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Long-term trends of groundwater temperatures in Austria

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Beneath the ground surface, temperatures mirror the long-term conditions in the atmosphere. At different locations, however, the thermal regime in the subsurface differs due to the substantial natural and anthropogenic impacts such urbanization. Thus, climate change is also expected to stimulate long-term warming of the ground, however within a small range so that temperature measurements rarely allow an unequivocal interpretation. For more robust insights, ideally long-term time series are examined and the conditions at different locations are compared. While there are already some studies available analysing the implication of climate change on selected wells, large scale studies are lacking until now. In this study, temperatures from 229 groundwater wells in Austria are therefore scrutinized to explain discrepancies and to reveal regional-scale temperature changes. Some temperatures have been monitored since 1966 enabling a long-term comparison with air temperatures. The latter is carried out by analysis of linear trends as well as stepwise changes in the measured temperatures.

The linear analysis reveals a temperature change of + 0.8 $\pm$ 1.0 K in the years from 1994 to 2013. In the same period, surface air temperatures in Austria increased by 0.72 $\pm$ 0.04 K, displaying a much smaller spreading. However, most extreme groundwater temperature changes, especially temperature decrease, can be linked to local circumstances affecting the local hydrogeological system. The influence of site-specific conditions also yields a high variation in the correlation between groundwater temperatures and nearby (< 5 km) air temperatures. For example, Spearman correlation coefficients range from -0.4 in the city centre of Linz to 0.8 outside of Graz. In contrast, the correlation between countrywide groundwater temperatures and air temperatures is remarkably good with a correlation coefficient of 0.8.

When modelling temperature change by a step function, so-called climate regime shifts (CRS) can be detected. Globally, these shifts were observed in atmospheric temperature time series in the late 1970s, 1980s and 1990s, and they were also detected in some groundwater wells. In the studied wells in Austria, only around 20 % show corresponding climate regime shifts. Instead, an additional, new climate regime shift in 2007 is observed in 33 % of the wells. Overall, groundwater temperatures are reproduced slightly better by the step function (root mean squared error, RMSE: 0.3 $\pm$ 0.2 K) than by the linear trend (RMSE: 0.4 $\pm$ 0.2 K).