Thank you for the valuable comments – responses to the comments are included below.

Because this work is building off of several recent studies, it feels like some of the details and background are missing which makes it difficult for someone to step into without having read all of the previous literature. For example, there is quite a bit in the introduction on recent work showing the dominant scattering mechanism is due to the ice-water surface scattering. That could be reduced to a sentence or two with the relevant references. A higher-level summary of radar remote sensing of lake ice – i.e. all of the potential scattering mechanisms and their contribution, which frequencies have worked best, what is the state of the art in terms of detection of lake ice thickness and other properties – would be useful. Other specific examples are given below.

The introduction/background has been reworked to address this by adding additional detail. The description of recent scattering mechanism work was three sentences long in the original version, and these have remained (L74-L79). Descriptions of all mechanisms were given from L66 to L74 and have been expanded to include further details about volume scattering. Discussion of radar applications to lake ice studies has also been expanded.

"The most common frequency for SAR remote sensing of lake ice is C-band, partially due to the availability of sensors that provide C-band imagery as well as the penetration depth, which is less impacted by upper ice layers and snow cover (Gunn et al., 2017). Observations of lake ice using L-band and X-band can provide additional information to C-band; for example, L-band has shown success in monitoring methane ebullition bubbles for lakes in Alaska (Engram et al., 2012). SAR is the most widely used radar remote sensing technology for lake ice studies; however, other technologies such as radar altimetry are being increasingly used to retrieve properties such as ice thickness. This was demonstrated in a recent investigation which used Jason-2/Jason-3 Ku-band waveforms to estimate lake ice thickness for Great Slave Lake in Canada (Mangilli et al., 2022).

In recent years there has been a shift in understanding how active microwave signals interact with lake ice. Scattering mechanisms (double-bounce, volume, and single-bounce/surface scattering) from lake ice cover is a key topic within the lake ice and radar remote sensing literature. Initial investigations of lake ice in the 1980s using X and L-band side-looking airborne radar systems connected high radar returns to the presence of tubular bubbles in the ice, stating that bright signals in the imagery were due to a double-bounce scattering mechanism (Weeks et al., 1981). This double-bounce was created as the radar signal interacted with the vertical tubular bubbles and then with the ice-water interface, where there is a high dielectric contrast between the ice and water. Further investigations using spaceborne C-band systems (ERS-1 and RADARSAT-1) continued to support this theory and quantified the backscatter observed from lake ice (Jeffries et al., 1994; Duguay et al., 2002). In addition, past research also acknowledged the role of bubbles in contributing to volume scattering of radar signals in lake ice (Gunn et al., 2017; Matsuoka et al., 1999). However, these contributions were found to be smaller compared to the double-bounce mechanism. In more recent years, with the advent of fully polarimetric SAR data, new research has analyzed the scattering contributions from lake ice and determined that the dominant mechanism is a single bounce or surface scattering mechanism (Atwood et al., 2015; Engram et al., 2012; Gunn et al., 2018). This is attributed to *roughness at the ice-water interface. Explanations for the roughness at this interface include the presence of tubular bubbles in the lower layers of the ice, methane ebullition bubbles, and differing ice growth rates (Gunn et al., 2018; Engram et al., 2012, 2013)."*

There are so many parameters affecting the signal that are being tested in this sensitivity study that it is at times difficult to follow. This is with in situ measurements providing a lot of model input. In the discussion it says it describes the "importance of properly parameterizing all aspects of roughness for the different interfaces" (line 485) and that "accurate information on the VWC throughout the snowpack is crucial" (line 576), but it's not clear what the relative impact of these properties (and others) have on the results. How would these parameters be constrained in a larger scale application of spaceborne SAR data for lake ice?

