

Response to Reviewer 2

Dear Dr. Andrea Vergnano,

Thank you for your constructive and positive comments! We found your suggestions regarding the difficulties of flipping between the supplement and main manuscript to be helpful, and have restructured our manuscript accordingly. Below, we provide detailed responses to each of your points (our responses are in blue).

Thank you very much for your time and expertise,

Kajsa Holland-Goon and Randall Bonnell, on behalf of co-authors

Dear authors, I had the opportunity to review your manuscript entitled "Brief Communication: Evaluating Snow Depth Measurements from Ground-Penetrating Radar and Airborne Lidar in Boreal Forest and Tundra Environments during the NASA SnowEx 2023 Campaign".

General comments:

In your work, you assess the lidar accuracy to map snowpacks in high-latitude environments, with a focus on boreal forests and tundra environments. You perform a comparison with GPR and manual excavation in several transects. The manuscript is clear and well-written, and highlights the importance of assessing instrument uncertainties in mapping the snow accumulation.

I am not a lidar expert; therefore, I do not comment on it. However, I performed GPR measurements in snowpacks. The GPR data collection, the instruments used, and the resulting radargrams are of good quality.

I appreciated your work because you highlighted the possible causes of the observed uncertainties, which I find very useful for further research. You do not always investigate in detail such causes, which you leave for future research, but I think that with the data you have, you could already extract more detailed correlations. Moreover, sometimes I found it a little difficult to follow your text, because the figures are in the supplementary materials, and I think that your manuscript lacks a figure in which you show the GPR radargram, the photomosaic and the lidar depth together on the same transect.

I do not find severe problems in the manuscript, but it may be improved if the relation between instrument uncertainties and their causes is discussed in more detail. I suggest the manuscript to be accepted after minor revisions.

Thank you for your review and suggestions. We particularly appreciated your review of the GPR component of our paper. We agree that flipping between the supplement and the main manuscript was frustrating and we have restructured our manuscript as a Research Article, instead of a Brief Communication. As such, we have moved supplemental figures and text to the main text, but propose keeping the tables in the supplement as those elements provide supporting information to the primary findings. Additionally, we have decided to revise Figures S1 and S2 to a single figure (now, figure 2 in the main text) that connects the physical features shown in the photomosaics to the associated reflections in the radargrams.

Specific comments:

Figure 1: Please, add a scalebar to panel f). Additionally, consider adding the location of Fairbanks in panel f), since it was mentioned several times in the text.

We have revised the figure and it is pasted below. Thank you for catching it.

