Review of: Local-scale variability of snow density on Arctic sea ice, King et al.

1 Summary

This manuscript addresses the spatial variation in the density of snow on sea ice through use of an extensive in-situ dataset from SMP and density-cutters. The paper is well written and highly rigorous; I believe it makes a significant contribution to the study of snow on sea ice and I recommend it for publication in The Cryosphere after some minor changes and clarifications.

On a side note, it was particularly pleasing to see the authors publishing their data and analysis code in an interactive, browser-based environment. As well as making the research output easier to review, it is likely to add to the impact of the work.

2 Minor Changes and Suggestions

- L57: "were used **to** address this problem"
- L58/339/471: Perhaps 'mm-scale' should be replaced with 'milimeter-scale' for readability.
- L129: "SMP transects **were** established"
- L184: "Eureka had a higher RMSE ... **than** measurements at AO sites"
- You'll presumably update your coefficient names to reflect the year of publication (K19a → K20a) in the final copy.
- L223: I think the reporting of the classifier's accuracy evaluation could be reworded for clarity. Presumably the 'prediction accuracy of 76%' means that 76% of the samples were assigned the correct layer type? Or does it mean that of the bulk layers that it identified (e.g. depth hoar, slab etc), they were right 76% of the time? Since the SMP makes measurements of F & L a couple of hundred times per mm, then does your classifier make a classification of the snow type with similar frequency, or is it as the frequency of your 2.5 mm density estimates? Or does it just identify boundaries between layers of different snow type?
- I think it would also be particularly valuable to break down the performance by layer-type. The average was 76%, but did the classifier do a better job of identifying different types? Were there some types that were particularly hard to identify?
- L326: As you subsequently mention, the primary scattering surface for radar altimetry may not be the ice surface. As such, I think this should be rephrased as 'radar measured distance to the primary scattering horizon may be overestimated'. On that note, I think you should mention explicitly in this section that calculations of δ_p assume (in line with convention for radar altimetry) that the ice surface is the dominant scattering horizon.
- L327: This reference is now quite challenging for many readers to track down, I suggest updating to the more recent edition: Ulaby and Long (2014).
- L332: I think it would be good to cite this equation (as it's reported differently in some literature), consider Tilling et al. (2018) or Mallett et al. (2020).

- L444: Consider pointing out in this section that as well as brine over FYI, morphological features in the snow or higher snow temperatures (Willatt et al., 2011) may also raise the primary scattering horizon, limiting the applicability of your path difference calculation.

References

Mallett, R. D., Lawrence, I. R., Stroeve, J. C., Landy, J. C., and Tsamados, M.: Brief communication: Conventional assumptions involving the speed of radar waves in snow introduce systematic underestimates to sea ice thickness and seasonal growth rate estimates, Cryosphere, 14, 251–260, https://doi.org/10.5194/tc-14-251-2020, 2020.

Tilling, R. L., Ridout, A., and Shepherd, A.: Estimating Arctic sea ice thickness and volume using CryoSat-2 radar altimeter data, Advances in Space Research, 62, 1203–1225, https://doi.org/10.1016/j.asr.2017.10.051, URL https://doi.org/10.1016/j.asr.2017.10.051, 2018.

Ulaby, F. and Long, D.: Microwave Radar and Radiometric Remote Sensing, The University of Michigan Press, https://doi.org/10.3998/0472119356, URL http://public.ebookcentral.proquest.com/choice/publicfullrecord.aspx?p=4537961, 2014.

Willatt, R., Laxon, S., Giles, K., Cullen, R., Haas, C., and Helm, V.: Ku-band radar penetration into snow cover on Arctic sea ice using airborne data, Annals of Glaciology, 52, 197–205, https://doi.org/10.3189/172756411795931589, 2011.