The Soil Moisture Active Passive Mission (SMAP) Science Data Products: Results of Testing With Field Experiment and Algorithm Testbed Simulation Environment Data

Dara Entekhabi (MIT)
Eni E. Njoku (JPL Caltech/NASA)
Peggy E. O’Neill (NASA GSFC)
Kent H. Kellogg (JPL Caltech/NASA)
Jared K. Entin (NASA HQ)

Talk Outline

1. Derivation of SMAP basic and applied science requirements from the NRC Earth Science Decadal Survey applications

2. Data products and latencies

3. Algorithm highlights

4. SMAP Algorithm Testbed

5. SMAP Working Groups and community engagement

(National Research Council, 2007)  http://www.nap.edu

SMAP is one of four missions recommended by the NRC “Decadal Survey” for launch in the first tier

Feb 2008: NASA announces start of SMAP project

SMAP is a directed-mission with heritage from Hydros ESSP
# Science Requirements

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<th>DS Objective</th>
<th>Application</th>
<th>Science Requirement</th>
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<tr>
<td>Weather Forecast</td>
<td>Initialization of Numerical Weather Prediction (NWP)</td>
<td>Hydrometeorology</td>
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<tr>
<td>Climate Prediction</td>
<td>Boundary and Initial Conditions for Seasonal Climate Prediction Models</td>
<td>Hydroclimatology</td>
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<td>Testing Land Surface Models in General Circulation Models</td>
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<tr>
<td>Drought and Agriculture</td>
<td>Seasonal Precipitation Prediction</td>
<td>Hydroclimatology</td>
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<td>Monitoring</td>
<td>Regional Drought Monitoring</td>
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<td>Crop Outlook</td>
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<td>Flood Forecast Improvements</td>
<td>River Forecast Model Initialization</td>
<td>Hydrometeorology</td>
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<td>Flash Flood Guidance (FFG)</td>
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<td></td>
<td>NWP Initialization for Precipitation Forecast</td>
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<td>Human Health</td>
<td>Seasonal Heat Stress Outlook</td>
<td>Hydroclimatology</td>
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<td>Near-Term Air Temperature and Heat Stress Forecast</td>
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<td>Disease Vector Seasonal Outlook</td>
<td>Hydroclimatology</td>
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<tr>
<td></td>
<td>Disease Vector Near-Term Forecast (NWP)</td>
<td>Hydroclimatology</td>
</tr>
<tr>
<td>Boreal Carbon</td>
<td>Freeze/Thaw Date</td>
<td>Freeze/Thaw State</td>
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</tbody>
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## Requirement Specifications

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Hydro-Meteorology</th>
<th>Hydro-Climatology</th>
<th>Carbon Cycle</th>
<th>Baseline Mission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>4–15 km</td>
<td>50–100 km</td>
<td>1–10 km</td>
<td>Soil Moisture</td>
</tr>
<tr>
<td>Refresh Rate</td>
<td>2–3 days</td>
<td>3–4 days</td>
<td>2–3 days(1)</td>
<td>Freeze/Thaw</td>
</tr>
<tr>
<td>Accuracy</td>
<td>4–6% **</td>
<td>4–6%**</td>
<td>80–70%*</td>
<td></td>
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</table>

(*) % classification accuracy (binary Freeze/Thaw)
(**) [cm³ cm⁻³] volumetric water content, 1-sigma
(1) North of 45N latitude
SMAP Mission Concept

- L-band unfocused SAR and radiometer system, offset-fed 6 m light-weight deployable mesh reflector. Shared feed for
  - 1.26 GHz dual-pol Radar at 1-3 km (30% nadir gap)
  - 1.4 GHz polarimetric Radiometer at 40 km
- Conical scan, fixed incidence angle across swath
- Contiguous 1000 km swath with 2-3 days revisit (8 day repeat)
- Sun-synchronous 6am/6pm orbit (680 km)
- Launch 2014
- Mission duration 3 years
Anthropogenic Radio-Frequency Interference (RFI)

RFI is evident and wide-spread (Early Data from SMOS)

SMAP is taking aggressive measures to detect and mitigate RFI in its instrument and data processing designs.
L-band Active/Passive Soil Moisture Mapping

- Soil moisture retrieval algorithms are derived from a long heritage of microwave modeling and field experiments: MacHydro’90, Monsoon’91, Washita92, Washita94, SGP97, SGP99, SMEX02, SMEX03, SMEX04, SMEX05, CLASIC, SMAPVEX08, CanEx10

- **Radiometer** - High accuracy (less influenced by roughness and vegetation) but coarser spatial resolution (40 km)

- **Radar** - High spatial resolution (1-3 km) but more sensitive to surface roughness and vegetation

- **Combined Radar-Radiometer** product provides optimal blend of resolution and accuracy to meet science objectives
## SMAP Data Products

