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Geoscientific Model Development Discussions

Interactive comment on "Evaluating the performance of coupled snow-soil models in SURFEXv8 to simulate the permafrost thermal regime at a high Arctic site" *by* Mathieu Barrere et al.

Anonymous Referee #1

Received and published: 24 April 2017

This paper evaluates model skill in reproducing snow and soil characteristics at a permafrost site in Canada. At this site, a variety of in-situ data were retrieved: snow height, snow stratigraphy, temperature, and conductivity. The aim of the study is to find out how good a coupled soil-snow model is at reproducing the transient temperature signal at this site, during two consecutive seasons (2013-2015). Model runs have been performed with the Crocus snow model and the ISBA soil model. Sensitivity experiments are performed one snow property and several soil properties. In addition, the simpler ES snow model has been included, for comparison.

I think this study identifies important shortcomings in these snow models, some of which will apply to other models as well. The article is well structured and contains material that complements existing studies with Crocus. Unfortunately, the paper is not particularly well written and tends to 'jump to conclusions' which undermines its academic quality. I recommend publication after the following issues have been addressed.

Major comments

The paper is too long in general. I believe it should fit on $\frac{3}{4}$ of the current number of pages. Leave out unnecessary sentences, e.g. only summarize site instrumentation, and refer to full discussion in Domine (2016a). Rewrite long sentences. More use of academic language which is shorter. Focus on main results. Suggest to combine Results and Discussion. Perhaps make two new sections out of those: (1) Snow model results and (2) Soil model results.

Grammar: the paper could have a better use of linking words to create flow and thus make it easier to read. There are grammatical errors that need to be fixed before publication. I listed some at Specific Comments but I did not aim for completeness.

Suggest to present the experiments in a table, instead of in the text. This would make them easier to refer to and would help to clarify the text, e.g. Sect. 2.3. Then, introduce the experiments earlier in the text, e.g. 'litter' on page 7 line 1, 'SOC' on page 7, line 8-14, 'wind' on page 8, line 8 . What confused me at first is that the additions are additions with respect to other experiments, not 'base'. It would be great if this could be made more clear.

One of the main results is Figure 3, that shows that snow density is not well reproduced by the models. It is hypothesized by the authors that this is due to a missing process: upward vapour fluxes. Yet they have no run with this process included so they cannot conclude that this process is fully responsible, only partially, or not at all. The abstract is therefore misleading (Page 1, line 20-22) and should be changed.

On page 8 line 8 the authors explain that compaction by drifting snow can now reach up to 600 kg/m3, compared to 350 kg/m3 before. The argumentation for this change is anecdotal ('we observed densities of 450 kg/m3'). Should the reader therefore regard this change as just a sensitivity test, rather than a real physical process that was misrepresented? Moreover, doing this you may be compensating for other biases / missing physics in the model, such as the missing upward vapour transport, and, my hypothesis, early melt and refreezing? This potential caveat is not discussed.

I guess the goal of simulation 'wind' is to simulate a hardened top wind slab. Rather than changing the upper limit to 600 kg/m3 in simulation 'wind', would it not be more effective to decrease the characteristic time scale in the drifting snow compaction (parameter Tau in Vionnet, 2012)? Looking at Figure 3, I see none of the model results exceed 300 kg/m3 at the top, so I wonder if 600 kg/m3 is ever reached at all.

In Figure 3, density in May 2014, the 'wind' experiment simulates lower density at the top than the others. This is counter-intuitive, as you would expect always higher densities in this simulation. Could you provide a possible explanation to why this is?

The analysis of snow temperature completely omits the effect of latent heat by rain and meltwater refreezing. What do the authors think is the importance of refreezing on temperature and how do the models simulate this?

Another key result is Figure 5, that shows that a simple density relationship for thermal conductivity is not sufficient to reproduce most observations. That said, it does not deserve the qualification 'totally inappropriate' (P18, L30).

