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The Cryosphere Discussions

Interactive comment on "Numerical modeling of permafrost dynamics in Alaska using a high spatial resolution dataset" *by* E. E. Jafarov et al.

E. E. Jafarov et al.

eejafarov@alaska.edu

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1. Getting the thermal ground properties right, is one of the most crucial points for successful modeling of subsurface temperatures. It therefore deserves more than five lines. Please specify: a) What are the physical variables provided by your basis data sets? b) How do you obtain the heat capacity, thermal conductivity and freezing depression from this basis information (which parameterization/classification is used)? For example, organic layers should be of crucial importance in Alaska, (how) are they included? Later, the authors describe an optimization procedure for AOL under "Sensitivity analysis". I think, the context between these two sections should become clearer, as they ultimately deal with getting subsurface thermal properties right.

To address this comment we added the following paragraph into the Methods section:

The thermo-physical properties (volumetric soil ice/water content, unfrozen water curve parameters, soil heat capacity and thermal conductivity, thickness of soil layers, etc.) for 18 ground temperature zones may be different and depend on many factors including surficial geology. The number of soil type classes we used in these simulations was 26 and each class had its own number of soil and bedrock layers with different thermal properties (e.g. peat, silt, bedrock, gravel etc). The multilayered soil columns were assigned for each of soil class according to the Modified Surficial Geology Map of Alaska (Karlstrom et al., 1964). The thermo-physical properties were assigned to each ground mineral layer according to surficial geological (soil type) class. The model was calibrated against the ground temperature measurements from the shallow boreholes, which were specific for each soil class and geographical location (the method used and its limitations were described in more detail by Nicolsky et al. 2007). Organic layer in the model was introduced as a separate layer(s) which could be added at the top of mineral soil column. For upper organic soil layers we used the data obtained from the numerous field observations and Ecosystem Map of Alaska from the National Atlas of the United States of America [http://www.nationalatlas.gov]. To further optimize the number and the thermal properties of the organic layers we developed an algorithm described in the Optimization of ground thermal parameters section.

For freezing point depression, please, see the response for p95 comment.

2. language: please go through the manuscript, and check the articles before the nouns. There are a lot of places, where the article is missing, e.g. p. 104, l.24ff: “However, the bias in THE climate model simulation of precipitation still remains high, THE correlation between GCMs and observations is ..” Also, check the language in general.

This time we gave the revised manuscript it to a larger number of internal reviewers. All the sections were reviewed by native English speakers, necessary corrections were made.

Minor comments: p. 90: l.8 ff: “Input parameters, ...” awkward sentence, please rephrase. The sentence was edited and split in two: The model input parameters are spatial datasets of mean monthly air temperature and precipitation, prescribed thermal properties of the multilayered soil column, and soil water content. These parameters are specific for each soil class and geographical location.

l. 14: Why are your results “preliminary”? Typo, removed

l.19: CALM must be explained when mentioned for the first time. done

p.92: This section is too detailed for the Introduction. It should be deleted or moved to the corresponding sections. We agree. We reorganized the introduction section, the extra information was removed where not needed.

p.93: 1.1: I would include this part in the Introduction, not in a specific section 1.1. We agree. The subsection was moved as paragraph into the Introduction section.

p.94: Eq.1: It should be indicated somehow that the time dependence in H is actually contained in “t”. H depends on temperature ’t’ and depth ’x’; where temperature depends on time ’tau’. It is the most common notation for that formula. For example, the sntherm89 snow model uses the same notation when they deal with heat flow within snow (https://webcam.crrel.usace.army.mil/SNTHERM/)

Eq.1: be consistent with the use of the gradient/divergence operators. Either “div ... grad”, or use the del/nabla operator twice. Since you are in 1D, I find it even preferable to use partial derivatives. We agree. We changed the notation to partial derivatives.

l.20: volumetric unfrozen water content is unitless. It is a fraction of 1. We changed the unit and added additional explanation on the formula in the Mathermatical model section

p.95: Eq. 6: There must be a relation between t*, a, and b in order to make the function continuous at t*. So, one parameter is redundant. There is a relation, t*=(1/a)ˆb. We added it into the corresponding section.

p.97: l. 7: initialization: I like that approach!

l.13: see major comment on ground thermal parameters We added the additional information in the Methods section.

