

Interactive comment on “Biogeophysical feedbacks enhance Arctic terrestrial carbon sink in regional Earth system dynamics” by W. Zhang et al.

Anonymous Referee #1

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Overall Evaluation

This manuscript presents the results of a study to understand how biogeophysical feedbacks of vegetation in the Arctic might influence climate and carbon dynamics in the Arctic. The analysis uses RCA-GUESS as a tool to conduct this study, and relies on the comparison of outputs from simulations with fixed vegetation and dynamic vegetation. I really like the design of this study. However, there are some issues/short-comings in the analysis that should be addressed in a revision: (1) the lack of consideration of shrub tundra, (2) no treatment or discussion of the permafrost carbon feedback issue, (3) the need for more discussion/comparison of the magnitude of albedo/latent energy feedbacks with other analyses that have been published, and (4) some rough text in

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certain places in the manuscript. Below I explain my concerns with these issues and finish off the review with specific comments.

The lack of consideration of shrub tundra

When I was asked to review this paper I was really looking forward to the analysis as I was thinking that it follows nicely onto the analysis of shrub tundra dynamics in Zhang et al. (2013, ERL). However, I was quite disappointed to find out on page 6722 that the analysis involved 6 global PFTs and not PFTs (such as shrub tundra) that are quite relevant to the region. The shrub tundra issue was highlighted in Chapin et al. (2005), which was cited in the manuscript, because shrub tundra has much lower albedo than graminoid tundra. Also, as pointed out in Figure 1 of this manuscript, an expansion of shrub tundra has the possible positive feedback to warming through snow masking. To me, the analysis represented in the paper is much less interesting without having the shrub issue represented and seems like a Bonan/Foley circa mid-1990s type of analysis with respect to dealing with mostly a C3 grass representation of tundra in the context of arctic/boreal biogeophysical feedbacks to climate. The shrub issue is mentioned in passing on page 6735 late in the manuscript, and warrants more discussion. Not sure what else to recommend here – just seems like a missed opportunity to build on the progress in Zhang et al. (2013) with respect to having considered shrub tundra dynamics considered in the analysis.

No treatment or discussion of the permafrost carbon feedback issue

My understanding is that the version of LPJ-GUESS used in this study does not represent the carbon stored in permafrost, and therefore is not capable of considering the permafrost carbon feedback in this analysis. The small increases in soil carbon storage in Table 2 could easily be large decreases (potentially much larger than the increases in vegetation carbon storage in Table 2). There has been a lot published on the permafrost carbon feedback in recent years (e.g., Schuur et al. 2013. Expert assessment of potential permafrost carbon feedback to climate change. Climatic Change

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119:359-374. doi:10.1007/s10584-013-0730-7). The permafrost carbon feedback issue warrants at least a paragraph of discussion late in the paper, probably in section 4.4. Also, the conclusion that 8.5 Pg C feedback is considerable (page 6734, line 8, as well as the abstract) doesn't seem very considerable to me compared to the possible magnitudes of the permafrost carbon feedback.

Comparison of albedo and latent energy feedbacks to other analyses

There are other time-dependent analyses of changes in albedo and latent energy feedbacks in the boreal and tundra regions. I had expected to see the magnitude of the albedo and latent energy feedbacks compared with these analyses (e.g., Euskirchen et al. 2009a and 2009b).

Euskirchen, E.S., A.D. McGuire, T.S. Rupp, F.S. Chapin III, and J.E. Walsh. 2009a. Projected changes in atmospheric heating due to changes in fire disturbance and the snow season in the western Arctic, 2003 – 2100. *Journal of Geophysical Research – Biogeosciences* 114, G04022, 15 pages, doi:10.1029/2009JG001095.

Euskirchen, E.S., A.D. McGuire, F.S. Chapin III, S. Yi, and C.C. Thompson. 2009. Changes in vegetation in northern Alaska under scenarios of climate change 2003-2100: Implications for climate feedbacks. *Ecological Applications* 19:1022–1043.

Some rough text in certain places

Most of the writing in the manuscript is pretty good from a grammatical perspective. However, there are places in the manuscript where the text is pretty rough and there is a need for the co-authors to step up to the plate and fix it. In particular, there are sentences in section 4.1 that make little sense. There were also some confusion in my mind about what was being depicted in some of the figures, and this could probably be avoided by more articulate description in the figure legends (see specific comments below).

Specific comments

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Page 6716, line 11: Should “an GCMs” be “a GCM”?

Page 6718, line 16: Should “efficient transports of momentum” be “efficient transport of momentum”?

Page 6720, line 2: I think “CO2 fluxes measurements” should be “CO2 flux measurements”.

Page 6720, line 6: I think “boreal forests productivities” would read better as “boreal forest productivity”.

Page 6720, line 23: I suggest changing “This increases” to “These responses increase”.

Page 6721, lines 9-12: This sentence should be rewritten, as it is pretty awkward.

Page 6722, line 21: Change “of world” to “of the world”; add “and” before “Arctic”.

Page 6722, lines 27 and 28: Please explain what you mean by “intolerant”. I don't think that is an adjective that is widely used in the community to describe PFTs.

Page 6723, line 25: “comprising” should be changed to “composed of”.

Page 6724, line 25: Note that “PNV has not yet been defined, so it should be spelled out here.

Figure 4c: You need to explain how you calculated percent difference as there are two different ways to calculate it. Also, is it possible to have the colors in Figure 4c consistent with the colors in Figures 4a and 4b?

Page 6727, lines 20-23: It is not clear in this sentence that the estimates (500-600 g C m⁻² yr⁻¹) are for the entire CORDEX region. Please state this explicitly if this is the case.

Page 6726, line 26: Add “for arctic tundra” after “inversion models”. Also, explain in Figure 5b that the estimates are just for arctic tundra.

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Figure 8: I need more explanation about how Figures 8b and 8d were generated.

Figure 9a: Is it an NEE anomaly that is really plotted in Figure 9a? If so, what is the period to which the anomaly is referenced (1960-1990 perhaps)? But I don't see why an anomaly needs to be plotted here, as plotting the actual values of NEE makes more sense.

Figure 9b and 9c: These panels need units on the x axis. Also – the legend for Figure 9b doesn't seem appropriate.

Page 6729, sentence spanning lines 21 and 22: There is not enough information here for me to understand how you sorted the grid cells and what is actually depicted in Figures 9b and 9c.

Page 6730, lines 2-4: Sentence is pretty rough, and needs to be rewritten.

Section 4.1: This section is really pretty rough and needs to be rewritten.

Page 6734, line 8: As mentioned earlier, I challenge whether 8.5 Pg C over a century is a very significant feedback. It is equivalent to one year of current fossil fuel emissions and is likely to be quite small in relation to the permafrost carbon feedback.

Page 6734, lines 11-14: I don't know how one can make this argument that vegetation dynamics (not actually succession) plays a more important role than a prolonged growing season since these issues were not analyzed relative to each other in the study.

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