Geophysical Research Abstracts
Vol. 18, EGU2016-17389, 2016
EGU General Assembly 2016

Modeling the time-varying interaction between surface water and groundwater bodies

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The countless kettle holes (small lakes) in the Late Pleistocene landscapes of Northern Europe have important ecological and hydrological functions. On the one hand they act as depressions in which water and solutes of mainly agriculturally used catchments accumulate. On the other hand they operate as biochemical reactors with respect to greenhouse gas emissions, carbon sequestration, and as major sinks for nutrients and contaminants. Even small kettle holes often are hydraulically connected to the uppermost groundwater system: Groundwater discharges into the kettle hole on one side, and the aquifer is recharged from the kettle hole water body on the other side. Thus kettle hole biogeochemical processes are both affected by groundwater and vice versa. Groundwater flow direction and velocity into and out of the kettle hole often is not stable over time. Groundwater flow direction might reverse at the downstream part, resulting in repeated recycling of groundwater and corresponding solute turnover within the kettle holes. A sound understanding of this intricate interplay is a necessary prerequisite for better understanding of the biogeochemistry of this terrestrial-aquatic interface.

A numerical experiment was used to quantify the lateral solute exchange between a kettle hole and the surrounding groundwater. A vertical cross section through the real existing catchment of a kettle hole was chosen. Glacial till represents the lower boundary. The heterogeneity of the subsurface was reproduced by various parameterizations of the soil hydraulic properties as well as varying the thickness of the unconfined aquifer or the lateral boundary conditions. In total 24 different parameterizations were implemented in the modeling software HydroGeoSphere (HGS). HGS is suitable to calculate the fluid exchange between surface and subsurface simultaneously and in a physically based way.

The simulation runs were done for the period from November 1994 to October 2014. All results were analyzed with regard to the intensity and duration of water exchange between kettle hole and surrounding groundwater. Finally the three variants with the smallest, average and largest number of days where water flow is directed from kettle hole to groundwater were chosen to extend the scope of this study to include solute transport. Therefore a non-reactive substance was injected at the kettle hole bed. As a result, the fluid dynamics and the spread of water flowing from surface to subsurface and vice versa could be closely monitored. Finally, the choice of these variants provides information on the range of distances and duration of water exchange between kettle hole and surrounding groundwater.