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Catchment and climate control on global hydrological drought across the world

For prediction of hydrological drought in ungauged basins, knowledge is needed on the processes underlying drought propagation through the hydrological cycle (i.e. conversion of meteorological drought into drought in groundwater and streamflow) and how that is related to climate and catchment characteristics. Many studies on the processes underlying hydrological drought development are on catchment scale. Synthesis and generalisation of process knowledge to global scale is needed to better assess the far-reaching impacts of drought, which often cover large areas of land.

We performed a controlled modelling experiment based on a soil water balance model and a linear reservoir groundwater model using global re-analysis data as forcing data. The model was run for the period 1958-2001 for a high number of randomly selected grid cells representing all climate types across the world. Drought events were identified from the outputs of the model with the variable threshold level method. Smoothed bivariate probability fields of drought duration and standardised deficit of the variables precipitation, soil moisture, and subsurface discharge were determined.

The shape and orientation of these density fields clearly reflect catchment and climate control on propagation processes. Catchment properties (e.g. aquifer properties, drainage density) determine the orientation of the density fields of subsurface discharge. Fast responding catchments have most attenuation of the drought signal in soil moisture, whereas for slowly responding catchments this takes place mostly in groundwater. Climate influences the shape of the density fields, e.g. the fields of subsurface discharge. Oceanic climates have most regular drought characteristics and both warmer and colder climates have droughts that last very long and have high deficits because they continue into the dry/ snow season, in which there is a low chance of recovery (no recharge due to high evapotranspiration / snow accumulation). These severe droughts in both cold and (semi-)arid climates are more pronounced when the climate is more extreme, so colder or warmer, respectively.

The obtained knowledge on the effect of catchment and climate control on hydrological drought at global scale can guide future drought research and predict drought propagation in ungauged basins on the basis of readily-available catchment characteristics and climate type.