SMAP and SMOS Integrated Soil Moisture Validation

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USDA ARS
Perspective

• Linkage of SMOS and SMAP soil moisture calibration and validation will have short and long term benefits for both missions.
• Follow-on to Hydros team proposal to SMOS C/V AO.
SMOS Cal/Val AO

• The *Hydros* Team prepared a proposal for the SMOS Cal/Val AO that focused on using SMOS to enhance the Hydros products.

• Hydros was cancelled in the interim…modified team and objectives.

• Proposal was sent to J. Entin (unsolicited)-no response.

• Key elements:
  – Validate SMOS SM using in-situ soil moisture networks
  – Field experiments to scale soil moisture and TB to SMOS
  – Satellite product intercomparisons with AMSR-E
  – Investigate alternative SM algorithms, in particular the use of the browse TB product (42.5°)
  – Assess SMOS SM using both forward and inverse models and in a data assimilation framework
Outline

• Basic SMAP description
• SMAP C/V planning
• SMAP and SMOS synergy
Soil Moisture Active Passive Mission (SMAP)

- NASA
- One of the first missions resulting from the NRC Decadal Survey
- Soil moisture and freeze-thaw
- Three day global coverage
- Launch 2013
SMAP Mission Concept

• L-band radar and radiometer system with 6-m reflector

• Solution to spatial resolution is two-fold; a technology that uses a large antenna (deployable mesh) and enhanced resolution by combining high accuracy radiometry retrieval with high resolution radar. Soil moisture products;
  – Radar resolution: 3 km
  – Radiometer resolution: 40 km
  – Combined product: 10 km
SMAP Validation
(Soil Moisture)

• Based on SMAP mission requirements and product ATBDs
  – Pre-launch: Address ATBD identified priorities, improve soil moisture algorithms and products, and establish infrastructure
  – Post-launch: *Demonstrate that the science requirements have been met* and improve soil moisture algorithms and products over the mission life
### SMAP Science Data Products

<table>
<thead>
<tr>
<th>Data Product</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1B_S0_LoRes</td>
<td>Low Resolution Radar $s_o$ in Time Order</td>
</tr>
<tr>
<td>L1C_S0_HiRes</td>
<td>High Resolution Radar $s_o$ on Earth Grid</td>
</tr>
<tr>
<td>L1B_TB</td>
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</tr>
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<td>L1C_TB</td>
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</tr>
<tr>
<td>L3_SM_HiRes_3km</td>
<td>Radar Soil Moisture on Earth Grid</td>
</tr>
<tr>
<td>L3_SM_40km</td>
<td>Radiometer Soil Moisture on Earth Grid</td>
</tr>
<tr>
<td>L3_SM_A/P_10km</td>
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<tr>
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</tr>
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ATBDs under development.

### Surface 0-5 cm

### Profile

{CC}
# SMAP L1 Requirements Traceability

<table>
<thead>
<tr>
<th>Science Objectives</th>
<th>Scientific Measurement Requirements</th>
<th>Instrument Functional Requirements</th>
<th>Mission Functional Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understand processes that link the terrestrial water, energy and carbon cycles;</td>
<td><strong>Soil Moisture:</strong> 4% volumetric accuracy in top 5 cm for vegetation water content &lt; 5 kg m⁻²; Hydrometeorology at 10 km; Hydroclimatology at 40 km</td>
<td><strong>L-Band Radiometer:</strong> Polarization: V, H, U; Resolution: 40 km; Relative accuracy*: 1.5 K</td>
<td>DAAC data archiving and distribution.</td>
</tr>
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<td>Estimate global water and energy fluxes at the land surface</td>
<td><strong>Freeze/Thaw State:</strong> Capture freeze/thaw state transitions in integrated vegetation-soil continuum with two-day precision, at the spatial scale of landscape variability (3 km).</td>
<td><strong>L-Band Radar:</strong> Polarization: HH; Relative accuracy*: 0.7 dB (1 dB per channel if 2 channels are used);</td>
<td>Field validation program.</td>
</tr>
<tr>
<td>Quantify net carbon flux in boreal landscapes</td>
<td></td>
<td>Constant incidence angle** between 35° and 50°</td>
<td>Integration of data products into multisource land data assimilation.</td>
</tr>
<tr>
<td>Enhance weather and climate forecast skill</td>
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<td>Develop improved flood prediction and drought monitoring capability.</td>
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<tr>
<td></td>
<td></td>
<td>Sample diurnal cycle at consistent time of day Global, 3-4 day revisit; Boreal, 2 day revisit</td>
<td>Orbit: 670 km, circular, polar, sun-synchronous, ~6am/pm equator crossing</td>
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<td></td>
<td></td>
<td>Observation over a minimum of three annual cycles</td>
<td>Three year baseline mission***</td>
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<td></td>
<td>Swath Width: 1000 km Minimize Faraday rotation (degradation factor at L-band)</td>
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* Includes precision and calibration stability
** Defined without regard to local topographic variation
*** Includes allowance for up to 30 days post-launch observatory check-out
Demonstrate That the Science Requirements Have Been Met Over the Mission Life

