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Coupled modelling of groundwater flow-heat transport for assessing river-aquifer interactions

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A three-dimensional finite element model for coupled variably saturated groundwater flow and heat transport was developed for the aquifer below the city of Zurich. The piezometric heads in the aquifer are strongly influenced by the river Limmat. In the model region, the river Limmat looses water to the aquifer. The river-aquifer interaction was modelled with the standard linear leakage concept. Coupling was implemented by considering temperature dependence of the hydraulic conductivity and of the leakage coefficient (via water viscosity) and density dependent transport. Calibration was performed for isothermal conditions by inverse modelling using the pilot point method. Independent model testing was carried out with help of the available dense monitoring network for piezometric heads and groundwater temperature.

The model was tested by residuals analysis with the help of measurements for both groundwater temperature and head. The comparison of model results and measurements showed high accuracy for temperature except for the Southern part of the model area, where important geological heterogeneity is expected, which could not be reproduced by the model.
The comparison of simulated and measured head showed that especially in the vicinity of river Limmat model results were improved by a temperature dependent leakage coefficient. Residuals were reduced up to 30% compared to isothermal leakage coefficients. This holds particularly for regions, where the river stage is considerably above the groundwater level.
Furthermore additional analysis confirmed prior findings, that seepage rates during flood events cannot be reproduced with the implemented linear leakage-concept. Infiltration during flood events is larger than expected, which can be potentially attributed to additional infiltration areas.

It is concluded that the temperature dependent leakage concept improves the model results for this study area significantly, and that we expect that this is also for other areas the case.