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Interactive comment on “Investigating vegetation-climate feedbacks during the early Eocene” by C. A. Loptson et al.

Anonymous Referee #1

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The study by Loptson et al. investigates the influence of the incorporation in the HadCM3L model of a dynamic vegetation model on Eocene climate. Using a series of sensitivity experiment with dynamic and fixed vegetation, the authors conclude that dynamic vegetation results in an increase in the global annual mean temperature, but not sufficiently to explain proxy evidence of warmth, particularly at high latitudes. The conclusions in this paper are similar to previous investigations of the influence of vegetation on warm time periods (e.g. Otto-Bliesner and Upchurch, 1997; DeConto et al., 2000; Zhou et al., 2012) and, in this regard, confirm using the HadCM3L these previously published relationships. Overall this is a nice contribution and should eventually be published in Climates of the Past. The separation of the climate response between those to CO₂ and to vegetation is well done and interesting. However, there are some loose ends and editing issues that require attention.

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I have two primary criticisms: (i) the reason for the climate responses to vegetation is almost never explicitly explained, and (ii) too many of the conclusions are inferred instead of demonstrated. Regarding point (i), the authors generally do not make the connection between changes in vegetation and the climate response. For example, on p. 4714, they state that changing the vegetation distribution from SHRUB to DYN has the effect of increasing high latitude temperatures by 1C. This is possibly due to decreases in albedo from the direct replacement of shrubs with trees and snow masking by canopy in the winter. However, no explanation is offered. Another (but not the only) example is on p. 4718, l. 8, where it is stated that vegetation has the greatest effect on temperature over terrestrial equatorial regions in JJA but give no description of the change in vegetation (shift from broadleaf trees and grasses to grasses and bare ground) and no climatological explanation (likely a reduction in soil moisture and enhanced sensible heating).

Along similar lines, and regarding point (ii), climate changes are often attributed to a change in albedo or clouds or water vapour (e.g. p. 4716, l. 20; p. 4718, l. 4-5; p. 4718, l. 12-13; 4718, l. 26-27; p. 4721, l. 6-8; p. 4722, l. 4-5), but these changes are never described in detail, quantitatively or shown in a figure. And, at times, the reasoning can be circular. For example, on p. 4716, a decrease in sea ice is inferred from a temperature change. (Presumably the authors examined sea ice and know that it did decrease, in which case the issue is the description of the results rather than the analysis). The benefit of using a climate model is that you can evaluate the mechanisms that cause the changes.

Additional information about the boundary conditions (CH₄, N₂O, O₃, aerosols, orbital parameters, solar luminosity, etc.) should be added to the Methods. Perhaps this information can be found in Lunt et al. (2010), but it's so fundamental to the modeling effort that it should be included here. In addition, information about the PFT characteristics should also be included, as well as the bioclimatic parameters that determine their establishment. Both of these are important, both for understanding the results and for

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comparing vegetation and climate responses between studies using different models.

Other studies have discussed the role of vegetation on ocean circulation and overturning (Ganopolski et al., 1998; Lohmann et al., 2006; Zhou et al., 2012). Does dynamic vegetation have any affect on overturning in HadCM3L?

Additional minor points

A paragraph should be more than one sentence. There are numerous places in the text, where this rule is not followed. In almost every case, the sentence could easily be incorporated into the paragraph that it either precedes or follows.

p. 4708, l. 4. Include a reference for poleward heat transport, e.g. Covey and Thompson (1989).

p. 4708, l. 5. In addition to these mechanisms, Beerling et al. (2011) show the possible role of other greenhouse gases (CH₄, NO₂, O₃) and Poulsen and Zhou (2013) suggest that overestimate of low cloud amounts may play a role in warming high latitudes.

p. 4709, l. 20-25. In the discussion of problems with oxygen isotopic data, I was surprised that the uncertainty of the isotopic composition of seawater was not also included, since this was likely different in the past. This has been addressed in at least two studies (Roche et al., 2006; Zhou et al., 2008).

p. 4713. It would be very useful to plot the location and type of fossil evidence. This could be added as a panel to figures 1 and 2.

p. 4714, l. 3. “uncertainties associated with the RMS error.” This implies to me that the RMS error calculation/equation is uncertain, when in fact the authors mean to express that there are uncertainties associated with the data.

p. 4715, l. 2-3. “...vegetation feedbacks have a larger influence on temperature at higher CO₂ concentrations...” Explain why this is. Is it because there is a larger difference between the simulated PFTs and shrubs at 4xCO₂ than 2xCO₂? Or is it

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because the mean state is warmer and more sensitive to thresholds, e.g. melting of sea ice?

p. 4715, l. 25-27. This calculation is not appropriate. There is no reason to think that climate sensitivity changes systematically (e.g. Caballero and Huber (2013)).

p. 4717, l. 3-4. Please comment further on the 10 C warming over the northwestern Pacific in Fig. 8a. It's interesting to note that Zhou et al. (2012) show a similar feature (Fig. 4b), which they attribute to the poleward displacement of the western boundary current.

p. 4720. The energy balance analysis requires more description. The energy balance, itself, doesn't require explanation. Most readers will be familiar with this, or can review Lunt et al. (2012). But, a few sentences explaining the procedure for moving from the GCM to the EBM would be helpful. Also, why discuss (in lines 11-16) changes in albedo due to atmospheric effects if no other details of the model are given?

p. 4720, l. 18-24. It might be helpful here to indicate that the results aren't shown.

p. 4720. "two dimensional energy balance analysis" Is the model one or two dimensional? If this isn't a misprint, more explanation is needed.

p. 4721, l. 14. "may be due to the root systems of some PFTs being more effective..." The authors shouldn't have to guess here. The physiological differences in PFTs should be documented.

p. 4722. l. 11. Cloud responses are mentioned in several places in the text. Please comment on how vegetation changes are affecting clouds.

Table 2. To be consistent in terminology, perhaps "FIXED" could be "4 x FIXED"? This would help the reader remember that the CO₂ values was 4 x, and make figure captions easier to comprehend.

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