New approaches for estimating groundwater drought in near real-time in the absence of observed groundwater level data: the 2015 European drought case

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In 2015 central and eastern Europe were affected by severe drought. Impacts of the drought were felt across many sectors, incl. agriculture, drinking water supply, electricity production, navigation, fisheries, and recreation. This drought event has recently been studied from meteorological and streamflow perspective, but no analysis of the groundwater drought has been performed. This is not surprising because real-time groundwater level observations often are not available. In this study we use previously established spatially-explicit relationships between meteorological drought and groundwater drought to quantify the 2015 groundwater drought over two regions in southern Germany and eastern Netherlands. We also tested the applicability of the Gravity Recovery Climate Experiment (GRACE) Terrestrial Water Storage (TWS) and GRACE-based groundwater anomalies to capture the spatial variability of the 2003 and 2015 drought events.

We use the monthly groundwater observations from 2040 wells to establish the spatially varying optimal accumulation period between the Standardized Groundwater Index (SGI) and the Standardized Precipitation Evapotranspiration Index (SPEI) at a 0.25^0 gridded scale. The resulting optimal accumulation periods range between 1 and more than 24 months, indicating strong spatial differences in groundwater response time to meteorological input over the region.

Based on these optimal accumulation periods, we found that in Germany a uniform severe groundwater drought persisted for several months (i.e. SGI below the drought threshold of 20th percentile for almost all grid cells in August, September and October 2015), whereas the Netherlands appeared to have relatively high groundwater levels (never below the drought threshold of 20th percentile). The differences between this event and the European 2003 benchmark drought are striking. The 2003 groundwater drought was less uniformly pronounced, both in the Netherlands and Germany, with the regional averaged SGI above the 50th percentile. This is because slowly responding wells still were above average from the wet year of 2002-2003, which experienced severe flooding in central Europe.

GRACE-TWS does show that both 2003 and 2015 were relatively dry, but the difference between Germany and the Netherlands in 2015 and the spatially-variable groundwater drought pattern in 2003 were not captured. This could be associated to the coarse spatial scale of GRACE. The simulated groundwater anomalies based on GRACE-TWS deviated considerably from the GRACE-TWS signal and from observed groundwater anomalies. These are therefore not suitable for use in real-time groundwater drought monitoring in our case study regions.

Our study shows that the relationship between meteorological drought and groundwater drought can be used to quantify groundwater drought and that the 2015 groundwater drought in southern Germany was more severe than the 2003 drought, because of preconditions in slowly responding groundwater wells. For sustainable groundwater drought management strategies the use of groundwater level monitoring is needed to study the spatial variability of local groundwater drought, which mostly coincides with drought impacts.

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