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Analysis, estimation, and modeling of soil moisture variation using empirical orthogonal functions

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Space-time patterns of soil moisture are an important element in the coupling of ecological and hydrologic processes in a watershed. Soil moisture patterns can be quite complex because they depend on multiple interacting processes and heterogeneous site characteristics. This research primarily explores the application of Empirical Orthogonal Function (EOF) analysis to interpret space-time patterns of soil moisture, interpolate between sparse soil moisture measurements, and to merge historical soil moisture observations with numerical modeling results. EOF analysis can be used to decompose space-time datasets into the spatial average, a series of underlying spatial patterns, and a set of time series that indicate the importance of each spatial pattern. EOF analysis is applied to remotely-sensed soil moisture from the SGP97 field campaign and in-situ measurements at the Tarrawarra catchment in Australia. At Tarrawarra, for example, it is shown that the three most important spatial patterns identified from EOF analysis are most correlated with the wetness index, potential solar radiation index, and elevation, respectively. The EOF approach is also applied to the problem of interpolating between soil moisture measurements. If more than one date of soil moisture observations is present, interpolation between the observations is found to be more efficient when the dataset is first decomposed into EOFs, which are then interpolated and used to determine the high resolution soil moisture patterns. Finally, it is also shown that the EOF approach can be used to estimate current soil moisture patterns from a historical soil moisture dataset if the current spatial average is known from remote sensing or a simple hydrologic model. The spatial patterns are derived from the historical data, while the significance of each pattern is estimated from the current spatial average soil moisture or other methods. The soil moisture estimates from the EOF-based method have smaller errors than those produced by comparable methods if the spatial average is known in these methods. A hydrologic model for simulating the spatial average soil

moisture is also tested using a dataset from the Fort Cobb watershed in Oklahoma, USA, where soil moisture measurements are available for one year at a 30-minute resolution. This model, which probabilistically models spatial variability, is found to adequately reproduce the spatial average soil moisture for this site.