High Resolution Soil Moisture Estimation in the Mississippi Delta via Data Assimilation Using the NASA Land Information System

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Introduction

The Lower Mississippi River Valley (LMRV), aka the *Mississippi Delta*, with the rich alluvial soil and abundant supply of water, is an area of intense agriculture practices as well as aquaculture. This quilted landscape, with a distinct pattern of soil textures, develops a complex mosaic of surface temperatures and soil moisture. The regional water management agencies and the farmers in this agricultural have a practical need to have a better understanding of the soil moisture conditions for general water management, drought monitoring and irrigation purposes. The current operational soil moisture products are not sufficient to address these specific regional needs.

Cureently, *in-situ* soil moisture meausrements are available from 12 Soil Climate Analysis Network (SCAN) stations, deployed by the USDA Natural Resources Conservation Service (NRCS). Our main objective in this research is to explore the feasibility of extending the soil moisture observations from SCAN to higher spatial resolutions by using NASA resources, namely models and remotely

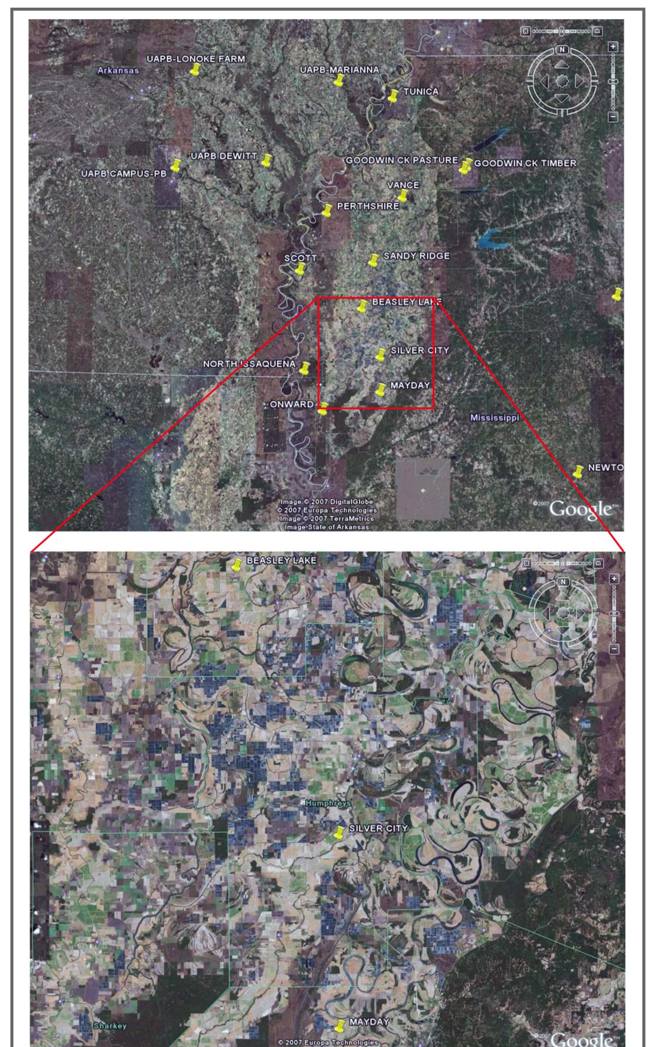

Figure 1: The Mississippi Delta, is characterized by farming and aquaculture. There are 12 SCAN sites located in our domain.

Methodology and Summary of Results

The *Noah* **Land Surface Model** (LSM) in the NASA Land Information System (LIS) was used to generate gridded soil moisture products at different spatial resolutions ranging from 1x1 km² to 25x25 km². The model was configured to use NLDAS forcings, UMD vegetation, and STATSGO soils data. After initial spin-up, the AMSR-E and SCAN data were assimilated using Ensemble Kalman Filtering (EnKF) methodology using two different versions of LIS. Prior to the control experiments, sensitivity studies were done to understand the model physics and boundary conditions. By default, the Noah model uses a free drainage condition at the bottom boundary which resulted in the bottom layers being excessively dry (Fig 3). A constant water head specification lead to an overall improvement in the entire dept but at the cost wetter conditions in the top layer(s). The NLDAS precipitation forcing was comparable to both NEXRAD Stage IV and *in-situ* rain fall measurements at the SCAN locations (Fig 2).

