SMAP Cal/Val Planning and Soil Moisture Validation

October 6, 2009

T. J. Jackson
USDA ARS

Introduction

- Timeliness of this workshop: both the SMAP Cal/Val plan and the Canadian SMAP Team are in their early stages. Both can benefit from this iteration
  - SMAP SDT has developed general approaches and guidance but is still open to refinement
  - Hopefully, the Canadian SMAP Team will consider this info as it moves forward
  - SMAP will integrate the specific contributions from the Canadian Team into the SMAP Cal/Val plan (i.e. networks and campaigns)

Outline

- General aspects of the SMAP Cal/Val Plan
- Pre-launch validation activities
- Ground-based (In Situ) validation
- Networks and Core Sites
- In Situ Testbed
- Field experiment planning
- Freeze-Thaw (KM)

SMAP Cal/Val Plan: Progress so far

- The SMAP mission is currently in its formulation phase, which requires the development of a calibration/validation (Cal/Val) plan
  - Preliminary Cal/Val plan developed by SDT
  - Cal/Val Workshop June 2009
  - Updated Cal/Val plan
  - Starting to initiate specific actions
  - Draft plan by PDR, Final plan by CDR

SMAP Cal/Val Plan: General

- Objectives, and Timeline
- Pre-launch versus Post-launch focus

SMAP Cal/Val Objective

- The objective of SMAP Cal/Val is to calibrate and validate Level 1 through Level 4 algorithms and products relative to the mission requirements.
  - Level 1 mission requirements
    - Provide estimates of 0-5 cm soil moisture with an accuracy of 0.04 m^3/m^3 at a resolution of 10 km and 3-day average intervals*
    - Provide estimates of surface binary freeze/thaw transitions in the region north of 45N latitude which includes the boreal forest zone, with a classification accuracy of 80% at 3 km resolution and 2-day average intervals.

SMAP Cal/Val Objective

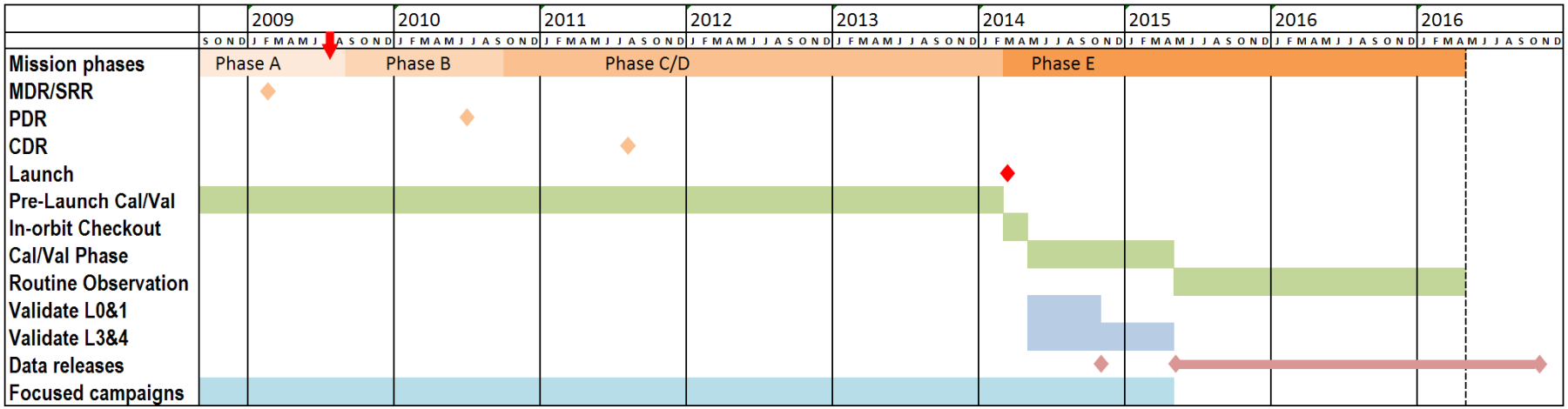
– Level 2 mission requirements for the baseline mission are:

