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Separating climate change from anthropogenic signals in long-term time series of lake water level and groundwater head in Northeast Germany

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Long-term decreases of lake water level and groundwater head are very common in large parts of Northeast Germany. This is consistent with predictions of regional climate models coupled with hydrological models. However, trends have not been consistent throughout the region. Non-significant or even reverse trends have been observed at adjacent sites. Thus an assessment of the local water resources authorities as required by the European Water Framework Directive is fraught with severe problems. It is speculated that anthropogenic effects might cause a substantial part of the observed variety. In fact in this region stream networks and lake water levels have been massively affected by hydraulic engineering for centuries. Another source of the observed variety of long-term trends could be the enormous heterogeneity of geological structures in the Pleistocenic sediments of the region, geomorphological structures, or spatial patterns of land-use, including drinking water withdrawal and irrigation.

This study aimed at disentangling the signatures provided by time series of lake water level and groundwater head data in Northeast Germany. Monthly readings covering the 1986-2014 period and an area of about 15,000 km2 were available, including data of most of the major lakes in the region. A principal component analysis of the time series was performed. This approach had been successfully applied to various data sets of soil water content, groundwater head, lake water level and stream discharge before to differentiate between different effects on the observed dynamics in a quantitative way.

Our results did not reveal any systematic difference between lake water level data and groundwater head data, confirming the hypothesis that the lakes were hydraulically closely connected to the uppermost major aquifer, and thus justifying a joint analysis. The largest fraction of spatial variety could be ascribed to different degrees of transformation of the input signal, that is, the damping and delaying of the temporal dynamics of seepage fluxes in the vadose zone. The degree of transformation was closely related to the thickness of the vadose zone above the uppermost aquifer. In addition, the probability of significant long-term trends increased with increasing degree of damping of the input signal. Thus trend analyses have to be treated with extreme caution. Another principal component seemed to reflect minor climatic gradients within the study region. Comparison of the residuals of the time series with documented changes of management confirmed that anthropogenic effects comprised only a minor fraction of variance. We conclude that the chosen approach was successful in disentangling signatures of regional hydrological behaviour, proving its potential as a powerful diagnostic tool in hydrological and climate change studies.