The control run of the Noah model, without any data assimilation, performed surprisingly well, when validated against the observations at the SCAN locations. The model had a tendency to dry out at a faster rate after rainfall events (Fig 4). The AMSR-E data were much drier when compared to the *Noah* model, and hence the assimilation of the AMSR-E data without any adjustments resulted in the worst performance. The AMSR-E data were then scaled using the *CDF Matching* technique before the assimilation. This improved the results somewhat but still the performance was degraded. The synthetic DA runs demonstrates a reasonable skill of the EnKF framework. SCAN assimilation has the most positive impact on soil moisture estimation, reflected not only in RMS errors but also in the correlations. The assimilation of AMSR-E was helpful in areas where the control run performed poorly. The emerging implementations of the 3D-EnKF methodology could help improve the results significantly.

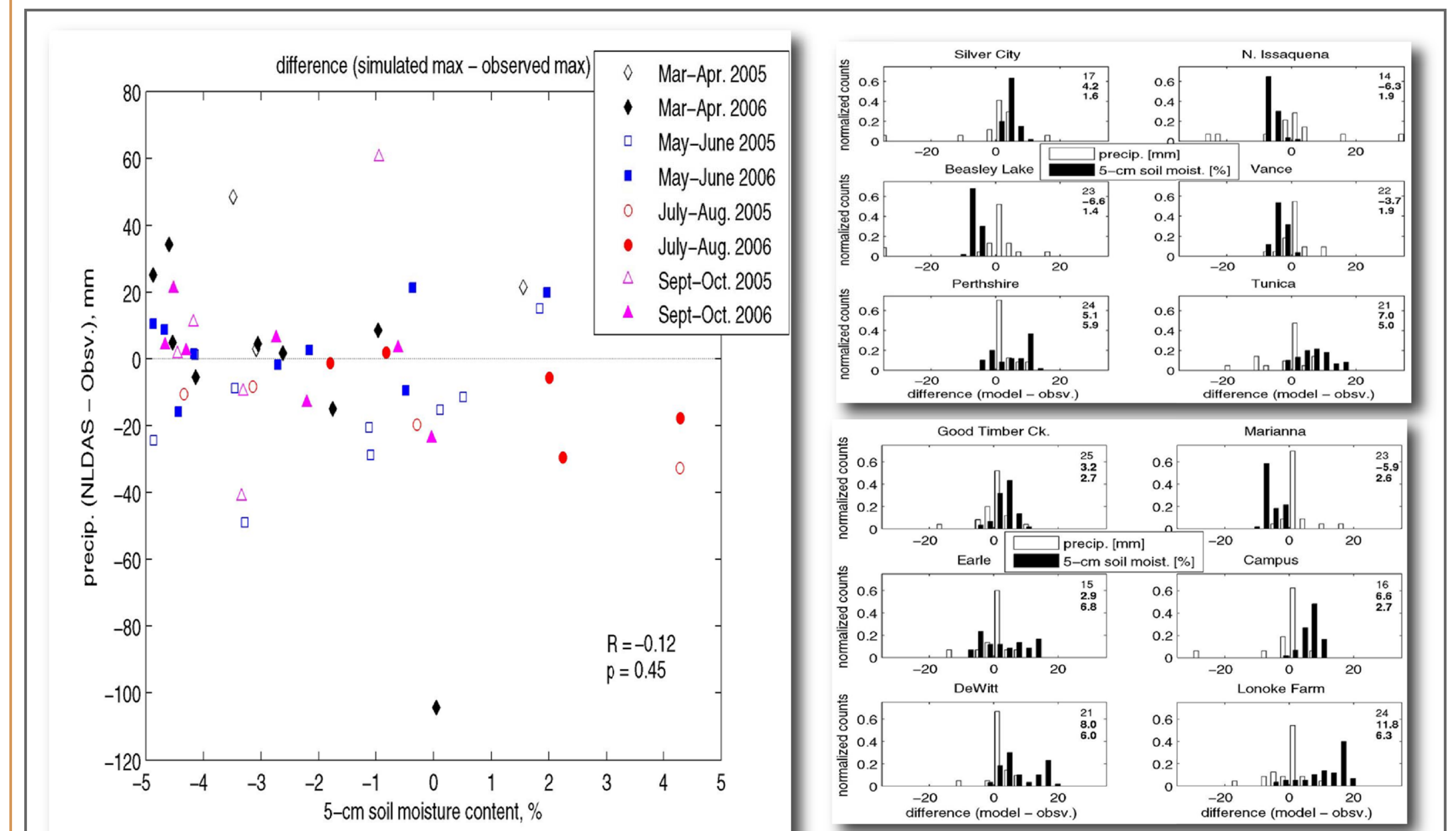

Figure 2: Error distribution due to the differences (NLDAS - observed) in precipitation forcings. The differences in soil moisture responses due to precipitation differences between in-situ measurements and NLDAS (left). The error distributions for the 12 SCAN sites (right).

