Soil Moisture Assimilation and Precipitation Error Modeling in the Ensemble-based GEOS-5 Land Data Assimilation System

Rolf Reichle, Viviana Maggioni (University of Connecticut), and Emmanouil Anagnostou (University of Connecticut)

A key issue in soil moisture data assimilation is that observational and modeling uncertainties are poorly known, and incorrect assumptions about these errors may compromise the efficiency of the land data assimilation system (LDAS). It is thus crucial to investigate the impact of the error characterization on the assimilation of soil moisture observations, in particular because LDASs often use very simplistic error models. As rainfall is the dominant meteorological forcing input to the land surface model for soil moisture estimation, a more comprehensive characterization of rainfall uncertainty may improve soil moisture estimates. Since soil moisture temporally integrates antecedent precipitation and is subject to lower and upper limits, the variability of errors in soil moisture is typically smaller than that of errors in precipitation. This error variance relationship is not linear and depends on the error properties of the rainfall fields (Maggioni et al., 2012b). Maggioni et al. (2011) showed that the use of a complex error model to characterize the spatial variability of rainfall errors could better capture soil moisture error properties. Furthermore, in a synthetic numerical assimilation experiment, Maggioni et al. (2012a) demonstrated that using the more elaborate rainfall error model may slightly improve surface and root zone soil moisture estimates obtained from assimilating soil moisture retrievals.

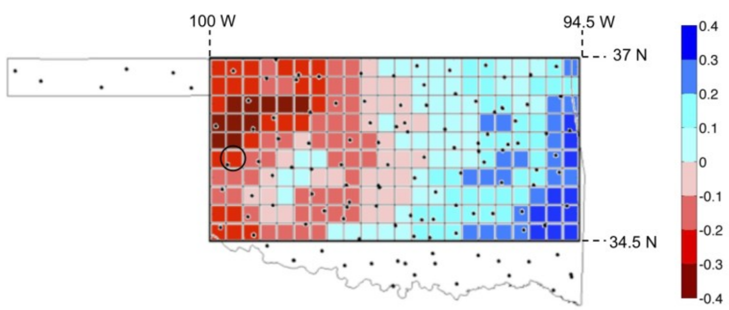

Figure 1: Experiment domain in Oklahoma, USA. Colors indicate the rainfall climatology parameter (dimensionless) used to bin the results in Figure 2. Blue (red) tones indicate "wet" ("dry") areas.

This study expands the synthetic experiment of Maggioni et al. (2012) by evaluating the assimilation of near-surface soil moisture retrievals from the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E). Data were assimilated for a three-year period (2004-2006) over a domain in Oklahoma, USA (Figure 1) into the NASA Catchment land surface model with the ensemble-based GEOS-5 LDAS.

Two different rainfall error models were considered: a complex, multi-dimensional model (SREM2D) and the simpler model (CTRL) used in the GEOS-5 LDAS. Specifically, five experiments were conducted: a "benchmark" simulation forced with Stage IV radar rainfall, and four experiments obtained by perturbing satellite rainfall fields with the two rainfall error models of different complexity, with and without the assimilation of AMSR-E soil moisture retrievals. Satellite rainfall was from the NOAA Climate Prediction Center morphing (CMORPH) product. Surface and root zone soil moisture outputs from each experiment were compared against Oklahoma Mesonet in situ measurements.

Figure 2 shows that the assimilation of satellite soil moisture retrievals provides a significant improvement of surface and root zone soil moisture estimates, indicating the ability of the model update to propagate to deeper soil levels. The improvement due to assimilation is apparent also in comparison to the AMSR-E retrievals themselves, i.e., starting from two poorer estimates of soil moisture, data assimilation provides a superior estimate. We also note that soil moisture estimates from data assimilation exhibited correlations higher than, or at least as high as, those estimated from the model forced with the most accurate rainfall (i.e., Stage IV). Furthermore, we observe that all simulation and assimilation results (but not the AMSR-E retrievals) perform better for the wetter conditions. Finally, the

