Response to reviewer 3 of the paper entitled
"Different response of surface temperature and air temperature to deforestation in climate models"
Ref.: esd-2018-66

We would thank the reviewer for the time he/she devoted on reviewing the manuscript, and for his/her helpful comments.

Below are the reviewers comments (***bold italic font***) and our responses to each point (normal font). All line numbers that we provide in our responses refer to the revised version of the manuscript in which track changes are not shown.
The original manuscript contained one paper (Winckler et al., 2018) that had not been accepted yet. This manuscript has now been accepted (doi: 10.1029/2018gl080211) and can be made available to the reviewers.

1. ***General Comments***
   The research described in this article addresses an interesting topic – how deforestation affects various measures of temperature, as calculated by global climate models. Overall, I thought the results were well presented, but I had some issues with the way the paper was written, which led to some confusion on my part that required repeated re-reading. Some important ideas were glossed over (e.g., deforestation leading to reduced longwave forcing from above), and I had to infer (possibly incorrectly) some cause-and-effect mechanisms. This will require more interpretation of the results than is presented here.

   We are happy that the reviewer is interested in the topic and the results are overall well presented. We see (also in the other reviewers' comments) that some more explanations are needed, so we improved the presentation of some ideas and mechanisms (see answers to the specific comments).

2. ***Specific Comments***
   Page 2 Line 13: The 2 effects often associated with deforestation are albedo increases (which cool the surface) and a reduction in transpiration (which reduces the latent heat flux, forcing the sensible heat flux to rise and increasing the surface temperature). Is it the balance between these competing effects that depends on latitude, leading to cooling at some latitudes and warming at others?

   The reviewer is right that the change in surface temperature depends on the balance between these competing effects. We now refer to the study of Bright et al. (2012) which highlights the different contribution of radiative and nonradiative effects at different latitudes (their Fig. 3).

3. ***a) Page 2 Line 24: I'm confused by the way the 'forest world' was created. I understand how forest was placed in areas where it existed in pre-industrial times (but currently does not). Figure 1, however, shows strong local effects in the Sahara and Gobi deserts. Was there any difference in the local forcing at these locations? A map of what the vegetation in the forest world looks like (along with the 34 world) would be helpful.***
   b) Page 2 Line 26: I'm not sure what 'three of four grid boxes' means. Were 3 out of every 4 forested ares randomly selected to be deforested, or was some kind of pattern used?

   a) We now provide a map (Fig. S1) showing which grid boxes were deforested (in a regular spatial pattern), The map also shows the fraction of vegetated areas in these grid box. In the forest world, forest is prescribed on all vegetated areas (e.g., 100% in most grid boxes where forest is present today,

but also on present-day grasslands) but close to 0% in areas with sparse present-day vegetation cover such as the Sahara or Gobi deserts. In the deforestation simulation, forests in the vegetated areas is replaced by 100% grasslands. The reviewer is right that there is some local change in surface temperature in the deserts although only a small fraction of the grid box was deforested. We hypothesize that this comparably large signal could be caused by the non-linearity in the response of surface temperature to changes in forest cover within a grid box (Winckler et al., 2017) (meaning that for low initial forest cover, small changes can have a large effect).
b) For the deforestation, a regular spatial pattern was used. In section 2.1 we now refer to the newly added deforestation map, see Fig. S1

4. ***Page 6 Line 4: They write 'nonlocal effects strongly depend on the areal extent and spatial distribution of deforestation'. I'm assuming that the deforestation patterns differ among the different climate models, which is why it is impractical to compare nonlocal effects between the different GCMs, correct?***

   We removed this point because it is not essential and it would require substantially more explanation to clarify.

5. ***Page 6 Line 25/26: I'm interpreting this as follows: deforestation leads to a global reduction in temperature and humidity (due to the increases in albedo and decreases in evapotranspiration?), and this leads to more longwave escaping to space and less coming from above. Is this correct, or do changes in cloud cover play a role? If the former, it should be stated more clearly.***
   Page 6 Line 27: The pattern of nonlocal effects in Fig. 1 needs some explanation. Why are the eastern Pacific Ocean currents warmer? And why are the forested areas in the Amazon and equatorial Africa warmer? How are they affected by their neighboring, deforested areas? Is this also due to changes in longwave forcing?
   Page 8 Line 4/5: Again, the idea here is that a local effect is propagated remotely by reducing humidity and allowing more IR to escape, correct? And if that is true, what is causing the nonlocal increases of the 3 temperature metrics in the Amazon and equatorial Africa? I'm assuming it is related to the dense forest in these areas, perhaps making the change due to deforestation more pronounced in these locations, but some explanation is needed.
   Page 8 Line 5: Now, it is stated that changes in atmospheric temperature and moisture are affecting longwave radiation. Is deforestation decreasing the global humidity, making the atmosphere more transparent to longwave?

