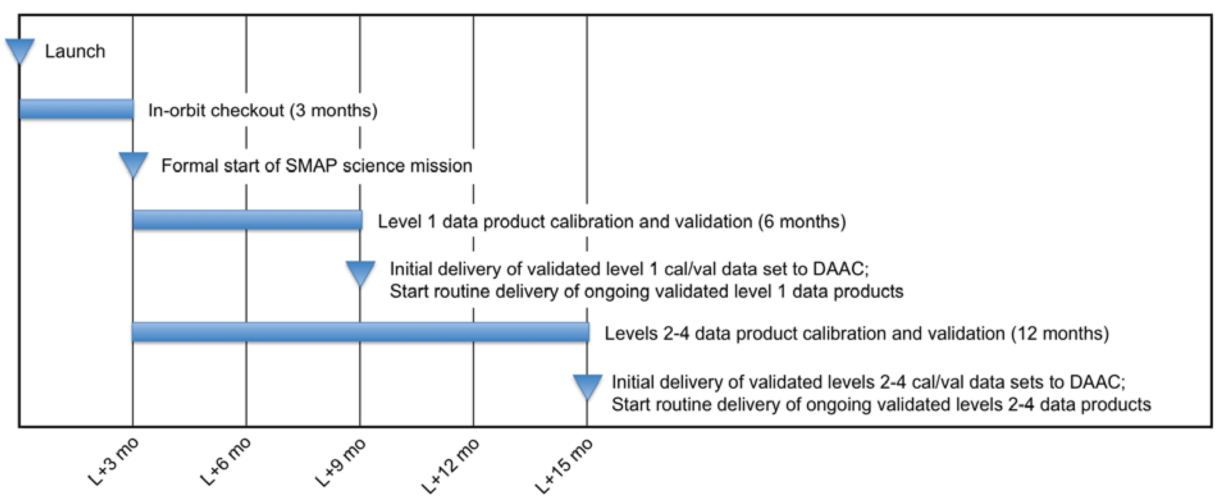


Figure 2. Timeline for Validated SMAP Data Product Availability after Launch

Table 6. Current Best-Estimate Average and High-End Data Latencies for SMAP Level 1 to Level 3 Data Products

Time Delay Categories	Average	High End	Requirement (Average)
Data observation to downlink	2.5	6.2	4*
Transfer from ground station through EDOS to JPL	1	2	2*
L1 processing	1.5	2.5	2*
Total L1 latency	5	10.7	12
L2 processing	2	4	2*
Total L2 latency	7	14.7	24
Total L3 latency	32	40	36

* Mission system allocation

3. Implementation

Development and implementation of the SMAP Applications Plan will be based on how the SMAP mission can *assist* the SMAP ApplWG and, conversely, what the SMAP mission *expects* from the SMAP ApplWG.

3.1. What the SMAP Mission can Offer the SMAP ApplWG

This report introduces a plan to engage SMAP end users and build broad support for SMAP applications. Though NASA's current budget does not support mission enhancements or products tailored specifically for applications needs beyond those required for SMAP's primary science objectives (Table 4), the SMAP mission is taking steps to increase collaboration and enable more effective leveraging by the broadest possible science and applications communities who might take advantage of the SMAP data set.

These steps include:

1) Implementing open access to planned SMAP data products via a to-be-defined NASA distributed active archive center (DAAC).
2) Making available instrument and geophysical retrieval products with moderate latencies of 12 and 24 hours (the SMAP project will make a best effort to further reduce these latencies; Table 5).
3) Establishing a community of early adopters within the community of practice that will have access to SMAP pre- and post-launch testbed data streams and conduct applications demonstrations in collaboration with the science team; the early adopter selection process may be through a competitive, peer-reviewed NASA announcement of opportunity as was done for the science definition team.
4) Steering end users to NASA Applied Sciences Program (ASP) solicitations with potential opportunities for SMAP product application.
5) Engaging end users in SMAP pre- and post-launch Cal/Val activities and providing access to aircraft and ground data generated in Cal/Val field campaigns.
6) Providing access where possible to simulated SMAP data products generated pre-launch by algorithm and observing system simulation experiments conducted on the SMAP algorithm testbed.
7) Using the SMAP testbed to develop value-added products in the simulation environment for general distribution.

To facilitate implementation of these steps, the SMAP mission plans to appoint a SMAP applications coordinator (SAC) to serve as a liaison between the SMAP project and government agencies and identify applications that could use SMAP data products for testing and/or operation. The SAC 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 (e.g., the data denial studies highlighted in Section 1). The SAC will also work with SMAP scientists to refine mission data products in order to best meet application needs.

3.2. What the SMAP Mission Expects from the SMAP ApplWG

The SMAP ApplWG is an inclusive group that accepts members through registration on the SMAP website at http://smap.jpl.nasa.gov/science/applicWG (follow the instructions for "Working Group Sign-Up"). Two key roles for members of the SMAP ApplWG are: (1) SMAP application development, and (2) feedback to the SMAP mission. Both roles are facilitated by partnering with SMAP science definition team members (http://smap.jpl.nasa.gov/science/team) and communicating with the SAC. The community of support (defined in the Introduction) 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 SMAP in new applications. Whenever possible, this research should be conducted with 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 via the SMAP ApplWG.

The ApplWG will also play a role in the design of SMAP calibration and validation (Cal/Val) activities. Tasks will include guiding the selection of field campaign sites and providing applications-related input to the design of field campaigns. In doing so, the ApplWG should attempt to maximize the relevance of Cal/Val activities for particular applications. The ApplWG can also provide a forum for publicizing planned field campaigns and attracting more involvement from groups interested in SMAP applications.

Any special data or assistance requests beyond the opportunities listed may require a white paper on the SMAP application that would include: (1) an application description; (2) data currently used; (3) desired SMAP product; (4) key people; (5) ancillary data needs (longer records, review internal data and products for use); (6) desire for simulated data products and field experiment demonstration; (7) potential implementation strategy; (8) next steps (deadlines/timelines); (9) how to integrate into future projects; and (10) product output format. This would assist the SMAP project in determining the magnitude of the effort required and the return on staff investment.

3.3. Performance Metrics

A question remains: How will we know if our applications plan is a success? According to Kaupp and Hutchinson (2009), common quantitative measures of performance in Earth science applications programs include

- Number of publications,
- Number of web hits, and
- Number of users of products or sustained demand;

and qualitative measures may include

- functioning, long-term projects,
- milestones met,
- movement of science (and SMAP products) into routine operations,
- oversight panel/stakeholder reviews,
- increasing non-core funding, and
- Congressional support.

Considering that additional research will be required to cross the abyss between SMAP products and operational applications, the number of publications related to SMAP applications may be a reasonable quantitative metric, along with a count of sustained and active participation in the SMAP ApplWG. A functioning and funded group of early adopters should produce qualitative metrics related to long-term projects, milestones completion, and movement of SMAP products into routine operations. The annual SMAP Applications Workshops should provide the inclusive and transparent oversight of the SMAP Applications Plan implementation as well as plan revisions in keeping with a living document.

4. First Engagement—Workshop Results from September 9–10, 2009

The SMAP Applications Working Group (ApplWG) held the 1st SMAP Applications Workshop September 9–10, 2009, at the National Oceanic and Atmospheric Administration (NOAA) in Silver Spring, Maryland. The workshop began with a series of presentations by NOAA leadership and the SMAP mission to give an overview of SMAP to the workshop. These were followed by presentations by the SMAP community of practice covering applications in the context of SMAP, including weather and climate forecasting, flood monitoring, agricultural productivity, human health, national defense, and ecological forecasting. Posters covered SMAP applications to insect infestation, landslide hazards, precipitation retrieval, and more. These introductory presentations and posters are available at http://smap.jpl.nasa.gov/science/workshops/.

