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Climate of the Past Discussions

Interactive comment on "The role of land cover on the climate of glacial Europe" *by* Patricio Velasquez et al.

Anonymous Referee #1

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Review of "The role of land cover on the climate of glacial Europe" by Velasquez et al. (cp-2020-147) from reviewer #1

Velasquez et al simulates LGM climate with a chain of asynchronous coupled models (GCM -> RCM -> DVM -> RCM etc). This is exactly what is needed in palaeo climate. High resolution enables better comparison with proxy data, and 18 km grid spacing is impressive in a palaeo context. A good description of vegetation is needed to get LGM conditions as realistic as possible. The authors make sure to have a vegetation compliant with the climate by making as much as 7 iterations with climate and vegetation models. This could be interesting for the readers of Climate of the past, but I think the paper need a lot of improvement before that. That the model set up is relevant is what makes me recommend major revision.

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My major concerns are with: i) the lack of discussion of the role of vegetation on LGM climate, ii) the lack of context and comparison with previous studies, iii) how the authors describe results, but don't explain them or try to understand them iv) the structure of the text where results from different sensitivity studies are mixed and where results and discussions are mixed.

Detailed comments follow below. As always, I might have misunderstood some things, and my comments could be invalid because of that. If such misunderstandings do occur, think about if your paper is written in a clear enough way.

* Major comments

The title of the paper is "The role of land cover on the climate of glacial Europe", but I don't think I get any new insights by reading it. Despite the ambitious model set up. It seems you did some sensitivity runs, but don't know what to do with them, and that you didn't study the literature on vegetation climate interactions. It's not enough to just say that LGM was cold and that vegetation affects climate, we know that already. Why does it? If you want to advance climate modelling you need to give physical reasons for your results. Otherwise your results could just be a random effect caused by different initial conditions. Try to explain your results. Look at variables that might be relevant. Albedo and heat fluxes are not analysed at all.

The results of the RCM simulations are highly depending on the driving GCM. But you don't discuss your GCM runs at all. What is LGM vegetation like in the GCM? this explains many of the differences between cycle 1 and 2. What is LGM climate like in the GCM compared to other PMIP3 runs, colder, warmer, wetter, drier? What is the general circulation like? Could that explain the precipitation patterns?

Temperature differences between the different cycles are hardly discussed. Temperature decreases with almost 0.5 °C between cycles 1 and 2. This could perhaps be explained by a large albedo increase when the forest disappears (albedo is not shown). But temperature increases with 0.5 °C between cycles 3 and 4 despite no significant

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vegetation changes. This is unexplained. Could it be that the differences are just a result of natural variability and not a result of vegetation at all?

A related issue to the above is the question of significance. The significance of the results are not tested here. Even though vegetation has a clear effect on climate the effect is small compared to the effect of different forcing, and sometimes also compared to natural variability. Therefore it is important to check if the results are significant. I feel that the paper misses to discuss some relevant previous studies, particularly Strandberg et al. (2011), henceforth S11. S11 studies LGM with more or less the same method as you do. The present model set up is an improvement from S11 so you shouldn't be afraid to discuss it. Why not get inspired by how S11 discuss the role of the GCM or the uncertainty in proxy data. Vegetation climate interactions is not the main number in S11, but there is a section about that too. Kjellström et al. (2010) used the same approach for another cold climate, MIS 3.

The structure of the paper makes it a bit difficult to follow. For example, section 4 "Comparison of the simulated land surface conditions to proxy reconstructions" deals in large parts also with vegetation differences between PD and LGM, difference in climate between PD and LGM, difference in climate between models and proxies and a discussion about simulated LGM climate in other studies. In a similar way section 5 "Atmospheric sensitivity to land cover" deals largely with differences between LGM and PD climate. I think it would be good if you could discuss one thing at the time.

* Minor comments

L10-14: I think these conclusions are too general given the title of the paper. Please quantify a bit and perhaps also explain why you get an effect

L11-12: "colder and drier", "warmer and drier". Is this LGM(LGM) - LGM(PD) or LGM(PD) - LGM(LGM)?

