Review: Wang et al, tc-2016-38

Dear colleagues,

This is a very nice and comprehensive study of a remote glacier in a barely investigated mountain range. I find it especially valuable since a very interesting set of field data are presented which are interpreted with the help of a numerical model. The modeling study is comprehensive, and the investigation of the importance of the individual advective terms, dissipation and basal motion (Section 4.4) is insightful.

My recommendation is to publish the manuscript after the comments below have been taken into account.

Sincerely, Martin Lüthi

Specific comments

Leave away colons (:) before equations, this is not usual in The Cryosphere.

You should decide on one version of English. Now there are "modeled" and "modelled" in the same sentence.

p1,1 "see" could be omitted

p3,11 also give the slope angle in degrees, i.e. $4.6°$.

p3,12 L is often used for the glacier length, y would be more common for a transverse coordinate.

p3,19 also indicate distance from terminus, or along-profile.

p5,13 omit ":", maybe writing "following Flowers et al. (2011)

p5,16 "horizontal diffusion is parametrized by glacier width" is quite opaque. Please explain what you are doing, since this is not standard. This seems to be middle term in the parentheses, but it is not clear where this comes from. Does this somehow parametrize lateral diffusion (along the y-Axis)? But then, why would the longitudinal velocity gradient dT/dx play a role? Please explain this in detail (maybe in an appendix).
Overall, it seems advantageous to ignore heat flow in y-direction (i.e. leave away the problematic term in Equation (6), since nothing is known about the boundary conditions there.

p5,26 What happens with water produced by dissipation? Does this stay in the ice, or does it drain at a certain volume ratio? Is a balance equation for the water content, or the enthalpy, solved?

p6,3 Even if the model is described elsewhere in detail, the main characteristics should be given here: solution method (finite difference, finite element, ...), discretization (element type, mesh size), solution method (solver, time-stepping, CFL condition) etc., and maybe some implementation details (solver libraries used, maybe Matlab, etc...).

p6,7 Parentheses should be adapted using \left(and \right)

p6,11 Strictly, this should be $\sigma_n - p_w$ using the normal stress on the bed, which might be quite different from the overburden calculated with the local vertical ice thickness. In which direction is H measured, vertically (along z), or perpendicular to the ice surface?

p6,30 This boundary condition is valid for cold ice, but what is used in temperate ice? There, any geothermal heat will contribute to melting.

p7,2 I assume that the G-term is not very important for the model results. In mountain topography, the geothermal heat flux can vary a lot on short spatial scales, so the importance of this should be at least discussed.

p7,22 So, the water content is assumed constant throughout the temperate ice? This is problematic and will obviously introduce some inaccuracies.

p8,3 "compare to"

p8,6 The omission of convergent flow is only one possible (and likely) explanation, but there might be others, e.g. basal motion. This statement should be made more carefully.

p8,7 Here you should qualify "the modeled basal sliding velocities", IIUC. The reality, again, could be that basal sliding is much higher there. This could be elaborated upon in the Discussion.

p8,8 "observed": this is confusing, as you talk about model results. Better say: "the model predicts"

p8,9 add space between "110m"

p8,10 "ice fluxes" (not "ice flows")

p8,13 More important than matching temperatures would be a discussion of the heat fluxes. While the measurements show constant fluxes below $50\,\mathrm{m}$ depth below the surface, the model shows zones of warming and cooling (bends in the temperature profile). It would be important to understand the reason for these excursions from a straight line, is the shape of this profile due to advection, dissipation, or due the temperature history?

Closer to the surface (above $50\,\mathrm{m}$ depth) the measured gradient is much higher, which might reflect the thermal properties of the firn in a steady state (lower conductivity k). Since ice conductivity is assumed everywhere in the model, this might explain the difference there (cf. Fig. 5 in Lüthi and Funk (2001) for a theoretical temperature profile with firn).

p8,27 It would be helpful to also show a graph of TIZ thickness (a second panel in Fig. 8c). It appears that the bed is temperate almost everywhere in the blue and green model runs, but with very small TIZ.

p8,31 "above" (leave away "in")

p9,11 ff instead of "drop" and "remove" you could consistently use "neglect" or "leave away"

p9,25 qualify "basal sliding" by "modeled"

p9,28 leave away "higher-order"

p10,2 "physically" should be "physical"

p10,9 consolidate the two citations

p10,11 Past changes can have a very important impact (see for example Lüthi et al. (2015)), as are warming processes in the firn (e.g. Machguth et al. (2016))

p11,16 Replace "e.g." with "of" (these are not just examples, but an exhaustive list of measurements used in the study).

p11,21 No need to show the symbol "(u)" here again (leave away).

Fig 1 A nice overview photograph would help setting the scene for this remote glacier that most readers won't know.

Fig 2 same labels on the horizontal axis of Figs. 3 and 4 would ease of comparison.

Fig 8d Caption: modeled and measured (lines vs symbols) should be interchanged.

References

Lüthi, M. P. and Funk, M. (2001). Modelling heat flow in a cold, high altitude glacier: interpretation of measurements from Colle Gnifetti, Swiss Alps. *Journal of Glaciology*, 47(157):314–324.

Lüthi, M. P., Ryser, C., Andrews, L. C., Catania, G. A., Funk, M., Hawley, R. L., Hoffman, M. J., and Neumann, T. A. (2015). Heat sources within the Greenland Ice Sheet: dissipation, temperate paleo-firn and cryo-hydrologic warming. *The Cryosphere*, 9:245–253.

Machguth, H., MacFerrin, M., van As, D., Box, J. E., Charalampidis, C., Colgan, W., Fausto, R. S., Meijer, H. A. J., Mosley-Thompson, E., and van de Wal, R. S. W. (2016). Greenland meltwater storage in firn limited by near-surface ice formation. *Nature Climate Change*.