Clim. Past Discuss., 11, C571–C579, 2015
www.clim-past-discuss.net/11/C571/2015/
© Author(s) 2015. This work is distributed under
the Creative Commons Attribute 3.0 License.

Climate of the Past Discussions
Open Access

Interactive comment on "Modelled glacier equilibrium line altitudes during the mid-Holocene in the southern mid-latitudes" *by* C. Bravo et al.

C. Bravo et al.

claudio@dgf.uchile.cl

Received and published: 9 June 2015

Author's response to Ann V Rowan (Referee)

General comments

We appreciate the review of Ann V Rowan. There are several comments that will help us to improve the manuscript including new and important references. We agree in the more quantitative look of our results. In the original manuscript we raised some cautions with our results considering the uncertainties, first in the PMIP2 model data and second in the parameterization in the glacier mass balance model. However the reviewer's comments indicate some points that we include in the manuscript as limitations of the glacier mass balance model, the input PMIP2 models and the resolution.

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

In this sense we still consider that our approach is appropriate, given:

- the regional scale and the spatial differences in the latitudinal range in Southern Alps and Patagonia;

- the use of ELA as an indicator, instead of a complete glacier reconstruction that is more appropriate for a smaller spatial scale (a basin or a specific glacier),

- the coarse resolution of the PMIP2 model and that the ELA is closely associated to climate conditions and could be representative of the climate over spatial scales of up to 500 km (Bakke and Nesje, 2011). We answer point by point the general comments (enumerated) of Ann V Rowan:

1) The experimental design for the application of the glacier model does not seem entirely suitable to achieve the aims of the paper.

The glacier mass balance model calculates the accumulation and ablation from climate variables and is based on the works of Jóhanneson et al. (1995), Braithwaithe and Zhang (2000) and applied in the glacier Franz Josef, New Zealand (Anderson et al., 2006), and glaciers in Iceland, Norway and Greenland (Jóhanneson et al., 1995). In these works the model inputs correspond to data from weather stations. It is important to indicate that this type of model already has been applied with information from general circulation models, for example, for the LGM in tropical glaciers, where Hostetler and Clark (2000) with information obtained of simulations GENESIS (v. 2.01) inferred ELA positions across the determination of the curves of balance sheet of mass (m w.e. v/s altitude). Radíc and Hock (2011), with data from general circulation models (ECHAM/MPI-OM, CCSM3, CSIRO-Mk3, GFDL-CM2.0, etc) obtained from CMIP, modeled the future glacier mass balance for different glaciated regions to estimate sea level rise projected to 2011 and using a degree day model. Finally Rupper et al. (2009) applied this kind of model (as a whole with an energy balance model) to the region of Central Asia, using data from re-analysis NCEP-NCAR for the present and data from general circulation models of the phase I of PMIP for the Holocene. The

CPD
11, C571–C579, 2015

aim was to reconcile Holocene glacier history with climate by quantifying the change in equilibrium-line altitudes (ELA) for simulated changes in Holocene climate. All of these cases used similar versions of the degree – day model that we used in the present work, nevertheless one of the big differences with the current work is that these applications of the model used climatological monthly information; while in the present work we used daily information. This point is not of small importance since according to Wagner et al. (2007), the statistical description of the relation between the circulation and the rainfall is better represented in a daily scale in the sense of catching events and synoptic-scale processes, so as we mentioned, we still consider that our approach is appropriate.

2) Moreover, the manuscript is some what disorganised, and would benefit from more thorough editing for structure and clarity, particularly to be more quantitative than qualitative throughout

As we indicated for a previous referee, we will restructure the manuscript considerably. The main points are the following:

- We will change the question stated in the introduction as objective of the paper. Instead of stating the orbital control on glacier extends we will talk about climate controls. In the conclusions we can address the orbital part again.

- We will leave out figure 2-5 and leave those as supplementary material if possible.

- We will further assess uncertainty of the ELA results by doing sensitivity experiments to the degree day factor.

3) Resolution of the glacier model. The glacier model was applied at the same grid spacing as the climate model results (0.5 degrees, about 50 km), and therefore does not capture the impact of the mountainous topography of the two study regions on mass balance. Topography exerts a major control on the extent and therefore ELA of small mountain glaciers such as those that are the subject of this paper, and these ELA

CPD
11, C571–C579, 2015

CC BY

reconstructions are likely to contain large uncertainties, potentially exceeding those given in the results, which already exceed by several times the inferred change in ELA between the PI and MH periods.

We agree with this comment; however the idea in this work was to obtain a regional view of ELA change in two comparable zones (Patagonia and Southern Alps). As we indicate (page 618, lines 17-18) the coarse resolution of PMIP2 models is a limitation for a direct comparison with geomorphologic evidence. In this sense this exercise represents a first step. Also ELA for small mountain glaciers are representative of climate conditions (Bakke and Nesje, 2011). Despite this, we agree in that use of climate models in a specific glacier reconstruction need an appropriate process of downscaling, that escapes of the scope of the present work. However the coarse resolution of the PMIP2 models output and the uncertainty in model parameters, the general pattern in the modeled ELAs in both regions is reasonable. We will make this point clearer in the revised manuscript.

