

# ***Interactive comment on “The growth of shrubs on high Arctic tundra at Bylot Island: impact on snow physical properties and permafrost thermal regime” by Florent Domine et al.***

**Florent Domine et al.**

florent.domine@gmail.com

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Responses to Reviewer 1

We thank the reviewer for his time and useful comments, which allowed to improve the manuscript. The reviewer’s comments are pasted below, labelled as comments (C) with our responses imbedded in the text and labelled as Response (R).

(C) General Comments: an initial section evaluating the overall quality of the discussion paper

(C) The Conclusion section is informative and validates the contribution of this study. Questions 10 and 13 in the review criteria are the only two that give me pause with

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regard to this paper. There are too many results, principally from the simulation modelling, presented in the Discussion section, and some material that seems appropriate for the Discussion section is currently placed at the end of the Results section.

(R) We have extensively reorganized the manuscript as detailed below.

(C) There is also not enough discussion on the opposing effects of shrubs on temperatures during the winter and summer. Given that this study is put in the context of changes to permafrost, the authors should consider summer effects at greater length. I have recommended two particular studies that are a reasonable starting point for this expanded exposition. Nonetheless, I do think that there is enough new information in this study to warrant publication after some rearrangement and extension of the discussion of alternative processes controlling permafrost dynamics.

(R) Thank you for these extra references, which we now discuss, as detailed below.

(C) Specific Comments: a section addressing individual scientific questions/issues

(C) Lines 44-45: Similar to my comment below, explicitly connect snow thermal properties to changes in soil temperatures. Read the final discussion section of Lantz et al. 2013 Ecosystems and also look at Blok et al. 2010 Global Change Biology for the counteracting effects of winter and summer processes.

(R) We have reorganized the introduction, and transferred there equations that were further down in the manuscript (lines 46-54). We believe that this explain in more detail the connection between snow properties and ground temperature. We now discuss thermal effects and the differential effects of winter and summer in the discussion, with reference to the works kindly indicated. The works of Lantz et al. and Blok et al. are mentioned in the introduction (lines 87-94) and discussed in detail in section 4.4 of the discussion (lines 423-438). On that occasion, we also discuss summer processes in more detail, and this includes effects of different vegetation covers on albedo, hydrologic regime and thermal properties (end of section 4.4).

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(C) Lines 80-81: I'd like to see you expand more clearly make the case for why "snow physical properties" are critical to relationships between shrubs and ground temperature.

(R) Towards the beginning of the introduction, we have explained with equations why changes in snowpack thickness and snow thermal conductivities were expected to lead to ground warming. The equations were initially in the discussion.

(C) Lines 81-88: Questions that are not explicitly addressed in this study would be better placed in the Discussion and expanded upon there. It is currently unclear exactly which questions are the focuses of this study.

(R) Lines 100-106, we have listed all questions relevant to the shrub-snow problem. Lines 107-110, we now specify which ones of these questions were addressed with new data and which ones were just discussed.

(C) Lines 104-106: How much higher than other vegetation (e.g. graminoids) are the shrubs? In other words, how tall is the herbaceous vegetation? I think if you are going to list shrub height, you should also state the height of the other vegetation types.

(R) We have added that "Herbaceous vegetation seldom exceeds a height of 10 cm" line 124.

(C) Line 117: Was the probe inserted horizontally or vertically? Please explicitly state this.

(R) Horizontally, as now mentioned line 140.

(C) Line 182: Why was this not also done in the other two perpendicular directions? Was there any reason for thinking that winds that redistribute snow could not move along the slope rather than up or down it?

(R) As explained lines 207 ff "From the surface structure of the snowpack, prevailing winds appeared to have been across the valley, i.e. coming from the north or south in

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the valley oriented east–west.” Our thinking is based on our field observation of snow structure.

(C) Line 197: I would like to see data or a specific reference that indicates that 2014 was in fact a low snow year.

(R) We have provided a link to time series of snow height in the valley, in the NordicanaD data base (CEN, 2016), line 365.

