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# Temperature acclimation of photosynthesis has only minor effects on gross primary productivity (GPP) in an Earth System Model (ESM)

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The productivity of terrestrial plants influences the dynamics of atmospheric $CO_2$. It is therefore crucial to understand and quantify productivity and predict its future responses to climate change and increasing atmospheric $CO_2$ concentrations. Recently, Booth et al. (2012) found that the temperature dependence of photosynthesis is the most important uncertainty of the climate-carbon cycle feedback in a comprehensive ESM. Kattge and Knorr (2007) found that photosynthesis, in particular the acclimation of the maximum carboxylation rate ($V_{max}$) and electron transport rate ($J_{max}$), acclimates to prevailing temperatures. As a first attempt to address temperature acclimation of photosynthesis on global scale, we replaced the simplified exponential formulation of the temperature dependence of $V_{max}$ and $J_{max}$ in the Max Planck Institute Earth System Model (MPI-ESM) by a physiologically more plausible and justified model with short-term optimum temperature. For temperature acclimation we then implemented the acclimation descriptions by Kattge and Knorr (2007). We conducted sets of simulations on site scale driven by meteorological observations, and simulations on global scale for present day climate and for a 6 K warmer climate.

The physiologically more plausible and justified model with short-term optimum temperature and temperature acclimation yields similar results as the old exponential formulation not accounting for either process. With the new model, global GPP for present day and in the warming scenario is increased by 0.7% and 0.5%, respectively. Acclimation causes a slight shift of productivity from high to low latitudes, too. A stronger effect on GPP has the replacement of the exponential formulation with the model with optimum temperature, resulting in a 1% decrease in global GPP under both climatic conditions. Acclimation thus compensates for the effects of the physiologically based temperature optimum of photosynthesis. As the effects are small, the model performance does not differ significantly between the different temperature photosynthesis formulation when compared to eddy covariance data. As Booth et al. (2012) did not account for acclimation but varied the short-term optimum temperature of photosynthesis they might have overestimated the importance of the optimum temperature. We conclude that long-term projections done with the MPI-ESM, as for example for the CMIP5 project, would not be strongly affected by the omission of acclimation, unlike suggested by Booth.

Kattge, J. and Knorr, W. (2007),Temperature acclimation in a biochemical model of photosynthesis: a reanalysis of data from 36 species, Plant, Cell and Environment, 30, 1176–1190.

Booth, B. B. B., Jones C. D., Collins, M., Totterdell, I. J., Cox, P. M., Sitch, S., Huntingford, C., Betts, R. A., Harris, G. R., Lloyd, J. (2012), High sensitivity of future global warming to land carbon cycle processes, Environmental Research Letters 7 (2), 024002.