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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</thead>
<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>
<td>Passive</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><strong>4 cm³/cm³</strong></td>
<td><strong>4 cm³/cm³</strong></td>
</tr>
</tbody>
</table>
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.
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.
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?