While other properties do impact backscatter and are included, this study and others before it has demonstrated that these properties have limited impact on backscatter from lake ice. To address this, a short statement has been added at the start of the discussion to mention the impact and provide an outline for the discussion: "The experiments outlined in this study looked at several snow and lake ice parameters (e.g., roughness, bubble size, snow stratigraphy, ice stratigraphy, snow microstructure properties, and volumetric water content). Several of these parameters are from field data collected during the 2020-2021 ice season, and others such as volumetric water content, RMSH, correlation length, bubble size, and porosity, must be estimated based on past observations. However, from the results of these experiments, it can be seen that the key properties impacting backscatter from lake ice are primarily RMSH and volumetric water content. Other properties have little impact on the backscatter, which is supported by other sensitivity studies (Gunn et al., 2015; Gherboudj et al., 2010; Murfitt et al., 2022). Therefore, the remainder of the discussion focuses on the impact of RMSH and VMC on backscatter and how observed backscatter from Sentinel-1 supports the modelling observations."

Comments:

Lines 75, 79, 495: There's no Murfitt 2023 citation in the reference list.

This is strange – in the submitted version, the citation appeared on line 746 "Murfitt, J., Duguay, C., Picard, G., and Gunn, G.: Forward modelling of synthetic aperture radar backscatter from lake ice over Canadian Subarctic Lakes, Remote Sens. Environ., 286, 1–18, https://doi.org/10.1016/j.rse.2022.113424*, 2023." This will be verified upon next submission.*

Line 92-93: Sentence starting with "However, these experiments…" is vague. Can you explain in a little more detail what the limitations in snow cover representation were?

Further detail has been provided, outlining the snow representation in both experiments, "for example, representing snow cover as only one layer (Wakabayashi et al., 1999) or only considering a bare ice surface (Han and Lee, 2013)".

Figure 1: What is the green dot on the inset map?

The green dot has been clarified as the Kajaani Airport meteorological station.

Lines 147-148: RMSH seems to be a key parameter, used extensively to throughout the analysis and results, but the description here is fairly minimal. Later (line 391) RMSH is described as a key property influencing backscatter as demonstrated by previous studies. It would be good to provide more of that background up front.

Additional background on both IEM parameters has been provided in the SMRT modelling section, "IEM is parameterized using root mean square height (RMSH), which quantifies the amplitude of the vertical variation of the surface (Ulaby and Long, 2014). Root mean square height is also termed the height standard deviation or the differences between random height deviations and the mean height of the surface (Ulaby and Long, 2014). Vertical roughness has been identified as a key parameter for backscatter from lake ice both at the ice surface and ice bottom (Atwood et al., 2015; Han and Lee, 2013). Increases in the RMSH are linked to higher backscatter values at oblique incidence and increased surface scattering. Interface correlation length, which quantifies the horizontal correlation between two points on the rough surface (Ulaby and Long, 2014). It measures how smoothly surface elevation is changing horizontally. While correlation length has also been evaluated, past modelling of backscatter from lake ice indicates that, upon retrieval, correlation length is more consistent than RMSH values (Han and Lee, 2013)."

Line 176: I assume the 82 EW and 69 IW SAR images make up the 151 Sentinel-1 images acquired, but right now it reads like a list. I would suggest editing it to read "151 Sentinel-1 (C-band, 5.405 GHz), comprised of 82 Extra Wide (EW) swath HH-pol and 69 Interferometric Wide (IW) swath VV-pol, SAR images…"

This suggestion has been incorporated into the text.

Line 221: Maybe I missed this, but how was water content measured?

This was not clear in the original text. Exact water content measurements were not available, and instead, conditions were developed based on first-hand information provided by the team that collected the field data. The text has been modified to reflect this, "Unfortunately, exact measurements regarding water content were not available. Therefore, qualitative observations of snow moisture conditions were used to generate the SMRT experiments outlined in Section 2.5."

Line 409: Why is one of the values negative (-11.8) and the other not (9.19)? Since you say "decrease" maybe the negative sign isn't needed?

Yes, the negative sign is not needed. This has been removed from the text.

Conclusion: There is not a clear take-home message. I recommend that conclusions and relevant findings from this work be clearly stated in this section, which I think would help strengthen the paper.

The first paragraph of the conclusion focuses on summarizing the results, and a pair of sentences have been added to re-iterate the key message from the paper, "The results of these experiments show how radiative transfer modelling is valuable in understanding the response of backscatter to lake ice conditions under both dry and wet conditions. These experiments highlight the impact *that surface roughness has on backscatter and the change in dominant interface with increasing snow water content.”*