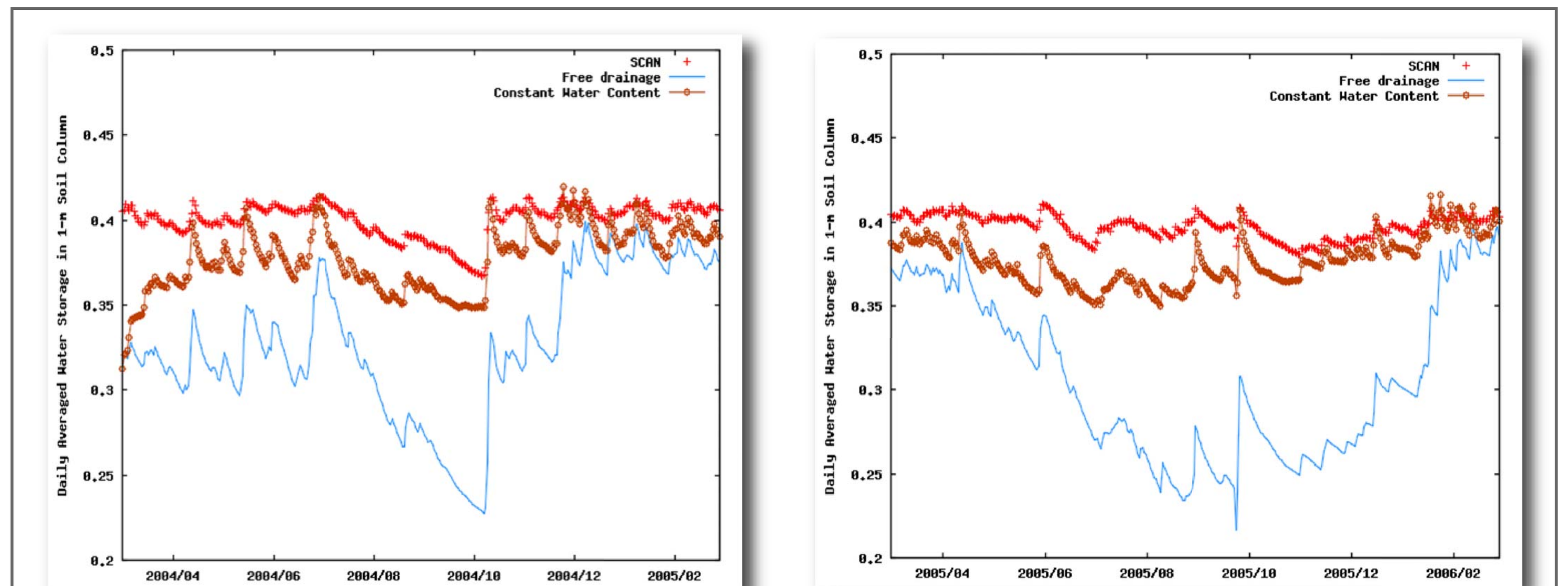

Figure 3: Daily averaged soil water content in the top 1 meter of the soil for year 2004 (left) and 2005 (right). The default bottom boundary condition of the Noah model resulted in excessive drying of the deeper layers. The free drainage BC is not appropriate for this domain. A constant water head BC provided more realistic soil moisture at the deeper layers.

