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Earth System
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Discussions

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

U. Port et al.

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Dear Chris Jones,

Thank you for reading our manuscript and for the helpful comments. Especially, your comment on the variability in precipitation inspired us to look into the data so we find an interesting connecting between vegetation dynamics, variability in precipitation, and soil moisture for the Sahara.

General comment:

Referee: As a general comment, I would like to see discussion of idea of "commitment" - much of the changes post 2100 are in some way committed - they are locked *in due to existing emissions and climate change and cannot be avoided regardless of complete emissions cuts. Hence this raises the issue that mitigation and climate targets must take into account time horizons beyond the point of stabilisation.*

Author: We agree and add the discussion of commitment to the conclusions part.

Referee: my other main comment is that there appears to be a BIG change in the Sahara/Sahel precip maybe caused by the land-cover change there. The change is not necessarily in the MEAN, but is clear in the VARIABILITY which seems to get noticeably smaller when the vegetation changes. Is there an important issue to discuss here therefore that climate effects do not have to be on mean climate state, but can have important impacts through changes in variability. It would be wrong to state that the vegetation changes do not cause a climate change in this region.

Author: Indeed, no significant difference in the mean precipitation occurs between the DYN and STAT_PS simulation. However, the variability in these simulations differs. The standard deviation declines due to anthropogenic climate change and less years with high precipitation rates occur (Table 1, CTL - STAT_PS). Including natural vegetation dynamics leads to a weaker decline in variability, and years with high precipitation rates occur more often than in the STAT simulation.
compared to the STAT_PS simulation, the soil moisture is higher by 3.1% in the DYN simulation. As the evapotranspiration is lower in the DYN than in the STAT_PS simulation, the soil moisture can not be the reason for the higher variability in precipitation, but can likely be the reason.
In summary, our simulations suggest that vegetation changes attenuate the reduction in precipitation variability and lead to a higher soil moisture. Thus, vegetation dynamics counteract the drying due to anthropogenic climate change in the Sahara.

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Table 1. Standard deviation and occurrence of years with high precipitation for the CTL, DYN, and STAT_PS simulation assessed based on the last 100 years of each simulation. Years with high precipitation are defined to have more precipitation than 20 % of the mean over the last 100 years.

	CTL	DYN	STAT_PS
Standard deviation	0.072	0.036	0.026
years with high precipitation	28	19	17

Specific comments:

Referee: page 489, line 17, "tree steps". Amusing typo!

Author: Yes, thanks. We will change it.

Referee: page 491. Here you should explicitly say that you do not consider anthropogenic landuse change. You mention this in the discussion at the end (by which time I had assumed it). But it should be up front in the methods.

Author: At 490/26 we state that land use-change in neglected. It seems like we need to emphasis this more clearly. Thus, we change 490/26 to:

Vegetation cover shifts due to land-use are not included, i.e. the biosphere only changes naturally.

Author: and add the following to the introduction (489/11):

As we focus on natural land cover changes, we only include natural vegetation dynamics and neglect anthropogenic land-use change.

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Referee: page 491, line 25 - when defining your regions of interest you might consider marking these on one of your maps.

Author: We will mark the regions in one of the maps of equilibrium vegetation and refer to the map instead of giving the specific region description.

Referee: page 493, line 15. Not sure what you mean by this differs from Betts et al due to water stress? Betts et al also included the effect of CO2 on WUE. You might also cite Good et al (Good, Peter, Chris Jones, Jason Lowe, Richard Betts, Ben Booth, Chris Huntingford, 2011: Quantifying Environmental Drivers of Future Tropical Forest Extent. J. Climate, 24, 1337-1349.) who look at the climate and CO2 effects on future vegetation vulnerability.

Author: The formulation at this point of the manuscript is misleading. We change it to:

The sensitivity of the Amazon forest to drying and the decline in Amazonian tree cover due to anthropogenic climate change is known from previous studies (Betts et. al, 2004, Notaro et. al, 2007, and Good et. al, 2011). However, the magnitude of forest cover decline differs.

Good et. al 2011 is an interesting study as the CO2 fertilisation effect is contrasted with the impact of extended drying season on the Amazon forest. This work back our findings that the declined precipitation rate is the driving mechanisms for the forest cover decrease and will refer to this work.

Referee: page 494, discussion of Sahel rainfall. Its hard to see the changes you discuss - can you also plot a smoothed time series? The variability change is also important as noted above - so you should discuss that too? (e.g. changes in frequency of wet years? or dry years?)

