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The effect of climate change on groundwater dependent temperate forest ecosystems

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Models developed to predict the influence of changing climate on ecosystems often concentrate on vegetation in connection with soil moisture, but usually omit groundwater. However in temperate climate zones, groundwater can have a profound effect on the reaction of vegetation to climate change, because it strongly influences the spatio-temporal distribution of soil moisture and therefore water and oxygen stress of vegetation. Here we focus on the qualitative and quantitative effects of climate change on the zonation of vegetation and groundwater dynamics along a hill slope. To study this we developed a fully coupled hydrological-vegetation model, for a groundwater influenced temperate forest ecosystem. The vegetation model is based on the carbon assimilation model of Farquhar et al. (1980) and the extension of Daly et al. (2004), which includes transpiration of vegetation and accounts for the response to low soil moisture content. We modified this model to account for vegetation response to high soil moisture contents due to high groundwater levels, and we extended the model to include light competition, phenology and vegetation growth. To simulate the hydrological system the saturated-unsaturated flow model by van Beek (2002) is used. The coupled model was first compared to measured semi-hourly flux tower data of H2O and CO2, showing good results. Than simulation runs of 1000 years were performed to study the effect of climate change on soil water, groundwater and vegetation. We performed simulation runs with competition between wet and dry adapted species under current conditions and after climate change. Meteorological time series for the 2100 climate (SRESA2) were obtained from downscaling 6 different regional climate model runs from the ENSEMBLES project with a stochastic weather generator (Kilby et al., 2007).
Results show that in the zones were the groundwater system is close to the surface, climate change causes shifts in vegetation zonation of the dry and wet adapted species along the slope. The increase in number of dry days during summer also causes an overall decline of biomass for both species, an effect that is partially mitigated by increased ambient CO2 concentration. This study shows the importance of using a coupled groundwater vegetation model when studying temperate lowland areas. The coupled hydrological-vegetation model allows for detailed studies of qualitative and quantitative changes in spatial temporal patterns of vegetation under changing climate.