SMOS soil moisture data assimilation in the NASA Land Information System: Impact on LSM initialization and NWP forecasts

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Goals

Soil Moisture Data Assimilation

Forecast Challenge

- Available moisture affects humidity, sensible/latent heating, diurnal heating rate, and convection

Objective

- Improve soil moisture estimates for regional NWP applications and situational awareness
  - Improve LIS soil moisture by assimilating satellite retrievals
  - Use LIS output to initialize NWP

Impact of using high-resolution LIS boundary conditions in WRF (rather than NAM fields).
From Case et al. 2008
Other Applications

– Drought/Heat Wave Monitoring
– Flood Forecasting
– Streamflow prediction
– Public health

Temperature anomalies
Soil moisture anomalies
Operational SPoRT Land Information System (LIS)

- NASA LIS used to perform long-term integration of Noah Land Surface Model (LSM) updated in real-time
  - Precipitation forcing: NLDAS-2, Multi-Sensor, Multi-Radar (MRMS), and GFS forecast
  - Vegetation coverage/health: Green Vegetation Fraction (GVF) from MODIS (VIIRS 2014)
  - Forecast data allows use of latent observations while retaining their impact on later cycles
- Assimilation of soil moisture should give even more accurate LSM soil moisture fields
- Used for situational awareness and local modeling
SPoRT-LIS Real-time Configurations

• Running Noah LSM at ~3-km resolution with *real-time MODIS GVF*

• “Operational” Southeast U.S. domain
  – Driven by NLDAS-2/Stage IV precip
  – Data used for both local modeling in WRF/EMS and display in AWIPS II
  – Used in current LIS assessment

• Experimental CONUS domain
  – Interest from SPoRT western partners
  – Driven by NLDAS-2/MRMS* precip

*Multi-Radar Multi-Sensor 1-km QPE*
# Soil Moisture Instruments

<table>
<thead>
<tr>
<th>Name</th>
<th>AMSR-E</th>
<th>SMOS Soil Moisture and Ocean Salinity</th>
<th>SMAP Soil Moisture Active/Passive</th>
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<tbody>
<tr>
<td>Agency</td>
<td>NASA/JAXA</td>
<td>ESA</td>
<td>NASA</td>
</tr>
<tr>
<td>Launch</td>
<td>2009</td>
<td>Nov. 2014</td>
<td></td>
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<tr>
<td>Orbit</td>
<td>Polar</td>
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<tr>
<td>Sensor Type</td>
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<tr>
<td>Frequency</td>
<td>6.9 GHz (C-band)</td>
<td>1.4 GHz (L-band)</td>
<td>1.41 GHz</td>
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<tr>
<td>Resolution</td>
<td>56 km</td>
<td>35-50 km</td>
<td>36 km</td>
</tr>
<tr>
<td>Accuracy</td>
<td>6 cm³/cm³</td>
<td>4 cm³/cm³</td>
<td>4 cm³/cm³</td>
</tr>
</tbody>
</table>

**Legend:**
- **AMSR-E**: Advanced Microwave Scanning Radiometer-Earth Observing System
- **SMOS**: Soil Moisture and Ocean Salinity
- **SMAP**: Soil Moisture Active/Passive

**Source:** NASA/JAXA, ESA, NASA
Data Assimilation with EnKF

- Use Ensemble Kalman Filter within LIS to assimilate satellite soil moisture retrievals into the Noah 3.2 LSM.
- EnKF combines the model **background** and **observations** to make **analyses**
  - Relative weighting is controlled by the specified **observation error** and by the **ensemble spread**
- Implemented EnKF assimilation of SMOS L2 data
  - QC based on model state and data flags for precipitation, RFI, data quality, frozen soil, snow cover, and high vegetation
  - Empirically tuned run-time settings including perturbations, number of ensemble members
  - Bias correction by CDF Matching
  - Capability of implementing landcover-dependent correction.
- Assimilation is 1-D (each grid cell independent). Observations can be spread over several grid cells for high-resolution model runs.
- Planned for use in near-real-time SPoRT LIS.
Bias Correction

• Initial tests had large dry bias in observations, so that only extreme rain events had correct sign.

• Discussions with other researchers confirmed need for bias correction

• Implemented CDF matching correction for SMOS retrievals.

• Assimilating retrievals (not radiances) lets us use established methodology

Uncorrected innovations (observations minus model) and increments. Red=dry bias in retrievals.
Bias Correction

• LIS can apply point-by-point correction curves. To increase the background dataset size, we are aggregating points by landcover type. We will also explore correction at each point and aggregating by soil type.

• In general, observations are drier than the model but have a higher dynamic range.
Irrigation Case Study

Model soil moisture concentration forced only by precipitation and misses magnitude of irrigation-saturated MS Valley

SMOS observes irrigated fields

Blended analysis of model and observations better represent irrigated area and should result in improved weather and hydrologic modeling

• Test Impact on NWP using coupled LIS-WRF
• Implications for regional climate modeling
  – Impacts of changing land-use, precipitation patterns
**Case Study: Irrigation Impact**

- **Irrigation scenario makes a good case study**
  - Forcing data is inaccurate due to irrigation
  - Demonstrate benefit of satellite DA
  - DA impact should also be enhanced in areas with sparse observation networks (mountainous terrain, underpopulated areas, developing countries, etc.)

- **Test impact on NWP using coupled LIS-WRF**
  - Validate soil moisture values
  - Examine impact on NWP
  - Verify NWP forecasts
  - Impact on boundary layer for a quiescent day
  - Active convection case
  - Validation over a longer time period

- **Implications for regional climate modeling**
  - Impacts of changing land-use, precipitation patterns
Current and future plans

• Validate analyses
  – TAMU North American Soil Moisture Database

• Test Impact of assimilating SMOS retrievals on NWP using coupled runs in NU-WRF
  – Impact on boundary layer for a quiescent day
  – Active convection case
  – Validation over a longer time period
  – Look at both sensitivity and forecast accuracy

• Assimilate active/passive blended product from SMAP; higher spatial resolution (9 km) should improve local-scale processes

Questions?