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The Cryosphere Discussions

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 #1

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General comments:

The authors used a simple heat conduction model to estimate ground temperature evolution over two centuries (from the little ice age to 2100) at three locations in southern Norway. Results provide interesting insights into the past and future development of permafrost, active layer and seasonal frost. A very similar model approach has already been applied in Svalbard (Etzelmüller et al., 2010) and Iceland (Farbrot et al., 2007). The present study further focuses on the comparison of the model results at several boreholes within each of the 3 locations, which are located at diverse elevations and within differing ground cover types. This approach allowed to make conclusions about

the spatial development of permafrost and the active layer thickness (ALT) at different altitudinal bands, and to study the effect of ground cover type as a buffer layer, for example. The study further shows that the strongest permafrost degradation and ALT increase occurred since 1990, whereas before (since the little ice age) not much permafrost degradation had occurred. Furthermore, the authors investigate permafrost development until 2100, considering differing climate change scenarios, and show a high probability of permafrost disappearance until 2100 at most of the study sites.

This is a valuable contribution to the scientific community addressing both past and future permafrost development in Southern Norway by applying a simple, very often applied modeling approach.

The reviewer thinks that the paper needs some substantial improvements concerning the paragraph related to the generation of the input data (historic air temperature time series), the treating of model uncertainties and the calibration of the model (examples and details are mentioned below). The reviewer therefore suggests that this paper can be considered for publication after the following major issues have been resolved.

Major issues:

1. Page 822, Section 3.4 (Historic and future temperature data), lines 9 - 23: This paragraph is very unclear. The procedure of generating historic air temperatures determines the main input factor to the heat conduction model to estimate the (past) permafrost conditions at all study sites. I am unable to understand how the historic air temperatures are generated, and can thus not judge whether the procedure is correct and of scientific use. Please be more precise:

a. Line 10 – 12: for what time period is the MDAT_grid data available?

b. Line 12: What are standardized air temperature series? How have they been generated (you do not need to go into detail, but since the generated air temperature series are the main input to your model, which strongly determine the model outputs, you

should give the reader a simple help to understand how they were generated)?

c. Line 15: Explain how this linear regression works? What are explanatory variables, what is the response? Which data (time period) was used to determine the model coefficients, and how (time period) were they extrapolated? What are the confidence intervals of the model coefficients?

d. Line 16: Where does the year 1957 come from? Why is it important, and why do you have to apply different methods before and after 1957?

e. Line 21: Give more detail on the method by Hansen-Bauer (2005). I do not understand Equation (2) and how historic MMAT is generated from that data.

2. Model uncertainty is treated to a certain degree in the discussion. However, some of the largest uncertainties (only two years of calibration data and its influence on n-factors, estimation of historic air temperature) are not treated. Include a section concerning the assessment of model uncertainties in the methods chapter.

a. Discuss the uncertainty due to the short periods of measurements. How does this influence the results (model calibration, influence on n-factors and thus on the upper boundary condition)?

b. Focus more on the description, interpretation and the uncertainty of and due to the n-factors, since these factors (which were derived from 2 year data only) pre-dominantly determine the upper boundary conditions of the heat conduction model. They are one of the main sources of uncertainty in your model. It is not enough to state that the two-year measurement period consists of 2 very different years (how is this exactly known?). The authors should perform at least a simple uncertainty analysis using both n-factors, and some values in between, and discuss the differences in the results.

c. Treat the uncertainties arising from generating historic air temperature series. Uncertainties come from interpolation in space and time, linear regression, etc. This should at least be discussed qualitatively in the discussion, if quantification is not possible.

d. Discuss the uncertainties due to the simple modeling approach, i.e. neglecting processes (advection for example).

e. What influence on the (historic) model results has the fact that during the validation period (2008 – 2010) the model is run with daily temperature values, and before 2008, with monthly data? The authors could quantify this by running the model with monthly data for 2008 – 2010, and comparing to the results.

3. Calibration and validation periods consist of 1 year each (except at PACE). It is unclear how the model is calibrated and validated (except for the n-factors, where the calibration, validation process is described). Give more detail of the calibration procedure/methods used, and the time period for calibration/validation. The calibration time period must be independent from the validation period. It is unclear whether the two periods were separated completely, and thus difficult to trust the validation results. Note that the time period of the data availability is very short for such large extrapolations in time, please discuss that further.

Minor comments:

Some further minor comments can be found in the attached PDF, where they were directly inserted into the text.

1. The structure of the paper should be improved:

SECTION 2: Subsection 2.3.1 is not necessary, since it treats both permafrost and seasonal frost conditions at all location (i.e. put the content of 2.3.1 in 2.3, such that 2.3 has NO subsections). Subsection 2.3.2 does not belong to Section 2.3 (permafrost conditions), it can rather be included in Section 3.2 (Model initialization and boundary conditions) or 3.4 (Historic and future temperature data). Subsection 2.3.4 could be included in Section 2.2 (Climate conditions).

SECTION 4: Section 4.3 (Future permafrost development) could also contain two subsections 4.3.1 (Ground temperature) and 4.3.2 (Active layer thickness). Thereby the

structure of Section 4 would be more consistent (similar to 4.2).

SECTION 5: We would suggest a section 5.1 (Model uncertainties), and then some subsections 5.1.1 (Snow cover and water content variability), 5.1.2 (Climate change scenarios). Include further uncertainty chapters (see major revisions).

2. Be consistent in the notation: use either italic or not when using abbreviations (and don't switch from one to the other). Please check that abbreviations are defined when they first appear in the text (excluding the abstract). Check the spaces used in the units.

3. English grammar, syntax and semantic of the text should considerably be improved to enhance readability and comprehension, and assure the correct logical meaning of the text. Some specific examples are given in the supplement.

Please also note the supplement to this comment:
http://www.the-cryosphere-discuss.net/5/C283/2011/tcd-5-C283-2011-supplement.pdf

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Interactive comment on The Cryosphere Discuss., 5, 811, 2011.