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# Extended Abstracts

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**Interactions of surface and ground waters**

title: **Impact of climate change and variability on groundwater-surface water interaction for unconfined aquifers in cold snow dominated regions**

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We are providing a methodology to estimate surface water–groundwater interaction in snow-dominated regions. The methodology was tested on an unconfined esker aquifer in northern Finland. Three models were linked together to estimate the temporal and spatial variations in the groundwater-surface water interaction. The physically based hydrological model CoupModel (Jansson, Karlberg, 2004) was used to estimate changes in the groundwater recharge in the present and under future anticipated climate conditions. Because in cold snow dominated, regions water infiltrates through frozen soil, too (Stähli et al., 1996; Sutinen et al., 2007), the recharge model must also provide for water flow through frozen soil and be able to simulate the temporal variation of the depth of frozen soil, snow cover, snowmelt discharge, evaporation, and thickness of the vadose zone, all of which affect the variation in groundwater recharge. In snow dominated regions, the maximum groundwater level in spring is dependent on the spring melt period. The onset of snowmelt and groundwater recharge may be important to estimate the timing of the maximum groundwater levels during and after the snowmelt period. The recharge rate was simulated with and without the influence of soil frost, and the variation of recharge was then compared with observed monthly groundwater levels. In determining the impact of climate change on groundwater recharge, we ran the model only with the influence of soil frost.

The watershed model WSFS (Vehviläinen, 2007) was used to estimate changes in the surface water levels under present and future anticipated climate conditions. In Finland, surface water intrusion typically occurs during and after the spring melt period. In summer, fall, and winter, the groundwater level is usually higher than the surface water level, and the groundwater discharges to the surface water. This intimate connection means that variation in the surface water level is important for assessing the groundwater discharge and focused recharge rates.

The results of the simulated surface water level and groundwater recharge were linked to the Groundwater Modeling System (GMS) version 6.5 (Brigham Young University, 2005), and the three-dimensional groundwater flow model MODFLOW was used to predict the effect of four climate change scenarios for Finland (periods 1971–2000, 2010–2039, 2040–2069, 2070–2099) on groundwater levels and groundwater–surface water interactions.

The groundwater flow model was run with an average pumping rate of 750 $m^3$/d to study the combined impacts of climate variability and groundwater pumping on the groundwater–surface water interaction. The intrusion of surface water into the aquifer was studied by comparing the surface water level with the groundwater level in the cell of the pumping well. Surface water intrusion was assumed when the water level in lake Pudasjärvi was higher than that in the cell of the pumping well. Monthly nonpumping and pumping scenarios, and one-year-long hot/dry (year 1988) and cold/wet (year 1981) scenarios were simulated by perturbing the regional temperature and precipitation data according to the projected climate scenarios. A constant pumping rate of 750 $m^3$/d was assumed in the simulations. The frequency of the surface water inflow to the aquifer was also plotted. The probability of surface water intrusion occurring was estimated by assessing the probability of surface water flow into the cell of the pumping well

The winter surface water level maximum is predicted to decrease and shift to earlier in the year due to increase in snowmelt and rainfall in winter. A rise in winter groundwater level, and a shift in the timing of the groundwater maximum to earlier in the year are expected to follow the increase in winter recharge. Flow reversal will increase more in cold/wet years than in hot/dry years because the surface water level will more often rise above the groundwater level in cold/wet years.

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