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Climate change effects of the vadose zone on runoff dynamics

Gunnar Lischeid (1,2) and Jörg Steidl (1)

(1) Leibniz Centre for Agricultural Landscape Research, Institute of Landscape Hydrology, Müncheberg, Germany (lischeid@zalf.de, +49-33432-82301), (2) University of Potsdam, Institute of Earth and Environmental Sciences, Karl-Liebknecht-Strasse 24-25, D-14476 Potsdam

Climate change is assumed to have substantial impact on water budgets in many regions. Many studies investigated the effect of changes of precipitation and/or evapotranspiration on total runoff as well as on groundwater levels. In contrast, runoff dynamics likely will be affected as well which has been considered less often: Climate change might affect the way how a catchment's runoff reacts to heavy rainstorms. Those effects should be considered with respect to flood risk assessment, seasonal stream water availability, etc.

Advanced methods of data analysis have been applied to a variety of different data sets of groundwater head, soil water content and discharge data from various catchments. There was no evidence for interflow runoff processes in these catchments. We identified two different effects. Firstly, we found clear evidence that the temporal pattern of groundwater heads in the first place reflected vadose zone processes. The precipitation input signal is transformed in a characteristic way during vertical seepage flux: Time series of soil water content are increasingly more low-pass filtered, damped, smoothed and delayed with increasing depth. Principal component analysis of these time series can be used to quantify the degree of transformation. It could be shown that the spatial heterogeneity of time series of groundwater head is closely related to the local thickness of the vadose zone as well as to local soil texture.

Secondly, applying the same approach to merged data sets of groundwater head and discharge data revealed that the hydrographs could be regarded as superpositions of the contributions of single flowpaths. Thus, more responsive hydrographs point to a rather large area of shallow groundwater in the riparian zone close to the stream, which increases with increasing density of the stream network. In contrast, upper reaches of the streams fell dry when groundwater levels drop below the stream bed. As a consequence, the stream behaves less responsive during heavy rainstorms. In fact, the hydrograph of a small catchment with long-term decreasing groundwater level exhibited a clear increase of the autocorrelation of the hydrograph as well as an increase of the slope of the respective power spectrum. Model experiments using the HydroGeoSphere model have been performed to validate these findings.

It is concluded that the thickness of the vadose zone, which is a function of the groundwater level, plays a major role for runoff dynamics and urgently needs to be considered in climate change model scenarios. On the other hand, advanced time series analysis approaches can be used to assess and to quantify ongoing changes of the catchment's behaviour.