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The Cryosphere Discussions

Interactive comment on "Numerical reconstructions of the flow and basal conditions of the Rhine glacier, European Central Alps, at the Last Glacial Maximum" *by* Denis Cohen et al.

Anonymous Referee #2

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This study simulates the Last Glacial Maximum (LGM) state of the Rhine Glacier using a state-of-the-art numerical ice flow model solving for full Stokes. Five different (simple) climate forcings are applied, and the resulting glacier characteristics are compared to geomorphological reconstructions. The study is interesting; especially the apparent mismatch between the simulated and reconstructed glacier state (simulations using more realistic LGM climate forcing result in a too thick glacier compared to the geomorphological reconstructions). The manuscript is in general clearly written, and very comprehensive. I do have, however, some comments, that I hope the authors will incorporate before the final publication of this work.

GENERAL COMMENTS

My general comments all deal with how the set-up of the model, the initial conditions and the climate forcing might affect the model results. I am basically asking you to explain and discuss this better in the manuscript.

1. Surface mass balance: I understand that the authors prefer to apply a simple surface mass balance (one that is also uncoupled to the surface temperature/energy), because of the uncertainties in simulated and reconstructed LGM surface mass balance and temperature.

(1a) However, to me it is unclear why these particular values for ablation and accumulation gradients, and these equilibrium line altitudes (ELA), are used? The values seem almost randomly chosen, and the five simulations have no logical sequencing of changing one parameter at the time (which would help to better understand the impact).

(1b) Related to Page 12, lines 19-28: This section is slightly confusing. Why is simulation s1 referred to as the "cold" simulation, while it actually has the lowest ELA of all five simulations? The surface temperature is defined by the ELA, or?

(1c) Also the directional component is confusing: "wetter climate in the south" "cold and dry in the north". I thought that the surface mass balance and the surface temperature both only depend on elevation, not on wind or moisture supply direction? Actually, including a directional component might improve the modelled glacier shape to the observations. By imposing a South-North gradient in accumulation, it might become more difficult to glaciate the Hornli ridge (as is now the case in s2, s4 and s5), better fitting the geomorphological observations.

(1d) Page 25, lines 23-26: It me it is unclear how you can calculate temperatures from your surface mass balance, if these are uncoupled. Please explain this more carefully.

2. Initial conditions for ice surface: To me it is not entirely clear which initial ice surfaces are applied. For simulation s1 the reconstruction of Benz-Meier is used, and for

simulations s2-s5, other simulations that ran 440 & 907 years provided the ice surface. In the latter case, are these also based on the Benz-Meier reconstruction? In other words, is the reconstruction always used as basis, followed by 440 or 907 years of simple climate forcing (before simulating s2-s5)? What is the reason for using different initial conditions? I am asking this, because I think that the initial conditions possibly have a strong impact on the model results. But it is difficult to extract this impact due to the (to me random) set-up of the model simulations.

3. Geothermal heat flux: I agree that adjusting and interpreting the geothermal heat flow data available is beyond the scope of this work, but it would be good to see a map of the values used in the simulations. How much does the basal temperature depend on the geothermal heat flux applied? And in how much does this boundary condition of geothermal heat flux define the basal conditions simulated in this study? In other words, does the geothermal heat flux pattern predefine the basal temperature pattern?

4. Steady state: I agree that you should not aim for reaching steady state with your simulations, as indeed climate and ice rarely reach a steady state due to the long response time of the ice compared to climate variability (DO and other variability). It would therefore indeed be unlikely that the Rhine glacier would be in equilibrium with the LGM climate. The argumentation for this (page 23-24) can be written more concisely. Also some studies suggest that DO1 occurred during the last deglaciation, so rather write: "... called Dansgaard-Oeschger (DO) events occurred repeatedly during Marine Isotope Stage 3 (MIS3, 60-30 ka BP)." Also, it is difficult to define the duration of the LGM, so I suggest deleting the sentence "That period lasted around 2000 years ... Bernese Alps)."

SPECIFIC COMMENTS

Page 1, line 3: "fully-coupled"; what do you mean with this? Readers might think that the model is coupled to a climate model – which it is not.

Table 2: Simulated time; why did you not run all simulations the same length of time, or

until they reached the same rates of (dis)equilibrium?

The Abstract starts with mentioning a study about the safety of repositories for radioactive waste, would be nice to come back to that in the conclusions or discussion, and possibly give a recommendation.

TECHNICAL COMMENTS

Figures 1-3 are difficult to compare for none experts of this region. Could you indicate the overlap in the figures, by for example, outline boxes?

Page 10 and Table 2: Please note that the notation of the upper bound for the accumulation rate is not the same.

Fig. 4: would it be possible to indicate the location of the terminal moraines in this figure?

Fig. 4-16: The double colour scale makes some of the figures difficult to understand. I would suggest to discard the ice-free topography, as this is the same in all figures; and make that white. If you do decide to keep the ice-free topography, than please label the colour scales in the figures, and possible use a more dissimilar colour spectrum for the ice-free topographies, as the brown and red are difficult to distinguish.

Fig. 4-16: please delete "(Table 2)" from the caption, not necessary.

Page 15, line 32: "similar" instead of "nearly identical"

Page 22 and fig. 11: Please use either ratio's (0-1) or percentages (0-100%), for consistency.

Fig. 14: This is an interesting figure to compare with Fig. 8. However, it would be clearer if only the extent and thickness of the temperature basal ice was shown, not the basal topography as well.

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