Data Assimilation Using Distributed Hydrologic Models for High-Resolution Analysis of Streamflow and Soil Moisture

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Soil moisture is a critical hydrologic state variable that exerts large control over water and energy balance in land-atmosphere systems over a wide range of space-time scales. As such, it is essential for any models in which soil moisture dynamics play a key role to be initialized and diagnosed with as accurate as possible soil moisture information. Soil moisture, however, is only very sparsely measured in-situ and usually not reported in real time. For these reasons, in operational hydrologic forecasting, soil moisture is almost always estimated indirectly from water balance calculations of hydrologic models based on precipitation, potential evaporation (PE) and streamflow, often with the aid of human forecasters to maintain closeness between model-simulated streamflow and the observed.

While streamflow is not a direct measure of soil moisture, it does represent space-time-integrated response of the basin to soil moisture, and is measured at many locations and reported in real time. As such, streamflow observations are arguably the most widely available source of information for estimating soil moisture. In this work, we assess the potential of assimilating streamflow, in-situ soil moisture, precipitation and PE data into distributed hydrologic models for high-resolution analysis of streamflow and soil moisture. The assimilation technique used is 4DVAR. The hydrologic models used are the heat transfer version of the Sacramento soil moisture accounting model (SAC-HT) and the kinematic-wave hillslope and channel routing models of the NWS Hydrologic Laboratory's Research Distributed Hydrologic Model (HL-RDHM). The models operate on an approximately 4x4 km^2 grid and are forced by hourly precipitation and PE.

Two synthetic and a real-world experiments were carried out in an ensemble framework to assess sensitivity of the potential of the data assimilation (DA) for analysis of streamflow and soil moisture to uncertainties in the model initial conditions and in the observations. The study basin is Eldon (ELDO2) in northeast Oklahoma. It is 795km^2 in size and has three USGS stream gauges (one at the outlet and two at interior points, Christie and Dutch) and one OK Mesonet soil moisture site at Westville. The precipitation data used are the operationally produced Stage III products at ABRFC. For PE, monthly climatology is used.