P17, L5-6: the effect of missing effect of solar zenith angle is stated like a fact. Yet you have no results or reference to support this. Make clear that this is a hypothesis, not a given fact.

The two previous comment exemplify a general critique that I have on this article: the wording is not precise enough. In the article, there are sentences without such modi-

fiers that read like facts, but are in reality claims or beliefs of the authors. This must be addressed in the final version.

The authors do not mention whether the model changes they did (litter/SOC/wind) have officially been incorporated into SURFEX.

Specific comments

P1, L19: soil and snow thermal regime. Simulated soil and snow properties.

P1, L20: compared with → compared to, add comma after 'temperature'

P1, L21: suggest to change 'erroneous' to 'unrealistic'

P1, L29: climate change.

P2, L31: ES is introduced as an intermediate complexity snow model. I would classify this as a simple (yet, multilayer) model, whereas Crocus is of intermediate complexity. A complex model is SNOWPACK (Lehning, 2002).

P4, L30: snow pits are two words

P5, L12: SURFEX v8, as in title?

P5, L11: why did you not do bias correction on the radiation data?

P8, L8: 'we increased this value to 600 kg/m3' → only in simulation wind!

P9, L8: models not model

P9, L28: units of thermal insulance are m**2 K / W , see your Figure 7. Units of thermal resistance are K/W. Rename to insulance, or change units to K/W.

P10, formula 5 and 6: parts are missing

P10, L20: this made me wonder, does SURFEX have a representation of snow cover fraction?

P11, L1: Snow height was not well reproduced in 2013-2014 so a 30% reduction to precip has been applied in the model runs. The authors do not discuss the phase of precip. Did you experiment with the temperature threshold for snow?

P11, L2: “in good agreement with the snowpits”. How about automatic gauge?

P11, L6: “it seems to be “ is not academic English

P11, L12: I’m missing the causal relationship here. Restate like belief or hypothesis.

P11, L30-31: suggest to restate: this partially compensates for the underestimation of density in the upper layers

P12, L5-6: why is the mean density in ES higher than in Crocus? Is this due to the discretization only, or are there differences in the physics?

P12, L9: Suggest to restate: thermal conductivity is primarily controlled by density.

P12, L25: ‘gross’ is not academic English.

P13, L9: suggest to start the sentence with ‘In winter, . . .’

P13, L21-22: suggest to move this to Methods.

P13, L23: unclear

P14, L14: unclear

P14, L17: spelling error ‘sate’. Suggest to check entire Latex document using aspell.

P15, L1: ‘which confirms’ too strong?

P15, L7: warm temperature -> high temperature, ‘and at the’ → ‘at all’

P15, L20: suggest to change ‘It is because’ to ‘This is attributed to’

P15, L27: R^2 is used, yet Table 1 lists R.

P16, L7: suggest to remove ‘but’, and start sentence with ‘Although’

P16, L22-26: discusses temperature, not soil water content.

P16, L29: suggest to drop ‘important’

P16, L31: suggest to drop ‘considerable’

P17, L1-3: need reference

P17, L5-6: need reference or rewrite.

P17, L8: move TARTES discussion to Methods.

P17, L17: maximum snow density reached by drifting snow

P17, L22: ‘main factor influencing soil properties’. Do you mean thermal and/or hydraulic properties?

P17, L28: suggest to change ‘increases’ to ‘enhances’

P18, L19: suggest to use ‘ERA-Interim’, not ‘ERAi’

P19, L2: provide reference to SNOWPACK, Lehning et. Al. (2002)

P19, L12: Crocus is no longer ‘most sophisticated’. It is intermediate complexity.

P19, L15: to GCMs

P19, L19: Figures.

P22, L6: Reference Elberling et al. should start on new line.

Figure 7: units for ksnow are misspelled. Suggest singular form in caption (snow height, thermal conductivity). Rename resistance to insulance.

Figure 9: Depth has positive value in the soil. Switch to height if you prefer negative values. No model output between 10 and 20 cm depth, why not include all points that the model has?

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