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Comparison of numerical and analytical modelling concepts for simulation of shallow open geothermal systems

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Shallow open-loop geothermal technologies such as groundwater heat pump systems (GWHP) and aquifer thermal energy storage systems (ATES) have gained acceptance for space heating and cooling due to their efficiency and low installation costs. In both applications, groundwater is used as heat carrier fluid. Depending on the operation mode, underlying aquifers are used as a heat source or sink. Both systems create temperature anomalies in the underground as well as local hydraulic gradients. The impact on aquifer temperature distribution can be approximated by different analytical solutions. However, each analytical solution considers specific heat transfer processes. In this work, synthetic test cases based on typical operational conditions of open-loop system are simulated using the numerical codes MT3DMS and SEAWAT. A three-dimensional model is set up accounting for an injection well in a confined aquifer. Convective-dispersive heat transport within the aquifer and axial conductive transport through the confining layers are evaluated. The numerical results are used to test the applicability range of the available analytical solutions. Estimated residual errors indicate that analytical solutions considering axial effects are more suitable to simulate scenarios with low or no natural groundwater flow conditions. For advective scenarios, the applicability of analytical solutions considering only lateral heat transport such as the planar source analytical model or the line source model depends on both the groundwater flow velocity and the well injection rate. For high injection rate and moderate groundwater flow the planar source fits better the numerical results than the line source model.