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’s Soil Moisture and Ocean Salinity (SMOS) retrieval is a data assimilation method that obtains a bias-corrected soil moisture with observations to generate an improved estimate of a model variable. A Kalman Filter calculates an optimal weighting between the observations and the prediction. The result is a product that can be used to correct the forecast model output. The sensor on the SMOS satellite, the Microwave Imaging Radiometer, uses a combination of soil moisture and salinity to produce reliable soil moisture estimates.

Description of Ensemble Kalman Filter

We assimilated SMOS soil moisture observations using an Ensemble Kalman Filter (EnKF) with LIS. Kalman filtering is a data assimilation method that obtains a forecast variable with observations to generate an improved estimate of a model variable. A Kalman Filter calculates an optimal weighting between the observations and the prediction. The result is a product that can be used to correct the forecast model output. The sensor on the SMOS satellite, the Microwave Imaging Radiometer, uses a combination of soil moisture and salinity to produce reliable soil moisture estimates.

Implementation of SMOS assimilation in LIS

Read ECMWF Level 2 Soil Moisture User Data Product (SMUDP) files
Read all available data in the time window (currently +3 hours) then exclude data outside the time window or the geographic region.
QC for RI: Remove soil, snow, vegetation, wetland, and data quality flag.
Use ESMF interface in LIS to assign observations to grid points.
Use LIS Ensemble Kalman Filter to produce model state updates.

Experiment Setup

Experiment Dry Soil Optimal Soil Optimal Soil
Dry Ctrl 0.7505% SMAP 0.61% Control 2.4% SMOS 0.61% SMAP 1.2%
Dry EnKF 0.7505% SMAP 0.61% Control 2.4% SMOS 0.61% SMAP 1.2%
Dry Open 0.7505% SMAP 0.61% Control 2.4% SMOS 0.61% SMAP 1.2%

Preliminary Model Results

Soil Moisture Retrieval

Case Study

Tropical Cyclone Activity in June 2013
Before landfall, precipitation in Florida and Georgia associated with drying soil bands.

Discussion

This is a first test of SMOS assimilation so many shortcomings still need to be addressed.
Model土 moisture forcing produces a dry bias which is accentuated between the dry and wet soil experiments (results 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 bias 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, based on 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.

Future Improvements

Apply a bias correction using the cumulative distribution function (CDF) adjustment of Reichle (2017), possibly making it landcover dependent (Blankenship and Crosson 2016).
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 SMOS Level 2 data available to SMAP Early Adopters.

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