

Catchment-Scale Variability of Soil Moisture: Controlling Factors and a Method for Estimation

Mark A. Perry and Jeffrey D. Niemann
Department of Civil Engineering, Colorado State University

Abstract. The spatial distribution of soil moisture affects numerous applications in hydrology, meteorology, ecology, and agriculture. For example, soil moisture patterns influence the response of river basins to precipitation events, rates of evaporation and transpiration, and growth of vegetation and crops. Often spatially-averaged soil moisture values are used to model these processes, but this approach can give poor results if the processes are non-linearly related to soil moisture. Unfortunately collecting data at a sufficient spatial resolution is usually prohibitively costly and time-intensive. As a result, it would be desirable to estimate spatial patterns of soil moisture from a limited amount of field data. In this study, Empirical Orthogonal Function (EOF) analysis is used to analyze and then estimate soil moisture patterns. EOF analysis identifies a series of time-invariant spatial patterns (EOFs) that can be weighted using time-varying coefficients to reconstruct observed soil moisture patterns. This study utilizes 13 days of high resolution ground-based soil moisture data from the 10.5 ha Tarrawarra Catchment in southeast Australia. The observed soil moisture patterns appear significantly different on different days, but using EOF analysis two underlying patterns (EOFs) are identified that explain 64% of the total variation. These two patterns are shown to be correlated to site topography and are related to lateral redistribution and evapotranspiration of soil water. After the EOFs are identified, an estimation method is developed whereby the most important EOFs estimation method is attention to observed observations. It has been observed to vary seasonally. The EOFs are used to estimate soil moisture patterns for times when only the spatial average soil moisture is known. The appropriate weighting of the EOFs is determined using the spatial average soil moisture for the selected time. This EOF estimation method is compared with other available methods and usually outperforms the other methods because it accounts for the distinct underlying patterns of variability.