(C) Line 274: Don't state that something is obvious, make it become obvious to the reader by explaining it thoroughly but concisely.

(R) We have replaced “obvious” with “striking”, line 396.

(C) Lines 271-280: Merge these paragraphs. There does not seem to be a good reason to separate them.

(R) Done.

(C) Lines 286-298: This entire last paragraph seems better suited to the Discussion section. If the authors feel it is most appropriate here, I would appreciate hearing their rationale.

(R) Indeed. In fact, the paper was significantly reorganized. A modelling subsection was created in the results section. Many paragraphs that were in the results section were moved to the discussion section. The discussion section was divided into 4 subsections for clarity.

(C) Discussion section: Much of the reporting from the model simulation exercise would be better suited to the Results section.

(R) Indeed, see response to previous comment.

(C) Line 391: The statement on location and ecosystem context being critical would be more easily accepted if it were supported by a reference.

(R) We thought it was clear we were talking about the work of Myers-Smith and Hik (2013), mentioned just one line above. The line after, we specify the vegetation type.

(C) Lines 400-402: As above, see Lantz et al. 2013 and Blok et al. 2010. This statement on lower thaw that is contrary to the conclusions of this particular study seems to be of vital importance to the general context that this work is supposed to inform.

(R) This is now discussed in detail in the discussion. In particular, the surprising conclusion of Blok et al. is critically examined and we conclude that “It therefore seems highly uncertain that the manipulations of Blok et al. based on shrub removal, allow conclusions regarding the impact of growing shrubs on the permafrost energy budget.” Lines 437-438.

(C) Line 402: Did the authors actually observe moss to have increased in abundance under shrubs, or was it simply that the authors observed frequent co-occurrence of mosses and shrubs? In other words, is there evidence for making this sound like a causal statement?

(R) We replaced “moss had grown” with “moss was present”. It is just an observation with no implication of causality. Line 434

(C) Figure 1: It would be tremendously more useful to simply show the location of Bylot Island in the Canadian Arctic as an inset in the figure, which should be a map showing the locations of the sites within Qarlikturvik valley.

(R) Agreed. Figure 1 has been completely changed to respond to this request.

(C) Figure 3 caption: If you know the location information (site, bush) for these pictures, include that information here.

(R) We have added that this was “near the “scattered willows 1” site”.

(C) It seems unhelpful to the reader that the authors switch back and forth from thermal

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conductivity (e.g. Table 2, Figures 5b and 7b) to thermal resistance (Figure 8).

(R) Thermal conductivity and thermal resistance are two different variables. A snow layer can be characterized by its thermal conductivity (Figures 5b and 7b) but a snow-pack needs to be characterized by its thermal resistance (Figure 8), which is calculated from the heights and thermal conductivities of all snow layers.

(C) Technical Corrections: a compact listing of purely technical corrections at the very end

Line 98: Allard and Gauthier 2014 is not listed in the references.

(R) We apologize. It has now been added.

(C) Line 137: Change to “not measured either” or otherwise correct the sentence.

(R) Sure, thanks for spotting this error.

(C) Line 389: Myers-Smith and Hik should probably be outside of parentheses.

(R) Sure. This is how End Note works. This is routinely fixed at the type setting stage.

(C) Line 414: remove comma after “snow density” and replace with “and”

(R) Sure, thanks.

(C) Figure 3 caption: Change to “enhanced with photographic modification software.”

(R) Sure, thanks.

(C) Figure 10: The main title of the plot should either be removed or cleaned up.

(R) Sure, it has been removed.

(C) Make sure to put a space between the semicolons when multiple articles are cited in the text.

(C) Also ensure there is a space between sentences, as this is sometimes missing

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(e.g. Line 58).

(R) This has been changed.

(C) Multiple references (e.g. Essery et al., Pearson et al.) should be checked for formatting.

(R) Yes. But again, errors caused by Endnote are fixed at type setting.

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