



Assimilation of SMOS Soil Moisture Retrievals in the Land Information System

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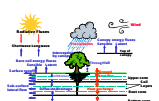


Abstract

Soil moisture is a crucial variable for weather prediction because of its influence on evaporation. It is of critical importance for drought and flood monitoring and prediction and for public health applications. The NASA Short-term Prediction Research and Transition Center (SPoRT) has implemented a new module in the NASA Land Information System (LIS) to assimilate observations from the ESA's Soil Moisture and Ocean Salinity (SMOS) satellite. SMOS Level 2 retrievals from the Microwave Imaging Radiometer using Aperture Synthesis (MIRAS) instrument are assimilated into the Noah LSM within LIS via an Ensemble Kalman Filter. The retrievals have a target volumetric accuracy of 4% at a resolution of 35-50 km. Parallel runs with and without SMOS assimilation are performed with precipitation forcing from intentionally degraded observations, and then validated against a model run using the best available precipitation data, as well as against selected station observations. The goal is to demonstrate how SMOS data assimilation can improve modeled soil states in the absence of dense rain gauge and radar networks.

The Land Information System

The NASA Land Information System (LIS, Kumar et al. 2006) is a modeling framework for running land surface models. To facilitate intercomparisons, users may select land surface models, forcing data sources, landcover and soil type data sources, and many other parameters.



Schematic showing major processes modeled in a land surface model.

SMOS and SMAP

- The current work is assimilating SMOS soil moisture retrievals
- SMAP (Entekhabi et al. 2010), a similar instrument, but with the addition of a radar for higher resolution, will be launched this year.
- Experience gained from SMOS assimilation will facilitate the rapid implementation of SMAP data assimilation.

Name	SMOS Soil Moisture and Ocean Salinity	SMAP Soil Moisture Active/Passive
Agency	ESA	NASA
Launch	2009	Nov. 2014
Orbit	Polar	Polar
Sensor Type	Passive	Active
Frequency	1.4 GHz (L-band)	1.2 GHz
Resolution	35-50 km	>+1-3 km
Accuracy	4 cm/cm ³	6 cm/cm ³

Applications

- SPoRT produces real-time US soil moisture products for situational awareness and local numerical weather prediction over CONUS, Mesoamerica, and East Africa
- Currently interact/collaborate with operational partners on evaluation of soil moisture products
 - Drought/fire
 - Extreme heat
 - Convective initiation
 - Flood and water borne diseases

Ensemble Kalman Filter

We assimilate AMSR-E soil moisture observations using an Ensemble Kalman Filter (EnKF) within LIS. Kalman filtering is a data assimilation method that combines a forecast (background) with observations to generate an improved estimate of a model variable. A Kalman Filter calculates an optimal weighting between the background and the observation. The EnKF uses the spread of the ensemble to represent the forecast error covariance. We used an ensemble with 16 members generated using perturbations of 3 forcing variables (incident longwave and shortwave radiation, and rainfall), 4 state variables (4 layers of soil moisture), and 1 observation variable (SMOS soil moisture).

SMOS Assimilation in LIS

- Read ECMWF Level 2 Soil Moisture User Data Product (SMUDP) files
- Read all orbits that fall in the time window (currently +/-3 hours) then exclude data outside the time window or the geographic region.
- Apply QC for RF, frozen soil, snowcover, falling precipitation, heavy vegetation, and data quality flags.
- Use ESMPF interface in LIS to assign observations to grid points.
- Use LIS Ensemble Kalman Filter to produce model state updates.

Experiment Setup

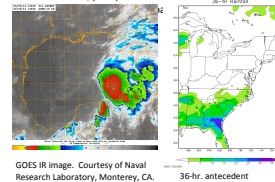
Experiment Name	Rain Forcing	Configuration	Purpose
Dry DA	0.5°GDAS	EnKF	Experiment 1
Dry Control	0.5°GDAS	Open Loop	Control 1
Wet DA	1.5°GDAS	EnKF	Experiment 2
Wet Control	1.5°GDAS	Open Loop	Control 2
"Truth" Run	GDAS	Single run	Validation

- 16 member ensembles.
- Spinup period of 8 months with state and forcing perturbations applied to generate ensemble spread.
- "Dry" and "Wet" runs with ±50% GDAS rain forcing are run in EnKF and open loop configurations to test the impact of SMOS soil moisture data assimilation on a known imperfect case as a proof of concept.
- Open loop runs are identical to EnKF runs with no data assimilated.
- Runs are validated against the run with the "correct" GDAS rain forcing.
- The EnKF runs assimilated data at 00Z and 12Z on 5 Jun 2013.

