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Using functional analysis to differentiate between anthropogenic and natural impacts on groundwater heads using scarce data

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Sustainable water resources management requires differentiation between natural variability, direct anthropogenic impacts and the effects of long-term shifts of climate, land use, etc on groundwater heads. A sound analysis usually requires comprehensive modelling studies and extensive data sets. As an alternative, the European Water Directive recommends performing trend analyses in order to detect detrimental anthropogenic impacts, e.g., groundwater overuse. However, long-term trends of groundwater heads might occur irrespective of anthropogenic impacts as well, reflecting interannual climatic variabilities and natural heterogeneities.

In this study an alternative approach is followed. It is based on the assumption that time series of groundwater heads in pristine systems reflect solely the temporal pattern of vertical groundwater recharge and of lateral groundwater inflow and outflow. Supplementary effects might alter that pattern at single sites. Spatial heterogeneity of hydraulic conductivity, thickness of the vadose zone, etc. might add spatial variability to the observed groundwater heads. The functional analysis allows differentiating between different input signals on the one hand, and effects of spatial heterogeneities of the unsaturated and the saturated zone on the other hand. It is based on a principal component analysis of time series of groundwater heads. The data set comprises groundwater heads from 31 observation wells and water level data from a lake close to Berlin, Germany. Whereas the first principal component depicted the mean behaviour of groundwater heads in that region, the second component provided a measure of the spatial heterogeneity of the underground which resulted in different damping of the same input signal of groundwater recharge. In addition, deviation from the expected behaviour at single sites could be identified. It could be shown that direct anthropogenic impacts were restricted to minor deviations from the typical behaviour in that region. In contrast, trend analyses of the same data set yielded significant trends in most of the time series that were not easy to understand. It is concluded that the functional analysis is a much more suitable tool to assess direct anthropogenic impacts on groundwater heads compared to trend analysis, whereas the data needs are roughly the same.