L13: "southward displacement". This sentence reads to me like "Even with a southward

displacement of the storm track regional climate is influenced by land cover". Is this what you mean? Why would a southward displacement counteract or diminish the influence of vegetation? Please rephrase.

L13: "increased importance of the Atlantic". What do you mean? In what way is the Atlantic more important? And why? I can't find anything about the importance of the Atlantic in he rest of the text.

L25: "Recent advances" It could be discussed how recent it is since S11 is 9 years old. See discussion above.

L45: There are better references to this than AR5, e.g. Rauscher et al., 2010; Di Luca et al., 2011; Prein et al., 2013; Iles et al., 2019 and Demory et al. 2020.

L52: Is Tao et a. (2013) the appropriate reference here? It's about the effect of vegetation on air quality in the US. If you want vegetation climate interactions in RCMs in palaeo climate (Consistent with Strandberg et al. (2011) and Ludwig et al. (2017)) I would recommend e.g. Kjellström et al. (2010) or Strandberg et al. (2014). If you want a more general reference on vegetation climate interactions you could start with Jia et al. (2019).

L61: There are two studies that use a similar approach as you, and in addition in cold climates: Kjellström et al. (2010) and Strandberg et al. (2011). Especially S11 would be worth to note as it simulates LGM.

L63-68: When I read this I understand that you have the following model chain: GCM->RCM->DVM->RCM-> etc. From section 2.4 I understand that the first DVM simulation is forced by the GCM. I suppose that the description in 2.4 is the correct one. Please, check and correct.

L72-75: Are these 31 years part of a longer simulation, in that case how were they selected? Is the LGM simulation a part of a transient simulation or is it steady state?

L74: Please add an explanation and a reference to these data models.

L87: 31 years were simulated by the GCM, 30 by the RCM. Why is one year not used? Which 30 years are used?

L88: “adaptive time-step to increase ... computer facilities” I don’t understand this at all. What does it mean?

L89: If you divide 30 years into two 15 year periods and start every simulation with a two-month spin-up this will give you 2x(14y 10m) = 29 years and 8 months. How do you get 30 years of data from that?

L90: 15 days seems to me to be a bit short. How do you decide that quasi-equilibrium is reached? In Velasquez et al. (2019) I can only find the following: “Tests show that the WRF land scheme reaches a quasi-equilibrium after approximately 15 d.” That doesn’t explain much. I guess that spin-up time also depends on the season. When do you start your simulation?

L93: What do you mean with “perpetual” here? Do you mean steady-state with constant forcing?

L93: “Reduced sea level and increased ice sheets”. This is somewhat ambiguous. I guess you mean that sea level was lover and ice sheets were larger than today. It could also mean that LGM conditions have been revised in the PMIP3 protocol compared to previous protocols. It’s not entirely clear.

L115 Are the “reconstructed CO2 concentrations” used in the RCM the same as used in the GCM (PMIP3 forcing)? It seems like an unnecessary complicated way to say that forcing is the same as in the GCM. If it’s not the same, why not?

L120-122: What vegetation field is used in the first GCM run? See also comment on L63-68.

L133: I would say it’s more correct to call this section “Results of the iterative...”. You don’t have other simulations to compare with so you can’t estimate the effect of the coupling. You could, however, describe the results of your simulations, and that’s what

you do.

L135: How do you determine that quasi-equilibrium is reached? Just by eyeballing or do you have a criterion for equilibrium. It seems like you just decide that equilibrium is reached, but how can you be sure without a proper metric?

L136: “this result and its effect” What result and effect? Please clarify.

L137: “variables that mostly govern” Do you mean variables that govern the interaction most of the time, but not always, or do you mean most of the variables that govern the interaction? Please clarify.

L138: “suitable to illustrate the asynchronous coupling” What does this mean? Please rephrase and clarify.

L140: Please define the green fraction. After several readings I’m still not sure what it is.

L147: “in all variables” In both variables?

