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Climate of the Past Discussions

Interactive comment on "Assessing the impact of late Pleistocene megafaunal extinctions on global vegetation and climate" *by* M.-O. Brault et al.

Anonymous Referee #2

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Review of "Assessing the impact of late Pleistocene megafaunal extinctions on global vegetation and climate" by M.-O. Brault, L. A. Mysak, H. D. Matthews, and C. T. Simmons.

Brault et al. investigate the potential impact of the extinction of mammoths and similar megafauna after the last glacial on the climate system. Assuming a boreal ecosystem where the growth of trees has been suppressed by large animals, they describe both biogeophysical and biogeochemical consequences of the regrowth of trees after the extinction of the megafauna using an earth system model of intermediate complexity.

The extinction leads to a northerly expansion of shrubs and trees into the areas originally kept tree-less by megafauna, modifying the surface albedo, which leads to a warming. In addition, soil carbon is released, leading to an increase in atmospheric

CO2, amplifying the warming.

Overall, it is a very good manuscript showing well-described original research. However, there are a few issues which warrant attention. I therefore recommend publication after minor revisions.

I very much applaud that the authors look into the transient changes in biogeochemical and biogeophysical feedbacks, which may show quite a different response from the changes in quasi-equilibrium states after all. The one drawback is that it is by no means clear what the final quasi-equilibrium state of the system will be like. Therefore I am missing one crucial experiment in the manuscript, an entirely unperturbed experiment in which tree cover was never suppressed in the first place. Since CTL, according to the paper, was spun off from a transient run from LGM to present day, this should actually be available to the authors.

I would like to see this for comparison because it is not clear from the paper whether the vegetation has reached a quasi-equilibrium state after the 500 yr model experiments. Judging from the figures, the affected areas are first covered by shrubs, and after about 300 years the shrubs begin to be replaced by trees. In year 500, the end of the experiments, tree coverage seems to still be increasing. This could either be because glaciers are still receding or because the tree cover has not yet reached quasi-equilibrium with the boundary conditions. If the latter, effects may actually be larger than described in the paper.

With regard to the biogeophysical effects of the regrowth, I generally find the paper convincing, though there are two questions left open:

The paper convincingly shows the transient changes in tree coverage and the corresponding changes in albedo and temperature. However, the reader is left wondering how close to equilibrium with respect to boundary conditions the system is at the end of the experiments, i.e., whether further would have to be expected after the end of the experiment. It would be great if the authors could discuss this aspect of the temporal dynamics.

In addition, it is not quite clear from the manuscript under which conditions the Weddell sea temperature anomaly occurs. I am especially wondering whether it also occurs in the "later extinction" scenario, but also whether it would occur in a scenario where no suppression of tree growth had ever taken place.

When it comes to the biogeochemical effects, I find the manuscript not quite as convincing. It is entirely plausible that grassland soils may store substantial amounts of carbon that might partially be lost under vegetation change, but whether the particular formulation of the TRIFFID soil carbon model is realistic in this respect warrants further discussion.

The authors' result hinges on the carbon release from SOM decomposition happening faster than the uptake of carbon during the forest regrowth. Unfortunately the authors do not discuss the final state the system would attain once forest regrowth is finished. How large is the total carbon stock (biomass+soil) before and after tree regrowth has finished? If the total stock is smaller after regrowth, the carbon release would occur anyway, no matter whether the particular time scales implemented in the TRIFFID model are correct. If total system carbon in the final stage is larger than before forest regrowth, on the other hand, the carbon release would be a completely transient effect depending on the exact model formulation, especially with regard to decomposition and forest succession times scales. An extended discussion of the size of the C pools, as well as the temporal dynamics, is required for the results to be credible.

Finally, Zimov et al. (see appended references) argue that the productivity of the mammoth steppe environment, as they call it, was very high due to grazing pressure and the fast cycling of nutrients if biomass is decomposed at mammal body temperature, as opposed to ambient temperature. While it is clear that the authors cannot actually model these hypotheses since MOSES and TRIFFID contain neither permafrost nor nutrients, a short discussion of the potential effects of nutrients and megafaunal

extinction would further improve the manuscript.

Some minor things:

p. 443, l. 22: CO2 should have the 2 as subscript, not superscript

p. 452, l. 11: Cox et al. is the model description, a Hadley Centre technical report, not a peer-reviewed publication. This is not the best citation for showing that model behaviour is realistic.

Fig. 1, 2c, and 3 are very difficult to read (printed manuscript). A higher resolution version would improve matters, I believe.

Fig. 6: Are units correct? A release of 1.4x10ˆ14 PgC seems an awful lot... After all, most models have roughly 1500PgC stored in soils globally.

Zimov, N. S., S. A. Zimov, A. E. Zimova, G. M. Zimova, V. I. Chuprynin, and F. S. Chapin III (2009), Carbon storage in permafrost and soils of the mammoth tundra-steppe biome: Role in the global carbon budget, Geophys. Res. Lett., 36, L02502, doi:10.1029/2008GL036332.

S.A. Zimov, N.S. Zimov , A.N. Tikhonov , F.S. Chapin III (2012), Mammoth steppe: a high-productivity phenomenon, Quaternary Science Reviews 57 26-45, doi:10.1016/j.quascirev.2012.10.005

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