Response to Referees on egusphere-2023-1556

First of all, we would like to thank Referee 2 for the approval of the manuscript. Since there is no comment from Referee 2, this document only includes the response to Referee 3. Please find the reply below, with the original comments in *italics* and the responses in blue. In addition, we would also like to appreciate the Editor for considering and supporting our manuscript.

This paper used machine learning (ML) and satellite microwave data to examine Antarctic firn density. The authors did a good job of responding to all comments in the first two round of review. I only have one comment.

The addition of Appendix A with SMRT simulation is good except the claims that C-band data is sensitive to changes in snow layers up to 20 m. The change in dB reported in the graph are negligible. A change in 0.1 dB is not. The usual radiometric uncertainty is around 1 dB (Schmidt et al. 2018), everything under that can be noise. I would remove all the statements that C-band is sensitive to snow layers up to 20 m.

The C-band signal (useful in the density RF model) is probably not sensitive to volume scattering like the passive data but is sensitive to change in snow surface roughness condition (wind) and snow permittivity which are both link to snow surface density. This could be shown by using a surface scattering model like IEM in SMRT.

We appreciate the suggestion of the referee, therefore we have adopted the IEM theory in SMRT to model the surface scattering and the sensitivity of C-band. This experiment varies the surface roughness, and obtains the sensitivity by comparing the σ_A^0 of a rough surface with the σ_A^0 of a smooth surface. The outcome has been added in the revised manuscript as Fig. A2 (or Fig. R1 as attached below). It is true that applying the surface scattering model can result in a sufficient sensitivity of C-band backscatter (exceeding 1 dB). We have also removed the statement related to C-band data being sensitive to changes in snow layers up to 20 m in the revised manuscript.

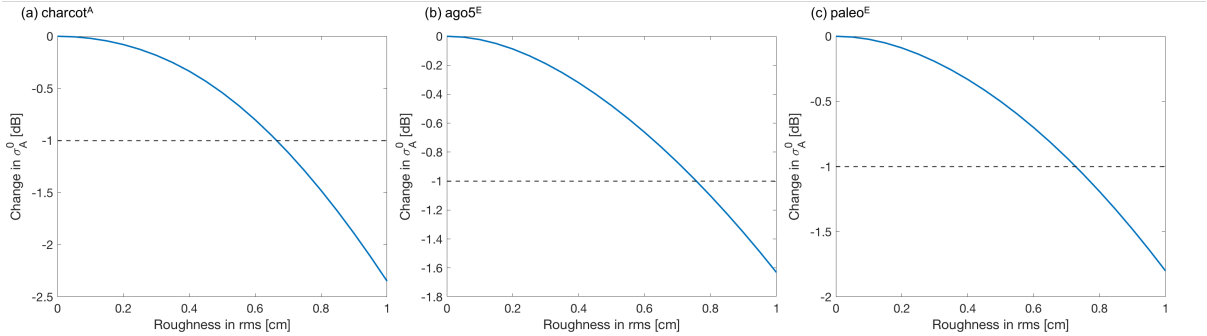

Figure R1. Change in σ_A^0 when the surface roughness (expressed as root mean square heights; rms) is changed.