SMAP Data Products						
Product		Accuracy	Resolution [km]	Refresh [days]	Latency [days]	Notes
L1	Radiometer	1.3 [K]	40	2 to 3	0.5	
	Radar	0.7 [dB]	3	2 to 3	0.5	
L3	Soil Moisture	0.04 [m^3/m^3]	(3), 10 and 40	3	1	*Surface soil moisture (0-5 cm) excluding regions of snow and ice, frozen ground, mountainous topography, open water, urban areas, and vegetation with water content greater than 5 [kg m^{-2}].
	Freeze/Thaw	80% Binary Classification	3	2	1	Freeze/thaw binary classification > 45° N.
L4	Root-Zone Soil Moisture	0.04 [m^3/m^3]	10	0.25	7	Land data assimilation products. Root-zone soil moisture (0-100 cm).
	Net Ecosystem Exchange	30 [$gC/m^2/yr$]	10	0.25	14	Net Ecosystem Exchange > 45° N.

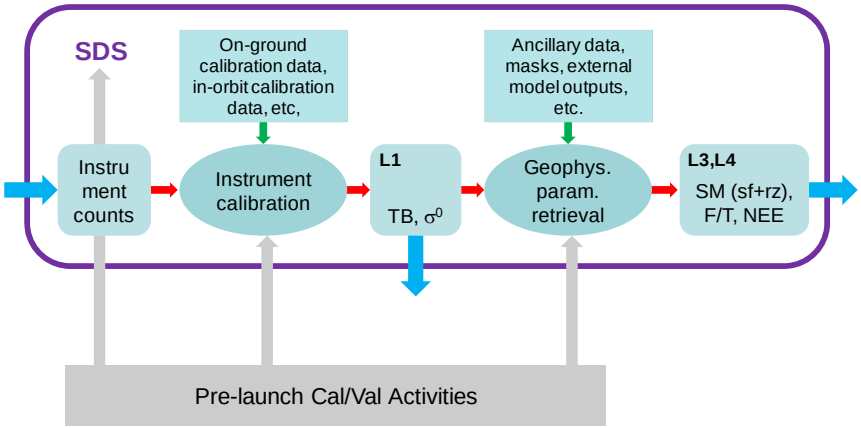
- The Cal/Val plan should describe how each requirement will be validated.

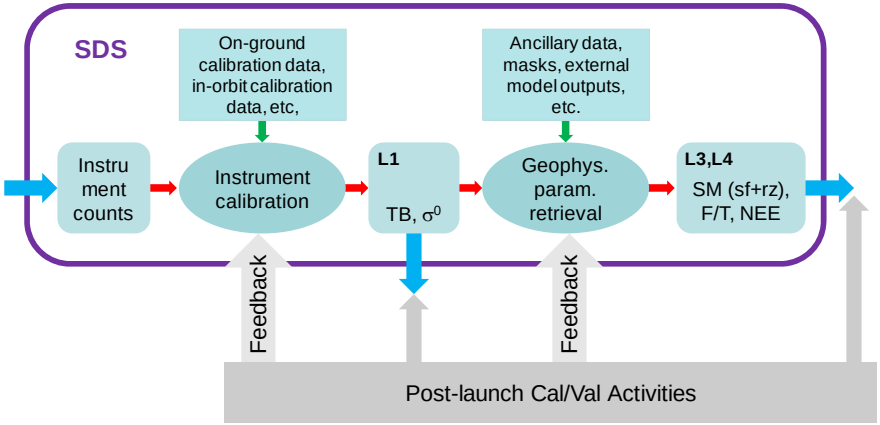
SMAP Cal/Val Timeline

- Important milestones for Cal/Val planning before launch are the Preliminary Design Review (PDR) and Critical Design Review (CDR)
  - Preliminary Cal/Val Plan in place prior to PDR, Final prior to CDR
- The Post-launch Mission is divided into In Orbit Check (IOC), Cal/Val, and Routine Observation phases
- Following IOC, brightness temperature and backscatter products are to be validated and released in **6 months**. Soil moisture (surface and root-zone), freeze-thaw state and net ecosystem exchange within **12 months**.