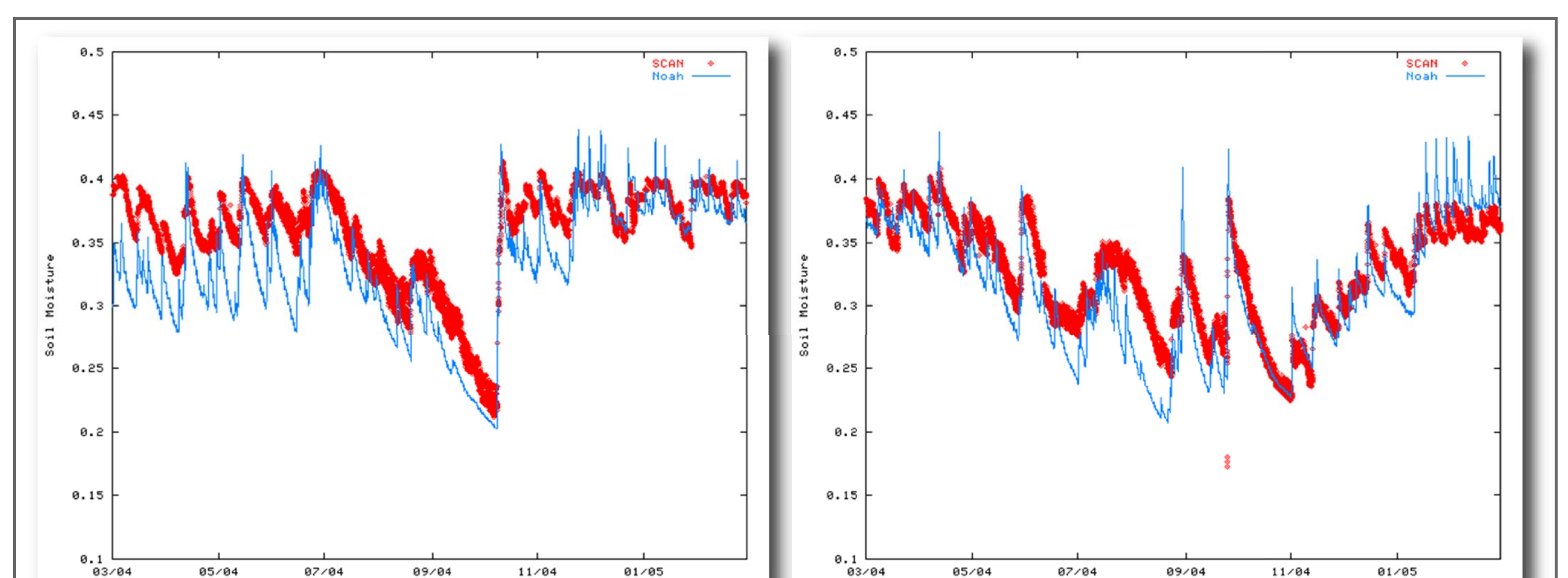

Figure 4: Daily averaged soil moisture content from the control run for the Noah model (blue) and 5 SCAN observations (red) located