Assimilation of SMOS (and SMAP) retrieved soil moisture into the Land Information System

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Short-term Prediction Research and Transition (SPoRT)

- **Location**: NASA Marshall Space Flight Center in Huntsville, Alabama, USA
- **Mission**: Transition unique NASA and NOAA observations and research capabilities to the operational weather community to improve short-term weather forecasts on regional and local scales
- **Proven paradigm for transition of research and experimental data to operations**
- Close collaboration with numerous NWS WFOs across the U.S.
- Began in 2002; co-funded by NOAA since 2009 through “proving ground” activities
• Goal: Accurate, high-resolution (~3 km) soil moisture in near-real-time
  – Situational awareness (drought assessment, flood and fire threat)
  – Local modeling applications (to improve sfc-PBL exchanges)
• Method: Assimilate satellite soil moisture retrievals into a land surface model
  – Combines high-resolution geophysical model data with latest satellite observations

**MODEL**
Noah LSM in Land Information System
*Driven by meteorological forcing + physics*

**OBSERVATIONS**
Soil moisture retrievals from SMOS/SMAP
Tools: Land Information System (LIS)

- Framework for running LSMs incorporating a wide variety of meteorological forcing data and land surface parameters
  - Developed by NASA-GSFC
  - Includes data assimilation capability.
  - Can be run coupled with Advanced Research WRF.
- Using Noah 3.3 Land Surface Model (LSM) within LIS
- SPoRT maintains near-real-time and experimental LIS runs over the US and East Africa.
LIS Modeling at SPoRT

Full Continental U.S. (CONUS) domain with 0.03° (lat/lon) grid resolution

Unique characteristics of “SPoRT-LIS”:
- Real-time S-NPP/VIIRS Green Vegetation Fraction
- Albedo scaled to input vegetation
- Restart simulation strategy to produce real-time output (timeline below)
- SPoRT-LIS ingested and displayed in AWIPS II at select NOAA/NWS weather forecast offices
- Land surface variables available to initialize modeling applications (WRF and STRC/EMS/UEMS)

Current SPoRT-LIS CONUS domain running Noah LSM, displayed in AWIPS II

NLDAS-2 forcing

Jan 1979

GDAS + MRMS forcing

t - 4 days

t = current

GFS forecast
Land Surface Modeling Applications:  
Soil moisture percentile application

- Near real-time soil moisture percentiles provide proper climatological context and allow for more thorough, accurate operational analysis
- Drought diagnosis especially important during times of “flash drought”
  - NWS contributes to the USDM and has made sub-county scale modifications based on LIS output
- Flood threat analysis
  - Flood guidance provided by RFCs
  - NWS forecast offices issues flood watches and warnings
  - Soil moisture over SC still exceeds 98th percentile over a month after major flooding in early OCT

SPoRT-LIS Percentile Product in NWS AWIPS-II decision support system for 22 November 2015

* LIS-CDRUS Surface 7-Day Composite Soil Moisture Percentile (m)  22.12: 08Z Sun 12:00Z 22-Nov-15
Observing Systems: SMOS and SMAP

• L-band radiometers (and radars) can be used to estimate soil moisture near the surface
  — Compared to previous generation (higher frequency) instruments:
    o See deeper in the soil (up to 5 cm)
    o Better vegetation penetration
    o Higher sensitivity (accuracy)

• Soil Moisture and Ocean Salinity (SMOS) retrievals assimilation tested and validated in LIS 6.

• Currently assimilating Soil Moisture Active/Passive (SMAP) retrievals experimentally in LIS 7
  — SMAP has higher resolution product but due to failure of radar, time period is limited to a few months.

<table>
<thead>
<tr>
<th>Name</th>
<th>AMSR-E</th>
<th>SMOS</th>
<th>SMAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agency</td>
<td>NASA/JAXA</td>
<td>ESA</td>
<td>NASA</td>
</tr>
<tr>
<td>Launch</td>
<td>2002</td>
<td>2009</td>
<td>Jan. 2015</td>
</tr>
<tr>
<td>Orbit</td>
<td>Polar</td>
<td>Polar</td>
<td>Polar</td>
</tr>
<tr>
<td>Sensor Type</td>
<td>Passive</td>
<td>Passive (synthetic aperture)</td>
<td>Passive</td>
</tr>
<tr>
<td></td>
<td>Passive</td>
<td>Active (Failed July 2015)</td>
<td>Combined (limited duration)</td>
</tr>
<tr>
<td>Frequency</td>
<td>6.9 GHz (C-band)</td>
<td>1.4 GHz (L-band)</td>
<td>1.41 GHz 1.2 GHz</td>
</tr>
<tr>
<td>Resolution</td>
<td>56 km</td>
<td>35-50 km</td>
<td>36 km 3 km 9 km</td>
</tr>
<tr>
<td>Accuracy</td>
<td>6 cm³/cm³</td>
<td>4 cm³/cm³</td>
<td>4 cm³/cm³ 6 cm³/cm³ 4 cm³/cm³</td>
</tr>
</tbody>
</table>
SMAP Data Assimilation in LIS

