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Catchment controls on soil moisture dynamics: from site-specific hysteresis in event responses to temporal stability of patterns

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Understanding soil moisture dynamics is a prerequisite for predicting hydrological response at the hillslope and catchment scale. Soil moisture is not only determined by its input characteristics such as rainfall, its redistribution by vegetation and evapotranspiration. Catchment characteristics resulting from the interplay of geology, topography, land cover and associated soil hydraulic properties also affect the distribution, storage and transport of water in the vadose zone. Successful process predictions and appropriate hydrological model structures thus rely on a good representation of soil moisture patterns and dynamics and benefit from insights into their dependence on catchment characteristics.
In a unique measurement setup at the CAOS hydrological observatory in Luxemburg (http://www.caos-project.de) we record hydro-meteorological variables at 45 sensor cluster sites. These sites are distributed across the mesoscale Attert catchment and cover three different geological units (schist, marls and sandstone), two types of land use (forest and grassland), different topographical positions (up- and downslope with north- and south-facing aspects as well as plateau and floodplain locations). At each sensor cluster, each covering approximately an area of 30 m^2, soil moisture is measured in three profiles at three different depths, in piezometers groundwater levels are recorded, and rain gauges collect throughfall or gross precipitation. At near-stream locations we also measure stream water levels.
This extensive sensor network enables us to study the influence of geology, land use and topography on soil moisture dynamics. In this study we focus on short-term hysteretic responses related to individual rainfall events and on longer-term temporal stability of soil moisture patterns. Similarities in the hysteresis loops of rainfall/soil moisture, soil moisture/groundwater levels and soil moisture/stream water levels can give some indication of the dominant catchment controls on storage and flow path activation. Examining the temporal stability of soil moisture patterns then helps to estimate the importance of these plot- and hillslope-scale hydrological processes on catchment-scale longer-term soil moisture dynamics.
First results of the event-based analyses indicate differences in thresholds of the soil moisture response to rainfall events as an effect of land use. These thresholds are also dependent on the actual soil moisture state and rainfall event characteristics. Longer-term soil moisture patterns seem to be affected by both land use and topographic controls. Further should enable a more comprehensive assessment of the catchment controls on soil moisture.