DEVELOPMENT OF SMAP MISSION CAL/VAL ACTIVITIES

A. Colliander[1], T. Jackson[2], J. Kimball[3], M. Cosh[2], M. Spencer[1], D. Entekhabi[4], E. Njoku[1], P. O'Neill[5]

(1) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA; (2) USDA Agricultural Research Service, Beltsville, MD, USA;
(3) University of Montana, Missoula, MT, USA; (4) Massachusetts Institute of Technology, Cambridge, MA, USA; (5) NASA Goddard Space Flight Center, Greenbelt, MD, USA

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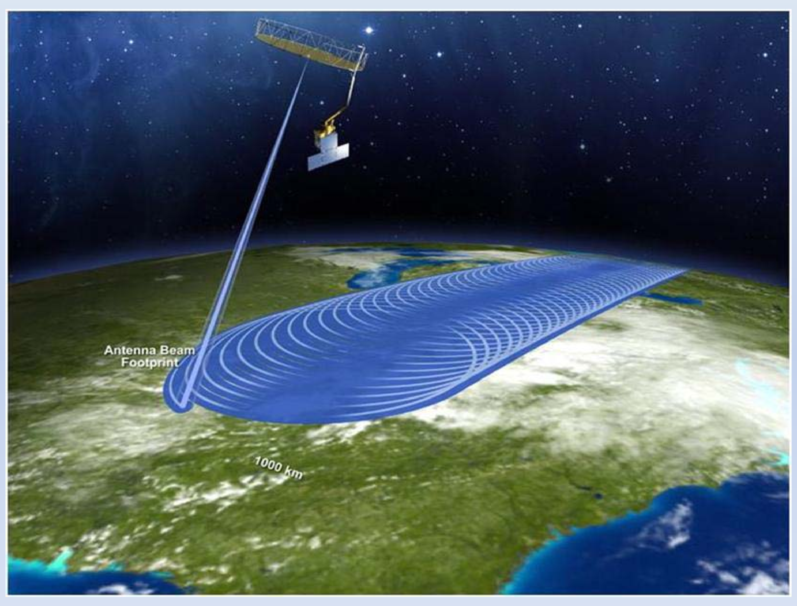
SMAP Mission



SMAP utilizes a conically scanning 6 m reflector antenna, yielding a swath width of 1000 km and spatial resolutions of 40 km and 1-3 km for the radiometer and radar, respectively.

The Soil Moisture Active Passive (SMAP) mission [1] is a NASA directed mission to map global land surface soil moisture and freeze-thaw state. Instrument and mission details are shown below.

The key SMAP soil moisture product is provided at 10 km resolution with 0.04 cm^3/cm^3 accuracy. The freeze/thaw product is provided at 3 km resolution and 80% frozen-thawed classification accuracy. The full list of SMAP data products is shown Table 1.

Table 1: SMAP Mission Products

Data Product	Description
L1B_S0_LoRes	Low Resolution Radar σ^o in Time Order
L1C_S0_HiRes	High Resolution Radar σ^o, on Swath Grid
L1B_TB	Radiometer T_B in Time Order
L1C_TB	Radiometer T_B
L2_SM_A	Radar Soil Moisture*
L2_SM_P	Radiometer Soil Moisture
L2_SM_A/P	Radar/Radiometer Soil Moisture
L3_F/T_A	Daily Global Composite Freeze/Thaw State
L3_SM_A	Daily Global Composite Radar Soil Moisture*
L3_SM_P	Daily Global Composite Radiometer Soil Moisture
L3_SM_A/P	Daily Global Composite Radar/Radiometer Soil Moisture
L4_F/T	Freeze/Thaw Model Assimilation on Earth Grid
L4_SM	Soil Moisture Model Assimilation on Earth Grid

**) Research product not for official release*

Instruments:

- Radar: L-band (1.26 GHz)
  - High resolution, moderate accuracy soil moisture
  - SAR mode: 3 km resolution
  - Real-aperture mode: 5 x 30 km resolution
- Radiometer: L-band (1.4 GHz)
  - Moderate resolution, high accuracy soil moisture
  - 40 km resolution
- Shared Antenna:
  - 6-m diameter deployable mesh antenna
  - Conical scan at 14.6 rpm
  - Constant incidence angle: 40 degrees
    - 1000 km-wide swath
    - Swath and orbit enable 2-3 day revisit

Orbit:

- Sun-synchronous, 6 am/pm orbit
- 680 km altitude

Operations:

- 3-year baseline mission

Cal/Val Activities

Instruments

During the pre-launch phase the instruments (radar and radiometer) will be calibrated to the required accuracy. Pre-launch instrument calibration will include modeling, analysis, simulations, and laboratory and test facility measurements.

