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Modelling Vegetation Response to Climate Change in the Upper Danube Subcatchment applying a Biophysical Landsurface Model.

T. Hank and W. Mauser

Department of Geography, LUDWIG-MAXIMILIANS-UNIVERSITÄT Munich, Germany

The manifold exchange processes that occur between landsurface and atmosphere are largely determined through the living vegetation cover that dynamically responds to atmospheric conditions such as humidity, temperature or the concentration of carbon dioxide respectively. When dealing with the mapping of biospheric feedbacks on changing climatic conditions, the numerical description of the involved processes represents a helpful tool and reliable instrument for the investigation of the dynamics that are part of these landsurface exchange cycles. A considerable number of current studies concentrates on the modelling of global dynamic reactions of the vegetation cover on changing atmospheric parameters. Nonetheless, questions concerning the regional effects of climate change are getting more and more important for stakeholders and decision makers worldwide.

Within the scope of the GLOWA-Danube cooperative project, which is funded by the German Federal Ministry of Education and Research (BMB+F), the physically-based hydrological model PROMET (process of radiation mass and energy transfer) is applied to investigate the consequences of climate change on the regional scale. PROMET largely represents the landsurface component of the DANUBIA decision support system, which has been recently enhanced by an explicit model of photosynthesis. The assimilation model was combined with a model of stomatal conductance and the respective physiological submodels to enable a spatial modelling of active vegetation growth, taking the sensitivity of the photosynthetic apparatus with respect to changing atmospheric conditions into account. The combined model approach was applied to a set of climate scenarios, all tracing the characteristics of the moderate IPCC A1B scenario, but featuring different realizations of this storyline. The meteorology for the scenario runs was generated, using a stochastic method that is based on a statistical analysis and rearrangement of measured meteorological data. The future extension of the calculation is limited by the population of measured input data and therefore is restricted to a 50 year period comprising the years 2011 to 2060. The spatial extension of this study concentrates on the Upper Danube watershed, which encloses an area of 76.000 square kilometres and is located with its largest part in Southern Germany at the Northern rim of the Alps.

The result analysis is focused on the major components of the surface water balance, PROMET being a landsurface model with a hydrological focus. Additionally, the near surface water supply is an important indicator for water related decisions. The availability of surface water may concern agricultural production, but also energy generation, shipping traffic etc. Since the photosynthesis component of PROMET shows sensitive reactions on climate parameters such as temperature, water supply and atmospheric carbon dioxide concentration, the model results are strongly affected by the assumed scenario conditions. Increasing temperatures naturally lead to higher evapotranspiration rates. Also the assimilation of carbon is increased due to accelerated chemical reactions within the chloroplasts, as long as the increase of temperature is limited to a certain degree. The temperature induced prolongation of the vegetation period and the shift of phenological phases, but also the increased effectiveness of photosynthesis under elevated carbon dioxide conditions, contribute to increased growth activity in the scenario simulations. Concerning the change of evapotranspiration behaviour, the reduced transpiration activity under elevated carbon dioxide conditions slightly dampens the increase of the evapotranspiration rates. Also the increasing frequency of drought conditions, which mainly is due to the expected decrease of precipitation sums during the summer months, leads to a reduced increase of the surface evapotranspiration rates. The consequences of increased temperatures and elevated carbon dioxide concentrations in combination with a seasonal shift of the rainfall distribution in the scenario meteorology therefore result in a competitive development of increased growth and elevated evapotranspiration activity on one hand, which on the other hand is opposed by a relative reduction of the gas exchange due to the increased photosynthetic effectiveness and a stagnation of growth caused by drought events.

Being applied to a medium sized river catchment, the landsurface Model PROMET, in combination with a plant physiological model, enabled the simulation of vegetation growth under climate change conditions. Through the explicit modelling of photosynthetic processes, the combined model approach can be expected to give more realistic insights into the landsurface evapotranspiration behaviour, compared to model systems that are not taking detailed gas exchange processes into account. The further development and enhancement of PROMET with respect to plant physiological issues therefore may contribute to strengthen regional landsurface models in the role of model systems that can reliably be applied to support crucial decisions in the field of climate change assessment and mitigation.