in Mississippi, for a period of two years -- 2004 (left) and 2005 (right).

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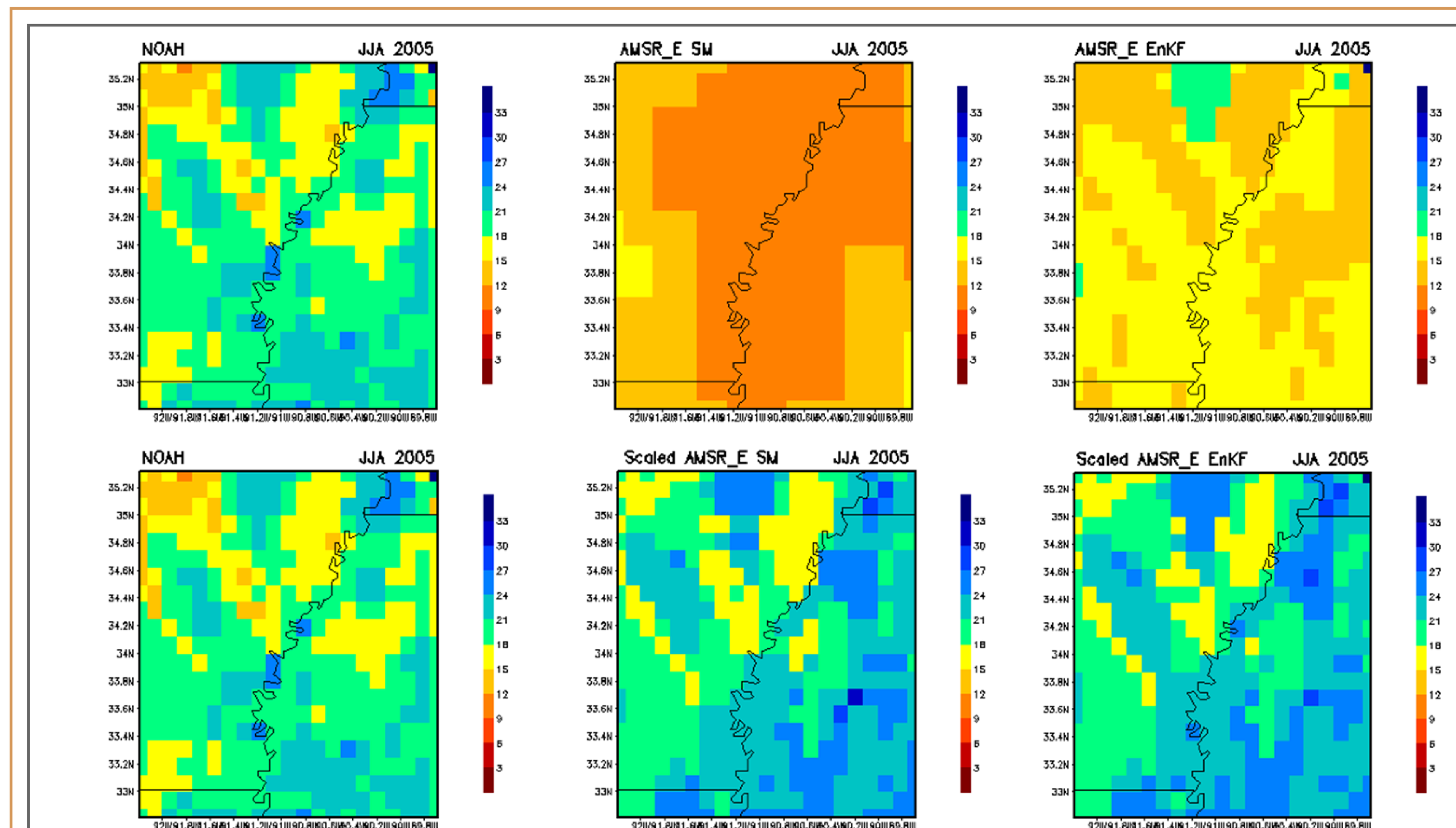


