Review Response to Michael Durand

Dr. Durand,

Thank you very much for your thoughtful review of our manuscript. Your suggestions are very helpful and we will work to incorporate them into the revised manuscript. Specifically, the suggestions regarding including a sensitivity test are important and we will design experiments to demonstrate the effect of snow density on brightness temperature and support the algorithm parameterization. In the future, we plan to apply the algorithm across the pan-Arctic and your suggestions will help to justify the methodology. Below are responses to the individual review comments.

1. Sensitivity tests

This is a very good point and we agree that a description of the influence of snow density on brightness temperature and sensitivity tests should be included in the revised manuscript – we will incorporate your ideas (i.e. varying density with constant snow depth and constant SWE) and have a couple ideas of our own for potential scenarios to include (e.g. effect of layer thicknesses). Thinking about this suggestion inspired a new way to handle, and justify, the layer thickness parameters in the model.

2. Units on Figure 2.

Agreed, and we will modify Figure 2 accordingly to provide more context on the sensitivity to the layer density parameters in the modelled output.

3. Brightness temperature in Figure 3.

This information was not included in Figure 3 in an effort to simplify the figures and make them easier to read – although, we recognized it is very important and will include those data in the revised manuscript.

4. Equation relating H to the layer densities

Upon review, our explanation of the heterogeneity parameter (H) was too brief and needs more explanation. We will elaborate on how the H parameter works and include the formulas to convert the plausible range to estimates for the specific layers using H.

5. Fixed depth hoar ratio

Regarding the two papers you cited: the King et al (2015) experiment was located in the Hudson Bay Lowlands which is a sub-Arctic transitional environment and not an Arctic snowpack. This study focuses on the high Arctic which is characterized by a relatively thinner depth hoar. Your comment regarding the Zhu et al (2018) study is interesting. But Zhu uses active microwave observations for which volume scattering is the dominant mechanism considered in both layers (after isolating it from surface and background scattering components). For passive microwave observations, volume scattering is the primary mechanism for the depth hoar layer and non-scattering emission contributions originate from the wind slab (Sturm et al., 1993). This second point (different contribution sources from the layers to passive microwave brightness temperature) has made us reconsider the usefulness of a static thickness ratio and instead are considering introducing a maximum depth hoar thickness (dependent on site characteristics, e.g. predominant vegetation types), which we think can be supported by sensitivity tests.

6. Equation for prediction of bulk density from H and layer ratio of depths

Similar to point 4, we think this is a good idea and will include an equation for deriving the final bulk density from the layer estimates derived with H.

7. Calibration of H parameter

The calibration of H would likely make more sense if the effect of H was more explicitly described in the manuscript (including equations, as per point 4 above). It seems H might have been confused with the layer thickness ratio, instead it is meant to quantify the difference in densities between the layers – ranging from the most conservative estimate where the layer densities are identical (i.e. minimum heterogeneity) to the situation with the most distinct contrast between layers (i.e. maximum heterogeneity). Again, this will be explained more thoroughly in the revised manuscript and visual example included in Figure 2.

References

King, J., Kelly, R., Kasurak, A., Duguay, C., Gunn, G., Rutter, N., et al. (2015). Spatio-temporal influence of tundra snow properties on Ku-band (17.2 GHz) backscatter. Journal of Glaciology, 61(226), 267-279(13). https://doi.org/10.3189/2015jog14j020

Sturm, M., Grenfell, T. C., & Perovich, D. K. (1993). Passive microwave measurements of tundra and taiga snow covers in Alaska, USA. *Annals of Glaciology*, *17*, 125–130. https://doi.org/10.3189/s0260305500012714

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