Review for:

"The sensitivity of satellite microwave observations to liquid water in the Antarctic snowpack"

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submitted to *The Cryosphere Discussion*

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Synopsis:

In this paper, the sensitivity of microwave brightness temperature to snow liquid water content at different frequencies from L-band to Ka-band has been investigated. Considering a recent interest in multi-frequency snow monitoring, authors have done a good job in drafting this paper. However, there are some issues that need to be addressed before this manuscript can be published in this journal. Please see below for my major comments.

Comments to the Author:

1. In line 66, where you mentioned that "… 4) when the surface becomes extremely wet (i.e. a saturated water layer, running water, surface ponding), the microwave signal is affected to the point that melt detection may become impossible despite the surface being obviously wet.", can you please explain why it becomes impossible? When it is very wet to the point to the point that a microwave signal is saturate (depending on the frequency of operation), a melt event for that specific season would be detected, but there may be a delay in detection (depending on frequency), or even uncertainty in the correct absolute value of liquid water content, as one frequency signal gets saturated, it cannot retrieve any further excessive wetness. And here is when multi-frequency detection becomes valuable as you mentioned. That said, please correct me if I'm thinking wrong.
2. In line 80, where you mentioned "This is only possible when the snowpack is dry, before or after the melt season.", isn't it different to use before or after melt season as a good dry snow condition? A snowpack that went through a longer winter season, will become closer to a more ideal dry snowpack; hence, a snow condition more to the winter season (further away from last day of melt season) would be a better dry snow condition. Can you please explain this a little bit here and where it's necessary in the paper?
3. In line 153, where you mentioned "A third regime described by Colbeck …", can you please add this sentence to the end of paragraph? It's too small to be a paragraph on its own.
4. In line 234, you mentioned "Water was always added by filling the air pores, which means that the ice mass (i.e. the dry snow density) is kept constant.", can you please why it has been decided to keep the density constant? Shouldn't the snow density change with snow melting, at least for the tope layers, where usually undergo metamorphism?
5. In Figure 2, please , mention in the caption the period (months of year) observed brightness temperature.

6. In line 254-255, where you mentioned “For instance, at H-pol, the brightness temperature is low and close to that at 6 GHz on Amery and Larsen C, whereas it is much 255 higher and close to that of 37GHz in the other sites. The reason for this is not clear.”, first of all, it is very important when these measurements have been performed. For example, some years, some ice shelves can undergo more metamorphism, which introduces more distinct vertical layer boundaries, which in turn decreased the brightness temperature drastically, mainly in H-pol. Also, surface scattering can decrease TB if it’s comparable to the wavelength, and maybe that’s why L-band is close to 6GHz in Amery and Larsen C. In general, as frequency increases, the applied electric field changes polarization faster and forces the dipoles in the dielectric to change directions faster as well. Hence, dielectric loss increases. In addition, as the frequency increases, E-field changes polarization faster than the dielectric dipoles’ relaxation time, which in turn decreases the displacement electric field in the material and decreases the dielectric constant. Hence, TB increases (less reflection). Perhaps, by comparing different measurement during different periods of year (or even same months but different years), you may be able to demystify why L-band behaves like this.
7. In line 256, it was claimed that V-pol suggests that scattering increases with number of melt days. Can you please explain why? This is contradictory with the statement in line 262, where you mentioned that H-pol and V-pol are controlled similarly by scattering. Your claim in line 256 could be right, but it definitely needs more proof and validation.
8. In line 266, where you mentioned H/V ratio becomes larger mainly due to the layering, can you explain this? Assuming that there is no attenuation, and no surface scattering, are we still seeing this effect? Usually, H and V observations becomes close to each other when there is enough surface scattering to make the signal to loose its coherency, then it becomes polarization-independent.
9. Please also explain why in figure 2, V-pol decreases and then increases, while H-pol monastically decreases by increasing the number of melt days.
10. Can you please compare your retrieved snow density with that of other available methods, such as “M. Mousavi, A. Colliander, J. Z. Miller and J. S. Kimball, "A Novel Approach to Map the Intensity of Surface Melting on the Antarctica Ice Sheet Using SMAP L-Band Microwave Radiometry," in *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 15, pp. 1724-1743, 2022.”?
11. In line 318, what do you mean by “pixel.day”? Can you please explain this unit to avoid confusion?
12. Please specify incident angle in Figure 4, and wherever it’s needed.
13. Can you please compare your result for snow wetness with other algorithms? You can convert it to liquid water column using density and thickness of wet snow layer.
14. In Figure 5, please specify in the caption that solid curve is V-pol and dashed one is for H-pol.
15. In line 404-407, it was claimed if the total liquid water content is fixed, wet snow layer thickness has little effect. First of all, can you please write an expression to relate volumetric liquid water content to the total liquid water content? If the thickness is normalized in the total liquid water content, the thickness should have zero effect with fixed total liquid water content, in other words, as thickness increases one would expect the signal loose more energy with exponential term depends on the thickness and the imaginary part of propagation constant. However, if the imaginary part is normalized by depth, and kept constant, the exponential term would be

constant. That said, I believe a bit more explanation with some equations would avoid any confusion.

16. In line 418-420, where it was claimed that total water content has more effect than volumetric water content, it is very confusing. It looks like there are two different parameters. This need to be clearly explained.
17. In line 470, where you mentioned "… saturated layer exceeds a quarter of the wavelength …", why quarter wavelength? It should depend on the penetration depth. Can you please explain where does this quarter wavelength come from?
18. In Lines 519 – 521, where you mentioned "This is in apparent contradiction with the results in Fig. 17 showing the brightness temperature at L band with a 30 cm thick wet layer at increasing depths (Experiment 3)." If there is a very wet layer, such that the thickness is greater than the penetration depth of the frequency of operation, it becomes a very reflective layer, and drops the TB, no matter what depth this layer has been resided. S, it is very confusing that you are claiming it is in apparent contradiction with (Mätzler, 1996; Macelloni et al., 2016, 2019) for L-band. For example, if there is 100m snow with some but small wetness, L-band can detect aquifer as penetration depth is higher, while higher frequencies cannot see the wet aquifer layer.
19. The results need to be compared with in-situ values or other algorithms. There are some other algorithms using L-band (refer to my comment number 10). Same authors, I believe have done a similar thing for Greenland.