Speakers emphasized the need to look to the future; the SMAP mission will be launched in 2015, and applications and technology will change within the next five years. Even the missions of the agencies involved in applications will change; for example, there is a new emphasis in DoD on responding to crises and support development and reconstruction. Also, work conducted on applications pre-launch with SMAP simulations will anticipate issues associated with known applications and potentially spawn new, unknown applications. All speakers emphasized that applications will require cooperation across agencies and across purposes. Speakers reminded the SMAP mission that product timeliness is as important as product accuracy and that the development of applications requires specific attention to the decision support interface (e.g., model or analyst-based) currently employed by each application. The speakers also posed questions to the mission, asking about the potential for a follow-on mission and how to best coordinate with other missions such as AMSR-E, SMOS, MIS, and existing *in situ* soil moisture networks to potentially extend SMAP mission data sets into long-term data records.

The presentations were followed by small-group discussions in breakout sessions designed to provide details about SMAP applications, contacts, and follow-up action items (Appendix II and III). The breakout discussion also provided a preliminary list of the agencies and entities identified as members of the SMAP communities of practice, potential, and support (Appendix IV). A general summary of results from these groups is presented in Table 7 in a format suggested for all Decadal Survey missions by Andrea Donnellan, NASA Headquarters Applied Sciences Program (ASP). Each listed application is color-coded based on whether it is a likely mission application (i.e., the community and procedures are mature enough to ingest SMAP data and assess their value to the particular application) or whether it is a potential mission application (i.e., the community interest is there but the procedures to use SMAP data may be a bit immature). The role of SMAP data in supporting disaster management systems is also addressed in the table.

The details in Appendix II and the summary in Table 7 are useful for identifying the most likely mission applications (green) and the early adopters. These should be the focus of attention in the short term. The potential mission applications (yellow) will require follow-up, as identified at the workshop and reported in Appendices II and III, as well as more funding to bring them to a maturity level sufficient to take advantage of SMAP products.

Table 7. SMAP Applications Identified at the 1st SMAP Applications Workshop (details given in Appendix II)

SMAP MISSION OBJECTIVES	POTENTIAL SMAP APPLICATIONS								
	Weather	Natural Disasters	Climate Variability & Change	Agriculture & Forestry	Human Health	Ecology	Water Resources	Ocean Resources	Insurance Sector
Soil moisture and freeze-thaw information for water, energy and carbon cycle processes (likely)	More accurate weather forecasts; prediction of severe rainfall; operational severe weather forecasts; mobility and visibility	Drought early warning decision support; key variable in floods and landslides; operational flood forecast; lake and river ice breakup; desertification	Extend climate prediction capability; Linkages between terrestrial water, energy, and carbon cycles; land / atmosphere fluxes	Predictions of agricultural productivity; famine early warning; Monitoring agricultural drought	Landscape epidemiology; heat stress and drought monitoring; insect infestation; emergency response plans	Carbon source/sink monitoring; Ecosystems forecasts; monitoring vegetation and water relationships over land	Global water balance; estimates of streamflow & river discharge; more effective management;	Sea-ice mapping for navigation, especially in coastal zones; temporal changes in ocean salinity	
(potential)		Fire susceptibility; global flood mapping; heat-wave forecasting		Crop management at the farm scale; Input to fuel loading models		Monitoring wetlands resources and bird migration	Monitoring variability of water stored in lakes, reservoirs, wetlands and river channels	Ocean wind speed and direction, related to hurricane monitoring	Crop insurance programs; flood insurance programs; tourism and recreation
SMAP MISSION OBJECTIVES	POTENTIAL SMAP RELEVANCE TO DISASTER MANAGEMENT								
	Coastal Inundation	Drought	Flood	Heat waves	Human Health	Ecosystem Health	Landslides & Debris Flows	Wildfires	Earthquakes, tsunamis & Volcanoes
Soil moisture and freeze-thaw information for water, energy and carbon cycle processes (likely)		Soil moisture is a key variable; Early warning decision support; desertification	Soil moisture is a key variable; improved forecasts, especially in medium to large watersheds; flood mapping; protect downstream resources; soil infiltration conditions; predict ice breakup;		Soil moisture is a key variable in monitoring vector population dynamics; decision support for malaria and other waterborne diseases	Monitoring of vegetation health & change; ecosystem dynamics	Soil moisture is a key variable; better prediction through consistent observations in mountainous regions		No relevance
(potential)	Maps of coastal inundation; Monitoring ocean winds for hurricane monitoring			Early warning decision support		Monitoring wetlands and bird migration		Improved fuel loading models, especially for non-heavily forested areas	

(green box) = likely mission application (yellow box) = potential mission application

5. Conclusions

5.1. Workshop Follow-on Activities

Plans for the second engagement (slated for fall 2010 or early 2011) are to include the same group attending the 1st Applications Workshop (Appendix I) and to extend to a larger community. Having the 2009 workshop at NOAA provided an exceptional opportunity to interact with key SMAP end users and receive feedback from NOAA scientists and administrators. Similarly, the 2nd SMAP Applications Workshop in 2010 should be held at the location of a SMAP early adopter. Also, we found that NASA Applied Sciences Program managers attending the workshop offered a great deal to the discussion of applications. An invitation to NASA Earth Science Division directors, particularly the Applied Sciences Program director, should be a standard protocol for annual SMAP Applications Workshops.

In preparation for the 2nd Applications Workshop, several steps must be taken in the short-term:

1) Follow-up on contacts and action items resulting from 1st Applications Workshop breakout discussions, highlighted in Appendices II and III. Complete these items and report on progress at the 2nd Applications Workshop.
2) Ensure that all steps in Section 3.1 have been achieved. High priority items include appointing a SMAP applications coordinator and implementing the process to determine and engage SMAP early adopters.
3) Work with the community of support to include more international applications. Investigate the feasibility of targeting international applications with the generation of simulated SMAP products for Africa and Asia using the SMAP algorithm testbed and geophysical land states generated from the NASA Land Information System (LIS).
4) Promote applications currently listed as "potential" in Table 7 and engage new applications through efforts by SMAP SDT members and SMAP community of support. For this, develop a generic presentation about SMAP applications (and possibly a SMAP applications fact sheet and poster) to promote SMAP applications at technical meetings and workshops, e.g., the upcoming U.S. drought monitoring meeting.
5) Work with the NASA Applied Sciences Program to determine performance metrics to list in the SMAP Applications Plan.

5.2. Coordination with Other Decadal Survey Missions

A topic of discussion at the 1st SMAP Applications Workshop was coordination of applications for all planned Decadal Survey missions (Table 8). Though this was not discussed in mission-by-mission detail, some broad ideas were expressed. NASA missions have historically been tasked to meet Technology Readiness Levels (TRL); is it possible to develop Applications Readiness Levels (ARL) across missions? If so, how would NASA Headquarters handle implementation of ARL to ensure that applications are ready to take advantage of mission products from Day 1? Alternatively, will NASA Headquarters develop metrics for application success across all Decadal Survey missions? These unanswered questions should stimulate a multi-mission dialogue led by the NASA Applied Sciences Program. In addition, other NASA mission science team leaders should be invited to annual SMAP Applications Workshops.

5.3. Concluding Remarks

The SMAP Mission is committed to the dual role—science and applications—defined by the NRC Decadal Survey and recently articulated by Dozier and Gail (2009). This is a new era in which this duality will be addressed more effectively than in the past. Through the first and through the successive Applications Workshops, the SMAP mission has and will continue to be listening, learning, and striving to be of maximum value to applications. This effort extends beyond posters and websites to a two-way conversation with end users and a genuine plan for implementation. This is an opportunity for SMAP to set the standard for engaging applications and preparing to take advantage of products from Day 1 after launch.

