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Earth System Dynamics Discussions

Interactive comment on "The influence of vegetation dynamics on anthropogenic climate change" *by* U. Port et al.

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Dear reviewer,
thank you very much for reading our manuscript so carefully and for your comments.

Referee: The authors designed four simulation experiment (as listed in Table 2) to investigate the effect of vegetation dynamic on global climate. It looks to me that the individual and combined climate influence from biogeochemical and biogeophysical effects can be represented by analyzing the following results:
DYN - STAT (Eq. 1) the combined biogeochemical and biogeophysical effects on climate;
DYN - STAT_PS (Eq. 2) the biogeophysical effects on climate;

STAT_PS - STAT (Eq. 3) the biogeochemical effects on climate.
The authors analyzed in detail the results of (2), but not (1) and (3).

Author: The structure of this paper is chosen in the way that the net effect is analysed by separating in the biogeophysical and the biogeochemical effect. In order to assess the biogeophysical effect, the energy balance is analysed on a regional scale. The biogeochemical effect acts globally. That is why we limit the analysis of the biogeochemcial effect on the global climate and the carbon cycle.

Referee: Also, it would be quite interesting to investigate the linearity of climate response from biogeochemical and biogeophysical effects, i.e., to compare the climate response between (1) and the sum of (2) and (3).

Author: The overview of the simulations and their objectives (Equations (1) to (3)) are correct. However, analysing the sum of (2) and (3) and compare it with (1) does not make sense to us since the sum of (2) and (3) and (1) are equivalent: Net effect = BGP (2) + BGC (3) = DYN - STAT_PS + STAT_PS - STAT = DYN - STAT (1).

Referee: Related to: "We assume anthropogenic CO2 emissions according to the RCP 8.5 scenario in the period from 1850 to 2120 and shut them down afterwards to evaluate the equilibrium response of the Earth System by 2300".
I believe the response of the Earth climate system, including the response of the deep ocean and dynamic vegetation, would not reach equilibrium by 2300. For example, it will take thousands of years for the response of the full ocean to reach equilibrium.

Author: Right, the term 'equilibrium response' is inappropriate in this context. We will change it to 'stabilising'.

Referee: RCP scenario is for atmospheric CO2 concentrations. How was transient CO2 emission, as used in simulations, derived from the RCP 8.5 concentration

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scenario?

Author: Next to CO2 emissions, the RCPs include pathways for CH4 , N2O and other trace matter. That is why we emphasise that we only use the CO2 emissions from the RCP scenario. The transient emissions for all the greenhouse and tracer gases according to RCP 8.5 can be obtained from the RCP database (http://www.iiasa.ac.at/web-apps/tnt/RcpDb/).

Referee: Bala et al. (2006), as cited by the authors, looked at the impact of dynamic vegetation on global climate over a period of 400 years. Therefore, in this respect, this study is not unique.

Author: Bala et al. (2006) analyse the effect of CO2 emissions on the biosphere and the resulting impact on climate. Thereby, the elevated atmospheric CO2 concentration leads to changes in the biosphere, but the greenhouse gas radiative forcing stays constant at the pre-industrial level. In our study, both the anthropogenic CO2 emissions as well as the resulting changes in radiative forcing cause shifts in the vegetation cover.
We will work on emphasising the special features of our study more clearly.

Referee: Does leaf area index respond to climate and CO2 in the STAT simulation? If so, it should be stated clearly. Note that even vegetation fractional cover does not change,change in leaf area index due to CO2 fertilization could feedback on climate.

Author: Yes, LAI changes in the STAT and STAT_PS simulation.

Referee: Related to: "Since the climate changes due to the different plant productivity and canopy conductance are very much smaller than the changes due to the vegetation cover shifts..."
This statement is weak. Is there any observational and/or modeling evidence to support this argument?

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Author: Levis et al. 1999 compare the impact of the physiological effect of elevated atmospheric CO2 on climate with the influence of vegetation cover changes on climate assuming 2xCO2 (345 ppm and 690 ppm). They find that in certain regions the physiological effect is of the same magnitude as the changes in climate due vegetation cover changes. In our DYN and STAT simulation, the plant physiology differs due to a variation in atmospheric CO2 by 40 ppm in 2300. Thus, we assume that the impact of changes in the physiology on climate due to the different atmospheric CO2 (40 ppm) should be smaller than the influence of vegetation cover changes, which are caused by an increase in atmospheric CO2 by about 600 ppm.

Referee: Related to: "Since the vegetation cover changes are strongest at the end of the simulation."
This statement is weak too. Two questions here: first, what is the metrics used here to quantify the strength of the vegetation cover change? Second, without any quantification, how will the reader know that the vegetation cover changes are strongest at the end of simulation?

Author: We choose the end of the simulations for detailed analysis since vegetation cover still changes after the atmospheric CO2 concentration reaches its peak in 2120. After the year 2260, the vegetation cover tends to stabilise.

Referee: In addition to precipitation change, it would be more interesting to show changes in soil moisture, which is a better indicator of water availability.

Author: Right, we will analyse the changes in soil moisture.

