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Climate variability and groundwater recharge in Irish fractured aquifers: A coupled wavelet transform-neural network approach

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Climate variability is generally expected to intensify the hydrological cycle by increasing rainfall extremes and droughts, thereby challenging the resilience of fresh water resources. In Ireland, most research to date has focused on assessing the possible impacts of climate variability on surface water resources, whereas the effect on groundwater has received relatively little attention. In this study, the potential impacts of climate variability on groundwater resources are evaluated within the Irish context.

The hydrogeology of Ireland is characterised by fractured bedrock aquifers with low storativity, which are often regarded as poorly productive (giving low well yields and low spring flows). Previous research has shown that the annual recharge of these aquifers is strongly influenced by the hydrometeorological seasonal variability. To be able to represent this variable storage capacity under future climate conditions, a method combining wavelet transform analysis and neural network forecasts has been applied. Firstly, an analysis using continuous wavelet transforms (CWT) is applied to identify trends in the rainfall, temperature, and groundwater level time series, and used to unveil the relationship between these signals. Secondly, the time series are pre-processed with maximum overlap discrete wavelet transforms (MODWT): the signals are decomposed in spectral components that then are fed into the neural networks as distinct inputs. Finally, the neural networks are trained to forecast monthly groundwater levels from the decomposed temperature, potential evapotranspiration (PE) and rainfall time series. In this case, nonlinear autoregressive neural networks (NARX) have been used as they predict a variable based on exogenous input signals (rainfall, temperature, and PE) and regressed values of the output signal (groundwater level). Once the networks are trained and validated, the model is ready to be forced with climate projections to forecast the groundwater level under future climate while considering the specific hydrogeological characteristics of the study areas. This methodology has been applied to two different Irish catchments with contrasting hydrogeological characteristics to explore the impacts of a changing climate on the groundwater resources.

The application of the CWT as a preliminary analysis has provided valuable information about the recharge processes in the study areas as well as relevant differences between the two catchments. In turn, the coupling of the DWT with the neural networks has increased their performance, resulting into simulated groundwater levels that are able to represent the seasonal dynamics of the groundwater level and the limited storage capacity of the aquifers.