EGU21-7170
https://doi.org/10.5194/egusphere-egu21-7170
EGU General Assembly 2021
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Using machine learning to downscale simulations of climate change induced changes to the shallow groundwater table

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The DK-model (https://vandmodel.dk/in-english) is a national water resource model, covering all of Denmark. Its core is a distributed, integrated surface-subsurface hydrological model in 500m horizontal resolution. With recent efforts, a version at a higher resolution of 100m was created. The higher resolution was, amongst others, desired by end-users and to better represent surface and surface-near phenomena such as the location of the uppermost groundwater table. Being presently located close to the surface across substantial parts of the country and partly expected to rise, the groundwater table and its future development due to climate change is of great interest. A rising groundwater table is associated with potential risks for infrastructure, agriculture and ecosystems. However, the 25-fold jump in resolution of the hydrological model also increases the computational effort. Hence, it was deemed unfeasible to run the 100m resolution hydrological model nation-wide with an ensemble of climate models to evaluate climate change impact. The full ensemble run could only be performed with the 500m version of the model. To still produce the desired outputs at 100m resolution, a downscaling method was applied as described in the following.

Five selected subcatchment models covering around 9% of Denmark were run with five selected climate models at 100m resolution (using less than 3% of the computational time for hydrological models compared to a national, full ensemble run at 100m). Using the simulated changes at 100m resolution from those models as training data, combined with a set of covariates including the simulated changes in 500m resolution, Random Forest (RF) algorithms were trained to downscale simulated changes from 500m to 100m.

Generalizing the trained RF algorithms, Denmark-wide maps of expected climate change induced changes to the shallow groundwater table at 100m resolution were modelled. To verify the downscaling results, amongst others, the RF algorithms were successfully validated against results from a sixth hydrological subcatchment model at 100m resolution not used in training the algorithms.

The experience gained also opens for various other applications of similar algorithms where computational limitations inhibit running distributed hydrological models at fine resolutions: The results suggest the potential to downscale other model outputs that are desired at fine resolutions.