Benchmarking a Soil Moisture Data Assimilation System for Agricultural Drought Monitoring

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Agricultural drought is defined as a shortage of moisture in the root zone of plants. Recently available satellite-based remote sensing data have accelerated development of drought early warning system by providing continuous soil moisture information in space and time. Nonetheless, the shallow sensing depth (top few cm) and uncertain accuracy of currently-available satellite soil moisture retrievals necessitated the integrating hydrologic models and surface soil moisture observations through data assimilation techniques to obtain more accurate root zone soil moisture estimates. Although a number of previous studied have demonstrated the benefits of soil moisture data assimilation system, relatively little is known about the relative merits of particular retrieval, modeling and/or data assimilation strategies. In particular, it remains unclear what level of complexity and/or nonlinearity is appropriate for each of these components.

In this study, we attempt to assess individual components of a drought-monitoring soil moisture data assimilation system and benchmark the efficiency of these components relative to simpler retrieval, modeling and data integration strategies. In this way, we improve our understanding of skill contributed by various components of the system and, ultimately, pinpoint specific aspects of such systems to target for improvement. First, the efficiency of a retrieval algorithm, Land parameter Retrieval Model (LPRM) is evaluated using data from the Advanced Microwave Scanning Radiometer-EOS (AMSR-E). Second, the two-layer Palmer water balance model being in operational use by the USDA - Foreign Agricultural Service is tested. Lastly, a well-proven data assimilation technique, Ensemble Kalman filter (EnKF) is evaluated. The metric to measure the performance of each process is the lagged rank correlation between the output of each component and the normalized difference vegetation index (NDVI). A simple statistical model, the multiple linear regression model is used as benchmarks (minimal reference level) against which the performances of different components of assimilation system are evaluated.

Interestingly, it is found that most of the benefits from the assimilation system to predict root zone soil moisture are attributed to the initial remote sensing observations (i.e., brightness temperature). The nonlinearities in the retrieval algorithm (LPRM) and hydrologic model (Palmer model) and the complexities in the EnKF marginally contribute to the predictive skills of the system. This suggests that there are considerable rooms for improvement in those nonlinear processes for effective agricultural drought monitoring. Specifically, for the hydrologic model, it appears there is no utility in enforcing a nonlinear saturation limit on soil moisture dynamics for coarse-scale agricultural drought monitoring. In addition, issues related to inappropriate implementation of the EnKF are discussed.