The post-launch calibration will make use of instrument parameters measured before launch, internal calibration sources, and external targets including cold-sky. During cold sky calibration the antenna is pointed to measure the known cosmic microwave background. Homogeneous well known Earth surface targets will also be utilized to calibrate and validate the L1 products. These sites include oceans, Antarctica ice sheets, rain forests and possibly deserts. The instrument Cal/Val includes verification of geolocation accuracy, Faraday rotation correction, and antenna pattern correction. Special attention is paid to RFI in the hardware design and post-processing.

Algorithm Pre-Launch Validation

The Science Data System Algorithm Testbed [3] plays a key role in pre-launch algorithm calibration and validation. The Testbed enables full end-to-end simulations of the algorithms. Land surface models are used as inputs to the forward models, and instrument characteristics are accounted for in simulating radar and radiometer outputs. Various algorithm options can be tested, including uncertainties in parameterizations and ancillary data, to test and compare the performance of the algorithms for each product. Field campaign data will also be used to improve the parameterizations and performance of the algorithms.

Satellite data will be utilized for testing and validation of algorithms as well. In particular, the L1C product of the European Space Agency's SMOS (Soil Moisture and Ocean Salinity) satellite will be exploited to exercise the SMAP radiometer based soil moisture algorithm with realistic brightness temperature fields. Other satellite data sets will also be utilized, including ALOS PALSAR and others.

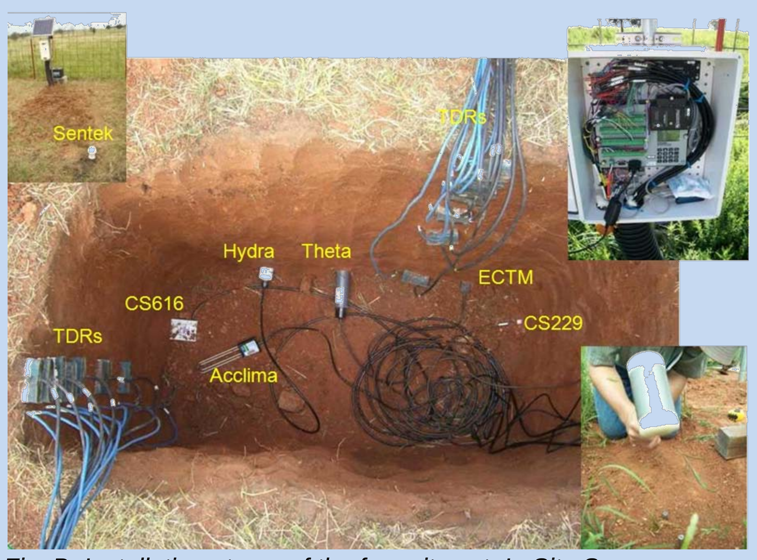


Fig. B: Installation at one of the four sites at In Situ Sensor Testbed in Oklahoma.

Field Campaigns

Numerous SMAP-relevant field campaigns have been carried out over the years. The SMAP project has plans for two major field campaigns: one before launch (SMAPVEX12) and one after launch (SMAPVEX15). In addition, SMAP plans to collaborate in SMAP-related field campaigns conducted by international partners both pre- and post-launch.

The primary objectives of SMAPVEX12 are: 1) to address unresolved algorithm issues from earlier campaigns, and 2) to contribute to establishment of scaling methodology and procedures. Both SMAPVEX12 and SMAPVEX15 are planned to take place over a subset of the Core Sites.

In Situ Networks

NASA plans to coordinate with operational observation networks to acquire in situ measurements globally. The objective is to gain as extensive coverage as possible encompassing the maximum diversity of conditions over the land surface of the Earth. Both the Core Sites and the Sparse Networks will be connected to the Cal/Val Database in order to ensure timely data availability from these sites for the calibration and validation activities.

