Clim. Past Discuss.,
doi:10.5194/cp-2016-1-RC1, 2016


Climate of the Past Discussions

# *Interactive comment on* "The Last Glacial Maximum in central North Island, New Zealand: palaeoclimate inferences from glacier modelling" *by* Shaun R. Eaves et al.

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Received and published: 2 February 2016

The authors present a glacier modelling study that reconstructs the LGM advance of glacier tongues from small ice caps on the summits of two volcanic peaks in the North Island of New Zealand. New Zealand is a key site for exploring the drivers and geomorphological impact of past climate change, and the North Island is relatively understudied compared to the South Island due to the much less extensive glaciation in the North, making this manuscript novel in attempting a 2-D model-based reconstruction of glaciers in northern New Zealand. These small, marginal glaciers (some of those under investigation have vanished since the last glacial) can provide important information about rapid climatic variations, which adds further value to this study. The main



limitation of the manuscript is that the glacier model simulations only investigate conditions approximate to the Last Glacial Maximum (LGM), rather than the present day or postglacial. A good test of this sort of modelling is if the study glaciers can be simulated under a range of known conditions. Although the authors may have performed present day simulations, and have data describing post-LGM glacier limits, the results are not presented. The manuscript is generally well written, although there are some minor inconsistencies in the text and some editing needed. The figures are clear and well presented although the manuscript would benefit from containing more visual information than is the case at present to communicate the simulations and results more clearly.

Main points

Model comparison with present day glaciers. The glacier model is tuned to LGM extents and the present-day simulated mass balance is shown in Fig. 2. However, a simulation of present day ice extents is not provided, which would give a much more valid comparison with the mapped ice extents presented in Fig. 2 as it is difficult for the reader to imagine the extents generated by the presented mass balance. Tuning a glacier model to a single snapshot of the glacial history is relatively easy compared to simulating multiple phases of glaciation to demonstrate that the model parameterisation is valid. The authors should present a simulation under present-day climate conditions, and if there is geomorphological evidence for glacier extents post-LGM then these simulations could also be presented even if their ages are unknown, which may be valuable to subsequent research projects.

Geomorphological evidence for glacier advance. The moraine limits presented in Fig. 1 are derived from field mapping by several studies including the thesis work of the current author. The manuscript would benefit from a more detailed, maybe separate, first figure presenting the different landforms mapped by each study and identifying landscape modification by post-LGM volcanism, to convince the reader that the geomorphological evidence used to constrain the modelling does represent (at least fairly)

stable LGM glacier termini. This could also clarify what was the basis for choosing the ice margins to fit the model to, as indicated by the red lines in Figure 1. Also, a useful point to add to the aims of the paper (P2) and address; is there evidence for post-LGM moraine formation, or is it likely that this would have been removed by volcanism? Does the difference in simulated dT for each volcanic peak result from the moraines in each location representing different stages of the LGM, or did each peak show a different response to LGM cooling?

Description of the glacier model. The description of the model set up (Section 3.1.1) needs to give more precise information about exactly what the input values represent and how these were varied. For example, does "temperature" refer to mean annual air temperature? (also see minor comments below).

Reference to unpublished data and author's PhD thesis. Where possible, either avoid reference to these materials that have not been peer-reviewed by only citing the literature, which is reviewed and accessible to the reader, or present the data referred to where this is not possible.

Minor points by line number

P1, line 16: missing 'the' - "from the central Southern Alps".

P2, 1–2: in addition to or instead of introducing the LGM in the NH, set the context in the SH.

P2, 9–13: changes in temperature are summarised by McKinnon, but changes in precipitation are not. Mention both here, making a summary of existing data for past precip change as needed.

P2, 22: give the ages assigned to the LGM here.

P4 31: whilst the authors are thanked for their citations to three of my papers, I think the citation here and elsewhere should refer to Rowan et al. 2013, Geology (glacier modelling) rather than Rowan et al. 2012, Quat Geochron (Canterbury Plains OSL).



P5, 4: misleading sentence as "other models" really only refers to different applications of the same model (Plummer and Phillips, 2003). Would be useful to mention here how these models are similar.

P5, 12 and throughout: the terms "contemporary" and "modern" are both used to refer to the observed glaciers. Both these terms are relative to the period under consideration, so slightly misleading here (e.g. could mean "contemporary to the LGM"). I suggest replacing both with "present day" throughout to avoid confusion.

P6, 4–7: the argument that geothermal heating does not affect glacier mass balance could be strengthened here, by adding a line estimating the total heat delivered to the glacier bed during a short period of volcanism and comparing this with the magnitude of other sources of energy for melting.

P6, 13–19: Although some of the present-day (recessional) glaciers are debris covered, the exclusion of rock debris cover from these simulations is a valid assumption for a study of advancing/steady state glaciers where high velocities through the entire glacier would have been likely to efficiently export debris and prevent the development of a substantial debris layer. However, the authors are investigating glaciers close to active volcanism. The impact of thin but extensive debris layers on ablation is likely to be more significant, but could be evaluated by comparison of simulated/measured glacier velocities with the intervals between eruptions to estimate the residence times of debris on the glacier ablation area surfaces. I would suggest moving this paragraph to the discussion of model uncertainties.

P6, 31: to be more precise, phrase as "mass balance imparts [the] greatest uncertainty [in simulated glacier extents]".

P7, 16: please state the lapse rates used here.

P7, 19: is the value of 2.5°C derived from the mean standard deviation in daily temperature for each month? This value seems reasonable for NZ, but it would be useful to

know how it was derived.

P7, 20: what is meant by “guide the interpolation of the station data”? How do your calculated precip grids compare to Tait’s?

P7, 22: How was steady state evaluated? State the model output required for the results to be classified as steady state in the model description section.

P8, 22: Slightly confusing terminology, here and elsewhere if “step coolings” are negative values, does that not imply warming? Replace the meaning of dT with “difference in temperature from present day values” or similar, as these steps represent different temperature conditions not simulations run under a constantly changing temperature (“temperature change”). This also allows you to always refer to your simulation temperature with the same sign making the text easier to follow, so always as “difference in temperature = –2°C” rather than “dT = –2°C” and “cooling of 2°C”.

P10, 13: remove “precise”

P12, 7–15: the impact of bed topography on glacier extent is interesting. Could you compare in a little more detail (i.e. quantatively) with McKinnon’s results here, and suggest how other studies could carry out similar reconstructions (what is meant by “expert-defined topo reconstructions”?) and testing of bed topo?

P13, 23–25: rather awkward sentence here, rephrase.

P13, 32: you could also cite here: Schaefer et al., 2015, Quaternary Science Reviews.

P14, 32: impact of surface debris on ablation needs a citation; suggest Ostrem, 1959, Geografiska Annaler, and/or Anderson, 2000, Journal of Glaciology.

P16, 15: “a reduction in precip of [up to] 25%”.

P16, Conclusions: I would prefer the conclusions to be written as continuous prose rather than numbered points. Worth mentioning here the value of these results in expanding the geographic range of glacier-based palaeoclimate reconstructions beyond



the Southern Alps.

P17, 5: avoid the use of “significantly” unless this is statistically the case.

Figure 2 caption. Under what climate condition was this simulation made?

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