   These four reviewer comments refer to the mechanisms and spatial patters for the nonlocal effects. The first paragraph in section 3.1 now provides a slightly more detailed explanation. At deforested locations, the input of latent and sensible heat into the atmosphere is reduced. This leads to a drier and cooler atmosphere, and this in turn reduces the longwave incoming radiation, also at locations that were not deforested (nonlocal effects). This explanation, as well as maps of the local changes in latent/sensible heat and nonlocal shortwave/longwave incoming radiation are included in the Supplementary Figures of Winckler et al. (2018) which is now also available to the reviewers. In the Amazon and in equatorial Africa the reduction of longwave incoming radiation is overcompensated by an increase in shortwave incoming radiation due to a reduction in cloud cover (see Figure 1 below).
   We feel that a more detailed analysis of the nonlocal effects, i.e. changes in the ocean circulation, goes beyond the scope of the current study.

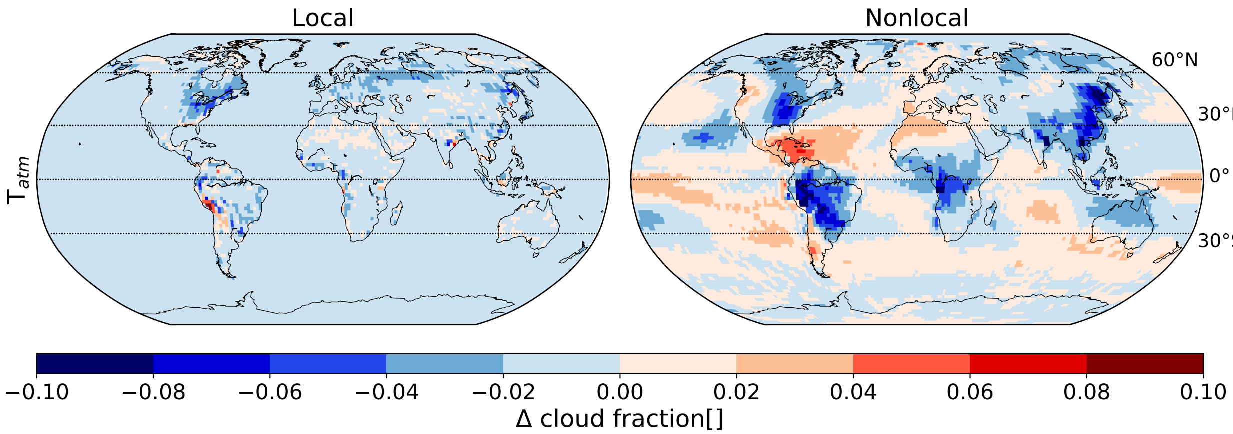

Figure 1: *Deforestation-induced annual mean changes in cloud cover in the '3/4' simulation using the MPI-ESM. The locations where cloud cover decreases for the nonlocal effects are co-located with regions with a nonlocal increase of incoming radiation (Fig. S6 in Winckler et al. (2018)).*

6. ***Page 8 Line 30-35:***
   a) If 'atmospheric conditions are unstable', why do we not see convective overturning of the atmosphere? This would eliminate the vertical gradient seen in Fig. S3b.
   b) Also, how does reducing the roughness length increase instability?
   c) I'm not quite following this explanation for the differences between Figs. S3a and S3b. First, Tsurf is shown to increase during the day and decrease at night. These are linked to changes in stability, and this leads to differences in the way T2m is calculated between night and day with Monin-Obukhov theory and Eq. 2. What is missing is an explanation of the changes in Tsurf, why they differ between day and night, and why the changes vary with latitude (Fig. 2). Are they related to changes in albedo, in evapotranspiration, or both? This seems to be the key driver for the local changes, and ultimately the nonlocal changes as well.
   d) Additionally, invoking the parameterization in Eq. 2 as the explanation of why the T2m values don't change as much as the Tsurf values is not really explaining why it is happening. Exactly what physical mechanism is causing the 2m temperature to vary less?
   e) Finally, this explanation of differing responses between Tsurf and T2m in summer and during the day is ultimately the reason that these 2 variables look different in the annual averages in Fig. 1, correct? And the way that local changes in Tsurf vary with latitude in Fig. 1 are because the changes in Tmin at the surface dominate at high norther latitudes, while the changes in Tmax dominate elsewhere, correct?