• Approach
  – Provide verified estimates of soil moisture over an area and depth equivalent to that measured by the SMAP radiometer and radar instruments or derived products throughout the project life
  – Provide a robust set of cover conditions and geographic/climate domains for validation
  – Provide continuous, consistent, and long term records with minimal latency

• Elements:
  – Ground based soil moisture observations that represent footprint/grid soil moisture either by replication or scaling, which has been verified
  – Field experiments
  – Satellite product comparisons
  – Model product comparisons
## SMAP Science Data Products

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<td>Networks</td>
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<tr>
<td>L1B_S0_LoRes</td>
<td>Low Resolution Radar $\sigma^0$ in Time Order</td>
<td>x</td>
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Where We are in the C/V Planning Process

• SMAP project start March 2008
• SMAP launch first quarter 2013
• Draft ATBDs March 2009
• Draft C/V Plan June 2009
• Algorithm and C/V Workshop June 2009
• C/V Plan ~August 2009
• Focused experiment September 2009
• Next major campaign Summer 2010
Demonstrate that the science requirements have been met post-launch and over the mission life

• Approach
  – Provide verified estimates of soil moisture over an area and depth equivalent to that measured by the SMAP radiometer and radar instruments or derived products throughout the project life
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Soil Moisture Networks

• Ground based networks are a core component. They provide actual quantitative soil moisture observations to evaluate algorithm performance

• Two basic types
  – Dense over limited spatial domains
  – Sparse over a large geographic region

• There are only a few available that provide the right kind of data for satellite validation (depth, frequency, latency, access)
  – A single point within a satellite footprint is not going to provide a reliable estimate of the spatial average for validation without some additional research.

• US resources: SCAN, CRN, ARS, ……
U.S. Watershed Soil Moisture Validation Sites

- All sites include 5 cm
- LW, LR, WG, RC since 2002
- WC, FC are new
Soil Climate Analysis Network (SCAN)

- Hourly observations
- 151 sites
- Meteor burst data transmission
- Web based real time
- Public access

- Precipitation
- Air temperature
- Relative humidity
- Wind speed and direction
- Solar radiation
- Barometric pressure
- Snow water content and depth
- Soil moisture and temperature (5, 10, 20, 50, 100 cm)
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In Situ C/V Priorities

- Continue dedicated dense networks and address the higher spatial resolution products (10 km, 3 km?)
- Support the continuity of established in situ networks (SCAN, CRN,..)
- Methodologies for scaling sparse networks
- Cooperate with new initiatives (COSMOS, GPS,..)
- Promote cooperation, expansion, and continuation of all ground based networks (SMOS, ISMWG, GCOM-W)
- Archival
Field Experiments and Validation

• Ties together point and footprint observations
  – Characterize spatial variability
  – Establish the representativeness of sparse networks
• Pre-launch: Address specific algorithm issues (i.e. topography)
• Post-launch: Products
# SMAP Major Field Campaigns