p.99 l. 9: Better: “Fig. 5 demonstrates that measured and modeled temperatures agree within 1 degree”. Done.

p. 100: l. 11 ff: It should be mentioned in one sentence that the agreement for ALT is not optimal. I fully agree with the following discussion of the reasons. This highlights again how important a proper documentation of the employed data set for subsurface properties is (see major comment), as future progress in AL modeling will mainly depend on improved data sets. We agree with this comment. We stressed that, by specifying that uncertainties came both from modeling and measurements.

p. 102: l.13: “If assigned ...”: please rephrase done

p. 101: 5 Model sensitivity analysis: I don’t really think that it is a sensitivity analysis what the authors describe here. Rather: Optimization of ground thermal parameters. Thank You for the suggestion. We renamed the Sensitivity Analysis section into the “Optimization of ground thermal parameters”

p. 103: l. 6: emphasizes done

p. 105: l.4: replace high order by strong replaced

l. 18: How would you include the effect of the forest fire in such a model? Especially, based on which data set/information would you determine when (or with which probability) a forest fire occurs? This response was not added to the manuscript. The stochastic fire generation model can be used to generate the forest fire. For example ALFRESCO SNAP model (http://frames.nacse.org/7000/7132.html, and Modeling the Impact of Black Spruce on the Fire Regime of Alaskan Boreal Forest T. S. Rupp, A. M. Starfield, F. S. Chapin and P. Duffy) . Based on the severity of fire we can identify how much of organic layer is burned. In the model we could remove the organic layer to some depth or entirely in case of sever fire. Later, we can add re-growing organic layer on top of the soil column.

p. 106: l. 9: Is there any indication in literature, that convective heat transfer through ground water movement could play a role on such large distances as 1km? If yes, please cite!

Good point. Thank You. We rephrased the sentence. However, for modeling watershed areas with grid resolution substantially finer than 1km, the convective heat transfer by ground water movement, most likely, needs to be taken into account. There is a reference, but it is not the exact one, so we did not include it in the manuscript. Rowland, J. C., B. J. Travis, and C. J. Wilson. 2011. The role of advective heat transport in talik development beneath lakes and ponds in discontinuous permafrost, Geophys. Res. Lett., 38, L17504, doi:10.1029/2011GL048497) talks about how ground water movement might affect the thermal state of the ground.

l. 11: The first step might be to have a 1D hydrological model to improve the annual dynamics of soil water contents and thus subsurface thermal properties. I'm not sure whether a 3D- hydrological model on a 1km grid would make much sense in many areas, considering the strong variability on much smaller distances. And again, such a model is only as good as the subsurface data sets that flow into it.

We agree. For a regional modeling, coupling the GIPL model with 1D hydrological model could add the dynamics to the soil water content which would affect the ground temperatures through its thermal properties. For modeling watershed catchment, or thermokarst like features 3D hydrological model, probably, will be more appealing to use.

p. 117: How many of these boreholes were used to infer the initial temperature profile for the different geothermal zones? Is it possible that part of the good agreement (especially for deep temperatures) is due to the initialization with measured data from these boreholes?

We analyzed the ground temperature profiles (boreholes ground temperature distribution is available online at Geophysical Institute Permafrost Laboratory and CADIS websites, [www.permafrostwatch.org, www.aoncadis.org]) in more than 25 relatively deep boreholes from 29 m to 89 m in depth (Osterkamp & Romanovsky 1999, Osterkamp 2003) along the Trans-Alaskan transect. We also performed a model spin-up before doing the actual runs. The good agreements are mostly due to a correct setup of the ground thermal properties including organic layer and less to the initial temperatures.

p. 121: I have trouble seeing the difference between the two figures. Maybe better one map for temperatures with additional organic layer, and one map showing the difference? Thank you for your suggestion. We introduced the difference between two maps: with and without additional organic layer. See Figure 10.

p. 123: Can you draw a smoothed 0 degree-iso-lines in the maps? This would increase the visual impact of this important figure. It is hard to draw smoothed 0 degree-iso-lines due to fine resolution and a small scale of the maps.

p. 124: Although clear, the abbreviations BR, HV, etc., should be explained in the figure caption. done. Thank You

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Interactive comment on The Cryosphere Discuss., 6, 89, 2012.