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Upscaling drought information from the catchment scale to the global scale: how seasonality in climate influences drought characteristics

Anne Van Loon (1), Erik Tijdeman (1), Niko Wanders (2), Henny Van Lanen (1), Adriaan Teuling (1), and Remko Uijlenhoet (1)

(1) Hydrology and Quantitative Water Management Group, Wageningen University, Wageningen, the Netherlands (anne.vanloon@wur.nl), (2) Department of Physical Geography, Faculty of Geosciences, Utrecht University, Utrecht, the Netherlands

The upscaling of the understanding of hydrological processes from the catchment scale to the global scale is not straightforward, especially not for hydrological extremes as floods and droughts. For large-scale water resources management, information on the development and persistence of soil moisture and hydrological droughts is crucial. The characteristics of these droughts (i.e. duration and severity) vary around the world and are dependent on climate and catchment properties.

In this study, we investigated climate controls on drought propagation (i.e. the translation of meteorological conditions to a soil moisture drought and/or hydrological drought) by isolating forcing effects from effects of catchment properties. We used a conceptual hydrological model, forced by the WATCH forcing data, that was run for 1271 grid cells distributed over the global climate zones. The precipitation that was used as input, and soil moisture storage and subsurface discharge that were outcomes of the model, were then analysed with a well-known drought identification method (variable threshold level method). Drought characteristics duration and standardised deficit (deficit below the smoothed monthly-varying threshold, divided by the mean of the variable for that grid cell) were determined for each drought event. These drought characteristics were clustered per subclimate type and combined into bivariate probability density fields. The shape and orientation of these density fields provide information on the propagation of drought in different climate zones.

Drought propagation features that are apparent on the catchment scale, such as pooling (meteorological droughts are merged into a prolonged hydrological drought) and attenuation (the damping effect of stores on the drought signal), were reproduced in all climate zones. But also seasonal drought types that can have severe impacts on the catchment scale (e.g. rain-to-snow-season drought) leave a pronounced signal in the density fields on the global scale. We found that strongly non-linear patterns in the density fields of the drought characteristics occur in climates with a pronounced seasonal cycle in precipitation and/or temperature. Hot spots for these seasonality effects on drought propagation were found in monsoonal, savannah, and Mediterranean climate zones. In these regions, both soil moisture and hydrological drought show deviating patterns in drought characteristics, relative to non-seasonal climates (e.g. temperate subclimates). Surprisingly, the effect of seasonality on drought propagation is even stronger in cold seasonal climates (i.e. at high latitudes and altitudes), where snow accumulation during winter prevents recovery from summer hydrological drought and deficit increases strongly with duration. This has important implications for water resources management in seasonal climates, which cannot solely rely on meteorology-based indices as proxies for hydrological drought characteristics.