<table>
<thead>
<tr>
<th>Data Product Short Name</th>
<th>Description</th>
<th>Data Resolution</th>
<th>Grid Spacing</th>
<th>Mean Latency*</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1B_S0_LoRes</td>
<td>Low Resolution Radar $\sigma_o$ in Time Order</td>
<td>5x30 km (10 slices)</td>
<td>-</td>
<td>12 hrs</td>
</tr>
<tr>
<td>L1C_S0_HiRes</td>
<td>High Resolution Radar $\sigma_o$ on Swath Grid</td>
<td>1x1 km to 1x30 km</td>
<td>1 km</td>
<td>12 hrs</td>
</tr>
<tr>
<td>L1B_TB</td>
<td>Radiometer $T_B$ in Time Order</td>
<td>36x47 km</td>
<td>-</td>
<td>12 hrs</td>
</tr>
<tr>
<td>L1C_TB</td>
<td>Radiometer $T_B$</td>
<td>40 km</td>
<td>36 km</td>
<td>12 hrs</td>
</tr>
<tr>
<td>L2_SM_A</td>
<td>Radar Soil Moisture</td>
<td>1-3 km</td>
<td>3 km</td>
<td>24 hrs</td>
</tr>
<tr>
<td>L2_SM_P</td>
<td>Radiometer Soil Moisture</td>
<td>40 km</td>
<td>36 km</td>
<td>24 hrs</td>
</tr>
<tr>
<td>L2_SM_A/P</td>
<td>Active-Passive Soil Moisture</td>
<td>9 km</td>
<td>9 km</td>
<td>24 hrs</td>
</tr>
<tr>
<td>L3_F/T_A</td>
<td>Daily Global Composite Freeze/Thaw State</td>
<td>1-3 km</td>
<td>3 km</td>
<td>50 hrs</td>
</tr>
<tr>
<td>L3_SM_A</td>
<td>Daily Global Composite Radar Soil Moisture</td>
<td>1-3 km</td>
<td>3 km</td>
<td>50 hrs</td>
</tr>
<tr>
<td>L3_SM_P</td>
<td>Daily Global Composite Radiometer Soil Moisture</td>
<td>40 km</td>
<td>36 km</td>
<td>50 hrs</td>
</tr>
<tr>
<td>L3_SM_A/P</td>
<td>Daily Global Composite Active-Passive Soil Moisture</td>
<td>9 km</td>
<td>9 km</td>
<td>50 hrs</td>
</tr>
<tr>
<td>L4_SM</td>
<td>Surface and Root Zone Soil Moisture</td>
<td>9 km</td>
<td>9 km</td>
<td>7 days</td>
</tr>
<tr>
<td>L4_C</td>
<td>Carbon Net Ecosystem Exchange</td>
<td>9 km</td>
<td>9 km</td>
<td>14 days</td>
</tr>
</tbody>
</table>
Temporal changes in $T_B$ and $\sigma_{pp}$ are related. Relationship parameter $\beta$ is estimated at radiometer-scale using successive overpasses.

Heterogeneity in vegetation and roughness conditions within radiometer-scale are evaluated by estimating sensitivities $\Gamma$ in radar cross-pol:

$$T_B (M_j) = T_B (C) + \beta(C) \cdot \left\{ \left[ \sigma_p (M_j) - \sigma_p (C) \right] - \Gamma \cdot \left[ \sigma_p (M_j) - \sigma_p (C) \right] \right\}$$

$T_B (M_j)$ is used to retrieve soil moisture at 9 km (consistent algorithm and ancillary data as radiometer algorithm)

Source: N. Das (JPL)
Baseline Algorithm:
\[ \Delta(t) = \frac{\sigma^0(t) - \sigma^0_{fr}}{\sigma^0_{th} - \sigma^0_{fr}} \]

- \( \sigma^0_{fr} \) = frozen reference
- \( \sigma^0_{th} \) = thawed reference
- \( T \) = threshold

\[ \Delta(t) > T \text{ (Thawed)} \]
\[ \Delta(t) \leq T \text{ (Frozen)} \]

Source: K. McDonald (JPL) and j. Kimball (UMT)
L4_SM Algorithm Concept

Main objectives:
• Provide estimates of root zone soil moisture (top 1 m) based on SMAP obs.
• Provide global, 3-hourly, 9 km surface and root zone soil moisture.

Baseline algorithm:
• Customized version of existing NASA/GEOS-5 Land Data Assimilation System
  – 3d Ensemble Kalman filter
  – Catchment land surface model

Source: R. Reichle (NASA GSFC)
Simulated products generated with prototype algorithms on the SDS Testbed

L1C_S0_Hi-Res Radar
Backscatter Product (1-3 km)

L1C_TB Radiometer
Brightness Temperature Product (36 km)

L3_SM_A Radar
Soil Moisture Product (3 km)

L2_SM_P Radiometer
Soil Moisture Product (36 km)

L2_SM_AP Combined
Soil Moisture Product (9 km)
Working Groups have been established as a means to enable broad science participation in the SMAP mission. The working groups are led by Science Definition Team (SDT) members. The working groups communicate via periodic workshops, E-Mail and at conferences and other venues.

There are four current working groups:

1. Algorithms Working Group (AWG)
2. Calibration & Validation Working Group (CVWG)
3. Radio-Frequency Interference Working Group (RFIWG)

http://smap.jpl.nasa.gov/science/wgroups/
SMAP will provide high-resolution, frequent-revisit global mapping of soil moisture and freeze/thaw state to enable science and applications users to:

- 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

SMAP data will be used in applications of national significance that range from agriculture to human health.

Join us for the SMAP Application Discussion
@Moscone Center South
End of row Z
Wednesday, December 15th, 2010 at 12:00 pm
(Immediately following the poster session)
Backup Slides
Global mapping of Soil Moisture and Freeze/Thaw state to:

- Understand processes that *link* the terrestrial water, energy & 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