Comment on egusphere-2022-368
William D. Harcourt (Referee)

Referee comment on "Snow stratigraphy observations from Operation IceBridge surveys in Alaska using S/C band airborne ultra-wideband FMCW radar" by Jilu Li et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-368-RC1, 2022

Overview

This paper uses radar measurements from OIB campaigns in summer 2021 over Alaska to 1) track annual snow layers in radargrams, 2) estimate the snow accumulation rate over Mt Wrangell, and 3) analyse snow strata within ice facies. The authors develop a radar age-depth model from Clark et al. (1989) to quantify the two-way travel time of the radar wave through the snow and ice, and constrain the associated parameters using a cost function that aims to minimise the difference between two snow depositional ages to annual increments (i.e. 1 year). The modelled age-depth relationship fits the derived data sets very well and hence provides confidence that the subsequent estimated accumulated rate is sufficiently accurate, with the caveat that local surface processes such as wind redistribution are not be completely accounted for. The key result from a glaciological perspective is shown in Figure 8 which shows increasing accumulation rates between 2004 to 2021.

General Comments

The paper is well-written overall and provides a very detailed account of the methods used to constrain the parameters in the age-depth model and the subsequent extraction of key variables such as annual snow accumulation rate. The results will be of significant interest to glaciologists and hydrologists interested in understanding glacier mass balance and its impacts on catchment hydrology. Whilst the technical details of the paper are well-described, the glaciological interpretation of the data set is under-developed. In particular, I think the paper would benefit from a discussion about surface mass balance processes and how these have changed over time e.g. what are the processes underpinning the increasing accumulation rates in Figure 8. Are there any regional SMB measurements that you can compare to?
I’ve noted some relatively minor technical corrections below which are mostly areas of clarification. If the authors can integrate these suggestions into a revised manuscript I believe the paper will be ready for publication.

**Technical Corrections (References to line numbers in preprint)**

**Abstract**

L9-L10: This sentence should come straight after your introductory line. Then you can launch into a description of your findings including observing snow strata in ice facies.

**Introduction**

L25: Not sure what is meant by ‘Earth’s ecosystem’. Maybe just ‘the Earth’s climate system’.

L25-26: Suggest change to: ‘in the Earth’s climate system and respond rapidly to changes in climate which impacts regional hydrology and the local economy.’

L29-L33: This is a long sentence and can be shortened. Focus on the global trend and then specify exactly the mass loss from Alaskan glaciers as an example. Where possible, avoid lots of clauses as it breaks up the flow of the sentence.

L34: Start new sentence here: ‘...Hill et al., 2015).The changes in glacier discharge...’

L35: ‘home to important’

L39: Maybe spaceborne?
L41: ‘However,“

L51-53: Worth stating that ground based measurements are also used for satellite validation of snow products.

L55: ‘at a glacier-scale’

L58: ‘within temperate firn’

L63: ‘with a 6-GHz’

L64: Reference Figure 1 here

L66: ‘using snow pit measurements to 10 m depth’

L71: ‘across a broader spatial region than compared to the 2018 campaign (Li et al., 2019)’

**Data collection and processing**

L79: ‘over 8 days covering 5115 linear km’

L80-88: It would be better to briefly describe and LiDAR system and discuss the radar antenna installation in a little more detail rather than referring to a previous paper. A table of critical radar system parameters would also be useful.

L81: ‘altitude above ground level (AGL)’
L83-84: To understand this the reader would also need to know the ADC sampling frequency, which can go into a table of parameters.

L85: State the vertical resolution before and after changing the bandwidth.

L90: Change brown to colour to distinguish from red; black might work?

L92-93: State spatial coverage in km$^2$?

L99: What was the magnitude of the correction applied to the radar system delay?

L101-104: It would be helpful to provide a little more detail on these processing steps e.g. general outline of how the processing performed, performance improvement and the reason for using each step. Does the order matter? Similar to the deconvolution, were any of these steps applied differently to previous campaigns?

Results analysis and discussions

L112: “above sea level”

L113: ‘focus on the analysis of

L114: ‘discuss observations along the transition from the accumulation to the ablation zone along

L122: I assume by ‘flattening’ you mean normalised to surface elevation? If so, was this from the lidar data?

L124-126: Both years have multi-modal peaks largely ranging between 1-6 m. Better to state this and the means of each individual distribution. This would also reveal the lack of
a third peak in the 2021 data. Why might this be? More melt?

L133: What month were the 1994 measurements taken and are you able to quantify differences in air temperature between that study and this one?

L139: Change ‘massive’ to ‘large’

L141: ‘researchers have been drawn to study glacier-volcano interactions

L144: ‘are also both’

L145: ‘covers a 4.2 km by 2.7 km area.’

L155: ‘subsurface layers’

L169: ‘shows a plot of the flight line’

L180: It might be beneficial to have a short sentence explain what is meant by an ‘interpretation model’.

182-189: It’s very hard to differentiate the notation for density and pressure. Maybe change the notation for pressure to capital P for readability?

L210: I agree with the assumption of steady-state conditions. Maybe also state that based on S3 there is also a skew towards more positive differences which could imply more snow accumulation in winter 2021.

L227: As far as I can see you haven’t stated how the layers were picked – manual, semi-automatic or automatic?

L228: What density values were used to calculate the permittivity, kg/m³?
L229: 1.127 km east, west, north or south?

L251: ‘values of the cost’

L257-258: Exactly how is the value of J applied to calculate the depositional ages of the tracked layers?

L259-261: Not entirely clear why these are accumulation layers – they broadly fit into the sequence of annual integer increments...

L269: “Therefore, our purpose” (i.e. because of the shift identified in the previous paragraph, only accumulation rates can be determined)

L279-309: These are interesting results and their glaciological interpretations should be assessed further. Why is there a rising trend in accumulation? How does this relate to glacier mass balance? Is there any evidence for melt on ice internal layers and radar backscatter? It’s worth highlighting in this section that you are interpreting radargrams from the dry snow facies to illustrate that melt layers are unlikely to be present.

L327-332: This description would benefit from some annotations of Figure 10a, particularly highlighting the broad locations of the facies.

**Figures**

Figure 1: A little difficult to see the flight lines. Could you have a small inset panel for the region and then extent indicators showing the two main regions surveyed?

Figure 3: A legend stating what the blue and red dots represent would be helpful.
Figure 4: Could you also annotate the location of the surface for clarity?

Figure 9: Better to state the elevation of the snow surface in panel d.