- J. Pumple and co-authors present a novel approach to estimate bulk density and volumetric ice content on permafrost cores. The study has been carried out thoroughly, the paper is very well written and of interest to the readers of the Cryosphere. The method is still in its early stages for this application but those are promising. Below are some minor comments and suggestions, which the authors may want to address prior to final submission:

  Firstly, thank you for your time and effort in reviewing our work.

  - Title: I recommend that the title be changed to "Non-destructive multi-sensor core logging allows rapid imaging, estimation of bulk density and volumetric ice content in permafrost cores" as the method is an estimation for both parameters.

  Response:

  We agree that the volumetric ice content is an estimation. Following this comment, we will change bulk density to also be an estimation. This was a discussion during the early stages of the project. We went with measurement given the close agreement with measured bulk density (destructive) but agree we are in fact measuring gamma ray attenuation and estimating bulk density from those values.

  Action:

  The title has been changed to the following: "**Non-destructive multi-sensor core logging allows rapid imaging and estimation of bulk density and volumetric ice content in permafrost cores**".

  - In general, the authors are encouraged to always use *volumetric ice content* and not just *ice content*

  Response:

  Agreed and changed.

  Action:

  We have switched all instances of "ice content" to "volumetric ice content" where applicable.

- In the introduction it's also worth noting that not only the recovery of the samples is expensive and complex, but also the storage on site and the transport, specifically if the thermal state of the sample should be protected.

Response:

Agreed and changed.

Action:

We have adjusted line 27 to include transportation and storage; "Despite the considerable cost involved in the recovery, **transportation and storage** of permafrost cores, most methods are destructive and rarely preserve physical or digital archives for future work."

- Add a reference to BNQ 2501-500 in the introduction regarding ice content

Response:

This is a great resource for geotechnical work and sampling and w have added the reference.

Action:

We have added this reference to lines 29 and 417.

- The paper does not mention salinity. However, in polar region, the determination of the salinity of permafrost samples is important as it impacts unfrozen water content and freezing point depression, hence the soil freezing characteristic curve.

Response:

We recognize the importance of salinity in permafrost but did not address it specifically in this study. We have added reference to it in the main text.

Action:

Following this comment, we have added a short statement to address the absence of salinity from this study (lines 186-190):

" **The cuboid method provides an opportunity to collect pH and conductivity measurements from ice rich samples following the thawing stage; however, for this study these data were not collected. We recognize the importance of salinity in thaw sensitive permafrost regions however given the analytical constraints, thermal stability was top priority during our analysis. The hope is to consider free water and salinity in future studies using alternative non-destructive methods (e.g., Roustaei et al., 2022).**"

- It is understood that the sample are stored at -25°C and the test being carried out at ~-12°C. In the ground, permafrost temperatures are much warmer and often the unfrozen water content is a critical parameter. It is also important to recognize that many soils have a freezing hysteresis, i.e. unfrozen water contents are different when thawing compared to freezing. How was the change in the soil structure, e.g. in response to freezing of unfrozen water when the sample was taken from the field and later stored, considered? Also, in section 2.1.3 the authors mention (line 140) that "... these electrical currents are likely to be altered by the differing abundance of ice and water ...". However, it is questionable how much unfrozen water is still present in the sample for the conditions the samples were tested at.

Response:

We agree that the initial conditions of the permafrost are not being represented in this study but that was beyond the scope of this study—that focuses on measurement and estimation of physical properties. We have done tests related to temperature dependent physical properties (e.g. Roustaei et al., 2022) but that is beyond this project scope. Here, we focus on robust acquisition conditions and measurement and comparison to high resolution destructive analyses. We have added some lines to make this point clearer.

Action:

We address the concern about initial ground temperature of the core's vs lab tested conditions (lines 96-98):

"**The data collected in this study are under colder temperatures than ambient field conditions. Future development will focus on designing of a chilling boat for the samples to maintain samples at much warmer temperatures (-0.5 – 5 C°) during measurement.**"

We address the comment about unfrozen water content at stated acquisition temperatures (lines 149-150):

"**We recognize that unfrozen water content will be minimal at temperatures below -5 C° and so an alternative insulated core boat would be needed if the sensors temperature sensitivity could be addressed.**"

- It would be interesting to compare the ice content with ice contents derived from image analysis. Similar to Arenson et al. (2008), it should be possible to get the ice structure from the images taken, specifically on samples such as the one shown in Figure 8.

Response:

We have a related project working on this which will extract ice content data from images using machine learning to create an automated approach. However the project was in its early stages during the final preparation of this manuscript.

- With regards to the core boat challenge, i.e. the air cap between the sample and the boat, it may be worth evaluating the possibility of creating a 3D scan of the samples and use a 3D printer for the perfect core boat.

Response:

We have recently developed a core boat with a transparent or void space bottom to address the impact of uneven core surfaces. Although we do have access to 3D printers the cost, time and waste would make this approach not viable for our research.

Action:

We now make mention that the thickness issue associated with the core boat/thickness laser has been solved (lines 296-298):

"Additionally, the core shape issue with the MSCL thickness laser (Sect. 4.1) had a compounding impact on the volumetric ice content data. This issue has since been resolved further reducing the sources of error for this MSCL method."

- Line 126: Check that you always use 'e.g.,'

Response/Action:

Changed.

- Line 252: check superscript for cm^3

Response/Action:

Changed.

- Line 356: make sure to use ‘NSERC PermafrostNet’ and not just ‘PermafrostNet’ in brackets.

Response/Action:

Changed.

Table 1: delete ‘.’ After peat in sample DH13-589

Response/Action:

Changed.