Soil moisture data assimilation at multiple scales and estimation of representative field scale soil moisture characteristics

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Soil moisture is a key variable in understanding the hydrologic processes and energy fluxes at the land surface. Therefore, accurate prediction of soil moisture in the vadose zone benefits irrigation planning and crop management, flooding and drought prediction, water quality management, climate change forecasts, and weather prediction. The three objectives of this study are to: (1) investigate the effects of surface soil moisture data assimilation on hydrological responses at the field scale using in-situ soil moisture measurements, (2) explore the effect of surface soil moisture data assimilation on each hydrologic process in a simulation model, including the effect of spatially varying inputs on the potential capability of surface soil moisture assimilation at the watershed scale, and (3) link two different scales of soil moisture estimates by upscaling single point measurements to field averages.

First, a well-proven data assimilation technique, the Ensemble Kalman Filter (EnKF), is applied to a field scale water quality model, Root Zone Water Quality Model, with in-situ soil moisture data from two agricultural fields in Indiana. Through daily update, the EnKF improvs all statistical results compared to the direct insertion method and model results without assimilation for the 5cm and 20cm depths while less improvement is achieved for deeper layers. Optimal update interval and ensemble size are also tested for the operational potential of data assimilation. This study demonstrates the potential of surface soil moisture assimilation to improve water quality and crop yield simulation, as well as, soil moisture estimation at the agricultural field scale.

Second, the EnKF is coupled with a watershed scale, semi-distributed hydrologic model, the Soil and Water Assessment Tool. Results shows that daily assimilation of surface soil moisture with the EnKF improvs model predictions of almost all hydrological processes. However, the EnKF does not produce as much of a significant improvement in streamflow predictions as compared to soil moisture estimates in the presence of large precipitation errors and due to the limitations of the infiltration-runoff model mechanism. Distributed errors of the soil water content show effects of spatially varying inputs such as soil and landuse types on the assimilation results. Results from this study suggest that soil moisture update through data assimilation can be

a supplementary way to overcome the errors created by limited or inaccurate rainfall data.

Proper linkage of soil moisture estimates across different scales of observations and model predictions is essential for the validation of remotely sensed soil moisture products, as well as the successful application of data assimilation techniques. Thus, this study also examines different upscaling methods to transform point measurements to field averages in representing small agricultural watersheds (~ 2 ha). The cumulative distribution function (CDF) matching approach, one of several statistical methods, is found to be the optimum upscaling method. Tests for temporal and spatial (horizontal and vertical) transferability of the upscaling equations indicate that they are transferable in space, but not in time. Rainfall characteristics and crop types are most likely major factors affecting the success of the transferability. In addition, the CDF matching approach is found to be an effective method to induce spatial soil moisture variance from single point measurements.

Overall, the results presented in this work can be utilized to improve applications of soil moisture data assimilation at field and watershed scales and better evaluate the scaling behavior of soil moisture.