Table 8. Missions Recommended to NASA by NRC Decadal Survey

Decadal Survey Mission	Mission Description
2010–2013	
CLARREO	Solar and Earth radiation; spectrally resolved forcing and response of the climate system
SMAP	Soil moisture and freeze-thaw for weather and water cycle processes
ICESat-II	Ice sheet height changes for climate change diagnosis
DESDynl	Surface and ice sheet deformation for understanding natural hazards and climate; vegetation structure for ecosystem health
2013–2016	
HyspIRI	Land surface composition for agriculture and mineral characterization; vegetation types for ecosystem health
ASCENDS	Day/night, all-latitude, all-season CO2 column integrals for climate emissions
SWOT	Ocean, lake, and river water levels for ocean and inland water dynamics
GEO-CAPE	Atmospheric gas columns for air quality forecasts; ocean color for coastal ecosystem health and climate emissions
ACE	Aerosol and cloud profiles for climate and water cycle; ocean color for open ocean biogeochemistry
2016–2020	
LIST	Land surface topography for landslide hazards and water runoff
PATH	High-frequency, all-weather temperature and humidity soundings for weather forecasting and sea-surface temperature
GRACE-II	High-temporal-resolution gravity fields for tracking large-scale water movement
SCLP	Snow accumulation for freshwater availability
GACM	Ozone and related gases for intercontinental air quality and stratospheric ozone layer prediction
3D-Winds (Demo)	Tropospheric winds for weather forecasting and pollution transport

6. Acknowledgements

The SMAP mission would like to thank Dr. Xiwu Zhan, the NOAA SMAP liaison, for organizing the SMAP Applications Workshop at NOAA Silver Spring, and Dr. Louis Uccellini, the director of the NOAA/NWS/NCEP, for giving an inspirational welcome to the SMAP Applications Working Group. We would also like to thank the SMAP Applications Working Group for providing the feedback needed to write this report.

7. References

Bélair, S., L.-P. Crevier, J. Mailhot, B. Bilodeau, and Y. Delage. Operational implementation of the ISBA land surface scheme in the Canadian regional weather forecast model. Part I: Warm season results. *J. Hydromet*., **4**, 352–370. 2003.

Bolten, J.D., W.T. Crow, T.J. Jackson, X. Zhan, and C.A. Reynolds. Evaluating the utility of remotely-sensed soil moisture retrievals for operational agricultural drought monitoring. *IEEE Journal of Selected Topics in Earth Observations and Remote Sensing* (in press)

Dozier, J. and W.B. Gail. The emerging science of environmental applications. The Fourth Paradigm: Data-Intensive Scientific Discovery, Eds. T. Hey, S. Tansley and K. Tolle, Pub. Microsoft Research, (*http://research.microsoft.com/en-us/collaboration/fourthparadigm/contents.aspx*). 2009.

Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond, *Space Studies Board, National Academies Press*. 2007.

Entekhabi, D., E. Njoky, P. O'Neill, K. Kellogg, W. Crow, W. Edelstein, J. Entin, S. Goodman, T. Jackson, J. Johnson, J. Kimball, J. Piepmeier, R. Koster, K. McDonald, M. Moghaddam, S. Moran, R. Reichle, J.C. Shi, M. Spencer, S. Thurman, L. Tsang, and J. van Zyl. The Soil Moisture Active and Passive (SMAP) Mission. *Proceedings of the IEEE* (submitted).

Kaupp, V. and C. Hutchinson. Applied Earth Sciences Programs in Select Federal Agencies: Final Report, February 24, 2009. Available from the *NASA Applied Sciences Program at NASA/GSFC.* 2009.

Appendix I. First SMAP Applications Workshop Attendees

Last Name	First Name	Affiliation
Ambrose	Stephen	NASA/GSFC
Bach, Jr	Walter	US/ARL/ARO
Bajpai	Shyam	NOAA/NESDIS/OSD
Barlage	Michael	NCAR
Bauer	Robert	NASA/ESTO
Belair	Stephane	EC
Bethel	Glenn	USDA
Bicknell	Tom	JPL/Caltech
Bindlish	Rajat	USDA/ARS
Bolten	John	NASA/GSFC
Bonnin	Geoff	NOAA/NWS/OHD
Brinker	Elisabeth	NASA/GSFC
Brown	Molly	NASA/GSFC
Campbell	Brian	NASA/GSFC
Carolyn	Vadnais	NOAA
Case	Kelley	JPL/Caltech
Champagne	Catherine	AgCanada
Clemente	Laura	USACE/ERDC
Colliander	Andreas	JPL/Caltech
Cosgrove	Brian	NOAA/NWS/OHD
Cosh	Michael	USDA/ARS
Crow	Wade	USDA/ARS
Dadamia	Danilo	CONAE
Davis	Robert	USACE/ERDC/CRREL
de Rosnay	Patricia	ECMWF
Dobson	Craig	NASA/HQ
Dong	Jiarui	NOAA/NWS/NCEP/EMC
Donnellan	Andrea	JPL/Caltech
Doorn	Bradley	NASA/HQ
Dutta	Mitra	NASA/HQ
Ek	Michael	NOAA/NWS/NCEP/EMC
Engman	Ted	NASA/GSFC
Entekhabi	Dara	MIT
Entin	Jared	NASA/HQ
Eylander	John	AFWA
Habib	Shahid	NASA/GSFC
Haynes	John	NASA/HQ
Hermreck	David	NOAA/NESDIS
Heymann	Roger	NOAA/NESDIS
Houser	Paul	GMU
Hyon	Jason	JPL/Caltech
Jackson	Thomas	USDA/ARS
Jacobs	Jennifer	UNH
Jai	Ben	JPL/Caltech
Johnson	Joel	OSU
Johnston	William	USNRL
Joseph	Alicia	NASA/GSFC

Last Name	First Name	Affiliation
Judge	Jasmeet	UF
Kellogg	Kent	JPL/Caltech
Kim	Ed	NASA/GSFC
Kimball	John	UM
Kitzmiller	David	NOAA/NWS/OHD
Koenig	Lora	NASA/GSFC
Koster	Randal	NASA/GSFC
Kumar	Sujay	NASA/GSFC
Kunickis	Sheryl	USDA/NRCS
Kurum	Mehmet	NASA/GSFC
Laymon	Charles	NASA/MSFC
Leon	Amanda	NSIDC
Levin	Maxine	USDA/NRCS
Li	Li	USNRL
Liu	Jicheng	NOAA/NESDIS/STAR
Mahfouf	Jean-François	Météo-France/CNRM
Mango	Stephen	NOAA/NESDIS/OSD
McDonald	Kyle	JPL/Caltech
Mcguire	James	NASA
McWilliams	Gary	NPOESS
Melo	Stella	CSA & EC
Meng	Jesse	NOAA/NWS/NCEP/EMC
Meng	Huan	NOAA/NESDIS/STAR
Modlin	Norman	NPOESS
Moran	Susan	USDA/ARS
Moses	John	NASA/GSFC
Nearing	Grey	UA
Nemani	Ramakrishna	NASA/ARC
Newman	Tim	USGS
Njoku	Eni	JPL/Caltech
ONeill	Peggy	NASA/GSFC
Palecki	Michael	NOAA/NESDIS/NCDC/USCRN
Pereira	John	NOAA/NESDIS
Peters-Lidard	Christa	NASA/GSFC
Plunk	Dorsey	USDA/NRCS
Podest	Erika	JPL/Caltech
Reichle	Rolf	NASA/GSFC
Restrepo	Pedro	NOAA/NWS/OHD
Santanello	Joseph	NASA/GSFC
Savinell	Chris	NASA/GSFC
Schneider	Stanley	NASA/GSFC
Schoenung	Susan	BAERI
Senay	Gabriel	USGS
Sjoberg	Bill	NOAA/NWS
Snyder	Greg	USGS
Tadesse	Tsegaye	NDMC
Temimi	Marouane	NOAA/CREST
Teng	William	NASA/GES DISC
Thibeault	Marc	CONAE

Last Name	First Name	Affiliation
Tischler	Mike	USACE/ERDC/TEC
Toll	David	NASA/GSFC
Tralli	David	JPL/Caltech
Tran	John	JPL/Caltech
Turk	Joe	JPL/Caltech
Uccelini	Louis	NOAA/NWS/NCEP
Verdin	James	USGS
Vicente	Gilberto	NOAA/NESDIS
Vollmer	Bruce	NASA/GSFC
Volz	Stephen	NASA/HQ
Wang	Weile	NASA/ARC
Webb	Allan	NPOESS
Weng	Fuzhong	NOAA/NESDIS/STAR
Williams	David	USEPA
Wu	Wanru	NOAA/NWS/OHD
Yang	Hu	NOAA/NESDIS/STAR
Yilmaz	Tugrul	GMU
Yuen	Karen	JPL/Caltech
Zhan	Xiwu	NOAA/NESDIS/STAR
Zheng	Weizhong	NOAA/NCEP/EMC

Appendix II. Results from the Application Engagement at the SMAP Applications Workshop September 9–10, 2009

Follow-on contacts are highlighted in bold italic in column 5.

