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Biogeosciences Discussions

Interactive comment on "A model-based constraint of CO_2 fertilisation" *by* P. B. Holden et al.

Anonymous Referee #1

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The quantification of the mechanisms governing the global terrestrial sink is an open research goal of the carbon cycle community. Various methods to constrain the atmospheric budget of carbon reveal that the land is currently taking up carbon, despite that a considerable amount of carbon is released to the atmosphere due to anthropogenic land use and land use change. A variety of mechanisms is proposed in the literature to explain this terrestrial sink. These include amongst others stimulation of carbon uptake in response to (i) increasing atmospheric CO2 ("CO2 fertilization") (ii) enhanced nitrogen deposition and thus a relaxation of nitrogen limitation, (iii) climate change including changes in temperature, precipitation, cloud cover or global dimming by tropospheric and stratospheric aerosols and (iv) woody encroachment, effects of fire suppression, forest regrowth in response to changes in wood sampling, abandoning of alpine pasture or other management practices not readily accounted for in the

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Interactive Discussion

Discussion Paper

conventional book-keeping approach to land use emissions.

The authors constrain the parameter governing plant growth due to carbon dioxide fertilization by applying an observational constraint in a statistical Bayesian approach to their model results. The authors apply the difference in atmospheric CO2 between modern and preindustrial time as their only constraint on land biosphere uptake in response to increasing CO2. They performed an ensemble of 671 simulations over the industrial period with different parameters settings with their GENIE Earth System Model of Intermediate Complexity and built an emulator to map the link between 28 model parameter values and atmospheric CO2 change over the industrial period. From this the authors estimate the postulated enhancement of global gross primary productivity on land due the CO2 fertilization mechanism and the total change in terrestrial carbon storage over the industrial period. In addition, the authors describe the implementation of a simple model for anthropogenic land use in their terrestrial module.

Overall, I believe this is a useful study and the application of observational constraints in a probabilistic framework is a very useful approach. However, I also believe that more thoughts and more work are needed before this study is publishable in BG.

1) Simulated changes in air-land carbon fluxes are driven by changes in atmospheric CO2, surface temperature and precipitation as well as changes in the area under anthropogenic use. This implies that other potential mechanisms such as nitrogen limitations or changes in management practices, fire, woody encroachment etc are not accounted for. These (and other) potential mechanisms for land uptake are thus assigned to the "CO2 fertilisation mechanisms" in the approach of the authors. This caveat must be addressed upfront as well as in the discussion in the manuscript.

One may also note that this mapping of any unknown sink process on fertilisation has implications for future simulations as the CO2 fertilisation mechanism is assumed to continue well into the future, whereas other mechanisms could potentially saturate earlier than a CO2 driven sink.

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2) It seems to me that the authors use heavy machinery (ensemble simulations, emulator) to constrain a single parameter by a single observational constraint. Is this necessary and what is the benefit? Traditionally the atmospheric carbon budget, the net carbon flux from the atmosphere, the net carbon emissions in response to land use, and their difference, i.e. the residual sink flux from the atmosphere to the land were quantified in IPCC reports using a variety of constraints and methods (information from O2/N2 and d13C , ocean models, book-keeping and other approaches to constrain land use emissions, inverse modeling of the atmospheric CO2 distribution, reconstructions of anthropogenic carbon in the ocean). As such estimates of the residual sink and their uncertainty as well as estimates of the net atmosphere-to-land flux are available that include various sources of uncertainties. In (Enting et al., 1994), the CO2 fertilisation parameter is constrained by requiring the atmospheric budget for the 1980ies to be closed for a range of deforestation fluxes (0.6 to 2.6 GtC/yr). While this approach is simpler, it implicitly includes all sorts of information and observational constraints on land-atmosphere carbon fluxes.

a) It would be nice if the authors could explain the benefit of their approach compared to this earlier method.

b) How do the author account for in uncertainties related to fossil fuel emissions?

3) The net terrestrial uptake flux is quantified in various publications by a method called single deconvolution. How do the authors' estimates for the net air-land flux compare with results from single deconvolution approaches?

4) The authors describe their land use model. However, I miss an evaluation of results.

a) There is no map about cumulative emissions from land use nor any figure that shows the evolution of global or regional emissions and how these compare with available literature estimates.

b) I also miss any discussion on the quality of the land use module. Where does the

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model excel and where has it difficulties?

c) I am concerned about the application of a single plant functional type and that no distinction is made between grasses and forest. This must have major implications for land use emissions as converting grassland to pasture or crop is something radically different than the conversion of forests to cropland. How is this justified?

d) I am also concerned that no distinction is made between cropland and pasture. Field studies suggest that soil carbon accumulation/depletion is very different for cropland compared to pasture. The authors acknowledge this fact. However, they do not account for differences in the evolution of pasture versus cropland and how this affect overall soil carbon changes is not considered in equation (3). This may be perhaps less relevant for this study, but for the application of the model to different land use scenarios in the future.

5) No information is given on the temporal evolution of atmospheric CO2 and the spatial and temporal pattern of the atmosphere-to-land fluxes

6) Page 9428, line 8: delete "for the first time" as many others have explicitly or implicitly done so before

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