Estimating Root Mean Square Errors in Remotely Sensed Soil Moisture over Continental Scale Domains

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Making the best use of recently developed remotely sensed soil moisture data sets requires confident understanding of their errors around the globe. However, current evaluation strategies are limited to a handful of intensely observed locations. Hence, this study compares two recently developed methods to provide global distributed estimates of the Root Mean Square Error (RMSE) in remotely sensed surface soil moisture: i) triple colocation and ii) error propagation through the retrieval algorithms. Triple colocation estimates errors using three independent data sets, and simulations from the GEOS-5 Catchment land surface are used as the third data set. The RMSEs in surface soil moisture derived from the Advanced Scatterometer (ASCAT; Naeimi et al, 2009), and the Advanced Microwave Scanning Radiometer (AMSR-E; Parinussa et al, 2011) are examined over a continental scale domain in North America, from January 2007 to October 2010 (4.75 years).

In the absence of a consensus about the climatology of soil moisture over large spatial scales, presenting a RMSE in soil moisture units requires that it be specified relative to an arbitrarily selected reference data set. In this study the RMSE is presented as a fraction of the time series standard deviation, fRMSE. The fRMSE metric is demonstrated to have several advantages over the traditional approach of presenting the soil moisture RMSE relative to a reference.

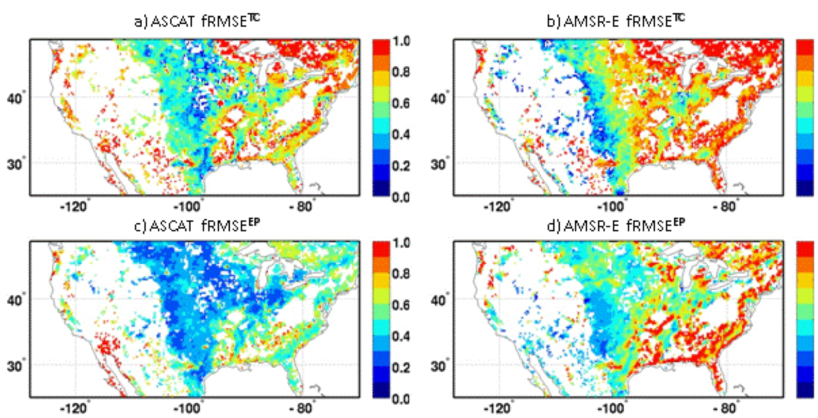

Figure 1: fRMSE of (left) ASCAT and (right) AMSR-E surface soil moisture retrievals, estimated using (upper) triple colocation and (lower) error propagation and plotted only where triple colocation results are available. Note the different color scale for the AMSR-E fRMSE^{EP} in d.

Figure 1 shows maps of the ASCAT and AMSR-E fRMSE calculated using triple colocation (fRMSE^{TC}) and error propagation (fRMSE^{EP}). Error propagation is designed to determine the spatial and temporal variability in the uncertainty of a given data set. The magnitude of the error propagation output depends on the uncertainties specified for the retrieval model parameters, and these uncertainties are not well understood at scales relevant to remote sensing. Hence, the unrealistically large fRMSE^{EP} for AMSR-E are not surprising (values above one indicate RMSE greater than the time series standard deviation).

In terms of the spatial variability, both methods are accurately detecting instances of relatively low/high fRMSE in surface soil moisture retrievals. For each sensor, the fRMSE^{TC} and fRMSE^{EP} show similar patterns of relatively high/low errors in Figure 1, and the mean fRMSE for each land cover class in Figure 2 is consistent with expectations. For example there is a general increase in the fRMSE in Figures 2a and 2b with increasing vegetation leaf area index (LAI) in Figure 2c. Also, the ASCAT fRMSE is very high for open shrubs, which are located in the arid southwest of the domain, consistent with known deficiencies in the ASCAT change-detection

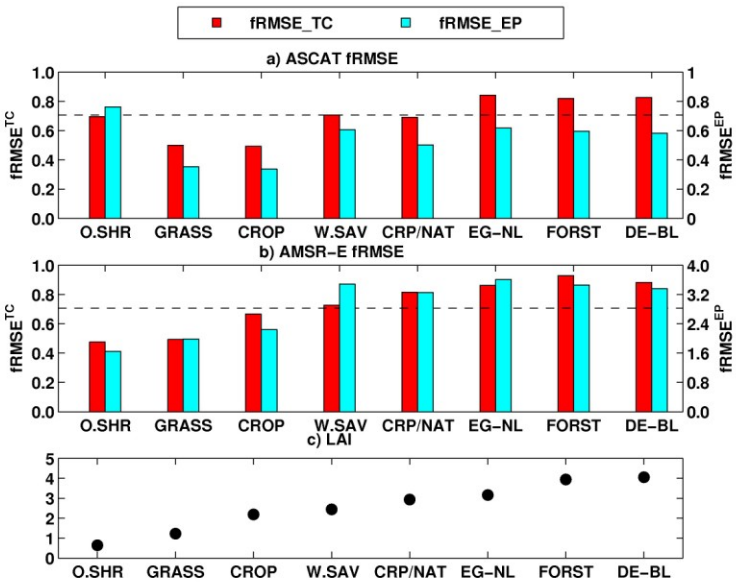

Figure 2: Mean by land cover type for fRMSE^{TC} and fRMSE^{EP} of a) ASCAT and b) AMSR-E, and for c) LAI.

retrieval model in arid regions. While they generally agree, there are some discrepancies between the fRMSE^{TC} and fRMSE^{EP} in Figure 2, from which shortcomings in the retrieval algorithms, leading to errors in the fRMSE^{EP}, can be identified.

Triple colocation accurately estimates the RMSE in remotely sensed soil moisture anomaly time series, and it is shown to be surprisingly robust to representativity differences between the soil moisture data sets used. In contrast to error propagation, triple colocation can be used to compare the errors in different data sets. Figure 2 shows that both sensors have similar accuracy across the land cover classes, with the exception of the high ASCAT fRMSE in arid regions noted above, and the relatively low ASCAT fRMSE over croplands – although neither of these differences is significant at 5%. As expected, both data sets perform well under sparse to moderate vegetation (LAI<3), which covers 63% of the domain plotted in Figure 1.

In summary, the substantial spatial variability in the fRMSE in Figure 1 highlights that an evaluation of soil moisture based on a limited number of locations is not necessarily representative of a larger domain. While the RMSE defined by triple colocation (unbiased RMSE of anomalies from the seasonal cycle) and error propagation (errors associated with model input and parameters only) differs from the definition commonly used to specify target accuracies for remote sensing data products, both methods can indicate regions where the accuracy from intensely observed locations can be confidently extrapolated, and regions where otherwise unforeseen problems may occur. For most applications, triple colocation will be more useful, since in addition to predicting the spatial variability in the errors, it also produces RMSE estimates with a reliable magnitude.

References:

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