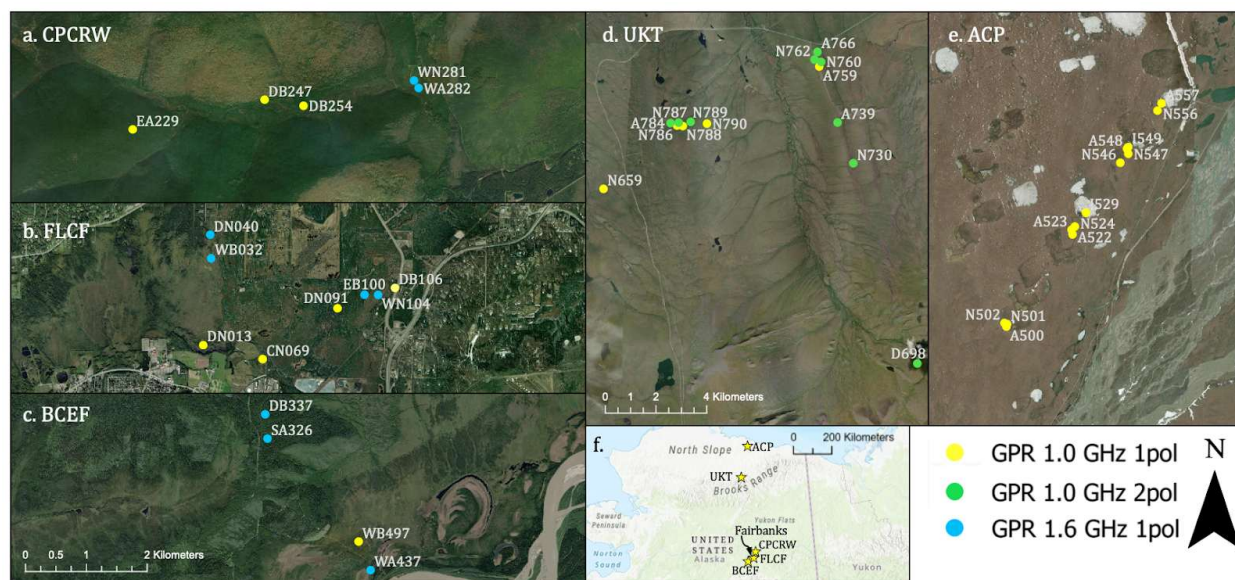


Figure: The updated field site figure for the main manuscript. Changes were made to panel f - we added a scale bar and the location of Fairbanks.

Data availability. Please, add a link to the NSIDC DAAC repository. Also, the fact that you put a part of data availability in the main text and a part in the supplementary material is confusing, in my opinion.

We have added links to each of the datasets listed in the Data Availability section and we have updated the availability section such that the supplemental materials match the main manuscript. Thank you for catching these issues.

Chapter S1 Ground-Penetrating Radar Systems and Methods: consider adding more details about which instrument was used in which site. Especially, one of the instruments (the GSSI one) had worse GPS positioning than the others. It would be important to assess if this introduced greater uncertainties in the GPR-lidar comparison.

Figures 1 and S3–S5 (now, figures 3, 5, and 6) note what instruments were used at each site. Additionally, we have added GPR system information to supplemental tables S2–S4.

Of the boreal forest transect surveys performed *after* the lidar surveys, three were collected with the 1.0 GHz 1 polarization (Sensors & Software) system, whereas five were collected with the 1.6 GHz 1 polarization (GSSI) system. The GSSI system was noted to have a larger GPS uncertainty, yet the GSSI surveys yielded lower biases for the lidar depth vs. excavated depth (median bias = -0.09 m) when compared to the Sensors & Software system (median bias = -0.22 m). We have added this note to Section 5.1. Thank you for the suggestion.

Figure S1: I think that you missed a great opportunity to show the DN013 radargram (and the lidar estimated depth) here. If you do so, you could elaborate on the buried vegetation that contributed to the GPR and lidar uncertainties (e.g. "at transect distance = 5 m, a buried little tree is also shown in the radargram as these hyperbola circled in red in the radargram, and this had this ... negative effect on the lidar snow depth estimation").

We think this is a great idea and we are working on a figure to add as Figure 2 to the main text. Thank you for the suggestion and we hope this revision improves readers' understanding of our research.

Figure S2: I am not convinced that the resolution difference you mention in the Figure caption is due to the different antenna frequency. In my experience, 1 GHz is already enough to show features as little as those recorded by the 1.6 GHz antenna, maybe just a little worse. I suppose that the perceived resolution difference between the two images is just due to the different spatial resolution: DB254 seems to have 1 trace per 10 cm, while SA326 has a much higher spatial resolution (I can't count the pixels, but they are much more than DB254). Also, similar to what I told for Figure S1, I really would like to see if the snowpack photomosaic of DB254 is different from that of SA326, to more constructively assess if the differences in the radargrams are related to the vegetation buried under the snowpack.

Upon evaluating this comment, we found an issue with figure S2 - the x-axes were not scaled the same, which gave the appearance of higher horizontal resolution for the 1.6 GHz

antenna. The newly updated Figure 2 will show a matching radargram and photomosaic. We agree that our comments regarding the vertical resolution of the GPR may be misleading and have removed these statements.

Figures S3 to S5: I would put at least one of them in the main text. Also, in the legend, please note on which date the lidar survey was performed, so it is easy to visually assess which transects were surveyed before and after the lidar.

Following your previous comments regarding readability challenges, we have decided to add the supplemental figures and supplemental text to the main text and reformat our article as a Research Article. Thus, Figures S3–S5 (now figures 3, 5–6) have been moved to the main text and we have added a note on the lidar survey date to the caption of each figure to improve the interpretability. Thank you for these suggestions.

Supplementary text, line 126: a full stop is missing at the end of the line.
Thank you for catching this mistake.