SMAP Cal/Val: Pre-launch vs. Post-launch





(schematic diagram of data processing flow; SDS = Science Data System)

- Pre-launch Cal/Val is focused on validating that there are means in place to fulfill the mission objectives. In particular
  - ATBD identified activities that will improve algorithms and products
  - Establish infrastructure necessary for post-launch Cal/Val
- Post-launch Cal/Val is focused on *validating that the science products meet their quantified requirements*, and on improving the algorithms and quality of products over the mission life.

Importance of Timing in SMAP Cal/Val

- Pre-launch activities and results will be most valuable in the early stages
  - Need to get moving
- Post-launch Cal/Val is focused on the first 12 months after IOC
  - Infrastructure must be ready to meet this requirement. There is ample time at this point but it must be started soon.

SMAP Pre-Launch Cal/Val Activities

- *Support ATBD identified activities that will improve algorithms and products*
  - Algorithm teams were asked to describe pre- and post-launch Cal/Val activities that would lead to algorithm or product improvements as part of their ATBDs
  - Cal/Val Workshop included a discussion and prioritization of these and categorized them based upon the type of activity (i.e. field exp.)
    - Modeling and analysis using the SMAP Algorithm Testbed
    - Field campaigns to support the development of algorithms and to resolve critical algorithm issues (Tower and aircraft)
    - Algorithm tests with equivalent data from other satellite resources
    - Assimilation trials with synthetic and/or other satellite data products
  - Actions initiated to support ATBD needs
- Establish and verify post-launch resources

SMAP ATBD Pre-launch Cal/Val Needs Examples: L3 Radar SM

A. Establish and extend the range of validity of Dubois model

   i. Aircraft (UAVSAR/PALSAR) over areas (50 km x 50 km) with varying amounts and types of vegetation. Preferably few acquisitions with different moisture conditions

B. Establish the effects of viewing geometry with scale

   i. Crossing flight lines over areas (50 km x 50 km) with topography and/or crops with row structure. Preferably few acquisitions with different moisture conditions

C. Verify algorithm scaling

   i. Aircraft over heterogeneous areas (50 km x 50 km). Preferably few acquisitions with different moisture conditions

D. Time Series Algorithm development

   i. Initially, truck mounted scatterometer observations over different vegetation classes with varying soil moisture. Long time series preferably on daily basis.

   ii. Aircraft, extension to representative and heterogeneous conditions.

SMAP ATBD Pre-launch High Priority Requiring Field Experiments

- L1 Radar
  - Verify the scaling of high resolution to moderate resolution radar backscatter over representative and heterogeneous domains using aircraft/satellites.
- L3 Radiometer SM
  - Refine model parameterizations of vegetation through additional data acquisitions; both tower and aircraft are useful
- L3 Radar SM
  - Establish and extend the range of validity of Dubois model through aircraft over large areas with varying amounts and types of vegetation.
  - Time series algorithm development using truck mounted scatterometer observations over different vegetation classes with varying soil moisture. Long time series preferably on daily basis.
- L3 Combined A/P SM
  - Validation of the baseline algorithm for a full range of soil moisture and vegetation conditions using combined aircraft and satellite data sets.
  - Development and evaluation of the alternative time series algorithm over extended time using combined aircraft and satellite data sets that represent the true resolutions of SMAP .
- L3 FT
  - Focused campaigns using available airborne (UAVSAR) and satellite L-band radar data spanning F/T transitions over regional gradients (climate, land cover, terrain);
- L4 SM
  - Use L4_SM system with established ground-based validation resources pre-launch to spin up system for post-launch validation.

SMAP Pre-Launch Cal/Val Activities

- Support ATBD identified activities that will improve algorithms and products
- *Establish and verify post-launch resources*
  - What's needed to "validate that the science products meet their quantified requirements, and improve the algorithms and quality of products over the mission life" The following tools will be used;
    - Ground-based observations that represent the footprint/grid cell either by replication or scaling
    - Field experiments
    - Satellite product comparisons
    - Model product comparisons
  - What infrastructure do we need to establish now?
    - Ground-based
      - Installation, calibration, and scaling of ground-based networks
      - Integration of operational validation data resources
    - Field experiments
      - Tower and aircraft SMAP simulators
    - Satellite products
      - Evaluation of complementary products (L1 through L4)

