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Interactive comment on "Radiative forcing by forest and subsequent feedbacks in the early Eocene climate" *by* U. Port et al.

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We thank the second referee for the constructive comments on our paper and the detailed suggestions for improvement. In the following, we reply to the comments point by point.

Referee #2
I am not sure what we are supposed to learn about actual Eocene feedbacks from an analysis like this, but I guess it puts a (model-dependent) upper bound on how important land surface biophysical feedbacks might have been...The rest of the feedback analysis is well thought out and thorough, but it is not clear to me what we learn from it, given that the results are state-dependent and model dependent.

My main suggestions are to improve the framing of the paper and to demonstrate that there is an actual scientific question being answered here (or even asked) and also that more care be taken to make it clear that the results make sense only within the context of the model that created them. Right now I am left asking myself, have we learned anything about the Eocene from this analysis?

For the current interglacial climate, the impact of vegetation on climate is fairly well understood. In comparison with bare soil or non-woody vegetation, boreal forests tend to warm the climate at high latitudes by masking the snow cover, while forests tend to cool climate the in the tropics mainly by enhancing evapotranspiration (e.g. Bonan (1992, 2008), Betts and Ball (1997), Bathiany et al. (2010)). In a much warmer climate, without ice sheets and without, or with only marginal, sea ice cover, like the early Eocene, the relative importance of the effect of forest on climate might change. Hence, we aim to answer the question to which extent radiative forcing and subsequent feedbacks triggered by vegetation differ between warm early Eocene climate and relatively cold late Quaternary interglacial climate. We will rephrase the introduction to clearly state our aim.

Since maps of vegetation reconstructions are fragmentary and modeling the Eocene vegetation cover is problematic due to limited knowledge about bioclimatic limits and physiology of early Eocene plant taxa, we compare a forest world to a desert world to analyse first-order effects.

Our results are surely model-dependent - as are the results of all single-model studies. Our model simulates current vegetation dynamics and biogeophysical effects in line with many other models, and our simulated Eocene climate is not completely out of the model ball park (see Figure C4). Hence, we are confident that our results provide valuable insights into vegetation impacts on warm climates like the early Eocene. We will add a critical discussion of these issues.

Referee #2
The model is fitted to the task and the gregory style analysis is well applied here, although both this technique and a better one (PRP) were applied previously in Caballero and Huber (2013).

Caballero and Huber (2013) estimate radiative forcing and feedbacks due to elevated atmospheric CO_2 in the Paleogene climate and in modern climate. They find that both, radiative forcing and feedbacks, change with the climate state. Other than in their study, our forcing is afforestation, and our results suggest that in this case, radiative forcing is of about the same strength in the Eocene climate as in the pre-industrial climate, while the feedbacks differ between both climates.

Referee #2
I have some suggestions for improving the paper. The coverage of the prior literature and the context which it provides is rather poor...

We thank the reviewer for these suggestions. We will extend our introduction and discussion to include the above mentioned papers.

Referee #2
The lack of a ground-truthing of the model by comparison with proxy data is hard to justify given that one of the main conclusions is that the results are state-dependent. If the simulations here are close to those of Heinemann presented in Lunt et al., 2012 then the simulated climate is not a good fit for the early Eocene and probably substantially too cold at high latitudes. Is there snow on those forests? It would be

useful to compare the model against the terrestrial paleotemperature data presented in a compilation such as in Huber and Caballero, 2011 to at least place the model within some sort of context.

Like in the Heinemann simulations, the modeled near-surface temperature matches proxy data in the tropics and the mid latitudes but slightly misses the warm northern high latitudes (Fig. C4). In comparison to the collection of terrestrial proxy data by Huber and Caballero (2011) and marine proxy data by Lunt et. al (2012), near-surface temperature/SST in the northern high latitudes is 4 to 8 K lower in our simulation. In the southern high latitudes, the simulation agrees fairly well with the reconstructions. Only the reconstructions by Sluijs et al. (2006) and Bijl et al. (2009) (marked with 1 and 2 in Fig. C4) indicate much higher temperature than in our simulation but, here, the warm bias in TEX_{86} reconstructions needs to be considered. We agree that an evaluation of our model against proxy data is needed in the manuscript and we will add it.