Up-Scaling and Validation Measurements

Several challenges exist in utilizing in situ sensors for SMAP product validation. Not only do sensor measurement technologies vary among networks but also the installation of the sensors varies. To investigate these issues, an In Situ Sensor Testbed activity was initiated by the USDA in Oklahoma in 2010 (see Fig. B). Utilization of results from this study, and application of robust inter-sensor calibration based on the thermo-gravimetric soil moisture sampling, will improve the reliability and consistency of the in situ data record for SMAP product validation.

Several methods have been proposed for scaling point in situ measurements to satellite footprint scales. The SMAP Science Definition Team will select the appropriate methodologies to be used for SMAP. An experimental Core Site design, accounting for up-scaling to SMAP grid resolutions, has already been implemented in Yanco, NSW, Australia. Each grid cell includes at five least measurements, and lower resolution cells include at least two sampled higher resolution cells (see Fig. C).

The baseline validation source for the freeze/thaw state product is the air temperature. However, the effect of snow, soil surface, and land cover temperatures on the L-band backscatter need to be quantified in the pre-launch phase in order to develop a comprehensive validation approach. Furthermore, an approach to account for the typically high landscape heterogeneity of northern latitudes will be developed. The Alaska Ecological Transect (ALECTRA) Network provides a basis for investigating these effects.

Post-Launch Priorities

A primary objective of the post-launch Cal/Val phase is to validate science products for release to the public. In order to accomplish this objective within the twelve-month period, validation data must be ingested into the Cal/Val database in timely manner. Tools for comparing SMAP products with the validation data must be in place before launch. Validation will be performed by assessing product accuracies relative to the specified requirements for each product. Beyond the twelve-month intensive Cal/Val phase, continuing product accuracy assessments and algorithm refinements will be performed over the entire mission lifetime.