Model Configuration	
LIS Version	6.2
Land Surface Model	Noah 3.2
Domain	Eastern North America 80x92 (25 km)
Meteorological Forcing	GDAS
Model timestep	30 minutes
Data assimilation timestep	6 hours (effectively 12 hours due to data availability)

Case Study

- Tropical Cyclone Andrea in June 2013
- Before landfall, precipitation in



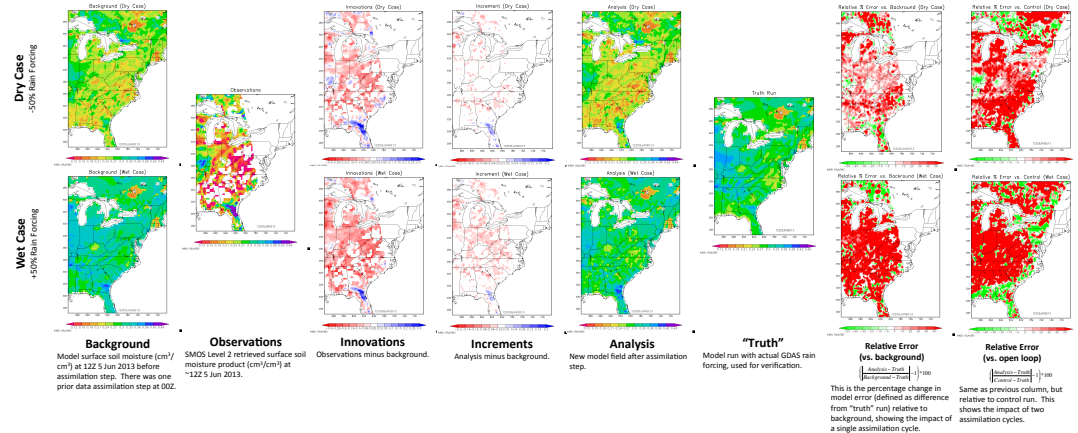
GOES IR image. Courtesy of Naval Research Laboratory, Monterey, CA.

36-hr. antecedent precipitation from GDAS forcing data.

Acknowledgements

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- We thank Susan Moran, Vanessa Escobar, and Molly Brown for including us as SMAP Early Adopters

Preliminary Model Results



Discussion

- This is a first test of SMOS assimilation, so many shortcomings still need to be addressed.
- Model "truth" (based on GDAS forcing and model physics) has errors which are not accounted for in this validation.
- There is a large dry bias in the observations (relative to the model background)
- Innovations are overall negative, even in the dry case, but there is a positive signal in the area of northern Florida/southern Georgia where precipitation occurred.
- Analysis increments have the same sign as innovations, as expected.
- Our relative error metric, hampered by model-observation bias, shows increasing error due to the analysis in most locations (red areas). However the total area with error reduction (green area) grows with repeated data assimilation cycles.

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Future Improvements

- Apply a bias correction using the cumulative distribution function (CDF) adjustment of Reichle and Koster (2004), possibly making it landcover-dependent (Blankenship and Crosson 2011)
- Test assimilation in a cycling run over an extended period of time
- Test in less-vegetated regions such as the Great Plains or tundra areas
- Optimize the perturbations to achieve a spread that is representative of the estimated model error.
- Determine the optimal observation uncertainty
- Perform validation against in situ soil moisture network observations.
- Implement with SMAP test data available to SMAP Early Adopters

See also...

- Details on SPoRT's real-time LIS and expected use of SMAP data can be found in
 - Case (26th Conference on WAF/NWP; P162; Tues. Feb. 4)
 - Case et al. (26th Conference on WAF/NWP; J9.4; Wed. Feb 5 @ 2:15 P.M.)