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Effects of a coupled soil water and heat transfer model on simulated winter runoff in mesoscale catchments

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The objective of the project GLOWA-Danube is the development and application of DANUBIA, an integrative Global Change decision support system (DSS) in the Upper Danube Basin (∼77,000 km2). To assist water management applications it can simulate water and related matter and energy fluxes on a regional scale. Part of the landsurface model in DANUBIA is the SOIL module which was upgraded recently to predict soil temperature and soil freezing in conjunction with the closure of the surface energy balance. In case of snow cover, a physically-based coupling algorithm was implemented to model heat fluxes between the upper soil layer and the base of the snow pack. Outputs of the Soil Heat Transfer Module (SHTM) are used by the DANUBIA components that model the biogeochemical cycle, the farming practices and runoff generation in the context of Climate Change scenarios. SHTM combines simplified physical algorithms for the computation of the actual temperature in the upper soil layers and an analytical lower boundary condition to represent Climate Change conditions. Changes in soil moisture and soil freezing are explicitly taken into account. Soil temperature of the upper layer feeds back into the energy balance of the soil surface or snow pack, while soil temperature in the root zone is used as input by biological and agro-economical model components of DANUBIA.

Regarding water management in alpine and pre-alpine regions, frozen soil water plays an important role in evaluating Climate Change because the relative duration of soil frost increases with elevation, up to the permafrost regions in high Alpine environments. Therefore we present a short validation of SHTM against measured time series of soil temperature, also during winter, and give an outlook on the reduction in soil frost in the next 50 years based on a moderate Climate Change scenario. On this basis a simple model to quantify the influence of frozen soil on runoff generation is proposed. Results show that even for mesoscale catchments, the simulated frequency of high runoff events during winter can be improved with a coupled soil water/energy model. As the regional warming trend in Europe will lead to shorter retention times of water as snow and ice and many models propose lower water levels in summer, the estimation of the effects of soil ice on runoff generation could be helpful to better quantify future amounts of water recharging the aquifers or running off laterally in winter.