L148-149: I don’t agree that the difference in climate is explained by differences in resolution. I would say that it is the difference in vegetation. A decrease in forest fraction from 35 % to just a few will have an effect on the simulated climate. The fraction forest can be 35 % with 100 km grid spacing and with 10 km grid spacing. The difference in climate between cycle 1 and 2 is an effect of the difference in vegetation, don’t you think?

L148-149. This sentence says: “the increase in resolution can be explained by the better representation of the circulation processes”. Is this what you mean? What does it mean? consider rephrasing.

L149: “horizontal resolution” Of what?

L149: “1° to 18 km” This is a not so pleasant mix of units. Since you say “approximately” and since your grid spacing is not exactly 1 I think its fine to say “approximately 100 to

18 km".

L155: I would say that no important differences in the land surface variables are seen after cycle 2. If you see differences between cycle 2 and 3, please describe them.

L155: What do you mean with "especially" here? Especially large differences between 1 and 2, or especially small thereafter?

L159-170: Why do you neglect to discuss temperature? Temperature is an important climate variable that responds to changes in vegetation and a variable that vegetation is limited by. You can't discuss equilibria and vegetation climate interactions without discussing temperature.

L164: "In response to the progressive changes in precipitation" Do you mean that vegetation is only sensitive to precipitation changes?

L164-170: Line 164 says that vegetation responds to changes in precipitation. Line 168 says that precipitation responds to changes in vegetation. What's your idea of how climate and vegetation interactions work? You mention temperature as a driver of vegetation on line 181. I don't think you explain it well enough.

L168-169: The correlation is not that good. Look at the Iberian Peninsula, France, the Balkans, Greece. There are lots of regions with increased precipitation and reduced green fraction. Remember that your explanation of precipitation changes is not vegetation but changes in the large scale circulation. This is not affected by vegetation. There is little support that vegetation changes drive large scale changes in mean precipitation (e.g. Belusic et al., 2019; Strandberg & Kjellström, 2019; Davin et al. 2019)

L170: Internal variability of what? I guess you mean in the climate itself. Otherwise you should add it to the list of possible explanations.

L173: This is not a correct naming of this section as it also deals with atmospheric conditions, comparisons between LGM and PD, description of LGM climate and some discussion. Consider reordering this section and to divided into more sections.

L174: What's your definition of tree cover? Is it the same as green fraction?

L180-182: It is true, of course, that LGM vegetation is explained by climatic conditions and CO2 levels. But it doesn't explain why LGM vegetation was different than PD vegetation, because PD vegetation is highly anthropogenic. I don't think its correct to talk about changes here.

L183: Add a reference to Fig 3b after "reconstructions".

L188-189. This sentence is not very precise. It seems like all areas with few reconstructions show tundra and grassland, but actually you are only talking about the Carpathian Basin.

L190: Temperature and precipitation are not land surface conditions. See also comment on line 173.

L199: "few locations" Which locations?

L200: "in line with similar findings" It goes without saying that your results are in line with other results that are similar. Are there also other results? Results that are not in line with yours? All the mentioned studies are made with GCMs. Wouldn't it be appropriate to compare also to S11 which uses a similar setting as yours?

L201: Don't forget that a lot of the shortcomings come from the driving GCM.

L203-217: This is a discussion, not results. Consider moving to "Discussion". It is also a highly confusing paragraph as it in the same time discusses model-proxy disagreement (line 204, line 216), climate anomalies (line 209) and LGM-PD (line 210, line 212). This needs to be straightened up.

L205: Do you have a reference for the model-proxy disagreement in the Iberian Peninsula?

L209: "climate anomalies" What anomalies LGM-PD?

L210-217: Changes in storm tracks could explain the increased precipitation in LGM in southern Europe, but it can't explain the model-proxy disagreement that this paragraph started with. Another important part of the puzzle is the circulation in the GCM. What do the circulation patterns in CCSM look like? Storm tracks should be easy enough to calculate, or at least a map of mslp. You don't offer any descriptions of the climate in the driving GCM. Another reason for the different precipitation patterns in LGM is reduced evaporation from the cold and largely ice covered Atlantic (Strandberg et al., 2011).

L232: This section is not entirely about atmospheric sensitivity to land cover. Consider restructuring.

