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A trait-based approach in modeling fluxes to and from vegetation in ESM projections

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Large uncertainties exist in projections of earth system models (ESMs) both with respect to the size and direction of change in terrestrial carbon pools, as well as to how vegetation will respond (e.g. diebacks). These uncertainties may be partly explained by differences in the way biophysical or biochemical vegetation processes and disturbances are modeled, which may affect carbon exchange between the terrestrial biosphere and the atmosphere.
Most models only contain a limited number of Plant functional types (PFTs) to represent the vast diversity in vascular plants. The currently static nature of PFT properties contrasts with the variation seen in natural vegetation, where plants adjust their traits in response to environmental change. As PFTs remain relatively inert under changing climatic conditions, they do not allow for such plant adaptation to the environment and plant-atmosphere feedbacks, with unknown consequences for model projections.
A way to solve this problem is to allow traits of PFTs to vary with environmental conditions. This can be achieved by implementing trait-climate relationships based on the ecological concept of habitat filtering, where abiotic conditions act as a filter and reduce the number of viable plant traits in a habitat, resulting in different community means across global environmental gradients. In this project, such relationships were incorporation in the DGVM JSBACH to allow for variable traits in PFT-means within grid cells. As projections concern elevated CO_2 concentrations, plant CO_2 adaptation was modeled as well, based on long-term FACE-experiments. Simulations were performed with and without increasing CO_2 affecting vegetation to disentangle the effects of climate and CO_2 fertilization on vegetation.
Equilibrium simulations with and without plant adaptation via variable traits already showed large differences in patterns of vegetation and productivity, with the model with variable traits performing better than the default model when compared to observed natural vegetation and carbon biomass. In addition, simulations with and without variable traits incorporated were compared for projections from the year 1850 till 2100. Preliminary analysis shows, that besides initial differences in carbon pools, productivity and vegetation coverage, in general, the mean response of the default simulations is stronger than of the simulations with plant adaptation. Furthermore, the effect of CO_2 fertilization seems to be stronger for the default simulation globally, whereas with plant adaptation a somewhat moderate response to CO_2 occurs. However, among simulations, strong local differences in CO_2 fertilization effects occur.
These results indicate that allowing for plant adaptation via climate induced trait variation moderates the effect of both CO_2 fertilization and climate change, and it may be concluded that current models may underestimate the potential of vegetation to respond to changes in climate and CO_2.