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Quantifying feedback processes between abstraction and groundwater droughts

Doris Wendt (1), Anne Van Loon (1), John Bloomfield (2), David Hannah (1), Richard Morgan (3), and Catriona Finch (3)

(1) University of Birmingham, School of Geography, Earth and Environmental Sciences, United Kingdom (dew637@student.bham.ac.uk), (2) British Geological Survey, Wallingford, United Kingdom, (3) Environment Agency, Lincoln, United Kingdom

Hydrological droughts are defined by below 'normal' surface water and groundwater availability. It is expected that occurrence and intensity of these extreme events will increase in the future. Projections indicate a decline in long-term groundwater availability, based on trends of the last 50 years globally, while water demand is expected to increase. Water demand is often sustained by groundwater abstractions that may rise during droughts. It remains uncertain how these groundwater abstractions change the development of hydrological droughts. There is limited research focussing on feedback processes between groundwater use and droughts. Hence, this study aims to undertake a quantitative analysis of groundwater droughts in areas dominated by abstraction.

Two principal aquifers in England were investigated, chalk and Permo-Triassic sandstone, using a near-natural observation network of the National Groundwater Level Archive. These long term near-natural groundwater level time series were clustered according to their similarity, defining a reference regional groundwater level variability for the last 30 years. Focus areas were chosen within each reference cluster to analyse the effect of groundwater use on a smaller scale during four major drought events in England. These four events were investigated using a dense network of observation wells and operational information on groundwater abstraction. Raw groundwater level time series were converted to standardized indices (SGI) that allowed an inter-cluster comparison. Statistical indicators were used to describe groundwater variation and (based on the dissimilarity with the reference clusters) the degree of human influence was established for each well.

Findings identified multiple differences in drought development between observation wells and reference clusters, which were visible in groundwater drought duration, magnitude and recovery. Highly influenced wells in the chalk aquifer showed more and intensified drought events compared to relatively natural groundwater level time series. Also, droughts seem to start earlier in highly abstracted areas. These differences were attributed to groundwater use based on the operational information. Influences of groundwater abstractions were noticeable for drought events in the focus areas for each aquifer, and it is the quantified deviation that characterizes impact of groundwater abstraction on groundwater droughts across aquifers in England. These results highlight the importance of careful groundwater management to safeguard groundwater availability, and stresses the need for effective measures to limit groundwater use, particularly during droughts.