SMAP Ground-Based Validation

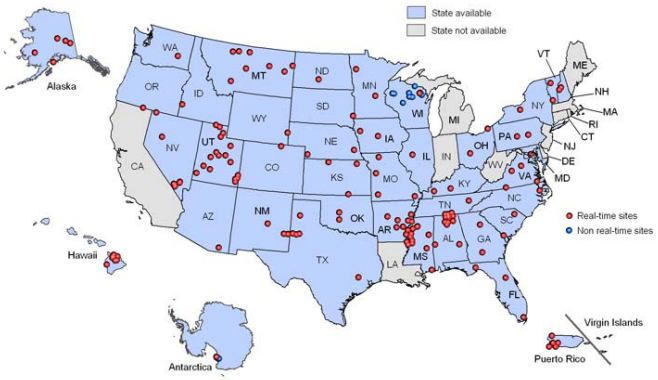
- SMAP will rely on in situ observations as one of the tools used to validate the L3 and L4 products
- As a first step, we conducted an assessment of the major ground-based resources available to validate the SMAP products.
  - Existing networks are a key resource/partners in SMAP validation (Cost, cooperation, data quality, mostly real time and public domain).
  - There are a substantial number of in situ soil moisture resources available for validation; however, they differ in many key features that we must consider.
    - Density is one of the key differentiating factors
    - Few if any are ready to provide exactly what is needed for SMAP

SMAP Ground-Based Validation

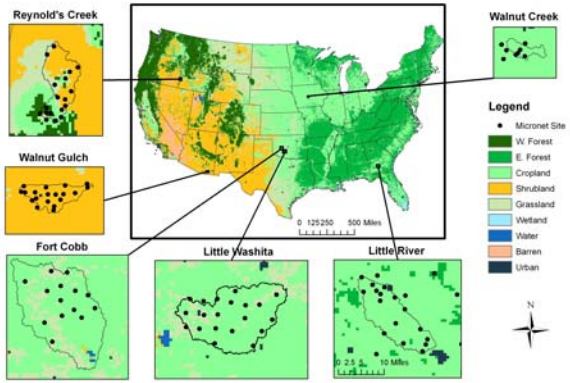
- SMAP will rely on in situ observations as one of the tools used to validate the L3 and L4 products
- As a first step, we conducted an assessment of the major ground-based resources available to validate the SMAP products.
- *At the Cal/Val Workshop several key issues were identified that would improve ground-based validation:*
  - *Roles of sparse and dense networks*
  - *Engaging both U.S. and international partners*
  - *In Situ Validation Core sites*
  - *In Situ Validation Requirements*
  - *In Situ Testbed*

SMAP Ground-Based Cal/Val Resources

- *Data from both sparse and dense networks will be of value. Each can serve a different role in the CEOS Hierarchy of Validation*
  - Sparse networks are those than provide no more than one sample location within a product grid cell



Sparse: USDA SCAN



Dense: ARS Watersheds

- Sparse network data are typically supported by government institutions and long-term programs.
  - Within the U.S. most sparse network data are in the public domain, which means that no special arrangements are required for the acquisition and use. However, it is desirable to establish partnerships with the organizations.
  - There are some global meteorological data sets that are in the public domain

SMAP Ground-Based Cal/Val Resources

- There are a number of dense networks that are in operation
  - Some issues; different “owners,” restrictions on data distribution, different measurement designs and instruments, only a few would currently meet the requirements for SMAP soil moisture validation
  - Most soil moisture candidates were developed for AMSR and SMOS
  - Long term commitments are a concern
- In Situ Networks Networks and Core Validation Sites

SMAP Cal/Val Core Sites Requirements

- Basic science requirements include
  - A study domain that matches the spatial scale of the product
    - Multiple nested scales and replication
  - In situ measurements that can be used to estimate the geophysical variable for the mission requirement depth.
    - The sensors must be calibrated to a project established standard
  - Multiple sampling locations within the site that can be used to accurately estimate the product grid average
    - Supporting studies of network representation
  - Supporting meteorological instrumentation
  - Supporting ancillary data sets such as soils, land use, and vegetation biomass
- Logistical requirements
- SMAP project priorities