   a) Indeed, during daytime we would expect potential air temperature to be similar for T2m and Tatm. We suggest two potential reasons for the temperature gradient in Fig. 3b): First, even without a vertical gradient in potential temperature we would expect a gradient in actual temperature due to the lapse rate. Second, the calculation of T_{2m} is based on semi-empirical formulas and does not explicitly account for the input of sensible heat from the surface or vertical mixing within the atmosphere.
   b) In the new version of the paragraph, we don't mention surface roughness because this was obviously confusing. We hypothesize that reducing roughness length could increase daily maximum surface temperature by reducing the ability of the surface to transfer latent and sensible energy into the atmosphere. The surface would have to warm up more (compared to a rougher surface) in order to get rid of energy via longwave outgoing radiation (Stefan-Boltzmann-law). Consequently also the

gradient between the maximum temperature at the surface and the atmosphere could increase.
c) Why surface temperature responds differently for daytime and nighttime is an interesting question, but has already been investigated in previous studies (e.g., Schultz et al., 2017). We now refer to the previous studies also in these sentences.
d) In the last two paragraphs of section 3.1 we now provide a physical explanation of what would intuitively be expected and how the differences in near-surface stability between day and night are taken into account in the models' calculation of T2m.
e) We now hypothesize that part of the difference between the response of Tsurf and T2m can be explained by differences during daytime/nighttime and during the different seasons. We now also discuss in section 3.1 that the way T2m is calculated in the model may be important for explaining why the response of T2m and Tsurf can differ even e.g. for Tmax in JJA, see Fig. S9, and that the annual mean response depends on the balance between the daytime and nighttime response, and the balance between the responses in different seasons.

7. ***Technical Corrections***
Page 1 Line 5: The acronym MPI-ESM should be spelled out here.
Line 7: The phrase 'effects affect' is awkward, and should be revised.

   Corrected, thanks!

8. ***Line 11: It was already established that the authors were using the MPI-ESM, so what is this 'inter-model comparison' they mention now? A sentence explaining that existing model data from multiple GCMs was examined for comparison to the MPI-ESM results is needed.***
Page 3 Line 15: The 'wide range of climate models' needs more context. As in the abstract, a sentence explaining the idea should suffice.

   We added such a sentence in the abstract and the introduction.

9. ***Page 5 Line 27: The first sentence of Section 2.3 is confusing and should be rewritten. The phrase 'In order to. . ..other climate models,' is not needed, since it just states the same idea in the rest of the sentence.***
Page 6 Line 6: Change 'deforestation in the difference' to 'deforestation as the difference'.

   We changed the respective sentences.

10. ***Page 7 Figure 1: These are annual means, correct? If so, it should be in the caption.***

    Done.

11. ***Page 8 Line 23: The sentence 'Similarly as in the case. . .' should reference Fig. 2.***

    Done.

12. ***Page 11/12 Some information in the Discussions/Conclusions section was already included in the introduction.***

    We revised the introduction and discussions/conclusions to avoid repetition of information.

References

Bright, R., Cherubini, F., and Str\omman, A. H. (2012). Climate impacts of bioenergy: Inclusion of carbon cycle and albedo dynamics in life cycle impact assessment. *Environmental Impact Assessment Review*.

Schultz, N. M., Lawrence, P. J., and Lee, X. (2017). Global satellite data highlights the diurnal asymmetry of the surface temperature response to deforestation. *Journal of Geophysical Research: Biogeosciences*, 122(4):903–917.

Winckler, J., Reick, C. H., Lejeune, Q., and Pongratz, J. (2018). Nonlocal effects dominate the global mean surface temperature response to the biogeophysical effects of deforestation. *Geophysical Research Letters*.

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