Author: You are right, displaying the ten year mean illustrates the precipitation changes more clearly. We will change it. For the discussion of changes in variability, see above.

Referee: p.496, line 15. You say trees are less sensitive to CO2 fertilisation, but it could just be they have a longer response time, and you have not seen the full response yet? In fact, how do you know by 2300 you are seeing equilibrium vegetation? would it change further if you ran to, say 2500?

Author: In 2300, the vegetation cover is not in equilibrium. Forest responds is on the scale of decades, for tropical trees the response time is about 30 years. Thus, the response time can not explain that trees survive and grass cover decline.
There are two possible explanations for the maintenance of trees while grass can not survive. First, the disturbances could occur less often. During fire, trees are substituted by grass. If less fires occur, trees survive and grass cover decline. Second, the productivity of trees could be higher. In the Sahara, predominantly C4 grass occur. C4 is not sensitive to elevated atmospheric CO2. Thus, C4 grass does not benefit for CO2 fertilisation, but trees do. We will evaluate both explanations.

Referee: p. 497. The snow masking effect is clearly important, but a warmer climate might also have less snow. So have you separated the initial cause (snow masking) from an amplifying feedback (reduced snow)?

Author: In the annual and spatial mean, the snow cover difference in the northern high latitudes between the DYN and the STAT simulation are small. However, dynamic vegetation influences the seasonal cycle of snow cover. In May and June, the snow cover in the DYN simulation is strongly reduced com-

pared to the STAT simulation. The strongest albedo reduction due to vegetation dynamics occurs earlier, in February, March, and April. Thus, we expect the impact of the snow masking effect on the snow cover in our experiment to be weak.

Referee: p.500 - calculation of change in temperature - for small delta-T using a linear approach might work, but you could do this more rigorously using radiative forcing calculation (depends on log(CO2)). This might give you a slightly smaller value.

Author: Defining the climate sensitivity as

$$\lambda = \frac{\Delta \mathbf{T}}{\Delta \mathbf{RF}}, \tag{1}$$

T...temperature
RF...radiative forcing

we get λ=1.3 K/W/m^2 (ΔT and ΔRF are 4.9 K and 3.8 W/m^2 in 2120, respectively). We use the logarithmic relation between radiative forcing and atmospheric CO_2 concentration by Myhre et. al 1998

$$\Delta \mathbf{RF} = \mathbf{5.53 ln} \frac{\mathbf{C}}{\mathbf{C}_0} \tag{2}$$

RF...radiative forcing
C...atmospheric CO_2 concentration
C_0...reference atmospheric CO_2 concentration.

C = 772 ppm is the CO_2 concentration in the DYN simulation in 2300 and C_0 = 809 ppm is the CO_2 concentration in the STAT simulation. That leads to a change in radiative forcing change by -0.25 W/m^2 and the corresponding impact

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on temperature as a cooling by 0.36 K.
The values obtained by the linear and the logarithmic assumption differ by 0.09 K. Thus, we will skip the part were we calculate the biogeochemical effect from the difference in atmospheric CO_2 concentration between the DYN and STAT simulation based on a linear assumption.

Referee: a final thought - we had some similar experiments which we never wrote up, but found that the response of vegetation and soil carbon were quite different between fixed and dynamic vegetation experiments and these offset. Have you looked at veg and soil carbon separately? they might be more interesting than the C_land total.

Author: Yes, we also looked at the different carbon pools in 2300. The changes in the vegetation, soil, and litter pool are consistent with each other. In other words, the carbon storage in the soil becomes larger in all region were vegetation carbon is larger due to vegetation dynamics. Thus, the difference in the total carbon reflects the pattern where soil and vegetation carbon become larger/smaller (Figure ??).
However, when we look at the time series of global mean carbon storage, we find different response times in the vegetation, soil, and litter pool. Therefore, we might get a less congruency between the different carbon pools for an earlier time step.

Referee: figure 2 - can you use colours that are more different? its hard to spot DYN from STAT

Author: We will change the colours to red and black.

Referee: you do a lot of maps, which are informative, but can be hard to compare by eye. E.g. to compare figures 11 and 12 you could do a zonal mean plot which shows relative magnitude clearly. Likewise to compare figure 10 with fig 3.

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Author: Large regions with no significant influence of vegetation cover changes on temperature occur (Figure 11 and 12 of the manuscript). Thus, the zonal mean is strongly biased. As the first reviewer would wish to see a more detailed analyses of the biogeochemical effect we will think about showing the differences between Figure 11 and 12 as these differences refer to the biogeochemical effect.