1. LIS Background Soil Moisture (0-10 cm)
2. SMAP Observed SM (after QC and bias correction)
3. Innovation (obs minus BG)
4. Model Increment
5. Model Analysis (blending background & obs)
Validation from SMOS Assimilation

<table>
<thead>
<tr>
<th></th>
<th>Near Surface (0-10 cm)</th>
<th>Root Zone (10-100 cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>3.6%</td>
<td>23.5%</td>
</tr>
<tr>
<td>SMOS DA</td>
<td>-0.5%</td>
<td>21.8%</td>
</tr>
</tbody>
</table>
SMOS Data Assimilation Validation (2)

1. Prairie SP, MO

- Bias: OPL -0.042, DA -0.037
- ErrSD: OPL 0.134, DA 0.104
- Corr: OPL 0.701, DA 0.917

2. Stillwater, OK

- Bias: OPL 0.035, DA 0.036
- ErrSD: OPL 0.071, DA 0.056
- Corr: OPL 0.678, DA 0.886

3. Pittsfield, IL

- Bias: OPL -0.072, DA -0.075
- ErrSD: OPL 0.101, DA 0.070
- Corr: OPL 0.702, DA 0.927

- 0-10 cm model soil moisture
- Compared open loop run to SMOS DA run

Results validated against soil moisture networks in U.S.
- North America Soil Moisture Database
- Better correlations
- Improved dynamic range
SMAP Data Assimilation Results: Positive impact on soil moisture artifacts due to poor forcing

- Problem with gauge QC at NCEP/CPC resulted in dry precip “bulls-eyes” in NLDAS-2 forcing input to SPoRT-LIS during 2015

- Notable dry bulls-eye in southern AR (left)

- Anomaly significantly reduced after first month of SMAP assimilation.

- Location-independent bias correction permits these type of artifacts to be reduced
South Carolina Flooding

**Preliminary results—no bias correction**
- top left: soil moisture from LIS control run
- top right: soil moisture from SMAP assimilation run, after 3 days assimilation
- bottom left: differences
- Differences are small in flooded area due to extremely strong forcing leading to saturation over a wide area.
- Differences elsewhere illustrate impact of SMAP on LIS products

**Research Questions**
- Does antecedent soil moisture improve flood prediction?
- Does SMOS/SMAP DA help resolve drydown?
Downscaling and higher-resolution data

**Challenge**
- Model resolution is ~3km, but passive observations are much coarser (~36 km). Currently assimilating one observation over several model grid cells.

**Original plan**
- Use SMAP Active/Passive product at 3 km (SMAP radar failed after ~3 months)

**Possible Future Methods...**

**Method 1**
- Downscale SMAP L2 retrievals using model background
- Apply the variability of the background to the observations

**Method 2**
- Use SMAP Enhanced data at 25 km (coming December 2016) plus downscaling

**Method 3**
- Use combined active-passive product from SMAP and ESA’s Sentinel 1 constellation, coming March 2017. (1-3 km but Sentinel revisit time is several days)
SMAP Data Assimilation
Example Products in Development

Calendar interface with drop-down menu for selecting products and diagnostics.
SMAP Data Assimilation
Example Products in Development

0–10 cm Volumetric Soil Moisture (m$^3$/m$^3$ x100) valid 15z 07 Sep 2016
## LIS product status at SPoRT

<table>
<thead>
<tr>
<th>LIS Version</th>
<th>Available*</th>
<th>Evaluating</th>
<th>Developing</th>
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</thead>
<tbody>
<tr>
<td>Base LIS (No DA)</td>
<td>CONUS</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Puerto Rico</td>
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<td></td>
<td>East Africa</td>
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<tr>
<td>SMAP DA</td>
<td></td>
<td>CONUS</td>
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<td>(planned Oct)</td>
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<tr>
<td></td>
<td></td>
<td>Alaska</td>
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<tr>
<td>SMAP+SMOS DA</td>
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<td>CONUS</td>
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<td></td>
<td>East Africa</td>
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<td></td>
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<td>(planned Nov)</td>
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*Products available at [http://weather.msfc.nasa.gov/sport/](http://weather.msfc.nasa.gov/sport/)

For current status, email [clay.blankenship@nasa.gov](mailto:clay.blankenship@nasa.gov).
See Also...


Products at [http://weather.msfc.nasa.gov/sport/](http://weather.msfc.nasa.gov/sport/)

Email: clay.blankenship@gmail.com