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FORHYCS – a coupled, spatially distributed eco-hydrological model for assessing climate and land use change impact in Switzerland at landscape scale

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Various modeling studies have shown that global climate and land use change are expected to have important impacts on the hydrology and vegetation dynamics of European mountainous regions. However, these models focus on either hydrological or ecological processes, while the respective other processes are represented in a simplified manner, e.g. using static parameters or empirical process formulations. This way, dynamic feedbacks between the water cycle and forest dynamics are neglected, which can influence long-term predictions. Integration of dynamic hydrological and ecological models increases the confidence in long-term forecasts by explicitly addressing this feedback. We present FORHYCS, a spatially distributed, coupled eco-hydrological model. FORHYCS is designed for application in temperate and Alpine regions at landscape scale, and consists of the integration of the rainfall-runoff model PREVAH and the forest-landscape model TreeMig. Both these models have previously been used in long-term climate impact studies in Switzerland.

In the new, coupled model, both individual models are run simultaneously while exchanging information via a set of interface variables. The forest-landscape model is driven by annual bioclimatic variables (drought stress, snow cover duration, degree-day sum and winter chill), which are obtained through yearly integration of the local water balance as calculated by the hydrological model at an hourly time step. Growth, establishment and mortality of tree species, as simulated by the forest-landscape model, are used to calculate vegetation parameters (leaf area index and fractional vegetation cover), which in turn influence the partitioning of precipitation into interception loss, transpiration, evaporation, soil moisture storage and runoff. Furthermore, the vegetation cover in each grid cell is used to determine and update its land cover class, which allows the simulation of forest advancement or retreat and its hydrological implications.

We present the results of the application of the coupled model in a dry inner-alpine region of Switzerland. Results include spatial patterns of vegetation and hydrological processes, discharge integrated over the whole catchment, as well as local water balance at some selected sites. The effect of including transient dynamics is shown by comparing the results of uncoupled, one-way coupled and fully coupled runs. The vegetation structures simulated by the forest-landscape model differ from the prescribed parameters in the hydrological model and show high spatial variability, which results in different spatial patterns of transpiration between the coupled and uncoupled models. At local scale, the model is validated against high-resolution observations of sap flow and soil moisture.