SMAP Cal/Val Core Sites Requirements

- Basic science requirements include
- Logistical requirements
  - Near real time availability of data
    - Data sharing is desirable
  - Site is accessible to researchers
  - Existing site facilities
  - Heritage of scientific studies to build from
  - Long term commitment by the sponsor/host
  - Agreement with SMAP
- SMAP project priorities

SMAP Cal/Val Core Sites Requirements

- Basic science requirements include
- Logistical requirements
- SMAP project priorities
  - An area that is homogeneous or has a uniform mixture of land covers at the product scale
  - Represents an extensive or important biome
  - Complement the overall set of sites
  - Operational by 2011

SMAP Cal/Val SM Core Validation Sites

- Basic science requirements
  - Represent the 10 km product area
    - Also consider providing 40 km and 3 km scales
  - Provide the equivalent of volumetric soil moisture obtained using the gravimetric method (Calibrated)
    - Establish that it provides a measure of the 0-5 cm layer
    - Also consider providing the 0-100 cm layer
  - Multiple sampling locations within the site that can be used to accurately estimate the product grid average
    - Statistical confidence must be established (Min. 6-9 depending upon specific conditions)
  - Supporting meteorological instrumentation
  - Supporting ancillary data sets such as soils, land use, and vegetation biomass

Candidate SMAP Cal/Val SM Core Sites

- While it is highly desirable that a site meets all the requirements, it is unlikely and there should be some latitude in selection.
  - For most sites, there will be additional costs that result from meeting the requirements of SMAP. These might include additional sites and sensors, calibration studies, and longer term site maintenance.
- For soil moisture, a set of potential core sites was identified that was close to meeting all of the requirements identified. These are shown on the following table and map.
- Exploring options for establishing partnerships with SMAP.

SMAP In Situ Testbed Background

- Variations in the design of in situ soil moisture networks results in uncertainty in how the observations relate to SMAP products.
- Investigation of each design under the same conditions would contribute to understanding the information provided by each resource and establishing methods for integrating them into a common validation data base.
- A sub-group of the C/V Working Group was formed (led by M. Cosh, ARS). Membership: 42.
- Objective: Examine through observations how differences in sensor design and installation influence the soil moisture data record for an in situ network.
- Approach: Establish one or more sites, install representation instrumentation, collect continuous measurements beginning in 2010 through the SMAP mission life, and provide periodic gravimetric samples for calibration.

SMAP In Situ Testbed Sensors

The following sensors may be included in the testbed

- Stevens Water Hydra Probes (*SCAN*, *CRN*)
- Delta-T Theta Probes
- Decagon ECH2O probes
- Sentek EnvironSCAN Capacitance Probes or similar
- Campbell CS615/CS616 TDRs
- CS 229-L heat dissipation sensors (*OK Mesonet*)
- GPS reflectometers
- COSMOS system

Field Experiments and SMAP Cal/Val

- Pre-launch: Address specific algorithm issues and post-launch infrastructure
  - Algorithms would benefit most from data collected ASAP
  - Some problems are best addressed with tower systems and others with aircraft
- Post-launch: Products
  - The primary validation effort needs to be completed within 14 months of launch

SMAP Major Field Campaigns

ver. 10/09

Year/ Quarter	1	2	3	4
2008			SMAPVEX08	
2009				**SMOS**
2010	SMAPEx SMOSEx	SMAPEx SMOS Europe	SMAPEx SMOSEx SMOS Europe	**Aquarius** SMAPEx
2011		SMOSEx		
2012	**GCOM-W**		**SAOCOM**	
2013				
2014	**SMAP**		SMAPVEX14	SMAPVEX14
2015				

Satellite Launch in Red

- SMAPVEX08
  - High priority design/algorithm issues
- SMAPEx 2010 (Australia)
  - 4 one-week campaigns to span four seasons
  - Aircraft Radar/Radiometer
- SMOSEx (Australia)
  - Several one-month campaigns in different seasons
- SMOS Europe
  - SMOS validation
  - No L-band radar
- SMAPVEX10 (or 11)
  - SMOS and Aquarius available
  - Focus of algorithm validation
- SMAPVEX14 (or ??)
  - SMAP product validation