

Interactive comment on “Transient thermal effects in Alpine permafrost” by J. Noetzli and S. Gruber

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Dear colleagues

The paper “Transient thermal effects in Alpine permafrost” by J. Noetzli and S. Gruber is an interesting continuation of the research of permafrost conditions in Alpine mountain ranges. The presentation is mostly clear, the figures are well done, and the bibliography complete (if not too big). I recommend the publication after the following points have been addressed.

Martin Lüthi

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General comments

1. Permafrost is certainly affected by changes in boundary conditions, most notably at the surface, but how this rather complicated, diffusive system “is an indicator of climate change” [p186,13] is not clear (delete that statement).
2. An explicit definition of the term “permafrost” that is used in the paper should be given, preferably in the beginning [p186,125]. The authors seem to implicitly use the definition “lithosphere material at a temperature below 0°C ”, as [p195,122], and all of their plots indicate. This choice might be useful for easy presentation of temperature fields, however it is somewhat meaningless in the context of mountain permafrost.

The fact that the melting point temperature in rock veins depends on vein geometry, and of course on overburden pressure, cannot be neglected in mountain permafrost. To be correct, the melting point temperature would have to be calculated. Most resulting isotherms in the interior of mountains would look different if the melting point (instead of 0°C) would have been used. I realize that a correct treatment is probably difficult at this stage of the study, so one would like to see a discussion of the simplified assumption, and of the meaningful(or -less)ness of the 0°C isotherm.

3. Frequently the statement is made that latent heat does not affect modeled temperatures on long time scales. In my experience this is only true for dry bedrock, or for truly stationary conditions. In a very long term thawing situation, as the deep Alpine permafrost experiences since the last ice age, the consumption of geothermal heat is effectively shielding the interior of mountains from the geothermal heat flux. This effect is clearly visible in Figure 9 from [Lüthi and Funk, 2001], especially in panel b). In that case study the elevation of the permafrost base is 300 m deeper due to the geothermal heat absorbed by thawing permafrost.

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The statements on pages [p185,l20], [p198,l6], [p200,l4] and [p205,l7ff] should be changed accordingly.

4. There is no indication whether the described model has been verified. Since spatial resolution and time stepping are both critical in the presence of a phase transition, numerical results should be checked against a solution in explicit form. Such a solution has been given by [Carslaw and Jaeger, 1959] and is described in [Wegmann, 1998] (p. 95).

5. It is not made clear why the TEBAL code is preferable to a simple analytic expression for the GST [p191,l9ff], especially for the model runs on synthetic geometries.

6. Why was the Corvatsch station chosen for the temperature history? Especially for the Matterhorn model, the Grand St. Bernhard station seems to be the obvious choice, with the additional benefit of a much longer time series.

7. The description of the latent heat formulation is not clear, and explicit formulas of what was implemented should be given. Presumably [p192,l15ff] you are using an approach as described in [Wegmann et al., 1998] (Eqns. 4 to 5) or [Lüthi and Funk, 2001] (Eqns. 6 to 8).

What is the meaning of w ? Is this the temperature interval over which freezing occurs? If so, the values of w on [p192,l17] should be in units of K, and the variable w could be renamed to ΔT .

8. For the accurate modeling of the transient temperature field in whole mountains it is crucial to extend the mesh far enough in the vertical, where a flux boundary condition is prescribed. No indication is given at what depth the model geometry starts. Again from my experience with [Lüthi and Funk, 2001] (see also [Medici and Rybach, 1995]) the boundary should be at least at sea level for the Alps.

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9. Are the model runs started with a steady state 18180;000 years BP? This is not explicitly stated [p194,l1ff].
10. In several places it is stated that “climate change” leads to permafrost degradation. Obviously such a statement would be wrong if “climate change” included cooling. Besides such nitpicking, there is also another process that might be relevant for the GST. Snow patches and glaciers at intermediate altitude can act as heat sources. Radiation melts the surface layer, meltwater infiltrates the cold firn and refreezes, thus raising the snow/firn/ice temperature above atmospheric conditions. A corollary is the conclusion that removal of snow patches and receding glaciers can, under certain conditions, lead to a colder GST [p203,l5ff].

Minor comments

- Question to the editor: Should citations to “extended abstracts” should be in the bibliography, e.g. Kohl and Gruber (2003)?
- “South side” and “North side” instead of “southern side, northern side” (several places).
- Use “years” in the main text and captions instead of “yr.”.
- [p186,l15] What do you mean by “warming on shorter time scales”. This does not add to the value of the paper.
- [p187,l20] [Wegmann and Gudmundsson, 1999] should be cited
- [p189,l5] and others: “Thermal properties” is usually used instead of “thermophysical properties”.

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- [p187,l29], [p189,l25] and bibliography: I missed the moment to change my name to “Luethi”, so I would appreciate the correct spelling “Lüthi”.
- [p188,l8] “go back in time” could be replaced by “it is necessary to initialize the model far enough in the past”.
- [p189,l6] The meaning of the “temperature depressions” is not clear.
- [p189,l20] Boreholes are “subject to one-dimensional heat transfer” (instead of “include”).
- [p191,l19] A table of thermal properties and boundary conditions used for the modeling would be very helpful. Now the readers is referred to another paper, but some values appear also in the text.
- [p192,l1] “advection by” instead of “effects of”
- [p192,l26] “is damped with depth due to the diffusive nature of heat flow.”
- [p194,l13] “scenarios” would be preferable to “variations”
- [p197,l13 and l20] “plane” instead of “plain”?
- [p198,l19] Define the anisotropy factor.
- [p202,l3] “numerical experiments”
- [p202,l20] “the future scenarios”
- [p205,l2ff] The sentence starting “Together with...” is not clear. Better speak of “changes” instead of “degradation”.

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