Figure 5: Data assimilation results of JJA seasonal averages of soil moisture for AMSR-E observations (top) and CDF-matched and scaled values of AMSR-R (bottom).

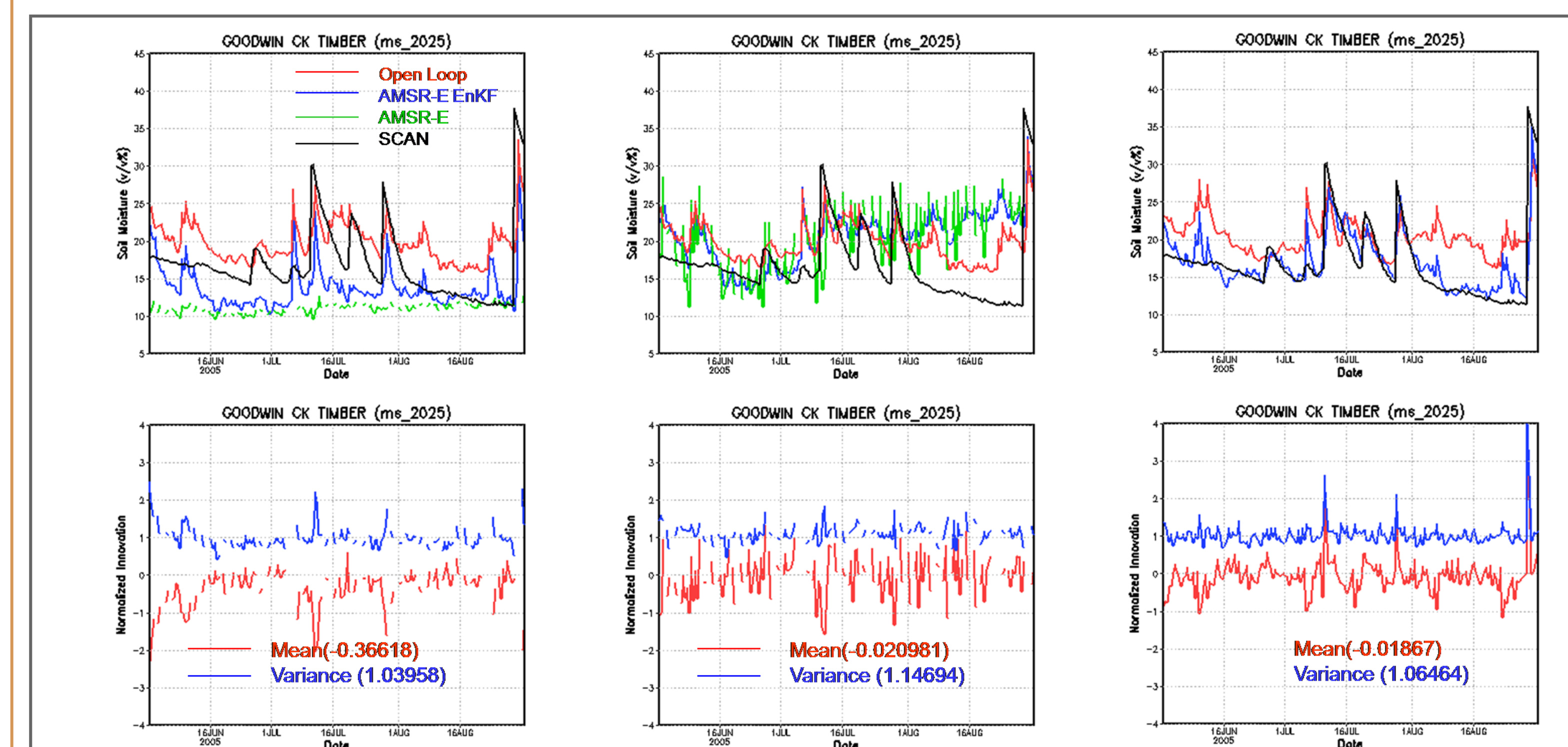
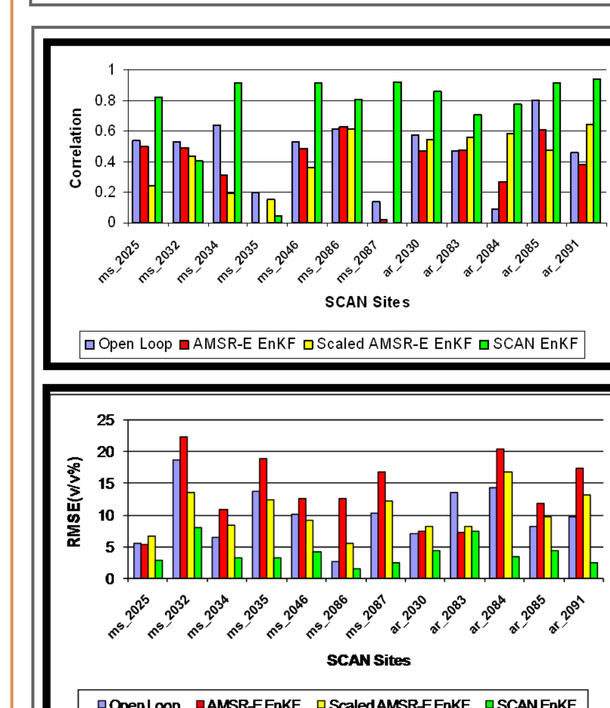


Figure 6: Performance of EnKF for AMSR-E (left), scaled AMSR-R (middle), and SCAN (right); and the respective normalized innovations (bottom). Assimilation of SCAN reduces the positive bias.



SCAN Sites	CR	Assimilation	AMSR-E	Years of SCAN
Perthshire	0.59	0.33	0.27	4.75
Silver City	0.65	0.65	0.57	3
Scott	0.43	0.49	0.43	3.6
Beasely Lake	0.35	0.31	0.18	5
NIssaquena	0.63	0.50	0.37	3
Tunica	0.68	0.44	0.38	5
Vance	0.62	0.41	0.35	5
Lonoke Farm	0.61	0.65	0.58	5
Campus PB	0.71	0.57	0.41	3
Marianna	0.65	0.35	0.35	2.5
Earle	0.55	0.63	0.54	2.75
DeWitt	0.22	0.30	0.28	2.6
Average	**0.56**	**0.47**	**0.39**	

Figure 7: Summary of the performance of EnKF assimilation for all 12 SCAN sites. The assimilation of *in-situ* SCAN observations performed the best and AMSR-E the poorest.

Conclusions and Recommendations:

NASA LIS is a robust framework for routine soil moisture estimation. Assimilation of AMSR-E is helpful when the uncertainties in the model and/or forcing and parameter data are larger. Assimilation of SCAN consistently improved the model results. New techniques need to be implemented in LIS to combine both AMSR-E and SCAN. The 3D-EnKF methodology has the potential to spread information from observed to unobserved locations. This technique needs to be implemented in LIS and further evaluated.

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