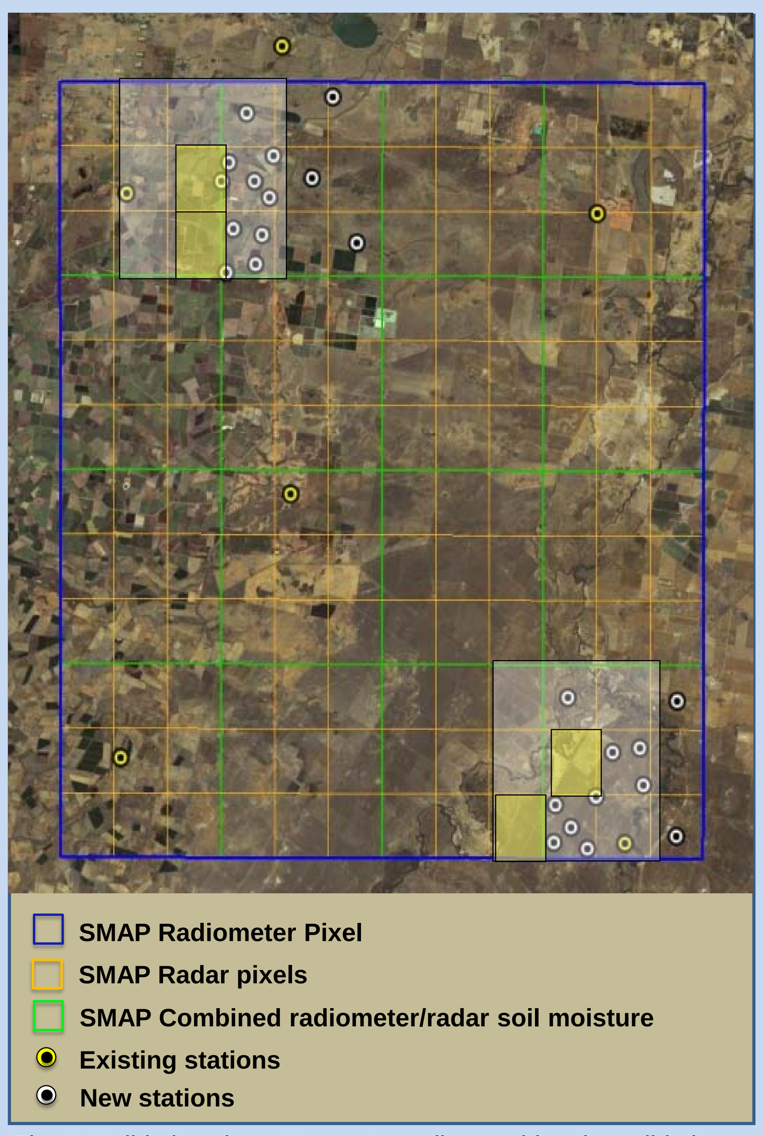


Fig. C: Validation site at Yanco Australia matching the validation site components with the nested SMAP grid (courtesy J. Walker, Monash University, Australia).

[1] D. Entekhabi et al., "The Soil Moisture Active Passive (SMAP) Mission", Proc. IEEE, Vol. 98, No. 5, May 2010.
[2] T. Jackson et al., "SMAP Science Calibration and Validation Plan", Preliminary Release, Ver. 1.0, November 2010.
[3] W. Crow et al., "The SMAP Science Data System Algorithm and Application Simulation Testbed", IGARSS10, July 2010.

Cal/Val Overview

The objective of the SMAP Cal/Val Program is to calibrate and validate Level 1 through Level 4 algorithms and products relative to the mission requirements. The overall strategy to meet this objective includes: (1) cold-sky and homogeneous, stable Earth surface targets; (2) in-situ monitoring using ground-based observation networks; (3) intensive field campaigns using airborne sensors and ground-data acquisition; (4) comparative satellite-based soil moisture products, and (5) land surface modeling. Spatial and temporal scaling techniques are used to make the connection between satellite and in situ observations. The Algorithm Theoretical Basis Documents (ATBD) will define the cal/val approach and requirements for each of the Level 1 through 4 data products.

SMAP Cal/Val activities are divided into pre- and post-launch phases. Emphasis during pre-launch is on algorithm development and characterization of uncertainties (parameterizations and algorithmic implementation). During this phase the infrastructure and methodologies for post-launch validation will also be established. Emphasis during post-launch is on algorithm refinement and L1 through L4 product accuracy assessments over different regions and spatial and temporal time scales.

Methodology

The algorithms are calibrated and validated pre-launch using both simulated and experimental data. Global end-to-end simulations with representative land surface and observational conditions are performed to exercise all algorithms. The simulation runs are tied to the real world by utilizing experimental data from field campaigns and actual satellite observations (e.g. SMOS). An Algorithm Testbed has been implemented on the SMAP Science Data System [3] for running the simulations. The Testbed also includes a Cal/Val Database that stores a wide range of experimental data. Establishment of procedures for timely transfer of required in situ data to the Cal/Val database is a key objective in the pre-launch phase. Methodologies for up-scaling in situ observations to the SMAP footprint scale (see Fig. A) will be established before launch and the processing for the scaling will be implemented on the Testbed. Intermediate-resolution airborne field observations and dense-observation networks are essential for development of reliable up-scaling functions.

In situ observation networks are classified in two categories: 1) Core Sites - dense networks, limited extent of a watershed or region, with multiple samples within a SMAP footprint, and 2) Sparse Networks - with perhaps just one or a few samples within a SMAP footprint (but covering a large extent; continental or global). SMAP product validation efforts in the post-launch phase will emphasize primarily the Core Sites for quantitative accuracy assessments due to their better representation of footprint-scale values. In situ network observations will be augmented by field campaign observations to implement the scaling methodology. Satellites with products similar to SMAP can be used for inter-comparisons and trend analysis. Land surface models can be used to extend the validation domains in space and time. All validation data will be utilized to calibrate and improve the algorithms to yield the best possible products.