Application	Description	Community of Practice	Community of Potential	Contact or Action Item
Weather				
Improve numerical weather predictions	SMAP data can be included in a land data assimilation system to improve numerical weather predictions. This includes improvement of land surface fluxes, surface characteristics for coupling with radiation and with upper-air data assimilation, and potentially prediction of atmospheric aerosol loading). More realistic soil moisture conditions will also be used to improve air quality and dispersion modeling, through better representation of boundary layer mixing. Freeze/thaw measurements from SMAP could be used to correct and/or validate land surface model freeze/thaw state simulations. High-resolution radar data from SMAP could also be used to improve analysis of near-surface winds over water near coastal areas.	DoD, EC, ECMWF, JMA, JCSDA, Meteo-France NCEP, NOAA/NESDIS, UKMet Note: DoD is very large and includes more than one agency interested in SMAP soil moisture (e.g., AFWA, USACE/CRREL, USACE/TEC, USNRL and others)	NCAR	AFWA: J. Eylander USACE/CRREL: B. Davis USACE/TEC: M. Tischler USNRL: W. Johnston EC: S. Belair ECMWF: P. de Rosnay Meteo-France: J-F Mahfouf NCEP: M. Ek NESDIS: X. Zhan
Determine ground mobility, visibility (dust and aerosols loading), and air quality / dispersion	This information could also be applied to land resources management and soil conservation (e.g. erosion, etc.) with community of practice USDA/NRCS, USFS, USBOR and more.	DoD, NOAA/NWS, American University Dubai	DHS, EASA, FAA, Nav Canada, NIH, EPA, CIESIN	NOAA/NWS: L. Friedl & J. Famigletti Am. Univ. Dubai: H. Gheddir
Specify land surface emissivity	The atmosphere is nearly transparent at L-band. SMAP measurements combined with calibrated models allow estimation of emissivity in the-low frequency microwave portion of the spectrum. Retrieval of precipitation over land from GPM and other microwave radiometers requires knowledge of land emissivity. Knowledge of emissivity reduces errors in estimates of precipitation based on remote sensing over land.	NOAA, NASA	ITWG	GPM Project.

Natural Disasters				
Operational drought forecasting	Drought forecasting involves the use of numerical weather and climate prediction models to forecast meteorological conditions that will impact the future evolution of drought conditions. The accurate characterization of surface soil moisture conditions has been hypothesized to improve the quantitative forecasting of precipitation and temperature in some areas. NOAA/NCEP (CPC and EMC) and NESDIS (STAR) are collaborating on assimilating satellite observations to the numerical seasonal climate prediction models for the US Drought Monitoring system. The NIDIS US Drought Portal is part of the interactive system to provide early warning about emerging and anticipated droughts, assimilate and quality control data about droughts and models, and provide information about risk and impact of droughts to different agencies and stakeholders. Assimilating SMAP soil moisture products into the US Drought Portal could improve drought forecasting ability. The US Drought Portal is currently using a soil moisture product and could potentially use SMAP products L2_SM_A/P, L2_SM_P and L4_SM. CONAE is a specialized agency of the Argentine State, and the only government body to understand, design, execute, control, manage and administer space projects and entrepreneurships throughout the country. It represents the Nation's civil research and development capabilities in space activities. SMAP data could be applied by CONAE through its Space Information System for Emergency Management to provide space information for early warning, prevention, crisis monitoring and recovering. Frequent users are the Agricultural and Water agencies, as well as the National Park Administration and the Fire National Management Plan. CONAE currently uses a soil moisture product and could potentially use SMAP products L2_SM_A/P and L4_SM. AWCI promotes integrated water resources management by making usable information from GEOSS, for addressing the common water-related problems in Asia. The AWCI goal is to better understand the mechanism of variability in the Asian water cycle and to improve its predictability, and to interpret the information applicable to various water environments in different countries in Asia. Thus, AWCI can help to mitigate water-related disasters and promote the efficient use of water resources. The addition of SMAP L2–4 products could be used to improve agricultural and forestry efforts embarked by AWCI through integration into numerical forecasting and fusion with local observations. AWCI currently uses a soil moisture product and could potentially use SMAP products L2_SM_A/P, L2_SM_P and L4_SM.	NIDIS, NOAA/NWS/NCE, NOAA/NESDIS/STAR, USDA/FAS/JAWF and NOAA/OHD CONAE, GEO/ AWCI		NWS/NCEP: M. Ek NOAA/NESDIS/NCDC: J. Bates & M. Brewer NOAA/NESIDS/STAR: X. Zhan FAS/JAWF: H. Shannon NOAA/OHD: B. Cosgrove NIDIS: J. Verdin CONAE: M. Thiebualt & D. Dadamia GEO/AWCI: Will Possi
Land degradation and desertification	Prolonged drought is associated with long-term changes in soil productivity and subsequent impacts on vegetation land cover type. SMAP data products could be used to map trends in land degradation and desertification.	USAID, AgroMet, WMO, UNESCO		USAID: C. Stokes & D. Healy AgroMet: ***[Fritz to follow-up]*** WMO & UNESCO: ***[T. Engman to follow-up].***

Fire susceptibility	Soil moisture is an important variable in the determination of fuel moisture content, which, in turn, is a critical prognostic variable for fire risk. As in other applications, fire susceptibility monitoring and decision support systems currently use proxy information for soil moisture content and would benefit from the availability of direct observations of surface and/or vegetation water content.		USDA/FAS	
Operational stream flow modeling and flash flood guidance	Antecedent soil moisture conditions typically exert strong control over basin-scale response to runoff and are therefore a required initial condition for event-based rainfall-runoff modeling. In current operational systems, such information is provided by simplistic water balance models and is unconstrained by any direct observation of soil moisture. While operational systems are not yet ready to operationally assimilate SMAP data products, SMAP soil moisture retrievals could easily be integrated into analyst-based flash flood warning systems as a vital piece of additional information describing the current infiltration capacity of the land surface.	NOAA/OHD, DoD, USGS, NOAA/NCEP, USBOR, NOAA/OHD, NOAA/NWS/RFC, HRC, CONAE, CIESIN		NOAA/OHD: B. Cosgrove DoD: B. Davis USGS: H.. Linns NOAA/NCEP: M. Ek USBOR ***[ask D. Toll for name]*** NOAA/NWS/RFC: ***[B. Cosgrove to follow-up],*** HRC: K. Georgakokos CONAE: M. Thibeault
Global flood mapping			FEMA	***FEMA: [B. Cosgrove to investigate]*** Dartmouth College: Brakenridge
Freshwater lake and river ice break-up	The current ice status of lakes and rivers is an important variable for predicting the extent and duration of cold-season flooding events. This information is potentially available from SMAP radar backscatter observations.	NOAA/NWS/RFC, USACE/CRREL, NOAA/NIC, USCG		USACE/CRREL: B. Davis NOAA/NIC: P. Colon ***USCG: [Fritz to follow-up]***
Heat wave forecasting			County and city government	
Climate Variability and Change				
Improve seasonal climate forecasts	Soil moisture is a climate state with enough memory to contribute some skill to subseasonal and seasonal weather forecasts, as demonstrated in several recent studies. Seasonal forecasting systems can therefore make good use of SMAP soil moisture information (through the root zone) for forecast initialization. Relevant SMAP products are L4_SM and L4_C. Note: For climate, there are currently few operational applications that will be able to use SMAP data, but there is much potential. The SMAP mission should raise awareness in the community of potential.	Operational seasonal forecast centers, including NOAA/NCEP/CPC, ECMWF, Environment Canada, and Australia's BMRC. Experimental seasonal forecast projects include that at NASA/GMAO	Various university groups	NCEP/CPC: M. Ek ECMWF: P. de Rosnay Env. Canada: B. Merryfield & A. Berg NASA/GMAO: R. Reichle & R. Koster

