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Separation of climate- and geology-induced variations in the hydrological response of a regional karstified aquifer: determination of a geologic transfer function

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Worldwide, karst hydrosystems represent a great potential in terms of water ressources. However, such heterogenous systems are characterized by a highly non-linear response to input signals. In the region of Upper Normandy (Northwestern France), where almost 100% of drinking water supply comes from ground water, the Chalk karst aquifer is characterized by the presence of a thick surficial formations cover which is unequally distributed over the area according to the regional geological context. This structural context also implies a significant spatial variability of the aquifer thickness. To assess the overall hydrologic variability of this aquifer, we use long-term hydraulic head and precipitation time series (20 years) to analyse their relationships according to such specific geological conditions. By continuous wavelet transform, the hydraulic head time series were found to exhibit long-term variations that represented a great amount of variance in some locations, what we could eventually relate to climate-induced oscillations. This was particularly the case of those locations where the aquifer thickness was important. The climate-induced oscillations found were of the order of 2-3-yr and 5-6-yr which would well correspond to some modes of oscillation linked to the positive/negative regimes of the North Atlantic Oscillation. In addition, the corresponding variations in hydrological time series exhibited a clear increase in the explanation of total variance from the early 90's up to the end of the series.
In a second time, in order to assess the role of the geological medium in the precipitation/head relationship, we proposed to filter out those long-term spectral components inherent to climate fluctuations. This allowed identification of the head response to precipitation throughout the entire 20-yr period of study for short-term infra-annual time scales. Cross-correlation between the input and output signals after filtering out of long-term components showed that response times to precipitations ranged from a few days to 6 months, which was not detectable by performing the same analysis on raw time series. These response times, corresponding either to recharge time of the aquifer or to karst-network connections reactivity, are strongly related to the geological and geomorphological contexts (thickness of surficial formations, downstream parts of the aquifer near karst outlets in valleys). The cross-correlation functions would then be representative (with a precipitation white noise-like input) of a so-called geologic transfer function which is ensured to define the filtering properties of the medium and then display spatial variations in the region studied.

Keywords: geologic structure, karstic chalk aquifer, Upper Normandy, cross-correlation analysis, continuous wavelet analysis, filtring, geologic transfer function, annual and multi-year variability.