Reply to Referee comments on CP-2021-51, "Holocene vegetation transitions and their climatic drivers in MPI-ESM1.2" by Anne Dallmeyer et al.

RC1:
We thank the referee Qiong Zhang for her constructive and valuable comments on our manuscript and her suggestions for improving the results.
In the following, we respond to her comments (typed in black) point by point. Our responses are marked in blue.

R: Dear Anne and co-authors,
I have read through your submitted manuscript, noticed it is the work you presented in EGU 2021, a really nice work. In this manuscript you have presented the results from a 8000-year long Holocene transient simulation with MPI-ESM1.2, focus on the long term trend in different vegetation type and changes in global and regional vegetation pattern. The simulated vegetation changes are compared with the pollen-based reconstructions and showed good agreement. The climatic drivers for these changes are identified using redundancy analysis, you conclude that the overall trend in global pattern is linearly following the orbital forcing, and some rapid non-linear changes are observed in a few regions - not only the well-know Sahara region but also in northern high latitudes and other monsoon margins. You also found that the precipitation is the main driver for regional difference in northern high latitudes, and the mechanism is associated to the changes in circulation that induced by the changes in global summer monsoon.
The manuscript is logically structured and very well written, has provided comprehensive information regarding the changes in vegetation both in MPI-ESM1.2 model simulation and in pollen reconstructions. Such detailed information on the trend and changes in global and regional vegetation pattern certainly contribute a good reference for both the climate modelling community and paleo-climate community. I have a few comments below for you to consider to improve the presentation.

A: Thank you for pointing to the scientific importance of our manuscript.

R: I understand that this long transient simulation is performed from 6000 BCE to 2000 CE for 8000 years. In section 2.3 (p7-line234) the authors explain that for an easier nomenclature they define mid-Holocene time slice to 8 ka b2k. However, it is not easy for most of us who always regard mid-Holocene as 6 ka, as showed in the literature in the introduction. When reading the manuscript I often have to remind myself this 8 ka b2k actually is the commonly mentioned 6ka, and have to do some convert when looking at the figures. I suggest to use conventional 6 ka in the paper, some readers may misunderstand (if not read carefully but only take a look at figures) that 8 ka here refers to 2000 years before 6ka. This manuscript focuses on the natural vegetation variability, and the presented results do not include the last 2000 years (past2K),
therefore present 6000 BCE (6ka) to 0 would nicely fall to the common understanding.

A: We see this point. Most time-slice studies have been prepared for the 6ka period and our study deals with the vegetation change from 8ka until 2.15ka. Since the vegetation change is rather linear, it can be expected, that the results and conclusions derived in this study do not change considering the 6ka time-slice instead of the 8ka time-slice. The absolute values in the vegetation change will of course be reduced, but not the sign and the order of magnitude of the signal. We will therefore keep the 8ka time-slice, but to reduce the confusion, we will name it “early mid-Holocene”, instead of just “mid-Holocene”.

R: For the different between the mid and late Holocene, you compute the difference for first 100 years and last 100 years without land-use (250-150 BCE). Considering that the simulation shows the multi-centennial variability (as mentioned in P4-line132), I suggest to use few more hundreds years' data to compute the change between the mid and late Holocene, or check the dominant frequency, I notice that for butterworth-Filter you used 500 years. This can remove the possible impact of multi-centennial variability. Besides, when presenting the changes between two periods, should provide the statistical significance test to show the changes are robust.

A: We decided to use 'only' 100 years because it is the commonly used period for climatological means and to be consistent to the cluster-analysis that is also based on 100-year running means. Since the simulation is transient, longer periods may be affected by trends.
We have tested the significance of the change in vegetation cover and climate by a paired t-test. The difference in vegetation shown before in Fig.7 are all significant, but please notice, that JSBACH uses partly multi-year climatological means to calculate the vegetation. Therefore the variability is expected to be small. We will revise the climate plots (Fig.8,9,10) that they will only show significant changes. Considering only significant changes does not change any results and conclusions presented in the original manuscript.

R: The changes in regional vegetation pattern are presented extensively in section 5, it would be nice to have a schematic diagram or table to summarise the major conclusion (vegetation type with changed percentage etc.) instead of long summary text that somewhat repeat section 5.

A: Thank you for bringing this up. We will include a summarising sketch of the Holocene vegetation change for the readers' convenience, but we decided to keep additionally the summary text. We agree that this may be longer than usual, but it was important to us to take up the five main regions (a-e) listed in chapter 4 in the summary again and to connect them with the summarized results from chapter 5.

R: It is interesting to see that there are more regions showing rapid vegetation shift besides the well-know collapse of green Sahara, the examples given in Figure 13 showing the rapid transition are impressive. However, the two grid box showed in Fig.13 seems they are selective examples, I would expect to see the transition features in Sahara first, also expect to see transitions in more PFTs as showed in Fig.12.

A: We appreciate Qiong's suggestion, and we are going to extend the text on the transition in the Sahara/Sahel region considerably. In addition, we will add a new sub-figure to Fig. 13 which depicts the transition between grass coverage to bare soil and the transition between tropical evergreen to deciduous trees. We will also add a new Fig. 14 which shows the transition in the Sahara/Sahel over a larger region.

R: P6-line 195, a "spin-down" is used, can you explain why use this instead of "spin-up"?

A:We agree that the term "spin-down" may be confusing for most readers. The reason for using this term was that the mid-Holocene equilibrium simulation was branched off the pre-industrial control run and ran somehow 'back in time' until mid-Holocene conditions have been approached. To distinguish this method technically from the spin-up of the PI control run, we called this "spin-down". To avoid this confusion we change "spin-down" to "spin-up" in the revised manuscript.

R: P10-line 335, mentioned "These events may at least partly be associated with the volcanic forcing prescribed to the model", more clarification would be good, does it mean those events do not present in the non-volcanic forced simulation in this model? A reference on this could help the understanding.

A: The volcanic forcing affects the climate response and contributes to the climate variability. In the vegetation change, this forcing is rather buffered, related to the model structure and equations. The analysis of the volcanic impact would go beyond this paper, but will be the subject of another study, prepared by our colleagues.

R: P11-line 396, "monsoon region is increased" better as "monsoon area is expanded".
A: okay.

R: P18, line 661, " last millennia", should be "last 8000 years"
A: okay