Referee: Related to: "As this decline in tree cover depends on water stress, it differs from the forest dieback found in previous studies."
I do not understand this sentence. Is the mechanism of decline in tree cover different

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from previous studies or the amount of decline in tree cover different from previous studies?

Author: As in previous studies, we find a decline in forest in the Amazon region. However, the decline we simulate is weaker than in Betts et al. (2004). The precipitation decrease in the Amazon region suggested by Betts et al. (2004) is stronger than in our simulation leading to a stronger decline in tree cover. We will express this more clearly.

Referee: Related to: "However, CO2 fertilisation becomes non-effective in regions of stronger water stress due to elevated temperatures (in parts of the Amazon region and central desert regions)."
It's just stated above that the tree decline in Amazon is due to water stress, but here the decline is attributed to elevated temperature.

Author: In the Amazon region higher temperatures and lower precipitation rates cause the tree cover decline.

Referee: Any possible explanation why in the model precipitation in Sahel increases until 2090 and then decrease?

Author: To answer the question why the precipitation evolves this way requires a more detailed analysis. Unfortunately, such an analysis is out of the scope of this paper.

Referee: Related to: "The biogeophysical effect of vegetation cover change has no significant effect on global annual mean temperature, but has an impact on regional climate change (Fig. 11)."
Please quantify the change in global-mean surface temperature.

Author: The difference in global annual mean temperature due to the biogeophysical effect of vegetation dynamics is a warming of 0.05 K. This value is very

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small and not significant. That is why we do not quantify the value.

Referee: Related to: "The maximum evapotranspiration increase occurs in summer (Fig. 13) as trees carry a maximum amount of leaves in this time. The resultant impact on continental temperature is evident in the annual cycle of temperature differences between the DYN and the STAT_PS simulation, as the strongest cooling occurs in May and July."
By looking at Fig. 13, temperature of DYN is larger than that of STAT_PS for the months between Jan. and Oct. I have no clue of why the author state "the strongest cooling occurs in May and July."

Author: We want to point out, that in summer the impact of evapotranspiration changes becomes dominant, while the influence of the albedo reduction becomes weaker. Indeed, the formulation is not clear enough, we will improve it.

Referee: By looking at the middle panel of Fig. 13, the albedo of DYN is larger than the albedo of STAT_PS, which is opposite to what is stated here.

Author: During visualisation an error occurred which switched the sign. We changed the plot.

Referee: Related to: "The smaller cloud cover leads to a cooling since the loss of thermal radiation is larger and thus net long wave radiation is smaller."
Presumably, a decrease in latent heat flux as a result of smaller tree cover in DYN should decrease low cloudiness, increasing solar flux reaching the surface and thus warming the surface. But the statement here seems to suggest that the cloud feedback is dominated by changes in high cloudiness and associated longwave flux. Without showing anything associated with changes in cloud cover and shortwave and longwave flux, it's not clear what is going on in the model.

Author: Here, we relate the lower longwave radiation in the DYN than in

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the STAT_PS simulation to the water vapour feedback. We will analyse the changes in water vapour in more detail to gain a more precise idea of the driving mechanism.

Referee: Fig. 13: What causes the decrease in temperature between October and December?

Author: We do not have a satisfying explanation for it, yet. Since there is little radiation coming in these months, we can say that albedo difference play no role. We may need to look into sea ice difference in these months. It could be that we have a shift in convection cell in the ocean, and this causes an early winter cooling in the DYN run.

Referee: If we think there is an approximately linear relationship between radiative forcing and global mean temperature change, and there is an approximately logarithmic relationship between radiative forcing and CO2 concentration, then there should be a logarithmic relationship between CO2 and temperature.

Author: We will recalculate and provide the climate sensitivity assuming a logarithmic relationship between CO2 and temperature, but do not expect a large difference to the linear approximation.

Referee: Also, the climate effect from biogeochemical impact of vegetation dynamics can be estimated directly from the difference between STAT_PS and STAT run. Why not show maps of temperature and precipitation change between these two runs?

Author: Since the temperature change due to the biogeophysical effect of vegetation dynamics is very small and not significant on global scale, we did not calculate the impact of the biogechemical effect directly from difference between the net effect and the biogeophysical effect.
Calculating the biogeochemical effect directly leads to:

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biogeochemical = net effect - biogeophysical = -0.22 K - 0.05 K = -0.27 K
We will add plots for the differences in temperature between the STAT and the STAT_PS simulations. Maps for precipitation differences are not meaningful since only small and not significant differences occur over land.

Referee: For the figures showing the model-simulated changes in terms of maps (Fig. 3, Fig., 4, Fig.6, Fig.8, Fig. 10, Fig. 11, Fig. 12, Fig. 14), the authors take the difference between two individual years (either the result of year 2119 minus that of year 2090 or the result of year 2299 minus that of year 2270). To reduce the signal-to-noise ratio, it would be more appropriate to take the difference in averaged simulation results between some periods. This is done in Fig. 7 where the differences in averaged 30-year results are taken (averaged results between year 2270 and 2279 minus that between year 2090 and 2119). Why not do the same thing for all other figures?

Author: In all these figures, the 30 yr average of the differences is shown.

We hope, that our answers are satisfying. If there are still things unclear or incomplete, we are happy to receive further comments.

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