Review on
On the influence of erect shrubs on the irradiance profile in snow

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Short summary

The authors describe measurements and model results of snow properties and light extinction is snowpacks in Nunavik, Northern Quebec, Canada. The two main findings are (1) black carbon, and not mineral dust, dominates the light extinction within snowpacks without shrubs and (2) buried shrub branches influence radiation extinction in snow locally.

General comments

This study and its major findings are well supported by a high quality dataset. The findings are interesting and relevant although a quantification of the branch effect would have been desirable. Independent estimates of black carbon content from a laboratory analysis would also help in further studies. The paper is well written and includes all information needed to understand the results.

My major comment is, that the paper would greatly profit from a separation of the results and the discussion section (both new sections structured in the same subsections). I think that in this way, it would be easier for the reader to distinguish between new results and older references and general findings. The following paragraphs can be moved to the discussions almost as they are: lines 51–91, 367–372, 401–410, 469–472, 504–519, 525–527, 529–553, 567–587. Furthermore, I am missing some interesting discussion points that could be included in the new discussion section:

Microtopography Does it affect your results that your measurement sites were situated on a wind-exposed plateau (lines 114–115)? Snow properties are likely different between sheltered valley locations and plateaus, even without shrubs.

Weather conditions Did the weather conditions influence the results (lines 156–157)? Can the reduced quality of the profiles on 23 November be attributed to shadows on the snow?

Spatial heterogeneity I assume that even without shrubs, and definitely with shrubs, the snowpack is highly spatially heterogeneous. Did you do additional irradiance profiles not accompanied by snow pits (which are much more work)?

ZOI3 and ZOI4 Please add some discussion on why ZOI3 and ZOI4 do not seem to support your main conclusion that black carbon is more important than mineral dust (Table 2).

Non-local effects Although radiative heating of branches buried in the snow have a mostly local effect (as you write), I think it would be good to discuss also possible non-local effects such as percolating melt water.

Effect size I understand, that it is difficult to quantify the effects of buried branches if the BC concentration is unknown. However, I would like to read some discussion on that topic. Maybe, you can also add a (very rough) estimate based on simplified assumptions? You write the effect is "weak" in abstract and conclusion, but it is not clear to me why.

As second general comment I would suggest to reduce the total number of figures while increasing the figure content as described in detail for each figure below. Figure quality could easily be improved with bigger fonts and joint axes for multiple panels. Please use pdf as figure format (in every step of saving the figure) and not a pixel graphic (except for pictures) to avoid blurry text and allow the reader to zoom in.

Specific comments

Short summary (online) The short summary only includes the branches and not the black carbon results (which are also interesting).

47–49 Please add another reference. Pelletier et al.,2018 do not discuss the light distribution in snow, rather snow depth in general and the formation of depth hoar.

Introduction The introduction is very informative but a bit too long. I suggest to move parts of lines 51–91 to the (new) Discussions section and remove detailed methods from lines 92–105.

Figure 1 I find it hard to compare the two different datasets as the y-axis is very different and the grid does not match both axis. Please compare reflectance of branches with reflectance of clean and dirty snow and show absorption of different particles per meter of snow in a second panel.

115 Are all sites on the "wind-exposed plateau", even the sites with taller shrubs?

Table 1 What do you mean by "average snow height"? As far as I understood, these are 7 snow pits with one snow height each. Did you measure snow height and shrub height at multiple points in the pit? If yes, please do not only show mean values but also the variability. In the current table it is a bit confusing, why shrub height changes that much between the dates. Furthermore, I would like to see whether shrubs protruded the snow at all times and shrub sites or whether they were sometimes completely buried. Please also include the weather conditions during the radiation measurements. Please highlight the names of the layers analysed in your paper (like ZOI1, BRAN4) in this table.

Figure 3 Which ZOI is this?

Methods It would be very helpful to see pictures of the measurement sites and landscape. Maybe this could be a second/third panel in Figure 2.

Figure 4 What is AFEC? Please avoid new (any) abbreviations in figures. Figure 4 (a) is the same as Figure 7 (a). As Figure 7 is much more comprehensive, I suggest to add the additional line of Figure 4 (b) into Figure 7 (a) (in a different colour) and omit Figure 4. Also the other panels of Figure 7 could profit from an additional line showing simulations with mineral dust. Especially ZOI3 and ZOI4, which reveal similar/better results when including dust instead of BC. R^2 and RMSE can be omitted from the figure if you refer to Table 2.

