Clim. Past Discuss., 11, C1153–C1158, 2015
www.clim-past-discuss.net/11/C1153/2015/

Climate of the Past Discussions

Interactive comment on "Stability of the vegetation–atmosphere system in the early Eocene climate" *by* U. Port and M. Claussen

U. Port and M. Claussen

ulrike.port@mpimet.mpg.de

Received and published: 27 July 2015

We thank the referee for constructive comments which help us to clarify some points which we had formulated in a misleading way.

Referee 1
The present manuscript seeks to explore the role of boundary condition vegetation cover on the climate of the Early Eocene. [...] Ultimately the study concludes that the vegetation is of secondary importance to the palaeogeography, but that different vegetation boundary conditions can lead to multiple climate states.

In a paper submitted to Climate of the Past Discussion (Port et al., CPD, 11, 997-1029, 2015), we compared radiative forcing of forests and feedbacks triggered by changes in forests between interglacial, pre-industrial climate and a warm, nearly ice-free climate. For the latter, we used the early Eocence as an example. We found that feedbacks considerably differ between the interglacial and the ice-free climate. In the present study, therefore, we aim to analyse whether the difference in feedbacks might lead to multiple states of the climate-vegetation system. The possibility of such multiple steady states has been investigated for pre-industrial climate, mid-Holocene climate, and glacial climate. But so far, no analysis has been done for a climate state that is much warmer and nearly free of ice.

Referee 1
Overall this is a pure modelling paper; geological time is used as a narrative for a series of sensitivity experiments, but geological data is not utilised in any meaningful way and in one instance (grasslands in the Early Eocene) is actually ignored. At the moment this paper is palaeoclimate modelling for the sake of palaeoclimate modelling.

It is more than just a narrative. We chose the early Eocene as an example of warm, ice-free, or nearly ice-free, climate. But we admit that it is more a theoretical study than an attempt of a best prediction of early Eocene climate-vegetation interaction. We will emphasize this point in a revised version of our manuscript.

Referee 1
No attempt is made to relate model findings to the reality of geological, palaeontological or geochemical data.

We made no attempt to put our findings in a geological context in this study. We did,

however, discuss the performance of the MPI-ESM in recapturing the paleoclimate of the early Ecocene in our study (Port et al. CPD, 2015) mentioned above. We agree that it would be useful to add essential points of the comparison of model results with paleontological data to the present paper (See our response to Referee 2).

Referee 1

Central Asian desert: The paper concludes that "a desert in central Asia is much larger in simulations initialised with bare continents". Is there any evidence for an Early Eocene desert in Central Asia? This is an interesting point that has a mixed message in the published literature. [...] What the current version of the manuscript lacks is any discussion on either previous modelling studies of the Eocene, modelling of the Asian monsoon in the Eocene [...] or proxy evidence for any of the model results.

Climate and vegetation reconstructions suggest that a dry to seasonally dry climate prevailed in Central Asia during the early Eocene. In a sediment core from central China, Wang et al. (2013) find a continuous change between evaporites and mudstone indicative of a dry climate with monsoonal influence. They argue that occasionally strong monsoons brought more precipitation to Central Asia which is now visible in the layers of mudstone. In agreement with these data, the flora fossils analysed by Quan et al. (2012) suggest a monsoon climate in Central Asia. Also Utescher and Mosbrugger (2007) conclude from their analyses of flora fossil assemblages that at least seasonally dry conditions were prominent in Central Asia, and Willis and McElwain (2002) suggest subtropical summerwet vegetation for this region.

Previous model simulations confirm that an at least seasonally dry climate occured in early Eocene Central Asia. Huber and Goldner (2012) find a monsoon climate in their simulations, while Zhang et al. (2011) see full-desert conditions with only weak monsoonal characteristics.

We will add an assessment of previous modelling studies and proxy evidence to a revised version of our manuscript.

Referee 1

Eocene grass: Even though it is rightly stated that grass in the Eocene was rare, and almost certainly restricted to the understory of forest environments (Bouchenak-Khelladi et al., 2010), the author's claim that grass behaves like shrubs and ferns in their vegetation model. My understanding of vegetation modelling is that grass and shrub PFTs have very different fire dynamic properties, which in the JSBACH model used, influence the mortality rate of PFTs (Brovkin et al., 2009). Furthermore, there is no justification provided for the use of C4 grasses, which did not evolve until the Late Oligocene and did not become widespread until the latest Miocene or Early Pliocene (Christin et al., 2009; Osbourne and Sack, 2012). Instead the justification is that the study intends to focus on the biogeophysical processes, but without making the vegetation scheme at least meaningfully Eocene the competitiveness built into the JSBACH model will only allow for the experiments to test the difference between the modern and the Eocene geographys.

As a first step, we kept the same PFTs for pre-industrial climate and early Eocene climate to isolate the geographic and climate factors affecting the difference in climate-vegetation interactions between pre-industrial climate and early Eocene climate. Adjusting our PFTs to early Eocene conditions would be a sensible next step future research should take. For the time being, we can only outline possible consequences of such an adjustment on the results of our present study. As briefly mentioned in our conclusion, we assume that specifically a removal of the grass PFT would not drastically alter our main conclusion.

A major difference between modern PFTs and early Eocene plant taxa concerns grasses. In JSBACH, grasses can grow only in the presence of disturbances such

as fire. Because grass can grow fast, they have an advantage over woody vegetation, after a disturbance has diminished parts of the woody vegetation. We assume that some plant taxa such as fern and herbs filled this niche of fast-growing plants during the Eocene. Hence, it seems plausible to assume that an extended fire module would have to consider fern and herbs in the same way as it considers grasses by mainly distinguishing between woody types (trees and shrubs) and non-woody types (grasses, fern, herbs). Such a fern/herb PFT would change surface albedo and increase moisture fluxes relative to bare soil like the grass PFT does for pre-industrial climate. Hence, the atmosphere model would response to a fern/herb PFT in a similar way as it responds to a grass PFT.

We have to make this point more clear, and we will expand our brief discussion on possible effects of adjusting our current set of PFTs to early Eocene conditions.

References

Huber, M. and Goldner, A., 2012, *Eocene monsoons*, Journal of Asian Earth Sciences 44, 3-23

Port, U., Claussen, M., Brovkin, V., 2015. *Radiative Forcing by forest and subsequent feedbacks in the Early Eocene Climate*, CPD 11, 997-1029

Quan, C., Liu,Y., Utescher,T., 2012. *Eocene monsoon prevalence over China: A paleobotanical perspective*, Palaeogeography, Palaeoclimatology, Palaeoecology 365, 302-311

Utescher, T. and Mosbrugger, V., 2007. *Eocene vegetation patterns reconstructed from plant diversity—A global perspective*, Palaeogeography, Palaeoclimatology, Palaeoecology 247,243-271

Wang, D., Lu, S., Han, S., Sun, X., Quan, C., 2013. *Eocene prevalence of monsoon-like climate over eastern China reflected by hydrological dynamics*, Journal of Asian Earth Sciences 62, 776-787

Willis, K.J. and McElwain, J.C., 2002. *The elvolution of plants*, Oxford University Press, U.S.A

Zhang, Z., Flatoy, F., Wang, H., Bethke, I., Bentsen, M., Guo, Z., 2012. *Early Eocene Asian climate dominated by desert and steppe with limited monsoons*, Journal of Asian Earth Sciences 44, 24-35

Interactive comment on Clim. Past Discuss., 11, 1551, 2015.