Investigating Controls on Soil Moisture Pattern Types and Their Time Instability

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Abstract. Soil moisture is an important hydrologic state variable, affecting both the partitioning of energy into sensible and latent heat fluxes and the partitioning of precipitation into infiltration and runoff. In addition, the spatial patterns of soil moisture within a catchment also influence the catchment's hydrologic behavior including the timing and quantity of runoff generated in response to a precipitation event. Topography is recognized as an important control on soil moisture patterns at the catchment scale, but the nature of its influence varies between catchments. Some catchments exhibit soil moisture patterns that are consistently wetter in the valley bottoms, whereas other catchments exhibit soil moisture patterns with wetter areas occurring on hillslopes that receive less insolation. In addition, the soil moisture patterns in some catchments exhibit topographic dependence that changes through time (a property called time instability). The objective of this research is to investigate the soil, vegetation, and climatic characteristics that influence the type of topographic dependence in soil moisture patterns and the strength of time instability. The Equilibrium Moisture from Topography (EMT) model is used to estimate realistic soil moisture patterns for three catchments with extensive soil moisture data (Tarrawarra, Satellite Station, and Cache la Poudre). Two metrics are used to measure the type of topographic dependence and the strength of time instability. The dependence of the metrics on the soil, vegetation, and climatic characteristics is then explored through varying the EMT model parameters. This exploration reveals that horizontal saturated hydraulic conductivity must be relatively low and horizontal pore disconnectedness relatively high for the wetter locations to occur on the hillslopes that receive less insolation. High transpiration efficiency also promotes such patterns. Time instability is encouraged by moderately high horizontal saturated hydraulic conductivity, moderately high horizontal pore disconnectedness, and moderately low transpiration efficiency.