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Spatio-temporal analysis of drought: A multidecadal study of European groundwater systems

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Groundwater, constituting approximately 65 percent of Europe's drinking water sources, plays a crucial role in sustaining both urban and agricultural needs. Particularly during periods of drought, groundwater abstraction becomes a key resource, alleviating adverse impacts on people's livelihoods. Recent European drought events, for example in 2003 and 2015, exhibited spatial coherence in surface water deficits across European regions, hinting at potential impacts on groundwater levels. However, the unique hydrogeological settings and recharge patterns of groundwater systems, coupled with diverse meteorological influences, can also lead to distinct spatial coherence in groundwater droughts. Despite these complexities, no comprehensive, decadal pan-European analysis of historic groundwater level data has been conducted until now.

To bridge this gap, we conducted a continent-wide assessment of groundwater drought responses, based on over 3000 groundwater level timeseries spanning from 1986 to 2015, and providing the first extensive overview of historic groundwater droughts across Europe. Utilizing the Standardised Groundwater Index (SGI), the spatio-temporal analysis allowed for consistent comparisons of sites across disparate regions. Impulse response functions were used to identify differences in response times of the aquifers and cluster analysis of the standardized hydrographs allowed for the identification of spatially coherent 'type' groundwater hydrographs, characterized by differences in autocorrelation and reflective of continental-scale variations.

Initial findings highlighted variations in groundwater system responses to meteorological drivers, distinctions between fast and slow responding sites and their spatial coherence. For example, differences in response times of the aquifers in Northern Germany produced local differences in the effects of the 2015 drought in this region and droughts in the late 90s showed good spatial coherence across large areas of Europe, but with distinctly smaller impact on groundwater levels in Balkan region.

This analysis, coupled with an examination of driving factors, promises to enhance our understanding of how catchment and local characteristics influence groundwater responses.

Additionally, areas particularly vulnerable to groundwater droughts will be identified, thus allowing for improved groundwater management.