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Interactive comment on "Modelling last glacial cycle ice dynamics in the Alps" *by* Julien Seguinot et al.

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Dear Giovanni Monegato,

Thank you very much for your public comment on our manuscript.

The manuscript is very interesting as approach on the Late Pleistocene Alpine glaciation, for which good data are available for the LGM onwards, but few is known about pre-MIS2. The present article does not solve the problem of what how the glaciers behave before the LGM, but casts new light on this topic suggesting interesting details and field to investigate. I would like to post some general comments on the manuscript especially regarding the Italian side of the Alps.

Thank you very much for your supportive comments!

1 – Reading the manuscript and watching the supplemental file, it is remarkable how few systems in the model result to have the same extension compared to the geomorphological/geological evidence. For the Italian side roughly the Riparia, Baltea, Ossola/Ticino and Tagliamento looks right. While other systems are much over-(western Alps) or under-estimated (from Adda to Piave). The overestimation of the western Alps can be related to the scarcity of updated chronological data; for example the glacier reconstruction in Gesso Valley of the Maritime Alps (Federici et al. 2017) shows a much larger extent than Ehlers and Gibbard (2004) compilation. Anyhow the sentence of line 30 page 14 is reliable and suggests that more data are needed about. Also the Eastern Alpine glaciers resulted very overestimated, for these and for the not-matching glaciers in the Italian side I think that paleoclimate forcing and especially precipitation models are one of the keys factors. The WorldClim model that is considered and showed in Figure 1 seems to be inconsistent respect to other models focused on the Alps. I suggest to take into consideration Isotta et al. (Int. J. Climatol. 2013) where distribution of the precipitations shows areas of high precipitation rates (both as annual mean and daily peak). This distribution would point to high precipitation rates also in the Piave, Adda and Oglio catchments, while the Tagliamento and Ticino systems fit well in the model as well. The knot of the Valais-Ticino-upper Rhine has also modern high precipitations, and this is one of the key areas for large ice accumulation and for the southerly component during the LGM according to Luetscher et al. (2015). Actually, considering the modern precipitation rates and comparing to your model, the underestimation for the Adige system sounds reasonable but not in agreement with the chronology and geomorphology found in the Garda. So other causes, and not only precipitation, have to be considered.

Thank you for this detailed analysis. We want to point out that WorldClim is not a model, but is also based on observations. However we agree, that the regional dataset by Isotta et al. (2013), tailored to the dense station network and steep topography of the Alps, is certainly a more robust precitation forcing that needs to be considered in future studies. A reference was added:

> *Finally, modern precipitation data from WorldClim also bear uncertainties and exhibit local disagreement with other regional data (Isotta et al., 2013).*

Besides, the following sentence was added to the discussion of glacier extent regarding the south-western Alps,

> *However, geochronological data from the south-western Alps are sparse, and the LGM extent compilation (Ehlers and Gibbard, 2004) is inconsistent with more recent regional reconstructions (Federici et al., 2017).*

2 – Concerning the ice-transfluence. I agree that it has to be much more considered. I wonder if the Adige had a great contribution from the Austrian Tauern (Toblach area) this would have increased the ice in Adige and deplete the Drava, or in Winschgau valley where the catchment upstream Mustar saddle is more related to Adige than the Inn. The same could have happened for the Piave catchment, which is very underestimated in the model. Again, ice flowing to the south did not flow to the east. But I think that this may be not enough for justifying the overestimation of the Eastern Alps. Concerning the Straninger saddle I am a bit skeptic because it is not the lowermost saddle (Plockenpass and Nassfeldpass are lower in elevation). The central Adda glacier (and not the Ticino as at page 14 line 26) is much underestimated and here the contribution from transfluence in St. Moritz area could have been remarkable. I attach a figure separately with transfluences (yellow stars and red arrows).

The amount of ice flowing through transfluences is certainly dependent on model resolution and basal sliding parameters. However, we agree that this will have little effect

on the ice volume overestimation in the eastern Alps in comparison to potential shortcomings in the climate forcing.

The tranfluence at the Straniger Saddle may be a byproduct of bedrock topography aggregation to the 1 km grid. As a follow-up study, we have begun to use higher model resolution to study the location of transfluences in more detail (Seguinot et al., 2018). In these results, the transfluence at the Straniger Saddle looses importance relative to other transfluences in the region including, in fact, Plöckenpass and Nassfeldpass. Because the choice of transfluences plotted on Fig. 4 is somewhat arbitrary, we have decided to update it.

3 – The basal sliding of glaciers and its overall velocity is another interesting factor to discuss. For Adige for example we know that at about 28 cal BP the Adige glacier was damming a tributary valley north of Trento around the same age (Avanzini et al 2009), while the same glacier arrived at Garda at 24.6 cal BP (Monegato et al., 2017). This means that the glacier front advanced of about 100 km in around 3.5 ka so 280 m/y. The same could have been for the Adda and Oglio glaciers, even if a such robust chronology is lacking. Is it possible that overestimated velocities produced large eastern glaciers?

Thank you. In fact basal sliding is one of the major uncertainties in our results which is now better acknowledged for in our manuscript following other reviewer's comments. However, basal sliding velocity are somewhat decoupled from glacier front advance velocities and glacier front maximum extent. Although this is not shown in our manuscript, increased basal velocities tend to result in thinner ice tongues. Due to the mass-balance-elevation feedback, this causes more surface melt and, in turn, lesser extent. However this effect is small in comparison to changes due to climate forcing.

4 – About the self-sustained ice domes, their importance is for me unclear and not well explained in the text. Why they are only two? Why the Adamello or the Tauern massifs, as an example, were not considered as self-sustained ice domes?

By self-sustained ice domes, we mean ice domes that are not sitting on top of basal topographic highs, but instead shift away from the modern topographic divides and “sustain” themselves by reaching higher elevation than the local mountains. We indicate these as a sign that ice begins to behave as in an ice sheet, and flow in directions independent from the local basal topography.

However, we agree that this is somewhat arbitrary, and again, as we found out, dependent on model resolution (Seguinot et al., 2018). Therefore, we decided to remove the “ice domes” from Fig. 4a and the main text, and save this discussion for future studies.

5 – Global circulation models (e.g., Löfverström et al., 2014, Beghin et al., 2015) suggest that the Polar front was at different latitudes during each cold phases of the Late Pleistocene. This could have effect of different impact on the Alps. For example during MIS4 if the westerlies were dominant this could have driven more effective precipitations in the western and northern Alps in respect to the southern and the eastern Alps. If this is true, and can be applied to the major cold phases. How was the behavior of glaciers during MIS 5 and 3?

We agree. In fact, our simulations are limited by the constant temperature and precipitation patterns applied throughout the glacial cycle. Although we can’t answer this question without new climate and glacier simulations, we have raised this important point in the very last paragraph:

> *Shifts in the North Atlantic storm track and polar front may have caused varied patterns of glaciations through different cold phases.*

With this, we would like to thank you again very much for the time and effort you have put into our manuscript.

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