Referee #2
More generally, much of the tone of the paper should be changed. The authors are talking about one particular model and most of their results are likely to be very sensitive to the model choice (as well as the fact that their basic state appears to be too cold).

We agree, and we phrase our conclusions more carefully and highlight the dependence of our results on the used model.

Referee #2
Similarly, "Polar amplification is still weak in the early Eocene climate due to weak sea-ice related feedbacks." But, there was no sea ice in the Eocene, yet there is good

evidence for polar amplification...

In this phrase, the formulation 'polar amplification' might be misleading. What we intended to say is that forest warms the northern high latitudes much stronger than the remaining latitudes in the pre-industrial climate due to the snow/ice albedo feedback. The same is true for the Eocene climate but the difference between high-latitude warming and tropical warming by forest is less pronounced than in the pre-industrial climate because the snow/ice albedo feedback is weaker. We did not want to say that the pole-to-equator temperature gradient is stronger in the Eocene climate than in the pre-industrial climate. Actually, the opposite is the case. We will rephrase the passage about the weak polar amplification in the Eocene climate to clarify that point.

Referee #2
...That suggests several things to me. First, in this model and in these simulations most polar amplification is due to sea ice. Other models have strong polar amplification without sea ice (Caballero and Huber, 2013; Lunt et al., 2012; Huber and Caballero, 2011), so this seems to be a particular weakness of this model. Second, it suggests at the least that this is an area of definite model dependence...

There is polar amplification in MPI-ESM even without sea ice as Pithan et al. 2014 show. Also in our Eocene simulations, the temperature change by forest is strongest in the northern high latitudes even though the snow/ice albedo feedback is weak (Fig. 7 in the manuscript). In other words, there is polar amplification in the Eocene simulations but it is less pronounced than in the pre-industrial climate.

Referee #2
...Third, it suggests that if this model was run at (presumably higher CO2) conditions

that were closer to what they were in the Eocene then the model would have a potentially different response (since some of the response might be due to high latitude conditions below freezing that are precluded by the data).

Performing the experiment with an even warmer early Eocene climate, we would expect results with a larger magnitude than the presented results but of the same sign. Without ice and frost in the early Eocene climate, we would expect the snow/ice albedo feedback to become absent. Presumably, the temperature change by forest would still be stronger in the high latitudes than in the tropics, but the high-latitude amplification of temperature change by forest would be weaker than in the pre-industrial climate. Further, we expect the combined water-vapour and lapse-rate feedback to be much stronger in the Eocene climate than in the pre-industrial climate because an enhanced water-vapour feedback in a warming climate is consistent with previous studies (Meraner et al. (2013), Loptson et al. (2014)).

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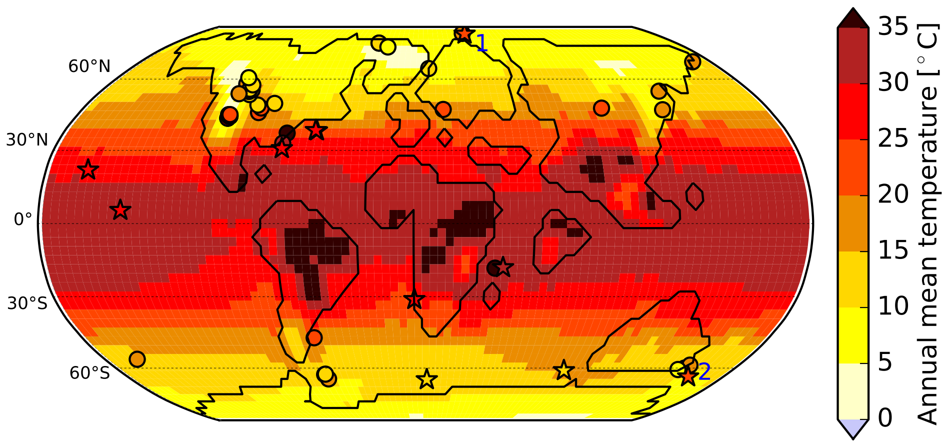

Fig. C4. Annual-mean near-surface temperature in the inital Eocene simulation (shaded) and MAT/SST estimates based on terrestrial (circles, Huber et al., 2011) and marine proxy data (stars, Lunt et al., 2012).