The authors would like to thank the reviewer for her comments and feedback. Our responses are presented in blue.

Reviewer #3, Angelika Humbert

The manuscript is concerned with a study of passive microwave sensing of the water content of snow/firn in the Antarctic. It contains high level extensive simulations of the brightness temperature for a variety of frequencies that correspond to satellite missions. In short – it is a fantastic work. The main critics are to explain the microstructure that is used for the simulations, to present the results in a way that not only radiative transfer modelers understand them, but also firn microstructure and hydrology modelers.

- In general it would be very good to show both, total liquid water content and volumetric water content in all graphs. This can certainly be achieved easily and would be super helpful for people who are working with modelling of snow/firn hydrology that think more in terms of volumetric water content.

We acknowledge that using a common variable used by the community (firn, snow and microwave) would be better, but the entire point of Section 4.3 (experiment 2) is to show that the simulations strongly depend on the layer thickness if the volumetric water content were used as the predictor, i.e. as the x-axis in Figures 4, 6, 7, and others. This is not our choice but a consequence of the physics of the radiative transfer, the brightness temperature is mainly driven by the total absorption in the case of a wet snowpack, and so on the total liquid water.

In principle we could add the volumetric water content as the x-axis or as a secondary x-axis (on the top x-axis) in those figures and write the layer thickness in the caption (usually 10cm). However, there would then be a risk that some readers will take these volumetric water content values without the layer thickness, and apply our results in a different context with a different layer thickness. That would be incorrect. For instance saying “brightness temperature saturates from xx % volumetric liquid water content” is meaningless unless the layer thickness is given. Several papers in the literature interpret volumetric liquid water content (often also called snow wetness) without also stating the layer thickness (the value is hidden somewhere in the methods section) and we believe that this is not a good practice anymore. This is the reason why, despite the wide use of volumetric water content in our community, we use the total liquid water here.

The ad hoc conversion from total liquid water to volumetric liquid water is easy, and we will add the equation explicitly to make it easy to translate the total liquid water to a pair: volumetric water content + layer thickness.

- I am missing a section that shows how well the parameter optimization is doing for the particular frequencies. This should be included in the next version of the manuscript either as a subsection of an appendix. But it is important to demonstrate the performance of this.

If we understand the comment correctly, this question is addressed in our Section 4.1 and Figure 2 (Fig 3 in the new future version).

- The manuscript needs to improve on building a link to microstructure observation and modelling. As an example 'we selected the exponential microstructure representation' is not enough for understanding what type of microstructure is chosen.

We will add the reference to a new paper (Picard et al. 2022), that was not published when this paper was submitted. This new paper demonstrates that the choice of the microstructure is a second order problem in the microwave domain, as opposed to what was believed before. For this reason using exponential or another microstructure is not critical for our simulations, as long as the same "microwave grain size" (as defined in Picard et al. 2022) is used with all the microstructures. Here we use the term correlation length with the exponential microwave which appears to be exactly the same as the "microwave grain size".

We will add "Very similar results would be obtained with a different microstructure representation as long as the same microwave grain size is taken for all microstructures as demonstrated in Picard et al. 2022".

- The way the temperature is simulated is problematic. I think the results could be substantially improved by using temperature simulations from snow/firn models. These simulations are provided by regional climate models such as RACMO, MAR and others. Given that the temperature is such a crucial parameter in the modelling, more efforts to get the simulated temperature of the snow/firn right are important.

It is true that the brightness temperature directly and linearly depends on the physical temperature profile and any uncertainty on the physical temperature has an impact on the properties estimation. However, we disagree with the fact that our temperature profile is problematic, given our objective. Here we only need a broad information on temperature (i.e. the averaged multi-year winter temperature using) to obtain "realistic" properties of a simplified multi-year averaged snowpack.
Even if the estimated properties were imprecise (and they are at least because the microwave observations are insufficient to constrain the snowpack even with perfect temperatures), our sensitivity analysis remains realistic and usable. By devising this estimation method, our goal was to get a bit closer to the reality than in previous studies where the snowpack was purely synthetic and oversimplified, but not to reach an accurate description or to retrieve useful properties for other goals than microwave simulations.

We believe that using regional climate models, which have not been extensively validated for the firn temperature to our knowledge, is too complex, relatively to the benefit we could get, given our final results (i.e recommendations for advanced melt detection algorithm). Our simple approach has the advantage of being readable and reproducible.

- The effect of heterogenous pixels: the coarse resolution of passive microwave sensors/missions, make it likely that the brightness temperature of a particular pixel is a mixture of different snow/firn/ice properties. This could be overcome by incorporating high resolution radar imagery, such as provided by Sentinel-1. In 10-30m resolution the homogeneity of a passive microwave pixel can be assessed. For the purpose of this study, wither pixels could be excluded that are not homogeneous or they could be characterized. To this end not a major effort is necessary, as no time series is required (in a first step) but it could help substantially to understand the differences between simulated and observed brightness temperatures.,

We agree with the reviewer that the heterogeneity of the melt and of the snow in 25 km wide pixels is an interesting topic and it could be addressed with Sentinel 1 or ASCAT. However, our goal here is to obtain “realistic” properties for an “averaged” snowpack over the 25 km resolution of the passive microwave observations (and over multiple years as explained in the previous comment). The fact that the observed brightness temperatures are the average emission of many different snowpacks within a pixel is in fact an advantage for this goal, not a disadvantage, because we want to estimate a representative “average” snowpack for the area rather than a particular snowpack. Our results are representative of the scale of the passive microwave observations.

- The manuscript lacks plots or diagrams showing the SMB, in particular melt rate in the study sites. This would help substantially to understand the results.

We don’t understand the problem that would be solved with SMB plots or diagrams. The SMB values are given in Table 1 for each site, and the melt rate at most selected sites is available in the paper Jakobs et al., 2020, which we refer to on multiple occasions in our paper.

Line 35: either peninsula or Antarctic Peninsula

will be done

Line 107: +-2K.

We don’t understand the comment.

Line 164: ‘They are likely invalid for high contents’ Contents of what? Elaborate more on what basis is that stated.

“water” will be added.

We don’t have much information to elaborate on. The sentence will be reformulated to a more neutral statement: “Their validity for high water contents is unknown.”

Line 192: property profiles

We will change to "the profiles of the properties"

Line 204: what are unknown tie points?

We will reformulate the sentence: "for 12 unknowns (3 properties at 4 tie-points)".

Line 235: The why is the seasonal temperature set to 273K? This does not seem to be appropriate.

Our sentence was misleading, we don't pretend the season temperature is close to 273K, but we want to generate a temperature profile that is realistic for the summer period, and we do so by setting Ts=273K which controls the near surface temperature.

We will reformulate by avoiding the term seasonal temperature:

"In addition to generate a temperature profile representative of the summer season, we apply the same method as in winter except that T_s is set to 273 K"

Line 254: 'Intermediate frequencies have intermediate behaviour' needs to be rephrased with clearer a statement.

We will change to "frequencies in between have an intermediate behavior"