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Exploring hydrogeological controls on river and groundwater vulnerability to droughts using synthetic models

Claire Carlier, Stefanie B. Wirth, Fabien Cochand, Daniel Hunkeler, and Philip Brunner
Centre for Hydrogeology and Geothermics, University of Neuchâtel, Neuchâtel, Switzerland

Characterising the vulnerability of watersheds to droughts is essential to guarantee water supply under changing climatic conditions. Numerous studies have analysed watershed processes under dry conditions focusing on surface flows. However, hydrological catchment dynamics, and especially river low-flows, are strongly dependent on the surrounding hydrogeological settings.

We thus propose an integrated quantification of the impact of prolonged dry periods on both surface water and groundwater. To achieve this, we consider various catchment properties representative of a wide range of geological and topographical environments. The relationship between these physical parameters and low-flow dynamics in a catchment is highly complex, and no straightforward correlation can be obtained by analysing easily measurable catchment properties such as slope or main geological units. A modelling approach is therefore developed to systematically and independently quantify the control mechanisms of catchment parameters on river and groundwater dynamics. The physically based numerical model HydroGeoSphere is used, which simulates surface water and groundwater in a fully coupled way. More than 200 synthetic models are designed with systematically varying geometrical parameters such as river and hill slopes, as well as hydraulic conductivities and porosities of the main geological units. A clear correlation between the porous storage volume in a catchment and the resilience to drought of both streamflow and groundwater is observed. An attempt to link these results to real watersheds is made by analysing the flows, the geology and the hydrogeological properties of a selection of catchments. The validation of the synthetic results with observations will allow the development of drought sensitivity indicators applicable to both groundwater and river low-flows based solely on watershed physical properties.