International climate monitoring	In an Integrated Earth System Analysis, a wide variety of remotely sensed and in situ measurements are combined in the context of a coupled ocean-atmosphere-land model to produce a mathematically optimal description of the full climate system and its variations. SMAP data (all products) could be an important component of such an integrated analysis, contributing in particular to estimates of land surface conditions, aerosols, trace gases, carbon, and dust. This application may need SMAP products in standard satellite data streams provided by, for example, NOAA/NESDIS, and may need near-real-time latencies.	NASA/GMAO, NCEP, ECMWF, JMA.	USDA/NRCS, EPA, NASA NEWS program, WCRP/GEWEX, general science community.	NASA/GMAO: R. Reichle & R. Koster
Develop a climate data record (CDR) for soil moisture	NOAA has identified soil moisture as an essential variable for the CDR, which is a data-based characterization of long-term means, variability, and potential trends of key climate variables. SMAP data can be considered an important component of the soil moisture CDR which must be constructed from a variety of soil moisture data sources (including *in situ* networks, SMMR and NASA/AMSR surface soil moisture, TRMM/TMI, WindSat, ESA/SMOS data, etc.) that span as long a time period as possible.	NOAA/NCDC, NOAA/NESDIS/STAR, USDA/NRCS, ADAGUC/Free University of Amsterdam , GEO/IGWCO/ISMWG		NOAA/NCDC: T. Karl NESDIS/STAR: X. Zhan ADAGUC: R. de Jeu ISMWG: W. Possi
Improve earth system models	Our most useful tools for long-term climate prediction (century-scale) are Earth system models, of the type used for the IPCC reports. The main limitations to this type of tool are deficiencies in model formulation, and the only way to get past these deficiencies is through model development work tied closely to the analysis of Earth system observations, including soil moisture. SMAP soil moisture products can serve as a useful resource for model development and verification, particularly with respect to the calculation of the land surface energy, water, and carbon budgets and the modeling of trace gases, irrigation, aerosols, dust, albedo, and land use. It can also contribute to the mapping of land surface physical and microwave radiative properties (soil texture, roughness, dielectric constants). All SMAP data products (L1-L4) are relevant to this application.		All Earth system modeling centers (GFDL, NASA/GISS, NCAR, NASA/GMAO, international groups, NOAA/ESRL, etc.), the general climate science community.	

Agriculture and Forestry				
Agricultural drought monitoring	Agricultural drought is defined as a deficit of soil water relative to use requirements for normal vegetation productivity. Current monitoring effects are based on the indirect inference of soil moisture via soil water balance modeling and/or vegetation conditions. Direct soil moisture measurements are limited in scope and inadequate for regional-scale characterization. SMAP will provide direct, large-scale observations soil moisture and reduce uncertainty in our ability to characterize the spatial extent and magnitude of agricultural drought.	NOAA/NCEP/EMC, NDMC, NIDIS, USAID, USDA/NRCS, NOAA/NESDIS, JECAM		NDMC: M. Hayes NIDIS: J. Verdin, USAID: C. Stokes USDA/NRCS: G. Schaffer NOAA/NESDIS: X. Zhan JECAM: C. Justice (UM) or J. Fan (GEO)
Famine early warning	The Famine Early Warning Systems Network (FEWS NET) is a USAID-funded activity that collaborates with international, regional and national partners to provide timely and rigorous early warning and vulnerability information on emerging and evolving food security issues. FEWS NET professionals in the Africa, Central America, Haiti, Afghanistan and the United States monitor and analyze relevant data and information in terms of its impacts on livelihoods and markets to identify potential threats to food security. SMAP data could be integrated in the FEWS NET to improve agricultural forecasts and more accurately identify anomalous agriculture conditions. FEWS NET currently uses a soil moisture product and could potentially use SMAP products L2_SM_A/P, L2_SM_P, L4_SM and L4_C.	FEWS Net		FEWS Net: G. Senay, M. Brown, J. Verdin & D. Cline

Improve crop forecasting	The addition of SMAP L2–4 products could be used to improve crop forecasting ability and assess global agricultural drought. In addition, the L3_F/T_A product could be used to determine times of winterkill. Seven programs were identified for SMAP applications. Three programs are already using a soil moisture product: 1) The Foreign Agricultural Service (FAS) of the U.S. Department of Agriculture (USDA) works to improve foreign market access for U.S. products, build new markets, improve the competitive position of U.S. agriculture in the global marketplace, and provide food aid and technical assistance to foreign countries. 2) Agriculture and Agri-Food Canada (AAFC) provides information, research and technology, and policies and programs to achieve security of the food system, health of the environment and innovation for growth. AAFC, along with its portfolio partners, reports to Parliament and Canadians through the Minister of Agriculture and Agri-Food and Minister for the Canadian Wheat Board. 3) SMAP data could be applied by CONAE through its Space Information System for Emergency Management. Four programs were identified that could use a more realistic soil moisture characterization to improve the assessment of agricultural conditions: 1) In collaboration with colleagues in the Sustainable Development Network and across the Bank, ARD works to reduce poverty through sustainable rural development. To this end, ARD provides analytical and advisory services to the Bank's regions on a wide range of agriculture and rural development topics. These services include the preparation and implementation of the World Bank's corporate strategy on rural development, monitoring of the Bank's portfolio of agriculture and rural projects, and promoting knowledge sharing among agriculture and rural development practitioners, inside and outside the Bank, in order to continually improve the Bank's activities in rural areas. 2) The Food, Agriculture and Natural Development (FANR) Directorate of SADC is one of four directorates at the SADC Secretariat. Its main function is the coordination and harmonization of agricultural policies and programs in the SADC region, in line with priorities in the RISDP. The main focus of FANR is to ensure food availability, access, safety and nutritional value; disaster preparedness for food security; equitable and sustainable use of the environment and natural resources; and strengthening institutional framework and capacity building. 3) ESA in the context of the CEOS, launched in 2002 the TIGER initiative aimed at: “assisting African countries to overcome problems faced in the collection, analysis and dissemination of water related geo-information by exploiting the advantages of Earth Observation (EO) technology”. TIGER efforts include monitoring agriculture and support to food security, and soil moisture monitoring service. More realistic soil moisture characterization could be used to improve the TIGER assessment of agricultural conditions. 4) The World Food Programme is the world's largest humanitarian agency fighting hunger worldwide. The WFP provides food security analysis including vulnerability analysis and mapping from field analysis and satellite observations.	USDA/FAS/IPAD, Ag Canada/AAFC, CONAE	USDA/NASS, WB/ARD, SADC/FANR, ESA/CEOS/TIGER, AGROmet, UN/WFP	FAS/IPAD: W. Crow & C. Reynolds CONAE: M. Thiebualt & D. Dadamia Ag. Canada: C. Champagne SADC: K. Masasvu Botswana ESA/CEOS/TIGER: ? Toshio, U. Tokyo WB: ***[W. Possi will follow-up]***