L235: What do you mean by "again" here. Consider deleting.

L236: The atmospheric response mentioned here is not response to changes in the surface, but rather the models response to different forcing (GHGs, orbital forcing, orography...).

L236: Comparing LGM and PD is not a way to estimate the atmospheric sensitivity to land cover.

L238-248: It starts with a "precipitation decrease" on line 238. This is illustrated by a "temperature response" on line 241. It then goes back to a "decrease of precipitation" on line 243. Please discuss on variable at the time. This is really hard to follow as it is now.

L240-248: It is not clear if this paragraph is only about southern Europe. Please, be more precise with what regions you are discussing.

L240: "atmospheric response" To what? Vegetation, GHGs, orbital forcing, orography...?

L243: "decrease of precipitation" Between what? PD-LGM? LGM(LGM) - LGM(PD)?

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L245: “winter wetter conditions”. On line 248 you mention a “general dryness in winter”. Which is it? Do you discuss different regions?

L248: Do you see a shift in storm tracks in you models? If not it could hardly explain the precipitation patterns. It is not enough to just reference other studies.

L249: “atmopsheric response to the LGM(LGM) with respect to the PD(PD)”. What does this mean? I don’t understand.

L254: “reduced by 43 % in DJF and enhanced by about 35 % in JJA”. I have difficulties to see this in Table 3. First of all the numbers in Table 3 are given in mm/day so its difficult to know the percentages. Second, for LGM(LGM) - LGM(PD), which I guess this is about, precipitation is reduce for both DJF and JJA. I don’t understand how JJA could see enhanced precipitation.

L256-259: What is the significance of your results? Is it enough to make conclusions on? Precipitation changes need to be quite large to be significant.

L259-264: This is a discussion, where are the results?

L259-264: Again, I would recommend you to take a look at S11 and see what is said there. In general, you shouldn’t have to speculate about how vegetation interacts with climate. There are plenty of papers to read about that. Furthermore, you have your own simulations. Why don’t do a proper study of how for example albedo and heat fluxes change in your simulations? If you want to have an example of how that could be done in a palaeo context you could e.g. look at Strandberg et al. (2014). For a more general analysis I can recommend Davin et al. (2019).

L262: “variability in land cover” Do you actually mean difference in land cover?

L266: There are several better references to this than AR5, e.g. Strandberg & Kjellström, 2019, Davin et al. 2019, Jia et al., 2020.

L280: Why do you expect the coupling to be particularly strong here?

L282-285: How would you explain these results? If you can't explain it with physical effects it might as well be random.

L293: Is "parkland" the right way to describe LGM vegetation? Parkland seems highly anthropogenic.

L296-298: I'm not sure if "illustrates" is the right word here. Shows?

L297: "may be related to fluctuations in circulation patterns". In the model one might add.

L302-305: How do you know this? You don't show it.

L304: "water fluxes" I guess you mean heat fluxes.

L303-305: I don't understand this sentence. "LGM land cover led to /.../ when influenced by reduced vegetation fraction". So, the land cover is influenced by the vegetation fraction? Consider rephrasing.

L304: Be careful with the use of parenthesis around "JJA". It don't play well with the other parentheses in this sentence.

Fig 2: You seem to use "land use" and "land cover" interchangeably. Choose one and stick to it. I think land cover is the proper one since there were not much land use during the LGM. Land use is an anthropogenic thing. Define "green fraction". "Green vegetation cover" is not an explanation, just another way to say it.

Fig 4: The colour scale in a) and b) is not good. It's practically impossible to distinguish between colours in the range -24 - -4, and when I see a colour in the map I don't know where to place it in the colour scale. Furthermore, it's very difficult to see the dots in the maps. Find another way to plot them, perhaps with white circles. It's also difficult to see the green and red rings. Think about if there is another way to plot significance.

* Technical comments

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L139: “climatological” -> “climatology”

L144: There is no reference to Fig 2 prior to this reference to Fig 3. Consider reordering the figures.

L179 “Fig. 4a and b” -> “Fig. 3a and b”

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