Table 2 Why are ZOI3 and ZOI4 separated by a line? In this table ZOI3 stands out as the fit with mineral dust is almost as good as the fit with black carbon; for ZOI4, only dust is even better that BC and the estimated BC concentration is very low. This was not mentioned in the text. It would be good to also show these examples in Figure 7. Please include this and the possible reasons in the discussion instead of just saying "Therefore, from now on we will assume that BC is the dominant impurity type for the remainder of this study." (lines 366–367)

Figure 5 Please increase the font sizes. As all three panels have the same axes, it would be good to place them all in one row with joined y axis. this would save a lot of space and facilitate the comparison. I think it would be good to include results from the fit with dust in panel (c) as these ZOIs had a similar/better fit with dust than with BC. If the panel gets to busy with the additional information, you could add a fourth panel. I also suggest to combine this figure with Figure 6 in a similar way as Figure 7. In this way, it would be easier to compare extinction with and without branches.

Figure 6 Please increase the font sizes. As all four panels have the same axes, it would be good to place them all in two rows with joined y axis or x axis, respectively (the labels IMP1, BRAN1,... can be moved into the plot area). In this way the size of the panels can be increased while the complete figure does not need more space.

496–497 What about IMP1? It also seems to diverge.

498 R^2 is always between 0 and 1, R ranges between -1 and 1. Did you confuse it with another variable? I assume that R^2 is Pearson's correlation coefficient (standard naming convention). This should be specified in the methods.

Figure 7 The writing in this figure is too small and blurry. Please use joined the axes to allow bigger panels. Are the spectra averaged over the complete layers? Please also show ZOI4, IMP4, BRAN2 and BRAN3. I understood, that those were to noisy to perform calculations, but still I find it interesting to compare them visually to the other spectra. R^2 is always between 0 and 1, what are your numbers of IMP3 and BRAN1? Maybe remove the R^2 and RMSE from the figures and include them in Table 2.

500–501 "..., calculated values can fit the observed values less well than a horizontal line (= the null hypothesis) which results in R^2 values below 0." This is a strange interpretation of the R^2. R^2 cannot be negative as it is squared (and you work with real numbers, I suppose). Negative values of R indicate that the dependent variable decreases if the independent variable increases and vice versa. A value of $R = -1$ is a very strong relationship and not a poor fit. I do not understand your comment about a horizontal line. This seems impossible as k_e varies as a function of λ.

454–455 & 488 You write that IMP4 and BRAN3 had a worse quality ("log-irradiance profile was less regular", "signal-to-noise ratio was too low"). As shown in Figure 6c, IMP4 and BRAN3 were measured under sunny conditions. Would that be a possible explanation of the decreased quality of the profile measurements? I imagine that branches above the snow cast irregular shadows which influence the irradiance profile in different depth as compared to your reference sensor. By the way, was the reference sensor located above or below the branches? Please include the profiles in Figure 7, add information on the weather to Table 1, and discuss the effect of direct sunlight and shadows in a (new) discussion section.

525–532 You describe the heating effect as very local. However, I wonder what happens to the melt water. If the water percolates through the snow and refreezes in different parts, this would lead to a significant transfer of energy to deeper layers of the snowpack. Please discuss such non-local effects!

529 "broad" seems the wrong word. I think "non-local" would be more precise.

Figure 8 Panel (c) does not seem to fit the message of this figure. It looks like a branch on a tree above the snowpack. In this case, wind can also remove snow, not only localized melting. Maybe remove that panel (or explain it in more detail).

567–587 The (new) discussion section could start (rather than end) with this part, as results on BC are also shown before results on branches. It can also be merged with lines 401–410 and 367–372.

594–596 State briefly the possible implications of dirty Arctic snow.

596–597 Do not devalue your own study. You found important indications. Of course you can suggest further research, but rather in a positive phrase like: "Based on our results, we suggest further research on the regional and long-term importance of waste management in Arctic regions."

598–604 Some more implications of your results would be good here. Maybe you can mention (again) the snow insulating properties and their importance for permafrost/flora/fauna?

598 How come you classify the effect as "weak"? As far as I understood, you were not really able to quantify it. The estimated BC concentrations (especially at BRAN4) may be much higher that the "true" BC concentrations as, in the model, they include the branch effect at $400–450\,\mathrm{nm}$.

605–608 This does not seem to justify the co-authorship of F. Domine and L. Arnaud.

References Please add the missing DOIs. The poor formatting of the references makes it hard to find details on papers.

Figure A1 Is Layer L1 the same as ZOI1? Please use consistent names and bigger fonts. The figure is a bit lost here in the appendix. How about combining it with Figure 3 (using the same example, of course)? Please change the word "plots" to "lines" ("red lines" and "black lines").

General It would have been more convenient if you used hyperlinks so I could click on the references and links.