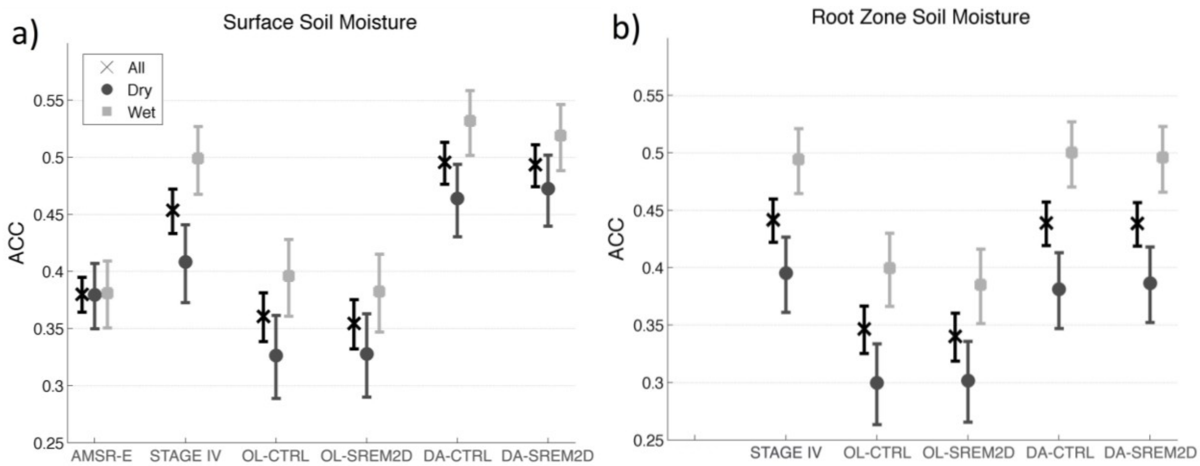

Figure 2: Domain-average of daily anomaly correlation coefficients (ACCs; dimensionless) calculated against MESONET station observations for (a) surface and (b) root zone soil moisture with 95% confidence intervals for all grid cells and binned by dry and wet conditions. Simulation experiments without assimilation of AMSR-E retrievals are labeled "OL" (for open loop). Experiments with assimilation of AMSR-E retrievals are labeled "DA" (for data assimilation). The rainfall error model (CTRL or SREMS2D) used in the simulation or assimilation experiments is also indicated. "Stage IV" is a simulation experiment that uses high-quality radar precipitation forcing.

use of the more complex SREM2D rainfall error model leads to only marginally better soil moisture analyses, which suggests that the simpler CTRL rainfall error model of the GEOS-5 LDAS may be adequate for soil moisture data assimilation. Nevertheless, the use of a more sophisticated error model, such as SREM2D, is suggested in future land data assimilation studies, in order to provide a more realistic representation of the sources and nature of errors in precipitation retrievals.

The results are encouraging towards the use of satellite retrievals (of both soil moisture and precipitation) in LDAS, especially because of the increasing availability of satellite soil moisture and rainfall observations from the Soil Moisture and Ocean Salinity mission, the Soil Moisture Active Passive mission, and the Global Precipitation Measurement mission.

References:

Maggioni, V., R. H. Reichle, and E. N. Anagnostou, 2011: The effect of satellite-rainfall error modeling on soil moisture prediction uncertainty, *J. Hydromet., 12*, 413-428, doi:10.1175/2011JHM1355.1.

Maggioni, V., R. H. Reichle, and E. N. Anagnostou, 2012a: The impact of rainfall error characterization on the estimation of soil moisture fields in a land data assimilation system, *J. Hydromet., 13*, 1107-1118, doi:10.1175/JHM-D-11-0115.1.

Maggioni, V., E. N. Anagnostou, and R. H. Reichle, 2012b: The impact of model and rainfall forcing errors on characterizing soil moisture uncertainty in land surface modeling, *Hydrology and Earth System Sciences, 16*, 3499-3515, doi:10.5194/hess-16-3499-2012.

Publication:

Maggioni, V., R. H. Reichle, and E. N. Anagnostou, 2013: The efficiency of assimilating satellite soil moisture retrievals in a land data assimilation system using different rainfall error models, *J. Hydromet.*, (in press), doi:10.1175/JHM-D-12-0105.1.