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The effect of sediment thermal conductivity on vertical groundwater flux estimates

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The interaction between groundwater and surface water is of great importance both from ecological and water management perspective. The exchange fluxes are often estimated based on vertical temperature profiles taken from shallow sediments assuming a homogeneous standard value of sediment thermal conductivity. Here we report on a field investigation in a stream and in a fjord, where vertical profiles of sediment thermal conductivity and temperatures were measured in order to, (i) define the vertical variability in sediment thermal conductivity, (ii) quantify the effect of heterogeneity in sediment thermal conductivity on the estimated vertical groundwater fluxes. The study was carried out at field sites located in Ringkøbing fjord and Holtum stream in Western Denmark. Both locations have soft, sandy sediments with an upper organic layer at the fjord site. First 9 and 12 vertical sediment temperature profiles up to 0.5 m depth below the sediment bed were collected in the fjord and in the stream, respectively. Later sediment cores of 0.05 m diameter were removed at the location of the temperature profiles. Sediment thermal conductivity was measured in the sediment cores at 0.1 m intervals with a Decagon KD2 Pro device.

A 1D flow and heat transport model (HydroGeoSphere) was set up and vertical groundwater fluxes were estimated based on the measured vertical sediment temperature profiles by coupling the model with PEST. To determine the effect of heterogeneity in sediment thermal conductivity on estimated vertical groundwater fluxes, the model was run by assigning (i) a homogeneous thermal conductivity for all sediment layers, calculated as the average sediment thermal conductivity of the profile, (ii) measured sediment thermal conductivities to the different model layers.

The field survey showed that sediment thermal conductivity over a 0.5 m profile below the sediment bed is not uniform, having the largest variability in the fjord where organic sediments were also present. Using the measured sediment thermal conductivity for the different model layers instead of a homogeneous distribution did not result in a better fit between observed and simulated sediment temperature profiles. The estimated groundwater fluxes however were greatly affected by using the measured thermal conductivities resulting in changes of $\pm$ 45% in estimated vertical fluxes.