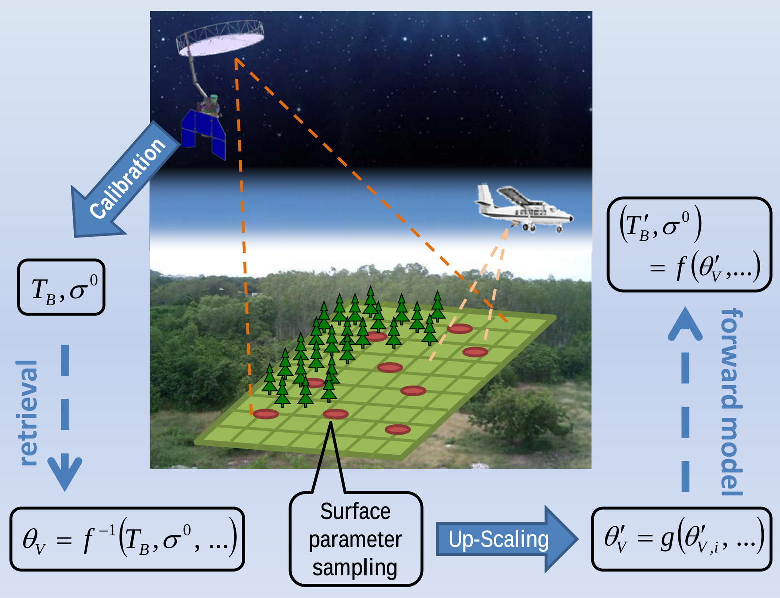
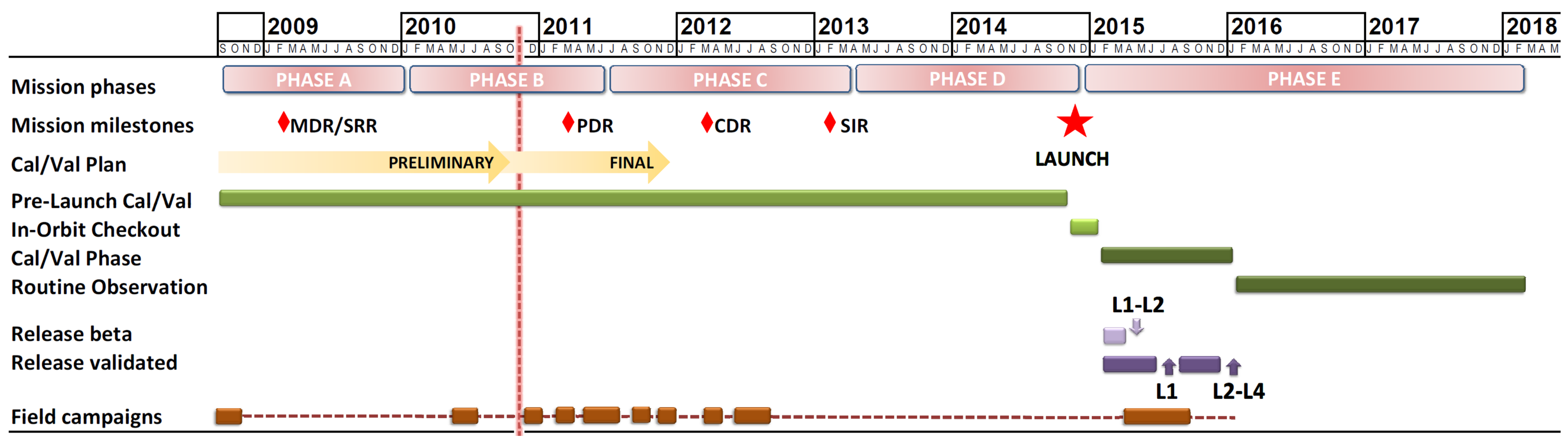


Fig. A: In situ observations are the key for validation of SMAP products. The in situ samples require up-scaling to the satellite footprint size.

The SMAP Science Cal/Val Plan (preliminary version) [2] is available at http://smap.jpl.nasa.gov

Timeline

SMAP is currently in Phase B and scheduled for launch in November 2014. The post-launch period (Phase E) is divided into In-orbit Checkout (IOC), Cal/Val and Routine Observation phases. An intensive calibration and validation program will be conducted during the first six months after IOC for Level 1 products and during the first twelve months after IOC for Level 2 and higher products. The cumulative mission science data will be reprocessed as needed to improve data product quality and accommodate upgrades in processing algorithms.



National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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This poster was prepared at the Jet Propulsion Laboratory, California Institute of Technology, under contract to the National Aeronautics and Space Administration