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Potential effect of changing soil temperature within an integrated biophysical-hydrological modelling system

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The projection of potential impacts of recent and future climate change on the ecological and geophysical condition of the land surface requires both, the scientific research into the processes triggered by a changing climate, as well as the analysis of the spatial and temporal patterns induced by altering climatic conditions. In general, the potential changes and future distribution of land surface properties (e.g. soil moisture) is investigated in modelling studies. Complex land surface models for regional change detection are typically driven by data from complex climate models. Consequently, the uncertainty of the land surface model results is strongly influenced through the bias and uncertainty inherent to the atmospheric models. Therefore, the impact assessment within the multi-disciplinary research project GLOWA-Danube, which this study is part of, concentrates on two types of climate change scenarios: Uni- and bi-directional coupling of the land surface model with regional climate models ("dynamic downscaling") on one hand, and stochastic rearrangement of climate stations data based on predefined trends in temperature and precipitation ("statistical downscaling") on the other. This allows for profound "what if" impact assessment, based on the historic climate characteristic of the investigated area, which in our case is represented by the 77,000 km2 Upper Danube basin.

The water and nutrient cycles of the land surface, as well as the subsurface plant development are strongly influenced by the physical and biochemical state of the soil. Again, the biochemical processes occurring in soils are largely influenced by ambient temperature and moisture. Therefore, knowledge of the temporal and spatial patterns of soil temperature is a prerequisite for impact assessment in the field of plant growth and nutrient cycles. The biological activity at the land surface again exerts impact on soil water availability and quality. The development of the integrated biophysical-hydrological model used for this study aims at the implementation of the highly complex interactions between climate, soil and vegetation with regard to the issues of scale of application and potential biases. The integrated model describes the hydrological cycle including SVAT of energy and water and implements dynamic plant growth modules.

Besides a short overview of the integrated SVAT scheme, model results are presented including the spatial and temporal changes in soil temperature based on a climate scenario, which is prepared using the statistical downscaling approach. The basic climate trend is derived from the regional climate model REMO, which assumes a warming trend of 5.2°C from 1990 to 2100, and a shift of precipitation patterns towards reduced summerly and increased winterly rainfall. Moreover, the differences in spatial pattern between interpolated air and modelled soil temperature and the significance of snow cover and frozen soil water on the energy balance of the soil are highlighted. The analysis of the frequency of soil temperature extremes in a 1x1 km grid cell, situated within an agricultural region of the Upper Danube river basin, shows a distinct decrease of soil frost and a strong increase of top soil temperatures above 25°C during a 50 year scenario period (2011 to 2060). In order to indicate the possible consequences of changing soil temperatures on biological land surface processes, the root depth development of an exemplary winter wheat is simulated. During the full model period ranging from 1960 and 2060, the simulated crop strongly responded with earlier root growth to both, the historic and future warming trend. This implicates earlier access to the full potential soil water storage during the vegetation period, which again might favour increased or seasonally shifted evapotranspiration activity.