4) Validation of climate and glacier modelling results. The authors compare their climate model results with present-day measurements from automatic weather stations (AWS). However, as stated in the text, the climate model represents a period that predates the climate data by 250 years so this validation is poor. The authors would give more confidence in their results if they compared a present-day climate simulation with the AWS data, or if this is not possible, applied their glacier model to calculate present day ELAs using the AWS data for comparison to present day observations. Moreover, the similarity in sign between results from NZ and Patagonia does not seem sufficient to justify the conclusions.

The climate models used correspond to the PMIP2 outputs, an international initiative, and they did not perform a 20th century experiments, that would have made a better comparison. This is indicated in detail in section 2.2. The comparison with weather station (these are weather station from meteorological government office in Chile, Argentina and New Zealand and does not correspond necessary to an automatic weather

CPD
11, C571–C579, 2015

station, AWS) and with CRU data, is in order to shows if the PMIP2 model represent the seasonality (Figure 2 and 4) and the spatially distribution (Figure 3 and 5) of the climate characteristics of each zone (section 3.1.). Hence comparison is just for show the model limitations. About the glacier model we indicate that this model is used by Anderson et al. (2006) with present meteorological data. Also we conducted a test run to assess the performance of our model forced with climatological information coming from a regional climate model ran at 25-km resolution and the ERA40 reanalyses (PRECIS-ERA40, Rojas et al, 2015 in prep.) for the hydrological year 2003-2004 in the Mocho glacier in the Lake District of Chile ($\sim$40°S), corresponding to the same year analyzed in Rivera et al. (2005) with the glaciological method (stakes). We use two precipitation lapse rates: 0, and 0.00252. We compared the modelled ELA with the observations (Fig1. Attached). This comparison showed a reasonable agreement between the observed and modelled ELA, for precipitation lapse rates (0 and 0.00252 mm/m). However, significant differences are found in the shape of the mass balance curve in the accumulation zone of Mocho glacier. One possible explanation is that these differences may be due to the exposure of the volcanic cone to strong winds, which results in less snow accumulation, a factor that is not considered by the mass balance model.

5) Treatment of precipitation data. Precipitation is poorly represented in the modelling as the authors assume a linear relationship between precipitation amount and elevation. The Southern Alps and Patagonian Andes are classic examples of orographic precipitation regimes, where the interaction of westerly circulation with high topography results in precipitation distributions that strongly deviate from the linear model used here. The use of a linear relationship to describe precipitation as an input to a glacier C300 model has been quantified for the Southern Alps, and will introduce a further uncertainty to the results equivalent to a difference in ELA of about 80 m (Rowan et al., 2014, JGR-ES). Certainly for New Zealand if not Patagonia, that availability of precipitation data are much better than implied in this manuscript; both range profile and gridded precipitation data based on interpolation of AWS measurements are available

CPD
11, C571–C579, 2015

CC BY

(e.g. Tait et al., 2006, International Journal of Climatology; Henderson and Thompson, 2000, Journal of Hydrology) and it is not clear why the authors did not compare their results to or use these data in their modelling.

We agree with this comment and we recognize that this is probably the main source of uncertainties in the model (page 618, lines 18-20) because the distribution of precipitation is difficult to predict. However we use a linear relationship in precipitation to facilitate the process of mass balance modeling considering that this is a regional view of ELA change. We applied the same procedure for both time slice and in this sense we are interesting in the difference more than the absolute values of ELA, of course we expect a reasonable value for ELA. In the scientific literature a great range of linear precipitation lapse rate has been used (even for regional modeling, e.g. Radic and Hock, 2011). However we keep in mind that the difficulty here is that we are working across mountain ranges and that the PMIP2 models does not represent the precipitation gradient in the Southern Alps

6) Link between glacier change and orbital forcing. The results presented here do not convincing achieve the aim of the paper to explore the influence of orbital forcing on glacier advance during the MH, as the model results cannot be linked to a particularly period. A very recent paper (Doughty et al., 2015, Geology) has demonstrated from moraine geochronologies that orbital forcing may not play a role in controlling Late Quaternary glacier behavior in New Zealand and the authors may wish to consider their results in light of this evidence.