Vegetation health and/or crop productivity monitoring	An obvious extension of drought monitoring and forecasting activities is the prediction of subsequent impacts of vegetation health and productivity. For agricultural, the ultimate goal of such predictions is forecasting agricultural yield. Since agricultural drought is the primary source of inter-annual variability in agricultural crop productivity, soil moisture estimates have a clear role in international crop monitoring activities. Partners involved in these activities and capable of participating in the community of practice include USDA/FAS [W. Crow/C. Reynolds], UN/FAO [K. Cressman, Desert Locust Information Service] and JECAM [C. Justice and J. Fan]. This group also potentially contains crop insurance providers interested in modeling exposure to crop failure. In a non-agricultural systems, vegetation health monitoring focuses on the impact of drought on plant productivity and broad ecosystem function.	USDA/FAS, NDMC, UN/FAO, JECAM		NDMC: M. Hayes & T. Tadesse USDA/FAS: C. Reynolds UN/FAO: K. Cressman & J. Bolten ***[J. Bolten will follow-up with FAO]*** JECAM: C. Justice (UM) and J. Fan (GEO)
Crop management	USDA/NRCS manages natural resource conservation programs that provide environmental, societal, financial, and technical benefits. SMAP data could be used to tell an individual farmer if it is economically feasible to plant a crop, and at finer resolutions, which crop to plant. The SMAP product L3_F/T_A could be used to identify winter kill. There is potential to forecast heat and water stress on agricultural crops. Soil moisture information is critical for scheduling of planting, harvesting, and irrigation. Relevant SMAP products include L2_SM_A/P, L2_SM_P, L3_F/T_A, and L4_SM. Arguably, the resolution of SMAP products is a better match for climate scales than crop management. Some applications will require downscaling approaches that have yet to be developed. For example, decision support for agricultural production must be at the USDA/NRCS/SSURGO, not the USDA/NRCS/STATSGO, level.		USDA/NRCS, USFS	USDA/NRCS: D. Plunk & G. Schaefer ***[W.Crow will investigation irrigation application]***
Fire forecasting and management at seasonal time scales	Soil moisture has potential to be used as an input to fuel loading models for fire forecasting and management.		USFS, CONAE	CONAE: M. Thiebualt & D. Dadamia
Human Health				
Landscape epidemiology	Most vectors, hosts and pathogens are commonly tied to the landscape as environmental determinants control their distribution and abundance. Soil moisture can be used as a predictor of risk patterns and environmental risk factors of vector-borne diseases including malaria, Chagas, hantavirus, and Lyme disease.	CDC [There is a NASA/CDC MOU]; DOD; EPA	RBM, WHO	CDC: K. Gage ***[Contact NASA J. Haynes for a list of funded NASA proposals on human health]*** ***[T. Jackson will follow-up with contacts in human health]***
Heat stress and drought monitoring	Water deficiency is a stress inhibitor in plants and may lead to drought. Soil moisture products from SMAP will provide direct, large-scale observations and reduce uncertainty in our ability to characterize the spatial extent and magnitude of landscape drought and vegetation heat stress. This application will provide better estimates for population water availability and agricultural productivity.	USDA, FAO		USDA: Wade Crow, FAO: M. Cosh
Emergency Response Plans	Areas of high risk for flooding or landslides can be determined through the combined use of soil moisture products and a DEM. Emergency response plans can be developed accordingly.	International Red Cross/red crescent:		

Insect Infestation	If plenty of water and vegetation for food exist in the locust breeding areas, a large number of the insects hatch and form swarms which destroy crops. Soil moisture can be used to determine areas most likely to become locust breeding grounds.	FAO, NASA/GSFC, IRI		FAO: K. Cressman; NASA/GSFC: J. Bolten, IRI: P. Ceccato
Ecology				
Ecosystem forecasts	A phase lag has been noted between wet soil and vegetation growth. Centers interested in forecasting the health and abundance of ecosystem resources (even regarding animal migration) may find value in soil moisture. Relevant SMAP products are L4_SM, L3_F/T_A, and L4_C.	CCRS	USDA/NRCS, USFS, State of Alaska, University community	CCRS: A. Trichtchenko
Carbon Source/Sink Monitoring, Carbon Management	The SMAP L4_C product processes SMAP F/T and soil moisture information with ancillary data to generate a wealth of carbon flux estimates. The product can thus contribute to national and international efforts to evaluate carbon sources and sinks.	Carbon Tracker	EPA, DoE, USDA, LSCE (France), NACP Fluxnet, LBA	CarbonTracker: P. Tans
Monitor wetlands resources and bird migration	The SMAP L1B_S0_LoRes product uses a "wetlands flag" that could potentially provide information on wetlands distributions (surface water, percentage of inundated area) that are key to tracking wildlife migration.		USFWS, USBOR, WRI, Ethiopia	WRI: K. McDonald ***[K. McDonald will follow-up with WRI]***
Water Resources				
Forecast seasonal water resources	Water resource managers in the west typically look to snowpack estimates to generate forecasts of streamflow in the spring. The soil underlying the snow, however, has an impact on snowmelt-generated streamflow – the drier the soil below the snowpack, the greater the infiltration of snowmelt into the soil, and the smaller the resulting streamflow and subsequent reservoir storage. Knowledge of soil moisture could thus contribute to water resource planning. For this potential application, the SMAP L4_SM product (measured prior to snowfall) would be most relevant, along with ancillary data such as snowpack estimates and seasonal climate forecasts. This application is in its infancy but could potentially be developed in time for SMAP launch.	NIDIS	USDA/NRCS, NRCS/SNOTEL, FAO, USACE, university groups.	NIDIS: J. Verdin

Monitoring variability of water stored in lakes, reservoirs, wetlands and river channels				
Mapping/modeling water recharge into groundwater			NASA/GRACE, NASA/GSFC, USGS	NASA/GRACE: M. Rodell NASA/GSFC: C. Peters-Lidard, USGS: C. Voss
Ocean Resources				
Retrieve sea-ice coverage using SMAP high-resolution SAR data.	Monitoring sea ice thickness and coverage provides valuable information on heat fluxes in the Arctic system. The SMAP L1_S0_HiRes product may provide valuable information if collected over the oceans (daily to weekly). Currently, RadarSat data are used. Also, the SMAP L3_F/T_A product may serve as an indicator for ice-free conditions of shipping lanes, useful for navigation.	NOAA/NIC, NSIDC	CCRS, CIC, NSIDC, NASA/GSFC, University community	CCRS: A. Trichtchenko NOAA/NIC: P. Clemente-Colon NSIDC: W. Meier NASA/GSFC: L. Koenig
Coastal sea-surface salinity	The NASA Aquarius mission is designed to retrieve sea-surface salinity using L-band radiometry and scatterometry. High-accuracy measurements are required due to the low sensitivity of the signals to open-ocean variations in surface salinity. The SMAP L-band radiometer does not have the same single-look accuracy as Aquarius. Nonetheless, the SMAP conical scan makes many more measurements that can be averaged to the resolution requirements of Aquarius-based salinity retrievals. A long-term data set on sea surface salinity is possible with the Aquarius and SMAP flights. Furthermore, SMAP higher resolution allows retrieval of sea surface salinity in the coastal zone where the dynamic range and hence L-band signatures are higher.	NASA, NOAA		
Ocean vector winds, High winds	PALS airborne and JERS-1 spaceborne L-band radar systems have been demonstrated to be capable of high-resolution mapping of sea-surface wind speed and direction. Current scatterometers dedicated to mapping ocean winds use C-band and Ka- and Ku-band frequencies. The wind-speed signature at these frequencies saturate for heavier wind-speeds. At the lower L-band deployed by SMAP the wind-speed signal does not saturate until about 50 m/s. SMAP high-resolution ocean surface wind speed and direction estimates can significantly enhance capability to monitor and track hurricanes. The high resolution allows critical near-coast monitoring.		NOAA/NHC, DoD JTWC	JPL: S.Yueh JAXA: T. Shimada
Insurance Sector				
Crop insurance	USDA/RMA provides policies for more than 100 crops, a number which would be much higher if every insurance plan available for the crops insured in every county were counted. USDA/RMA also conducts studies to determine the feasibility of insuring other crops. Federal crop insurance policies typically consist of the Common Crop Insurance Policy, the specific crop provisions, and policy endorsements and special provisions. Relevant SMAP products include L2_SM_A/P, L2_SM_P, and L4_SM.		USDA/RMA, crop insurance community	RMA: B. Teng & J. Hipple ***[B. Teng will follow-up]*** ***[Contact B. Gurney for more information]***

Flood insurance				
Tourism and recreation				

During the break-out sessions, some cross-cutting applications were raised regarding the use of SMAP data:

Application	Action Item
Improvement of precipitation estimates from soil moisture increments	Identify and engage community of practice and/or potential for these applications
Determination of temperature profiles within permanent ice (down to 60m) from the L-band radiometer	
Societal vulnerability maps: Can F/T data feed into analysis of village relocation?	
Fluxes of methane and trace gases in the Arctic during springtime	
Energy demand (and source) forecasting	
Construction of roads and building (e.g., use of F/T data in Alaska)	
Space weather (mapping of Faraday rotation, Total Electron Content, especially in the polar auroral zone)	
L-band RFI detection and mapping, for policy enforcement	
Ecological impacts of rain on snow	

Appendix III. Results from the Application Engagement at the SMAP Applications Workshop September 9–10, 2009 (continued)

At the workshop, groups were identified that could provide information about SMAP applications to the broad science community to build support for application of SMAP data products [termed SMAP Community of Support]. This list is not exclusive.		
Group	**Description**	**Contact or Action Item**
GEO/GEOSS IGOS-P IGWCO ISMWG JECAM	The Group on Earth Observations (GEO) is coordinating efforts to build a Global Earth Observation System of Systems, or GEOSS. The Global Water Cycle theme has been established by the Integrated Global Observing Strategy Partnership (IGOS-P). The overall objective of the IGWCO is to develop and promote strategies for the coordination of diverse global water cycle observing systems, and to make progress towards an integrated water cycle observation system that unites data from different sources (e.g. satellite systems, in-situ networks, field experiments, and new data platforms) with emerging data assimilation and modeling capabilities. The International Soil Moisture Working Group (ISMWG) was established in 2005 to handle the main objectives of this IGWCO water cycle variable. JECAM is an ongoing effort of GEOSS. The focus of this initiative is to identify cropland pilot sites around the world (representative of a range of agricultural systems) and collect time series datasets from a variety of Earth observing satellites and in-situ data sources at each site. The goal is to facilitate the inter-comparison of monitoring and modeling methods, product accuracy assessments, data fusion and product integration, for agricultural monitoring. It is hoped that these comparative studies will enable international standards to be developed for data products and reporting.	JECAM contacts: C. Justice & J. Fan ***[Dr. Possi (NOAA) will send a letter of support from IGWCO to SMAP Mission.]***
NOAA/RISA	The NOAA/RISA program supports research that addresses complex climate sensitive issues of concern to decision-makers and policy planners at a regional level. The RISA research team members are primarily based at universities though some of the team members are based at government research facilities, non-profit organizations or private sector entities. Traditionally the research has focused on the fisheries, water, wildfire, and agriculture sectors. The program also supports research into climate sensitive public health issues. Recently, coastal restoration has also become an important research focus for some of the teams.	Contact: C. Simpson & J. Verdin ***[J. Verdin will follow-up with RISA]***
USDA/RSCC	Several agencies within the U.S. Department of Agriculture (USDA) use remote sensing data, tools, and related technologies to support research, program, and operational activities. Although each agency has a different mission and responsibilities, similar data sets and technologies are used by multiple agencies to help them accomplish their objectives. The Remote Sensing Coordination Committee (RSCC) brings together experts from each of these agencies to promote information sharing within USDA and to help ensure the most efficient and cost-effective use of these data and technologies by the Department.	Contact: M. Cosh ***[M. Cosh made a presentation about SMAP mission and applications to RSCC]***
RCMRD, SERVIR-Africa	RCMRD is an Inter-Governmental organizational which promotes the development and use of Geo-Information and and Information Technology, in the sustainable development of Africa, by assisting in human resources and institutional capacity building. **SERVIR Africa**: A 21st Century System for Improved Environmental Decision Making for Africa. SERVIR is a regional visualization and monitoring system for Africa that integrates satellite and other geospatial data for improved scientific knowledge and decision making. SERVIR addresses the nine societal benefit areas of the Global Earth Observation System of Systems (GEOSS): disasters, ecosystems, biodiversity, weather, water, climate, oceans, health, agriculture, and energy. The effort intensively utilizes and integrates NASA satellite observations and predictive models, along with other geographic information (satellite, sensor, and field-based). SMAP data could be applied to SERVIR effort to improve soil moisture characterization.	

NOAA	NOAA and NASA can partner to make best use of assets like SMAP for the benefit of the public. NOAA leadership and the SMAP Mission can explore ways of making the collaboration even more meaningful and make data readily accessible as we go forward with the project. In the pre-flight period there are many preparatory activities that may be implemented. These include working with simulated mission data to test data protocols and assess their value in hindcast applications. Given the SMAP launch readiness in early 2014 and three-year baseline operational period, the SMAP data stream can also be an important gap-filler for the NPOESS series of satellites that have soil moisture as a Key Performance Parameter (KPP). Until the NPOESS Microwave Imager/Sounder (MIS) is flown, SMAP can provide valuable soil moisture information for the NOAA community. In fact given SMAP's low-frequency microwave radar and radiometer approach to measurements, SMAP soil moisture retrievals exceed the Integrated Operational Requirements Document II (IORD-II) Threshold Requirements and begin to approach the Objective Requirement. In this sense SMAP data can also serve as the benchmark data for improving NPOESS requirements and algorithms. [taken from Dara's letter to Dr. Mary Kicza, NOAA Assistant Administrator for Satellite and Information Services]	Contact: X. Zhan ***[D. Entekhabi (SMAP SDT lead) sent an informational letter about SMAP applications to NOAA Administrator Dr. Kicza]***
WGA	The Western Governors' Association serves the governors of 19 US western states and 3 US-Flag Pacific Islands. It includes initiatives on climate change and adaptation, energy and transmission, forest health and wildfire, radioactive waste transportation, regional biomass energy, transportation fuels for the future, western regional air quality, renewable energy and wildlife habitat.	
International Red Cross	The International Red Cross and Red Crescent Movement is the world's largest humanitarian network. The Movement is neutral and impartial, and provides protection and assistance to people affected by disasters and conflicts.	
RBM	Roll Back Malaria (RBM) is the global framework to implement coordinated action against malaria.	***[J. Verdin will follow-up with Steve Conner]***
Other Missions	A topic of discussion at the 1st SMAP Applications Workshop was coordination of applications for current and future satellite missions, particularly other microwave missions and the planned Decadal Survey Missions. Some of the missions identified included: • NPOESS/MIS • NOAA/DoD/NASA WINDSAT • NASA/AMSR • DoD/SSM/I • ESA/SMOS • NASA/TRMM/TMI • NASA DS Missions listed in Table 7	NPOESS Contact: G. McWilliams AMSR Contact: Y. Kerr

Appendix IV. Acronyms

AAFC	Agriculture and Agri-Food Canada
ADAGUC/Free University of Amsterdam	Atmospheric data access for the geospatial user community
AFWA	Air Force Weather Agency
AgCanada	Agriculture Canada
AgroMet	Agro Meteorology
AMSR-E	EOS-Advanced Microwave Scanning Radiometer
ApplWG	Applications Working Group
ARL	Applications Readiness Levels
ASP	Applied Sciences Program
Australia's BMRC	Bureau of Meteorology Research Centre
BAERI	Bay Area Environmental Research Institute
CCRS	Canadian Centre for Remote Sensing
Cal/Val	Calibration/Validation
CDC	Center for Disease Control
CIC	Canadian Ice Centre
CIESIN	Center for International Earth Science Information Network (Columbia University)
CONAE	National Commission on Space Activities, Argentina
CONUS	Contiguous United States
CPBS	Center for Pacific Basin Studies
CSA	Canadian Space Agency
DAAC	Distributed Active Archive Center
DHS	Department of Homeland Security
DoD	Department of Defense
DoD/JTWC	DoD Joint Typhoon Warning Center
DoD/SSM/I	DoD Special Sensor Microwave Imager
DoE	Department of Energy
EASA	European Aviation Safety Agency
EC	Environment Canada
ECMWF	European Centre for Medium-Range Weather Forecasts
EOS	Earth Observing System
ERS	European Remote Sensing
EPA	Environmental Protection Agency
ESA	European Space Agency
ESA/CEOS	ESA Committee of Earth Observation Satellites
ESA/CEOS/TIGER	ESA/CEOS space technology for water resource management in Africa
F/T	Freeze/thaw
FAA	Federal Aviation Agency
FAO	Food and Agricultural Organization
FEMA	Federal Emergency Management Agency
FEWS Net	Famine Early Warning Systems Network
Fluxnet	Global network of micrometeorological tower sites
GMU	George Mason University
GEO	Group on Earth Observations
GEO/AWCI	GEO Asia Water Cycle Initiative
GEO/IGWCO	GEO Integrated Global Water Cycle Observation
GEO/IGWCO/ISMWG	GEO/IGWCO International Soil Moisture Working Group

GEOSS	Global Earth Observation System of Systems
GFDL	Geophysical Fluid Dynamics Laboratory
HRC	Hydrologic Research Center
IGOS-P	Integrated Global Observing Strategy Partnership
IOC	In-orbit Checkout
IRI	International Research Institute for Climate and Society (Columbia University)
ITWG	International TOVS Working Group
JAXA	Japan Aerospace Exploration Agency
JCSDA	Joint Center for Satellite Data Assimilation
JECAM	Joint Experiments on Crop Assessment and Monitoring Initiative
JMA	Japan Meteorological Agency
LBA	Large-Scale Biosphere Atmosphere Experiment in Amazonia
LIS	Land Information System
LSCE	Le Laboratoire des Sciences du Climat et l'Environnement, France
Météo-France	French Meteorological Service
Météo -France /CNRM	Météo -France Centre National de Recherches Météorologiques
MIS	Microwave Imager/Sounder
MIT	Massachusettes Institute of Technology
NACP	North American Carbon Program
NASA	National Aeronautics and Space Administration
NASA/ARC	NASA Ames Research Center
NASA/ESTO	NASA Earth Science Technology Office
NASA/GES DISC	NASA Goddard Earth Sciences Data and Information Services Center
NASA/GISS	NASA Goddard Institute for Space Studies
NASA/GMAO	NASA Global Modeling and Assimilation Office
NASA/GRACE	NASA Gravity Recovery and Climate Experiment
NASA/GSFC	NASA Goddard Space Flight Center
NASA/HQ	NASA Headquarters
NASA/JPL	NASA Jet Propulsion Laboratory
NASA/MSFL	NASA Marshall Space Flight Center
NASA/NEWS	NASA Energy and Water Cycle Study
NASA/SMAP	NASA Soil Moisture Active Passive mission
NASA/SMAP SDT	NASA SMAP Science Definition Team
NASA/TRMM/TMI	NASA Tropical Rainfall Measuring Mission Microwave Imager
Nav Canada	Navigation Canada
NCAR	National Center for Atmospheric Research
NDMC	National Drought Mitigation Center
NHC	National Hurricane Center
NIDIS	National Integrated Drought Information Service
NIH	National Institute of Health
NOAA	National Oceanic and Atmospheric Administration
NOAA/CREST	NOAA Cooperative Remote Sensing Science and Technology Center
NOAA/NESDIS	NOAA National Environmental Satellite, Data, and Information Service
NOAA/NESDIS/OSD	NOAA/NESDIS Office of Systems Development
NOAA/NESDIS/NCDC	NOAA/NESDIS National Climate Data Center
NOAA/NESDIS/NCDC/USCRN	NOAA/NESDIS/NCDC U.S. Climate Reference Network
NOAA/NESDIS/STAR	NOAA/NESDIS Center for Satellite Applications and Research
NOAA/NHC	NOAA National Hurricane Center
NOAA/NIC	NOAA National/Naval Ice Center

NOAA/NWS	NOAA National Weather Service
NOAA/NWS/NCEP	NOAA National Centers for Environmental Prediction
NOAA/NWS/NCEP/CPC	NOAA/NCEP Climate Prediction Center
NOAA/NWS/NCEP/EMC	NOAA/NCEP Environmental Modeling Center
NOAA/NWS/OHD	NOAA Office of Hydrologic Development
NOAA/NWS/RFC	NOAA/NWS River Forecast Centers
NOAA/OAR	NOAA Oceanic and Atmospheric Research
NOAA/OAR/ESRL	NOAA/OAR Earth Systems Research Laboratory
NOAA/RISA	NOAA Regional Integrated Science and Assessments
NOAA/TOVS	NOAA TIROS Operational Vertical Sounder
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	Net Primary Productivity
NRC	National Research Council
NSIDC	National Snow and Ice Center
OSU	Ohio State University
RBM	Roll Back Malaria Partnership
RCMRD	Regional Center for Mapping of Resources and Development, Kenya
SAC	SMAP Applications Coordinator
SADC	Southern African Development Community
SADC/FANR	SADC Food, Agriculture and Natural Development
SADC/RISDP	SADC Regional Indicative Strategic Development Plan
SDT	Science Definitions Team
SERVIR-Africa	System for Improved Environmental Decision Making for Africa
SMAP	Soil Moisture Active and Passive
SMOS	Soil Moisture and Ocean Salinity mission
STM	Science Traceability Matrix
TRL	Technology Readiness Level
UA	University of Arizona
UF	University of Florida
UKMet	United Kingdom Meteorological Office
UM	University of Montana
UN	United Nations
UN/FAO	UN Food and Agriculture Organization
UN/FAO/DLIS	UN/FAO Desert Locust Information Service
UN/WFP	UN World Food Program
UNESCO	UN Educational, Scientific and Cultural Organization
UNH	University of New Hampshire
US/ARL	U.S. Army Research Laboratory
US/ARL/ARO	US/ARL Army Research Office
USACE	US Army Corps of Engineers
USACE/ERDC	USACE Engineer Research and Development Center
USACE/ERDC/CRREL	USACE/ERDC Cold Region Research and Engineering Laboratory
USACE/ERDC/TEC	USACE/ERDC Topographic Engineering Center
USAID	US Agency for International Development
USBOR	US Bureau of Reclamation
USCG	US Coast Guard
USDA	US Department of Agriculture
USDA/ARS	USDA Agricultural Research Service
USDA/FAS	USDA Foreign Agricultural Service
USDA/FAS/IPAD	USDA/FAS International Production Assessment Division
USDA/FAS/JAWF	USDA/FAS Joint Agricultural Weather Facility

USDA/NASS	USDA National Agricultural Statistic Service
USDA/NRCS	USDA National Resources Conservation Service
USDA/NRCS/NWCC	USDA NRCS National Water and Climate Center
USDA/NRCS/NWCC/SNOTEL	USDA/NRCS/NWCC SNOwpack TELemetry
USDA/NRCS/SSURGO	Soil Survey Geographic Database
USDA/NRCS/STATSGO	State Soil Geographic Database
USDA/RMA	USDA Risk Management Agency
USDA/RSCC	USDA Remote Sensing Coordinating Committee
USEPA	US Environmental Protection Agency
USFS	US Forest Service
USFWS	US Fisheries and Wildlife Service
USGS	US Geological Survey
USNRL	US Naval Research Laboratory
WB	World Bank
WB/ARD	WB Agriculture and Rural Development
WCRP	World Climate Research Programme
WCRP/GEWEX	WCRP Global Energy and Water Cycle Experiment
WGA	Western Governors' Association
WHO	World Health Organization
WMO	World Meteorological Organization
WRI, Ethiopia	World Resources Institute