Contribution of Soil Moisture Retrievals to Land Assimilation Products

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Project Objectives: Satellite retrievals of surface soil moisture are subject to errors and cannot provide complete space-time coverage. Data assimilation systems merge available retrievals with information from land surface models and antecedent meteorological data, information that is spatio-temporally complete but likewise uncertain. For the design of new satellite missions it is critical to understand just how uncertain retrievals can be and still be useful. We conducted synthetic data assimilation experiments to determine the contribution of retrievals to the skill of land assimilation products as a function of retrieval and land model skill.

Project Description: A common approach to estimating soil moisture is to drive a land surface model (LSM) with observed meteorological forcing. The LSM integrates the forcing and produce estimates of soil moisture and other land surface fields. Indirect measurements (retrievals) of surface soil moisture can be obtained from satellites. Both the model and the satellite estimates are subject to errors. Data assimilation systems propagate the surface retrieval information into deeper soil layers, giving otherwise unobtainable information (e.g. root zone soil moisture) needed for applications such as weather and climate forecasts. Data assimilation systems are thus an invaluable part of any satellite-based soil moisture measurement mission.

Consider a mission assimilation product for which there is a target accuracy requirement. For a given level of model skill, a specific level of retrieval skill would be needed to bring the assimilation product to the target accuracy. Knowledge of such retrieval skill requirements is directly relevant to the planning of the L-band (1.4 GHz) Soil Moisture Active-Passive (SMAP) mission (projected launch in 2013). In this project, we developed a Data Assimilation-Observing System Simulation Experiment (DA-OSSE) that measures the contribution of surface soil moisture retrievals to the skill of the assimilation estimates (of surface and root zone soil moisture and evapotranspiration) as a function of the errors in the satellite retrievals and in the LSM.

Results: We conducted 96 assimilation experiments with synthetic observations (see Figure 1). Each experiment is a unique combination of a retrieval dataset (with a certain level of skill, measured in terms of R) and a model scenario (with its own level of skill). We can thus plot 2D surfaces of skill in the assimilation products as a function of retrieval and model skill.

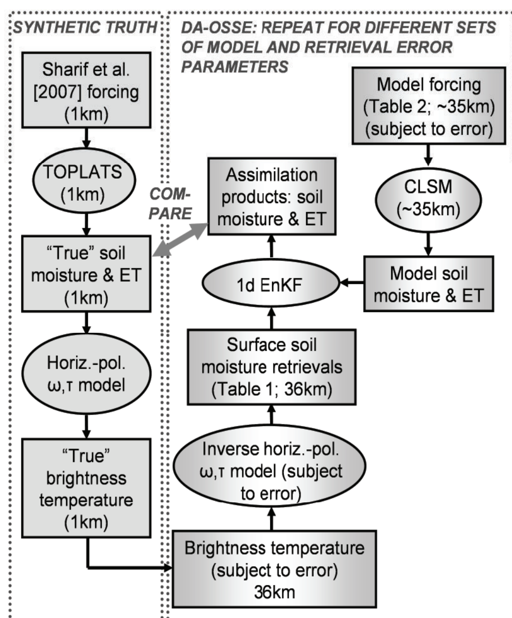

Figure 1: Flow diagram of the DA-OSSE.

Figure 2 shows skill *improvement* through data assimilation, defined as the skill of the assimilation product minus the skill of the model estimates (without assimilation). Specifically, for a given level of accuracy in the stand-alone model product, the figure shows how much information can be added to the *root zone* soil moisture product through assimilation of satellite retrievals of *surface* soil moisture with a given uncertainty. Note that the skill of the root zone soil moisture assimilation product always exceeds that of the model. As expected, the improvements in R through assimilation increase with increasing retrieval skill and decrease with increasing model skill. Perhaps most important is that even retrievals of low quality contribute some information to the assimilation product, particularly if model skill is modest.

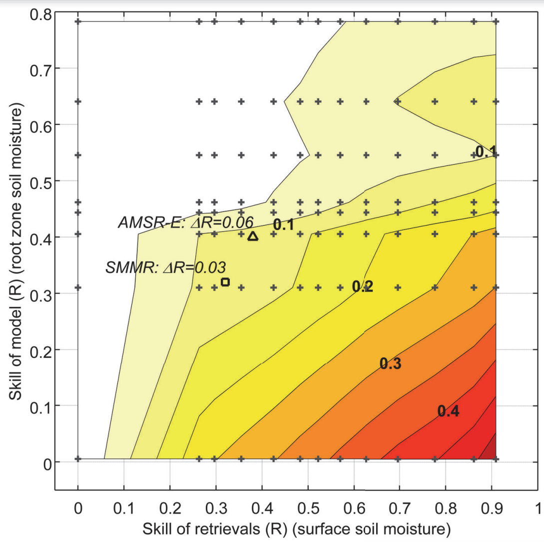

Figure 2: Skill improvement (ΔR) through assimilation for root zone soil moisture as a function of (ordinate) model and (abscissa) retrieval skill. Skill improvement is defined as skill of assimilation product minus skill of model estimates. Each plus sign indicates the result of one 19-year assimilation integration over the Red-Arkansas domain. Also shown are results for (triangle) AMSR-E and (square) SMMR.

We can compare previously published skill levels with these results. For 23 locations across the U.S. having *in situ* observations for validation, Reichle et al. [2007] report average R values of 0.38, 0.40, and 0.46 for AMSR-E retrievals, model root zone estimates, and the root zone assimilation product, respectively. From the figure we expect that for retrievals with R=0.38 and a model with R=0.40, the skill improvement through assimilation would be about R=0.1, which is roughly consistent with the AMSR-E result (indicated by Δ). The actual root zone improvements through assimilation of AMSR-E observations fall somewhat short of those suggested by the OSSE. Possible explanations include (i) the imperfect translation of information from the surface layer to the root zone in the data assimilation system and (ii) the fact that the *in situ* data used for validation of the AMSR-E result are themselves far from perfect (unlike the perfectly known truth of the synthetic experiments). The figure also includes the Reichle et al. [2007] results for assimilating retrievals from the Scanning Multichannel Microwave Radiometer (SMMR). Note that R values for SMMR results are based on monthly mean data, and that the validating *in situ* data for the AMSR-E and SMMR results are not within the geographical domain of our synthetic experiment.

This general framework to quantify the information added to land assimilation products by satellite retrievals of surface soil moisture will be used to provide comprehensive error budget analyses for SMAP data assimilation products.

Publications:

Reichle, R. H., W. T. Crow, R. D. Koster, H. Sharif, and S. P. P. Mahanama, 2008: Contribution of soil moisture retrievals to land data assimilation products, *Geophys. Res. Lett.*, **35**, L01404, doi:10.1029/2007GL031986.

Reichle, R. H., R. D. Koster, P. Liu, S. P. P. Mahanama, E. G. Njoku, and M. Owe, 2007: Comparison and assimilation of global soil moisture retrievals from AMSR-E and SMMR, *J. Geophys. Res.,* **112**, D09108, doi:10.1029/2006JD008033.