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Advances and limitations in carbon and water cycle modeling using the Biome-BGCMuSo biogeochemical model in a Central European beech forest

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Approximately 30% of anthropogenic carbon dioxide emissions are removed from the atmosphere annually by land-based carbon sinks, mainly forests. Extreme weather events such as droughts and heatwaves are expected to be more frequent and severe in the future affecting the carbon-water balance of ecosystems. Although empirical studies elucidate many of these processes, some questions cannot be addressed directly and require constructing *in silico* representations of real ecosystems. Process-based ecosystem models have recently received increased recognition due to their structural improvements and the increasing success of reproducing complex feedback mechanisms of carbon and water cycles.

We used the Biome-BGCMuSo biogeochemical model to simulate pools and fluxes of carbon, water, and nitrogen in vegetation, litter, and soil on a daily scale. The model is under continuous development and in the last few years, the hydrological cycle submodel went through substantial improvements. We examined the model performance regarding water and carbon cycle simulation using the data from an ecosystem station covered by a circa 100-year-old unmanaged beech forest. The site is included in the FLUXNET global network of micrometeorological tower sites and is operated by the Global Change Research Institute of the Czech Academy of Sciences. The extensively tested model can help to understand complex feedback mechanisms under drought events as well as future climatic conditions and estimate future carbon sink potentials in Central Europe.

In particular, we (i) evaluated the model performance using biomass, leaf area index (LAI) measurements, five-year-long eddy-covariance measurements of net ecosystem exchange (NEE) and evapotranspiration (ET), (ii) developed an efficient benchmark framework that highlighted structural and/or functional errors in the model, (iii) analyzed the simulated carbon and water cycle under drought events (consecutive dry days) occurring different time of the year and (iv) projected the effects of climate change on the forest carbon and water cycle up to 2100 using climate change scenarios from the FORESEE climatological dataset.

We found that the simulated biomass and LAI values are in the range of the observations, NEE and ET are overestimated by 5% and 11% during the vegetation period, respectively. Simulation runs assuming 30-days drought events at different months in five different years caused immediate NEE decrease compared to simulations without drought events. We found the largest NEE difference (up to 10% on the average of five years) in the cases when the drought occurred in July, August, or in September. Simulations driven by climate change scenarios showed that NEE is expected to increase by the of the century, while the ET does not show any significant change in the future.