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Interactive comment on “Simulated single-layer forest canopies delay Northern Hemisphere snowmelt” *by* Markus Todt et al.

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This document contains comments by reviewers (regular font), **responses to reviewers (bold)**, and *citations from the manuscript (italic)* including additions to the manuscript (blue).

Reviewer 1 Comments:

...However, the validation of the proposed improvements is not clearly demonstrated,

using for example independent external database such as Globsnow2, including daily snow cover extent evolution, and/or MODIS snow cover products.

It is true that a validation of the impact of corrected sub-canopy longwave radiation on snow cover and/or snowmelt had not been part of our initial submission. We included comparison of meltout between simulations and a state-of-the-art snow water equivalent product in this revision, which revealed a general delay of snow-off dates across boreal forests in simulations. Correction of sub-canopy longwave radiation was found to decrease this bias.

A blended data set of five global observation-based SWE products (henceforth, Blended-5) covering the period 1981 to 2010 (Mudryk et al., 2015) was used to estimate snow-off dates across the Northern Hemisphere and evaluate simulation of snowmelt in CTRL and CORR. In contrast to simulations, observations display snow persisting for physically unrealistical durations, which necessitates a SWE threshold to estimate snow-off dates (Krinner et al., 2018). While Mudryk et al. (2017) and Krinner et al. (2018) used thresholds of 4mm and 5mm, respectively, for estimates of spatial snow cover extent, a smaller SWE value was necessary to represent the precise timing of meltout within individual grid cells. A threshold of 1mm was used in this study to define meltout for the Blended-5 mean, and snow-off date was defined as the first day of a year for which SWE did not exceed this threshold. Sensitivity of snow-off dates to threshold values was tested for the range 0.5mm to 4mm, however, the overall conclusions of this study are unchanged for different thresholds.

Simulated and observed snow-off dates are compared in Fig. 10 for grid cells with consistent snow cover throughout preceding December and coverage by evergreen needleleaf trees of at least 50%. Simulations CTRL and CORR generally feature a narrower probability density function (PDF) of snow-off dates, indicating a shorter snowmelt season, and later meltout compared to observations across the entire Northern Hemisphere (Fig. 10a). While shapes of observed PDFs are well represented by *simulations over Eurasia (Fig. 10b, d), observations show a clearer, shorter peak of meltout compared to simulations over mountainous western North America (Fig. 10c). Correction of sub-canopy longwave radiation displays little impact when accumulated over the entire Northern Hemisphere, however, it systematically reduces the delay of simulated snow-off dates throughout the snowmelt season. PDFs of snow-off dates for regional subsets reflect spatial patterns seen in Fig. 7h, with minor differences between CTRL and CORR over most of western North America (Fig. 10c) and eastern Siberia (Fig. 10d) but substantial acceleration of snow-off dates over western Siberia and eastern Europe (Fig. 10b) due to correction of sub-canopy longwave radiation.*

The regionally limited impact of corrected sub-canopy longwave radiation is highlighted by filtering PDFs of snow-off date for grid cells with average differences in snow-off date between CORR and CTRL of at least 3 days (Fig. 10e, f). Correction of sub-canopy longwave radiation improves timing of meltout in filtered grid cells, especially over western Siberia and eastern Europe where the filtered PDF for CORR, in contrast to CTRL, closely resembles observations. PDFs of snow-off dates derived from Blended-5 SWE display sensitivity to threshold choices, however, this uncertainty is generally smaller than differences between simulations and observations.

For the near future for validation and/or assimilation, the authors could mentioned the new radar Sentinel datasets that allow to monitor the wet snow evolution through open forest canopy (Small, David; Rohner, Christoph; Miranda, Nuno; Rüetschi, Marius; Waser, Lars; Vögtli, Marius; Schaepman, Michael E (2018). Level 3 wide-area backscatter time-series for wet-snow mapping and forest classification. In: EGU General Assembly 2018, Vienna, 8 April 2018 - 13 April 2018.). For closed forest area, the uncertainties seem still important?

Thank you very much for this suggestion! We did not know about this recent development.

Please clarify how you estimate the “Longwave enhancement” parameter?

Values for longwave enhancement are calculated as the ratio of below-canopy to above-canopy longwave radiation. As this is stated in the introduction, we did not take any action.

Why do you differentiated day to night sky emissivities? (Fig. 3 d and e)

We initially tried to create a correction for both daytime and nighttime sub-canopy longwave radiation, but found that one set of regression coefficients led to unrealistic variations in sub-canopy longwave radiation around noon as well as to inconsistencies in sub-canopy longwave radiation at sunset and (mainly) sunrise. Calculation of separate regression coefficients for day and night resulted in smoother transitions of sub-canopy longwave radiation between day and night, and one potential reason for this is the impact of topography during low solar elevation, especially at (sub-)alpine sites Alptal and Seehornwald. Note that daytime regression coefficients would yield different correction factors for zero insolation than nighttime regression coefficients do, which might be due to other variables also governing deficiencies in simulated sub-canopy longwave radiation as our corection only explains 60% of variance in simulation errors. However, correction reducing diurnal ranges in sub-canopy longwave radiation does not depend on separating daytime and nighttime regression coefficients.

Which ground (or snow?) emissivity value do you consider?

CLM4.5 calculates ground emissivity as a weighted sum of emissivities of snow (0.97) and soil (0.96), weighted by the fraction of snow covering the grid cell.

This has been added to the description of equation (4).

...with emissivity of the ground ε_g *and temperature of the ground* T_g. *Ground emissivity in CLM4.5 is calculated as a weighted sum of emissivities of snow (0.97) and soil (0.96), weighted by the fraction of snow covering a grid cell.*

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