The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2020-148-RC1, 2020

Interactive comment on "Modelling perennial firn aquifers in the Antarctic Peninsula (1979–2016)" *by* J. Melchior van Wessem et al.

Kristin Poinar (Referee)

kpoinar@buffalo.edu

Received and published: 15 August 2020

General comments

This paper describes the first climate / SMB model study of perennial firn aquifer (PFA) presence in Antarctica, specifically the Antarctic peninsula. This analysis is timely and relevant. Currently, Antarctic melt is generally represented as refreezing immediately in the firn, running off directly into the ocean, or (in the most advanced representation) forming supraglacial lakes atop ice shelves. Recently, Lenaerts et al. (2016) and Dunmire et al. (2020) demonstrated that melt also persists within the firn, as buried lakes, in a specific region of Antarctica. This paper extends that discovery by demonstrating the great spatial extent of subsurface water (here, PFAs) along the Antarctic Peninsula.

The paper is well constructed, clearly written, and informative. The figures are strong and illustrate the points well. The analysis performed is fairly simple: spatiotemporally varying properties of the firn layer, including and culminating in its perennial liquid water content (PFA presence or absence), are compared between two snow models and to available data. Both models are forced by the same regional climate dataset over the same period. Both models have been fully developed in previous work and have also been applied, with success, to PFAs in Greenland (Steger et al., 2017a and 2017b). Both models are moderately complex, with detailed physical representation of depth-dependent snow properties, vertical water transport by the bucket scheme, and no horizontal water transport or ponding. The more advanced model, SNOWPACK, is run in a simpler mode for better comparison to IMAU-FDM. Each model has its strengths and weaknesses; the authors use two models to allow a more diverse approximation of reality, rather than to evaluate which is better.

This exploration teaches that PFA climates in Antarctica are broadly similar to those in Greenland, as found in previous model-based studies of Greenland PFAs by this group. This is the first such study of PFAs in Antarctica. It will be useful for scouting of potential field sites for campaigns on SMB or ice-shelf stability. Furthermore, this work sets up future study of potential links between PFAs and ice-shelf disintegration events, e.g. as hypothesized by the authors on the former Prince Gustav and Wordie Ice Shelves.

Specific comments

- P5 L14-15: "At colder locations, firn temperature is somewhat overestimated." The data on Figure 2 do not bear this out – the models underestimate T_{10m} at all temperatures. Extrapolating the linear fits to colder temperatures makes the modeled temperature go above the 1:1 line, but this is not actually constrained by the data. I suggest removing this sentence.

- P9 L1-2: “it is likely that more PFAs will be formed” – this is not quite true. That conclusion would be based on Figures 9c-d, which showed no strong pattern for accumulation, as described in the previous paragraph. What should be said here is what Figures 9e-f show: that more meltwater will be retained in PFAs. This actually strengthens the conclusion here – higher melt influxes would increase rates of lateral water flow through PFAs, increasing the likelihood that hydrofractures drive to the bottom rather than refreeze / arrest partway (Poinar et al., 2017).
- Figure 11: The remarkable longevity of the IMAU-FDM aquifers on Wordie Ice Shelf (compared to the other ice shelves studied) suggests that they may have had a role in its collapse. Causation is far from certain, as is stated in the paper, but there is a potential mechanism: The persistence of the PFA for 10+ years (remarkable in this area) would increase the chance that lateral flow would bring the water to a crevasse, and the high LWC here (Figure 5) would increase the chance of deep hydrofracture, as in my above comment. This should be explicitly addressed in the manuscript, probably in Section 6.4, which is a little thin and would benefit from some mechanisms.
- P12-13 Section 7 and P1 Abstract: Many of the sentences in the abstract and conclusions section are very similar to one another. Both sections contain a lot of detailed facts related in somewhat choppy fashion. These sections should be smoothed and strengthened to better highlight the broad findings and important implications of this work, rather than specifics of its methods or more than a handful of quantitative results.

Technical comments

- Title: The parenthetical (1979-2016) in the title is odd and should be changed.

- P3 L22: I think the model time step is 3 hours (L27). For clarity, this should be stated here, rather than indirectly a few sentences later.
- P3 L29: Use “is” instead of “was”
- P4 L17: Use “is” instead of “was”
- Section 2.2 / 2.3: I suggest including the number of vertical layers in each model. I believe it is variable place to place depending on the firn properties; thus perhaps state the maximum and/or a typical number of layers in these runs.
- P5 L28: The abbreviations CI and WI are unclear and undefined here in the text. After a little hunting, I found them on Figure 1. I suggest referring to these cores by location and/or pointing back to Figure 1 when they are mentioned.
- P6 L3: “dry snow”
- P6 L21: “more quickly” instead of quicker
- P7 L32: Write out “1990s”
- P8 L1-8: These few sentences are confusing. Which model predicts a larger surface area of PFAs? I believe that the sentences contradict each other.
- P8 L26: I don’t see this pattern or the threshold of <1500 mm we /yr
- P8 L27-28: Furthermore, the 100% points are sparse; their neighbors are more like 50-60%. This noise makes it even less likely that these 100% points are “real”.
- P9 L8: The observations in Scambos et al. (2009) are satellite-based, not in situ

- P9 L18: “as temperatures decrease” – the surface temperature data are not shown, which is fine, but that should be briefly acknowledged. Alternately, they could be added to Figure 10c / 11c / 12c.
- P12 L 24-25: with with
- Figure 1: Add label for Wordie Ice Shelf. I eventually found it on Figure 5, but I expected it here.
- Figures 8,9: I very much like these figures.

Review summary

This is a good paper with structured organization, clear writing, and comprehensive figures. It connects climate to the subsurface hydrology of the Antarctic Peninsula, which is an important new step in understanding drivers of ice-shelf disintegration. It is a timely study that I enjoyed reading.

References

Dunmire, D. et al. (2020), Observations of buried lake drainage on the Antarctic Ice Sheet, Geophysical Research Letters, doi:10.1029/2020GL087970.

Poinar, K., et al. (2017), Drainage of Southeast Greenland Firn Aquifer Water through Crevasses to the Bed, Frontiers in Earth Science, doi:10.3389/feart.2017.00005.

Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2020-148, 2020.