

Interactive comment on “Modelling the temperature evolution of permafrost and seasonal frost in southern Norway during the 20th and 21st century” by T. Hipp et al.

Anonymous Referee #2

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General Comments

The paper presents the application of an heat conduction model in three areas of southern Norway and focus on the evolution of ground temperature and permafrost conditions from the Little Ice Age to 2100. Model results are compared for several boreholes located along altitudinal gradients in the 3 areas. The paper gives an interesting overview of possible future permafrost conditions in Southern Norway

I think that the paper needs some improvements mainly in the first sections concerning sites and dataset description, generation of model input data and model calibration/validation. More specific comments are presented below. Therefore, I think that

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the following major revisions are needed before accepting the paper for publication.

Specific Comments

SECTION 1

p 814 line 8-14: this paragraph is too detailed for an introduction. Just focus on synthesizing the aim of the work and explain the method in following section

SECTION 2

This section (sub-sections 2.1 and 2.2) must be re-organized to make it more understandable: there are too many repetitions. It should be probably more clear if you start with a description of borehole sites (merge page 814 line 15-19 and subsection 2.1) and then explain which data are collected at each site and time series length (merge page 814 line 19-27 with the first paragraph of subsection 2.2). Remove from subsection 2.2 the first paragraph.

page 814 line 23-25: which is iButton sensors distance on the pole? Say something on this topic so that the accuracy of the snow depth estimation can be evaluated

Why in the second paragraph of subsection 2.2 you do not mention Jetta site?

Sub-subsection 2.3.1: as in the text you discuss ALT in the different sites during the two seasons, why don't you put ALT values in table 1 as you did for MAGST and MAGT10?

Sub-subsection 2.3.2: this section does not describe permafrost conditions at your sites: consider the idea to move it in section 3.2 where you introduce the concept of GST as upper boundary condition given also the fact that in figure 3 you show modeled data without having introduced the model yet.

Change the order of figure 3 and 4: in the text you mention figure 4 before figure 3 and thus consider the idea to change their order.

Subsection 2.3.3: In this part your are mainly discussing GST variation between the

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two years and so you can move it in sub-subsection 2.3.1 (that now can simply become 2.3), where you are already discussing ALT and MAGT variations between the S1 and S2.

SECTION 3

Subsection 3.2

page 820 line 13-18: Explain more clearly (or at least give some pertinent reference) how you can derive GST time series using Tair and n-factors.

page 820 line 18-21: how can you demonstrate that air temperature and snow conditions observed in S1 and S2 represent the variability of the last decades? Find very pertinent references or smooth this sentence

page 820 line 28: is figure 5 necessary? Consider the idea to simply provide fitting accuracy statistics and eliminate figure 5

Subsection 3.3

Calibration and validation results need to be treated separately.

Considering the manual tuning of ground parameters: which is the accuracy statistic you used to evaluate model agreement when varying parameter values? To which extent ground parameters influence model accuracy?

Considering the validation of the n-factor approach and table 3: to evaluate model accuracy the use of the Nash–Sutcliffe model efficiency coefficient (EF) is preferable. EF is a measure of the coincidence between observed and modelled data and it is sensitive to systematic deviation between model and observation. See Janssen and Heuberger (1995) for more details.

Table 3: present separately the accuracy statistics for calibration and validation. Use the same statistics for GST, GT and ALT rather than showing r^2 and RMSE for GST and GT and modelled and observed data for ALT. GT in table 3 is referred to which

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depth?

Figure 7: Right panel: plotted data are referred to calibration or validation period? Do not present them together. I suggest again to use EF rather than R^2 . Is model accuracy dependent on depth?

Figure 7 caption: What does “Only one season was available for calibration and validation for Juv-BH4P” mean? You have calibrated over the period Sept-Feb and validated over the period Mar-Jul?

Subsection 3.4

This section is not clear. I can not understand how the historic data are generated; please restructure this part and explain more clearly how this data are calculated.

SECTION 4

Subsection 4.2.3

ALT increase values: what does cm a^{-1} mean? Does it mean cm per years? If yes maybe it's better to use cm yr^{-1} .

In this section many ALT increase trends (cm a^{-1}) are reported. How these trends have been estimated and are they all really significant? Have you checked them with non-parametric Sen slope estimate or Mann–Kendall nonparametric trend test, or other methods different from linear regression?

SECTION 5

Subsection 5.1

You discuss the effect of n-factors on GST estimation (line 14-23). Consider also the idea to evaluate the effect of different n-factors values on GT and ALT estimations.

Technical Corrections

page 813 line 3: surficial: change with superficial.

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page 813 line 8-11: this paragraph is too detailed for an introduction. Just say that the monitoring network has been increased in 2008 with new boreholes.

page 813 line 25: "For Scandinavia in general ..." new paragraph.

page 814 line 18: give a reference for PACE as you do later (815 line 10).

page 815: sites are presented in the order Juvvasshoe, Jetta, Torn. In order to help the reader, change the order of panels in figure 1 so that Fig1b is Juvvasshoe and so on.

page 816 line 17: is there a reference for this climate normal data?

page 816 line 24: change "devided" in divided.

page 817 line 22 (Fig. 4e): Tro-BH1 is 4c.

page 818 line 14 (Fig. 4d): Jet-BH3 is 4e. Why in the text you use the order Juv-Tro-Jet and the figure 4 is in the order Juv-Jet-Tro? I suggest you to be more consistent to help the reader.

page 820 line 2: change Table 1 with Table 2.

page 821 line 7: "measured values for" ... erase the first "measured".

page 821 line 10: change Table 2 with Table 3.

page 826 line 3: change obeservations with observations.

Table 4: check the coherence between column header MAT(2008/2009) and table caption: "Surface air temperature change at each borehole from the 1860s until the 2090".

Figure 9 caption: say why Tron data end in 2010. Permafrost degradation already occurred?

Figure 10 caption: say what the grey vertical dashed lines represent.

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