

Interactive comment on “Environmental controls on the thermal structure of alpine glaciers” by N. J. Wilson and G. E. Flowers

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To Dr Aschwanden,

Thank you for the encouraging feedback. The main point of the comments in this review is that many assumptions are introduced in Experiment 3, sometimes without strong support. We have tried to make caveats about these assumptions clear, and we now compare the results in Experiment 3 to an alternative assumption in which the near-surface aquifer thickness is invariant.

We respond to specific comments below:

Major comments:

What is the justification of the assumption that the aquifer thickness is related to the net balance (Eq. 21)? This assumption is later used in Sec. 3.2.2, and conclusions are drawn based on this assumption. I think this is needed, otherwise Sec. 3.2.2 would be weak.

– It should be noted that this assumption is only relevant to the dashed lines plotted in Fig. 6, and that the parameter space map is still valid with any other presumed trajectories. Next, the assumption in Eq. 21 is a qualitative guess that approximately reproduces (overestimates) the slope in shallow dry snow firn using a (very) simple compaction model (Ch. 2 of Cuffey and Paterson, 2010). Ice lenses refreezing in the firn column should have a major steepening effect on the gradient, perhaps justifying the overestimation. We have added detail to the text regarding our assumption, and made it more clear that only the dashed lines in Experiment 2 are based on this. See also response to referee #1.

The role of basal sliding is only briefly touched, and not very well discussed. I understand that, for simplicity, basal sliding is ignored in the model. On p. 3787, l. 2 the authors promise to justify their decision later on, however, I cannot find it in the manuscript; especially since basal heat flux is part of the sensitivity study, but it's not well addressed in the results section.

– Yes, we ignore basal sliding for simplicity (cf LeMeur et al, 2004). We have added to section 3.1 - we mean to draw attention to the insensitivity of the model to basal heat fluxes to justify our simple parameterization of frictional heating. As for the increased advection near the base implied by sliding, this is to some extent covered by our experiments with C_u , although we recognize that this is crude. In order to better address the role a slightly more physical sliding would have, we have performed experiments using a Weertman-style sliding parameterization, appended to section 3.1. We have explored the effect of sliding in the context of real glacier geometry in a separate study (Wilson and Flowers, submitted Dec 4, 2012).

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Minor comments:

p 3783, l. 12: change “polythermal ice” to “polythermal conditions” (a glacier can be polythermal, but ice can't).

– Agreed.

p 3783, l. 14 (and p. 3800, l. 13-14): It was actually Greve (1997), using a polythermal ice sheet model based on a front-tracking method, who first observed a thinner temperate ice layer compared to using a cold-ice method. Using an enthalpy method, Aschwanden et al. (2012) just confirmed Greve's findings.

– Thanks; the reference has been corrected to Greve, (1997).

p. 3785, Eq. 4 and 5: why do you switch from k to k_{eff} , is there a difference. For ice, you switch to talking about diffusivity directly; I find this a bit confusing. I don't think Eq. 4 is really needed, maybe you could write Eq. 5 in terms of diffusivity, e.g.

$$\kappa = 0.138$$

$$-1.01 \times 10^{-1} \rho + 3.233 \times 10^{-6} \rho^2 c_p^{-1}, (1)$$

where ρ and c_p are density and heat capacity, respectively.

– Good idea; this has been adopted.

p. 3787, Eq. 9: A is used here for the first time, but not introduced.

– fixed

p. 3787, Eq. 10: Since Eq. 10 has a term $1/h_{aq}$ I assume that Q_m is calculated over the whole aquifer thickness.

– Yes. We have clarified this; see referee #1 comments

p. 3798, l. 19-22: You state an equivalent difference of up to 1.8 K if Eq. 13 is used.

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First, you refer to Fig. 3a. Do you mean 3c? Second, I think the figure reference should be at the end of the previous sentence: "by an equivalent difference of up to 1.8 K (Fig. 3c)". Third, looking at Fig. 3c, I see dark blue colors corresponding to equivalent temperature differences greater than 1.8 K. Please clarify.

– These were unfortunate mistakes, which have been corrected.

p. 3799, l. 2 and 15: "Cooler temperatures" sounds odd to me, I'd prefer "lower temperatures" (but that's just a suggestion).

– Not sure, but changed to "lower" to be safe

p. 3800-3803, Sec. 3.2.1 Basal heat flux Q_b and run off fraction r are listed in Table 2 Interactive as part of the sensitivity tests, but are not discussed in Sec. 3.2.1. Maybe you could also add the two corresponding graphs to Fig. 5?

– We did not originally include them in Figure 5 because Q_b does not have a noteworthy effect on the thermal regime, and run-off fraction r is not independent of f_{dd} . Considering these and referee #1's suggestions, we have added r to Fig. 5. Q_b is now addressed in the text.

"In contrast, basal heat flux (Q_b , not shown) does not have a significant effect. This is consistent with the results from Experiment 1."

Fig. 1: Structured grids with stretched vertical coordinates are standard enough so that this figure could easily be removed, I don't think it adds to the understanding of the paper. But this is probably a matter of taste, and I don't mind if the figure stays.

– We agree that the figure is unnecessary, and have removed it.

References: Please clean up references. What are the numbers (like 3782 in Robin, G. 1955) after the year.

– These numbers refer to the page numbers in the TCD article that made the reference,
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and seem to be added automatically.

Nat Wilson and Gwenn Flowers, Dec 2012

Please also note the supplement to this comment:

<http://www.the-cryosphere-discuss.net/6/C2554/2012/tcd-6-C2554-2012-supplement.pdf>

Interactive comment on The Cryosphere Discuss., 6, 3781, 2012.

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