

Evidence for changes in groundwater drought in temperate environments associated with climate change

John P. Bloomfield, Benjamin P. Marchant, and Andrew A. McKenzie

There is currently a significant gap in our understanding of the effect of anthropogenic warming on groundwater drought. This is due to a number of factors including the limited availability of long groundwater level time series suitable for analysis, the low signal-to-noise ratios characteristic of many hydrological systems, and the infrequent nature of episodes of groundwater drought in temperate systems. Formal attribution of groundwater droughts due to anthropogenic warming is also challenging because of the potentially confounding influences of land use change and groundwater abstraction on groundwater drought. In the present study, we have not attempted to formally attribute groundwater droughts to climate change. Instead, we investigate how known centennial-scale anthropogenic warming may be modifying the nature of groundwater droughts when other factors are discounted, and address the following question: how has the occurrence, duration, magnitude and intensity of groundwater drought, as expressed by changes in monthly Standardised Groundwater level Index (SGI) and in episodes of groundwater drought changed since 1891 under anthropogenic warming?

Standardised indices of monthly groundwater levels (SGI), precipitation (SPI) and temperature (STI) are analysed, using two long, continuous monthly groundwater level data sets from the UK, for the period 1891 to 2015. Precipitation deficits are the main control on groundwater drought formation and propagation. However, long-term changes in groundwater drought include increases in the frequency and intensity of individual groundwater drought months, and increases in the frequency, magnitude and intensity of episodes of groundwater drought, are shown to be associated with anthropogenic warming over the study period. There is a transition from coincidence of episodes of groundwater and precipitation droughts at the end of the 19th century, to an increasing coincidence groundwater droughts with both precipitation droughts and with hot periods in the early 21st century. In the absence of long-term changes in precipitation deficits, it is inferred that the changing nature of groundwater droughts is due to changes in evapotranspiration (ET) associated with anthropogenic warming. Given the extent of shallow groundwater globally, anthropogenic warming may widely effect changes to groundwater drought characteristics in temperate environments.