

Biogeosciences Discuss., referee comment RC2
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Comment on bg-2021-121

Anonymous Referee #2

Referee comment on "Model simulations of arctic biogeochemistry and permafrost extent are highly sensitive to the implemented snow scheme in LPJ-GUESS" by Alexandra Pongracz et al., Biogeosciences Discuss., <https://doi.org/10.5194/bg-2021-121-RC2>, 2021

This article presents the new snow module implemented in LPJ-GUESS and shows how this newly implemented module affects the simulation of snow depth, soil temperature and ultimately biogeochemistry and vegetation distribution. The study is focussed on the arctic and sub-arctic regions of the northern hemisphere.

Showing how physical realism is important for biogeochemistry although the traditional separation between the two scientific communities tends to disappear.

This paper is well written in a clear style. I have however a few major comments, followed by detailed comments and questions.

- I understand the need to limit the length of the paper but the authors tend to describe differences in simulation results without explaining them, or the explanation given is not sufficient. The authors present results for snow depth, soil T and water content at 25 cm depth and C fluxes, but they don't clearly show how their change in snow model affects those variables. They show results for the winter and summer seasons but the explanation often has to do with what happens during the spring, and the reader doesn't have a figure about spring
- The authors present site level simulations that were forced by large-scale atmospheric forcing (CRU). I don't see the point since some of these sites, like Zackenberg, have very detailed meteorological data. It also makes me wonder if the authors did just 2 pan-arctic simulations and compared the results with local data or if they used local data (like soil texture, or else) to perform these site-level simulations.
- I believe an analysis of the changes in water content might be necessary
- There are quite a few errors in the figures, errors in the units of the equations

Detailed comments:

Eq 6 : as written, the units of this equation don't match: I_k is supposed to be in kg/m^2 and r_w don't have units (according to Table A2), so W_{cap} can't be in mm.

Figure 2: sublimation is not taken into account ? as represented there is no snowfall on bare ground and I don't understand why the rain on bare ground affects the thermal properties. Are those boxes related to snow only or to snow and soil processes? If soil processes are represented, then why would thermal properties be based on density ? Is it an average of soil, water and ice density ?

S1: typo : I don't think the Q10 was changed from 200.5 to 2.9 !

L190-191: as shown in Figure 3, soil temperature is higher than observations in summer only for 2 sites out of the 5: Kytalyk and Samoylov. Also, it is not really discussed in the following sections.

L192-193: I agree that soil temperatures have a smaller variance with the Dynamic than the static run but that is not true for snow depth, except in Abisko.

Figure 3 : are the site statistics calculated with monthly values ? or monthly anomalies ? (departure from the average seasonal cycle). Since the average seasonal cycle is shown, I would show the statistics from the anomalies.

Figure 4: The Y axis of the observed soil T and static snow results are mixed up: The observed soil T axis should be -40 to 0 like the simulations. Similarly, the Y axis from the snow depth for the static scheme should go from 0 to 35 like the other 2 snow panels.

L222 : Figure 5a doesn't show at all large changes in Scandinavia and in Western Russia. The blue in coastal Norway can be mistaken for the coastal line and lakes (like in Canada

and Finland) and western Russia seems less red than central Siberia for instance and shows much less change than N-E Canada (Baffin etc) or far East Siberia. I suggest other colors (especially the blue that is impossible to distinguish from lakes) and may be give longitudes instead of "western Russia"

Figure 5c: the TTOP PF rectangle in the legend should be solid grey (not just the border)

L235: This explanation is wrong. Maximum ALD happens at the end of the summer, early fall. The authors can't use the warmer winter temperatures as explanation for the deeper ALD ! According to figure 6, Dynamic has cooler temperatures in summer, not warmer. I would assume that it is more related to the speed at which the soil refreezes in the fall. Static refreezes earlier and faster, hence stopping the summer melt earlier and reducing the increase in ALD.

Section 3.3.2: in all this section (text and figures) and in the supplementary material, the units of the C fluxes are wrong. They should be in mass of carbon per unit area **per unit time**. The authors wrote g/m² but the reader has to wonder if it is per year, per month, per season...

L266: "soil carbon outputs were used to normalize Rh ..": the authors should say how here or in the legend of Figure 8 because I don't understand the units of the normalized Rh (g /m²)

L 268: "winter respiration ... increased, except for ..." : this is totally invisible on Figure 8a with the current colormap

L 270-280 : - the authors should refer to the figures in Annex Fig S7 to S9

- Figure S8 winter (and Figure 9a) : There is something wrong here Static has values around 0.250 g/m² (dark green) where Dynamic only has 0.125 but the difference doesn't show anything as if a mask had been applied. Also, white for negative NPPs is not very visible.

L 275 : "increased autotrophic respiration" : why ? I know winter temperatures of the soil at 25 cm are higher. But how does that affect autotrophic respiration? I guess the question is how is vegetation temperature calculated ?

L275 "but higher in summer". Again why is that ? T is lower in summer. Could it be linked

to water content ?

L279-280 : when discussing NEE, it would be interesting to have annual values too.

Fig S9: the grey is really disturbing because it can be confused with light blue. Is Nee decreasing in large parts of Siberia and Canada in winter ?

L 295 – text section S3.5: typo Fig ??

Figure 12 : The signs on the figure are not explained. A typo may be ?

I don't understand the colors of the arrows – I think the caption is not completely correct : it states that "The colour of the arrows show whether there has been a net increase or decrease in the particular variable" but this is shown by the color of the box it-self. I assume the color of the arrow means how the change in one variable affects the change in the other (higher soil temperature favors higher heterotrophic respiration for instance). But that doesn't seem the case either because increasing Rh should favor increasing NEE, but the arrow is blue for the 2 left panels. I might have missed something but the figure should be better described.

L 320: 3N mineralization decreased in wintertime": why is that ?

L344 : "the model-observation fit may be improved by using site-specific climatic forcing"
: yes indeed ! why not do that ?