The results of the model correspond to 6 ka and PI. As we mentioned in the paper (page 618, lines 14-17), the PMIP2 initiative use as an initial conditions the greenhouse gases and the orbital parameter corresponding to 6 ka and pre–industrial times (https://pmip2.lsce.ipsl.fr/), these boundary conditions are different between the two periods so we expect also differences in ELA. Doughty et al. (2015) consider the orbital influence on glacier extent in the Southern Alps during the period between Marine Isotope Stage 4 and the Last Glacial Maximum. The climatic boundary conditions at

CPD
11, C571–C579, 2015

CC BY

this time were very different than during the Holocene and we are not surprised that (direct) orbital variations may not have played a critical role at this time, when large ice sheets existed in the Northern Hemisphere, CO2 varied considerably, and oceanic circulation was different. The Holocene is another matter; climate during this time was relatively stable and we believe it is important to carry out a first-order estimate of the effect of orbital forcing on Southern Hemisphere glacier fluctuations during this period. However as we mentioned for a previous referee, we are going to take this point with extremely precaution because we understand that the data discussed in the paper does not allow us to state that Neoglacial advances happened around 6 ka but it can help in determining if the climatic conditions of the MH would permit to have glaciers larger than PI, and this could be part of the discussions around the timing and causes of glacier advances at 8-6 ka.

References

Anderson, B., Lawson, W., Owen, I., and Goodsell, B.: Past and future mass balance of 'KaRoimata o Hine Hukatere' Franz Josef Glacier, New Zealand, J. Glaciol, 52, 597-607, 2006.

Bakke, J. and Nesje, A.: Equilibrium-line altitude (ELA). En Encyclopedia of Snow, Ice and Glaciers, ed. Singh, V., Singh, P. y Haritashya, U.K., Springer. pp 268 – 277, 2011.

Braithwaite, R. and Zhang, Y.: Sensitivity of mass balance of five Swiss glaciers to temperature change assessed by tuning a degree-day model. , J. Glaciol 46(152): 7 – 14, 2000.

Doughty, A., Schaefer, J., Putnam, A., Denton, G., Kaplan, M., Barrel D.J.A., Andersen, B., Kelley, S., Finkel, R., and Schwartz, R.: Mismatch of glacier extent and summer insolation in Southern Hemisphere mid-latitudes. Geology, doi:10.1130/G36477.1

Hostetler, S.W and Clark, P.U.: Tropical climate at the Last Glacial Maximum inferred from glacier mass-balance modeling. Science 290, 1747-1750, 2000.

Rivera, A., Bown, F., Casassa, G., Acuña, C. and Clavero, J.: Glacier shrinkage and negative mass balance in the Chilean Lake District (40°S), Hydrolog Sci J 50(6), 963–974, 2005.

Rupper, S., Roe, G., and Gillespie, A.: Spatial patterns of Holocene glacier advance and retreat in Central Asia, Quaternary Res., 72, 337- 346, 2009.

Wagner, S., Widmann, M., Jones, J., Haberzettl, T., Lücke, A., Mayr, C., Ohlendorf, C., Schäbitz F., and Zolitschka, B.,: Transient simulations, empirical reconstructions and forcing mechanisms for the mid-Holocene hydrological climate in southern Patagonia. Clim. Dynam 29:333 – 355, 2007

Interactive comment on Clim. Past Discuss., 11, 603, 2015.

CC BY

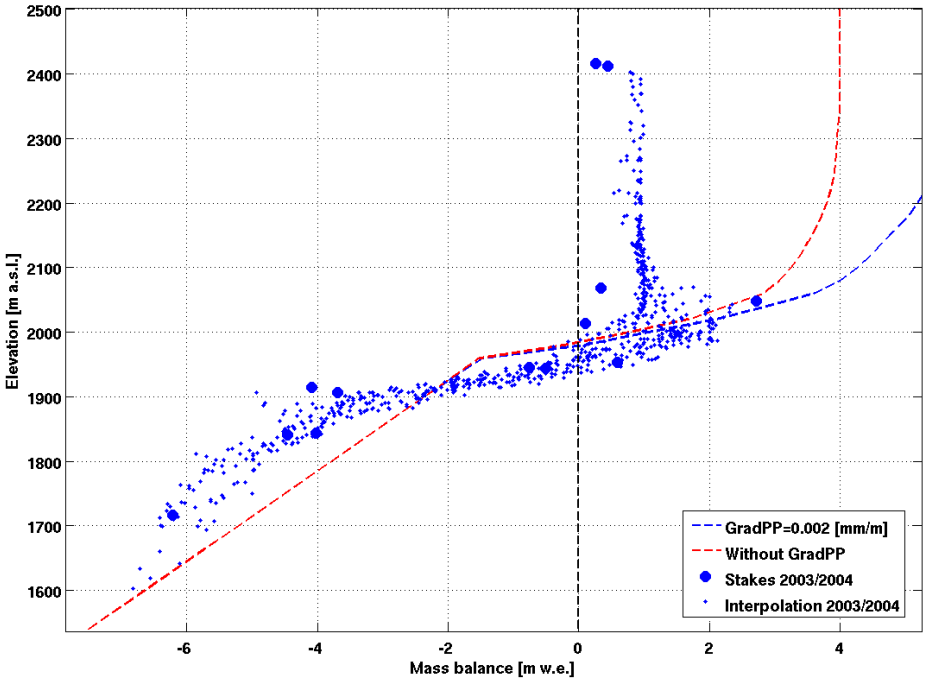

Fig. 1.

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper