Review of *Mapping Greenland's perennial firn aquifers using enhanced resolution L-band brightness temperature image time series*

Summary

In this manuscript, an empirical model is developed to map the extent of firn aquifers over the Greenland ice sheet using L-band brightness temperatures time series. L-band signatures of firn aquifers are shown to exhibit a slow exponential decrease before reaching stable magnitudes late in the freezing season in contrast to non-firn aquifer areas with rapid exponential decrease. Sigmoidal curves are fitted to the L-band time series and the classification of firn aquifers is based on the modelled rate of decrease. The empirical algorithm developed is calibrated using airborne surveys of firn aquifers. Using this new method, the authors found that perennial firn aquifers are found over 66, 000 km^2 of the Greenland ice sheet.

General Comments

This is an interesting paper using L-band brightness temperatures from the SMAP satellite to map perennial firn aquifers. The paper is well-written and the empirical method developed here seems to provide a consistent mapping with airborne surveys of aquifers. However, there are a few points that I think would substantially improve the paper:

1) On the calibration of the model, you need to explain why you decided on the interval $\zeta \in$ [-0.04;-0.008] to produce the final map. This is very important as your mapping is dependent on the interval chosen for the rate of decrease.
2) I think that the paper is missing a quantitative comparison to previous studies. Based on the present form of the manuscript, it is hard to evaluate how the new method developed here performs compared to other surveys of firn aquifers. Despite Figure 3 showing a consistent pattern with previous airborne surveys (which is expected as the model developed here is calibrated using these airborne observations), the paper lacks some form of quantitative analysis of the performance of the model.
3) I find that Figures 1b&d and 3b&d lack clarity. The legends of Figure 1 and 3 need some clarifications and the authors need to check the consistency between the colours used in Figure 2 and what is stated in the text (see comments below).

I think that the manuscript mainly requires clarifications of the points above and I therefore recommend the paper to be published after minor revisions. I expect that this paper will be an interesting addition for studies of firn aquifers and will be of interest for the scientific community.

Specific Comments

L66: This newly published paper could be of interest here as it uses Sentinel-1 to map firn aquifers from space: Brangers, I., Lievens, H., Miège, C., Demuzere, M., Brucker, L., & De Lannoy, G. J. M. (2020). Sentinel-1 detects firn aquifers in the Greenland ice sheet. *Geophysical Research Letters*, 47, e2019GL085192. https://doi.org/10.1029/2019GL085192

L90: It would be helpful if you could state here what the resolution needed to map firn aquifers is and in how many passes this can typically be achieved

L233: I would say in steps of 0.004 rather than in time steps of 0.004 which is confusing as you increase the exponential rate and not the time parameter

L235-237: How did you choose the calibration interval [-0.04;-0.008]? You need to explain how you came to choose these values as the final binary maps are based on this interval. For instance you could provide a histogram of the exponential decrease rate you obtain for your whole set of time series.

L237 and L253: typo [-1;-0.04]

L242: What about H-pol time series? You mention at L186 that you analysed the H-pol time series as well but you only fit the V-pol time series?

L267: You state that the number of iterations is between 1 and 10 but based on Figure 2, the number of iterations seems to be higher (21 at sites 3 and 4)?

L273: Based on Figure 2, the colours corresponding to sites 1-4 are blue, cyan, red and green and not blue, teal, yellow and green

L278: In the text, Test Sites 4 and 5 are reported as marked with orange and red lines but in Figure 2, Test Sites 4 and 5 are marked by the green and orange lines. Don't you mean Test Sites 3 and 5 instead (see my comment below)?

L273-280: Aren't Test Sites 3 and 5 (red and orange lines) examples of other facies areas and Test Sites 1, 2, 4 and 6 sites with firn aquifer signatures?

L311: Please state how many grid cells.

L287: It would be interesting to comment on how the firn aquifer extent you derived from L-band data relates to previously reported estimates of firn aquifer extent

L306-320: Please be more specific in your comparison to MCoRDS and Accumulation Radar-derived firn aquifers and provide some quantitative metrics.

Figure 1: In the caption, I think that what is labelled as Figure b) is actually Figure c). I think that it would be best to change the colour of Test Site 1 for something different than blue as the MCoRDS-derived firn aquifers are also marked in blue (same for Figure 3). Also what is the difference between the yellow lines in b) and the black lines in d)?

Figure 3: Idem as in Figure 1, Figure c) is labelled as Figure b here. I think that you need to clarify the legends of Figure b) and d). I guess that MCoRDS-derived firn aquifers are in blue and not in yellow and blue circles? I find it hard to understand what you are showing on b) and d)