

# RC2

## Review of Thermal conductivity of snow on Arctic Sea ice

This manuscript describes the variation of the thermal conductivity of snow, its density and how it varies according to the type of ice it falls on based on the MOSAIC campaign. Snow on sea ice is still one of the more uncertain topics in the Arctic environment and with its large impact on the development of sea ice studies that improves the understanding of this are welcome. The MOSAIC campaign includes a large and valuable dataset, which has the potential of improving the understanding of the Arctic environment. That being said snow is difficult and the findings are accompanied with large uncertainties, which should be discussed more. In addition, some of the definitions are a bit loose. This is especially the case in the introduction. At last it would generalize the conclusions if additional data set were used or if parts of the dataset were used for calibration of the polynomial and other parts of the data set were used for validation.

Thank you for your valuable feedback on the manuscript. I have implemented all your suggestions and have made substantial changes to the introduction, discussion and conclusion upon receiving these comments and I believe the paper has improved substantially as a result of your help and comments.

I find that the manuscript needs some revisions and it should be read through and updated where language seems a bit rough as this makes it difficult to follow. This blurs the conclusion.

### Major

Leads are normally openings of the sea ice due to dynamics. What the authors mean is likely refrozen leads where new, thin ice is formed and snow has just started to accumulate. This needs to be specified more clearly.

Thank you for this suggestion, I have changed this throughout the manuscript

An increase in density until March can be seen, however the uncertainties are large enough. Is it statically significant? Sometimes it seems as if snow and ice are mixed up. This is a bit confusing.

We concluded that there was insufficient data to draw any conclusions about May, so we have excluded this from the manuscript. I have explained further in the manuscript when snow and ice are being analysed, I agree due to the nature of the dataset we have data for the complete range of snow - ice, however this isn't used consistently throughout the manuscript as sometimes we use thresholds, so I agree it was previously difficult to follow. Hopefully this is now clarified throughout the manuscript.

### General

Figure text should be the same same font all the way

I believe the same font is used, does this comment refer to the size? Please specify which figure you are referring to If I have not made sufficient changes to the re-submitted version.

Figures with multiple sub figures would benefit from nation such as figure XXa, XXb....

Thank you for this suggestion, I have added this to all sub-figures.

### Minor

line 6. This is related to the definition of leads. I don't see that leads are in the ice age category, thus the parenthesis is a bit misleading. I would rephrase this.

This is now changed to refrozen leads

Line 7 I would change dynamics to seasonal variation or something like that. I don't think that dynamics is the right word.

Thank you for the suggestion, changed dynamics to seasonal variation

Line 10: I would not call the thermal resistance constant when uncertainties for first and second year ice is that high.

Changed to "the average thermal resistance of snow on level sea ice remains approximately constant with substantial variability with values of..."

Line 12: I think that the uncertainties should be mentioned here as well as it seems, as there are snow on sea ice. The uncertainties are large and the thermal resistance of snow on ridges can be the same as the two other categories.

Added "with substantial spatial variability"

Line 13: I would skip the last sentence that starts with: "The implications of our findings...." It does not really fit into an abstract.

Thank you for this suggestion, I have removed the last sentence

Line 27-32 This describes heat transfer through snow, however ice is mentioned. I am not sure that it is intended.

Changed to "Snow's thermal conductivity and insulating properties directly impact heat transfer from the underlying sea ice to the atmosphere and directly inhibit ice growth in the winter season."

Line 35 remove "the". FEM is a general model not one specific.

Changed this throughout the manuscript, thank you for the suggestion

Line 38 a model do not measure it calculates.

Changed measure to calculate

Line 41: I think that short fall should be shortcoming.

Changed shortfalls to shortcomings

Line 44 please rephrase without parenthesis

rephrased

Line 46. Rephrase as "on a snow"

Rephrased to "realised the influence of temperature on the thermal conductivity."

Line 47 remove "," and replace with and

Reworded to “\cite{calonne2019thermal} created upper bounds to ensure that the thermal conductivity is in agreement with the thermal conductivity of ice at specific temperatures in the higher density ranges.”

Line 52 A faster method? Faster in what way?

Added: A faster method is needed (the  $\mu$ -CT on MOSAiC took 7 hours to measure 10 cm of snow).

Line 65 I would rephrase

Removed previously impossible

line 65 to we can draw new conclusions about the...

thank you for the suggestion

Line 68: Where does the  $\pm 0.01$  originate from. I assume that this is a constant.

This originates from the different values used in the models, change this to “value of 0.31 to 0.33”

Line 72 coordinates are listed as N/S. North and South. One of them should be E/W

Thank you for noticing this, I made a mistake with the coordinate system, which has now been changed.

Line 83. I did not think that the instruments are the focus of this study. It should be the snow properties.

Changed to “we analyse the MOSAiC snowpit”

Line 96 replace “to” with “in order to”

Thank you, changes made to the manuscript

Line 96 replace “,” with and

Change made to the manuscript

Line 110: it is not clear what kair and kice are used for.

This is the thermal conductivity of ice and air, which are the basis for the calculations of the thermal conductivity of snow,

Line 114 to 120: This section is unclear. There are more x values than a, b, c. A table might help.

Provided an overview table

Line 125: Ag? Is it assumed that the reader reads Löwe (2013) as well?

Ag is reference on line 96.

Line 129. Is SMP and SMP force the same?

The SMP is the instrument, the SMP force is the output. Rephrased this to “The snow micro penetrometer (SMP) instrument measures the penetration force resistance of a snow profile”

Line 132: Not sure what the sentence that starts and end in this line refer to.

Added "(more details of the measurement protocol can be found alongside the published dataset and datapaper \cite{macfarlane2021smp})."

Line 145: What is the current literature?

Changed this to "After testing the listed parameterizations in Table..."

Line 168 It is not clear what the first sentence mean. Is it only high density variability or also KFEM and Ak?

Re-worded this sentence

Line 170 to 171. The reference to KFEM seems to be inserted into a discussion on density. I think that this should be reorganized.

Reworded this to include density and Ak variability and the impact of this on KFEM values.

Line 180: cover all. I would rephrase to a wide range.

The ranges are now included in the text

Line 185. I assume equation 4. The parenthesis before Adapting due not have a start

Thank you for noticing this

Line 195: Is the seasonal variability significant compared to the uncertainty and variability of the measurements?

Included more details in this section about the averages and ranges of the data.

Line 208 Results in table 1 is mentioned but not really used.

I agree, I have now used a lot more data in the main text

Line 234 rephrase to avoid parenthesis

Removed parenthesis

Line 255 and ridges? This should be rephrased to its own sentence.

Thank you for this suggestion

Line 263: Any considerations on how the change of thermal conductivity would change the result of the models?

In general a lower thermal conductivity would increase ice growth in the winter season due to the snow cover being less thermally insulating, Merkouriadi (2017) is now referenced in the paper and they conduct a very interesting study on thermal conductivity parameterisation influence on ice growth.

Line 338: This article that the conductivity of snow is 0.32 in sea ice modelling. Is this Crocus and SNOWPACK? I don't think that any of these models are normally included in sea ice modeling.

Removed this section now as a result of previous suggestions, but thank you for this

Figure 1 Remove " We could simulate...using the FEM method Is the snow depth of each sample known?

Changed we could simulate to "we simulated". Snow depth is indicated in the figure through height from/to

Figure 7. Is there a dependency on the snow depth?

Due to the high variability within the snow profiles (seen in figure 1) there is no dependency of force on depth. We see a large influence of thermal resistance to snow depth, as mentioned in the previous sections.