**ver. 11/08**

<table>
<thead>
<tr>
<th>Year/Quarter</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2008</strong></td>
<td></td>
<td></td>
<td>SMAPVEX08</td>
<td></td>
</tr>
<tr>
<td><strong>2009</strong></td>
<td>Canada FT?</td>
<td>SMOS</td>
<td>Australia Europe/Canada</td>
<td>Australia</td>
</tr>
<tr>
<td><strong>2010</strong></td>
<td>Australia</td>
<td>Aquarius</td>
<td>SMAPVEX10</td>
<td>Europe SMAPVEX10</td>
</tr>
<tr>
<td><strong>2011</strong></td>
<td></td>
<td></td>
<td></td>
<td>SMAPVEX11</td>
</tr>
<tr>
<td><strong>2012</strong></td>
<td>GCOM-W</td>
<td></td>
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<tr>
<td><strong>2013</strong></td>
<td>SMAP</td>
<td></td>
<td>SMAPVEX13</td>
<td></td>
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<tr>
<td><strong>2014</strong></td>
<td></td>
<td></td>
<td>SMAPVEX14</td>
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<tr>
<td><strong>2015</strong></td>
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**Satellite Launch in Red**

- **SMAPVEX08**
  - High priority design/algorithm issues
- **Australia 2009-2010**
  - 4 one-week campaigns to span four seasons
  - Aircraft Radar/Radiometer
  - Separate SMOS validation
- **Europe/Canada 2009-2010**
  - SMOS validation
  - No radar
- **SMAPVEX10**
  - Spring-Summer 2010
  - Oklahoma?
  - SMOS and Aquarius available
  - Focus of algorithm validation
- **SMAPVEX11**
  - Focus on different problems; FT, regions, seasons
- **SMAPVEX13 and 14**
  - SMAP product validation
Field Experiment C/V Priorities

• Pre-launch
  – Establish ground and aircraft SMAP simulators
  – Experiments that address critical algorithm/science issues
  – Experiments that provide validation of algorithms
  – Support for satellite studies; SMOS and Aquarius

• Post-launch
  – Validation of products
  – Scaling issues
Model Product Intercomparison

• Regional and global forecast models
  – Comparable spatial scales
  – Improving surface layer components
  – Sink term

• Data assimilation
Satellite Products C/V Priorities

• Pre-launch: Participate in the ALOS, SMOS, Aquarius and GCOM-W missions
  – Validation of SMAP algorithms
  – RFI
  – Establish cross-reference between mission products

• Post-launch
  – Exploiting the sensor products from SMOS and Aquarius as calibration resources
  – Exploiting the soil moisture products from SMOS and GCOM-W as validation resources
SMAP Synergy With Other Missions/Applications

- A decade L-band?
- SMAP provides continuity for L-band measurements of ALOS, SMOS, and Aquarius.

*Material from SMAP Science Team*
SMAP-SMOS Synergy

- SMOS experience with RFI and scaling studies
- SMOS $T_B$ for SMAP L3 soil moisture algorithms
- SMOS experience in providing NRT data and its impact in ECMWF activities
- SMAP continuity of SMOS $T_B$ and soil moisture products (as well as salinity)…SMOSOps
- SMAP/SMOS
  - Algorithm validation
  - In situ observations
  - Field experiments
- .......
Specific SMAP Contributions to SMOS C/V

- Continuous long-term in situ soil moisture observations. These will consist of the SM/Climate Networks and Watershed Networks in the U.S., at a minimum.

- Large scale field campaigns. Campaigns are being planned for an extended spatial/temporal domain for 2010 and beyond with aircraft mapping.

- Forward modeling of brightness temperature, hydrologic modeling of soil moisture, and problem focused experiments.

- SMAP algorithm retrievals. SMOS brightness temperature data products that are similar to the planned SMAP radiometer products will be used to generate soil moisture fields using candidate SMAP algorithms.
Summary

• A great era for applications based on L-band remote sensing
• SMOS will offer the first opportunity to observe global L-band TB.
• SMOS can contribute significantly to SMAP by proving actual spaceborne radiometer data for algorithm development and validation
• SMAP, with soil moisture resolutions as fine as 3 km, will have to deal with unique validation issues.
• Cooperation will benefit both missions and applications.