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Multivariate analysis of soil moisture and runoff dynamics for better understanding of catchment moisture state

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Soil moisture is a key state that controls runoff formation, infiltration and portioning of radiation into latent and sensible heat flux. The experimental characterisation of near surface soil moisture patterns and their controls on runoff formation is, however, still largely untapped. Using an intelligent sampling strategy of two TDR clusters installed in the head water of the Wilde Weißeritz catchment (Eastern Ore Mountains, Germany), we investigated how well "the catchment state" may be characterised by means of distributed soil moisture data observed at the field scale. A grassland site and a forested site both located on gentle slopes were instrumented with two Spatial TDR clusters (STDR) that consist of 39 and 32 coated TDR probes of 60 cm length.

The interplay of soil moisture and runoff formation was interrogated using discharge data from three nested catchments: the Becherbach with a size of 2 km^2, the Rehefeld catchment (17 km^2) and the superordinate Ammelsdorf catchment (49 km^2).

Multiple regression analysis and information theory including observations of groundwater levels, soil moisture and rainfall intensity were employed to predict stream flow. On the small scale we found a strong correlation between the average soil moisture and the runoff coefficients of rainfall-runoff events, which almost explains as much variability as the pre-event runoff. There was, furthermore, a strong correlation between surface soil moisture and subsurface wetness. With increasing catchment size, the explanatory power of soil moisture reduced, but it was still in a good accordance to the former results. Combining those results with a recession analysis of soil moisture and discharge we derived a first conceptual model of the dominant runoff mechanisms operating in these catchments, namely subsurface flow, but also by groundwater. The multivariate analysis indicated that the proposed sampling strategy of clustering TDR probes in typical functional units is a promising technique to explore the soil moisture control on runoff generation and can be an important link between the scales. Long term monitoring of such sites could yield valuable information for flood warning and forecasting by identifying critical soil moisture conditions for the former and a better representation of the initial moisture conditions for the further.