Authors point-to-point response on Referee Comment #1 to tc-2021-230

1. General comments

In this paper, the authors presented direct pRES measurements of basal melt rates on 79 locations of Filchner Ice Shelf. The study region covered a rather large region between ~50 km downstream of Support Force Glacier and Berkner Island. Two pRES measurements are conducted in 92 locations repeatedly between about two years. The distribution of basal melt rates suggest in the study region, basal melt rates are quite evenly distributed. Results are also compared to the basal melt rates produced by remote sensing data sets. It's suggested that the quality of basal melt rates derived from remote sensing data sets is limited by the precision of vertical strain rate, and this can be improved by using state-of-art velocity fields.

The data set is a very useful product to constrain ocean model and remote sensing products in this region. However, there are some technical questions need to be addressed, such as the uncertainties of the measurements due to the methodology. Furthermore, ocean mechanism in this region and its impact on the basal melt rates should be better explained. Details will be mentioned in the specific comments.

2. Specific comments

L14: 'buttressing of'→ 'buttressing to'

Thanks! We will correct this.

L20: 'satellite remote sensing data'→'remote sensing data'

Thanks! We will correct this.

L45: Can you give more details of the measurements either here or in the method session? For example, how did you track the location of the measurements, using bamboos or gps coordinates...? Shifts of locations might leads to ill alignment of the basal layer.

In the revised version, we will add more information about the measurement itself.

The new sentence in the methods section will be:
"The pRES transmits a frequency modulated sweep (chirp) from 200 to 400 MHz over a period of one second ***via two skeleton slot antennas, separated by roughly 9 m. The exact locations were marked with two bamboos for precise relocation a year later."***

Just curious, why no measurement is conducted closer to the grounding line of SFG, where more variability may appear? Is it a security consideration?

Indeed, it has been due to a large crevasse field that is south of our first crossing. There is a region further west, where one could potentially conduct such measurements until the grounding line, but this was just figured out by a seismic campaign a year later. If we could redo such a campaign, we would then try to set up an ApRES at those locations. However, that is linked to a melt channel and won't give a 'background' field of melt rates.

L65: 'location' → 'locations'

Thanks! We will correct this.

L66: How much does the periods influence melt rates? 323 days are more than a month less than a year. In the previous study of Sun et al., (2019) where hourly measurement of 1-year length is conducted in Roi Baudouin ice shelf, there is a clear seasonal variation in the time series. Melt mainly happens in summer, while in winter time the melt rate is close to zero and refreezing happens. That means without contribution of 42 melting time in summer, melt rates may be underestimated.

Thanks for raising this point. It is true that our measurements may underestimate the melt rate in case of enhanced melt rates in summer. While there are up to 356 days between the repeat measurements in the southern area, this period is somewhat shorter in the northern part of our study area with 323 days. The period that was not covered by these measurements is between the beginning of December and mid-January. However, due to a lack of time series in the vast part of our survey area, we cannot assess if we indeed underestimate it. In the dataset we are providing, the date of first and second measurement is given and the interested reader has all detailed info.

For the northernmost cross-section (CSE), an autonomous pRES (ApRES) measurement was conducted by our partners of BAS in the same time period as our pRES measurements. This ApRES was located next to a single-repeated pRES measurement that indicates refreezing. However, the derived melt rate from the ApRES time series shows no enhanced melting in summer.

In the revised version, we will add a discussion on the possibility of a seasonal cycle that might influence the derived melt rate.

L66: 'between 323 and 356' → 'from 323 to 356'

Thanks! We will correct this.

L76 and equation (1): Here vertical strain rate is assumed to be constant within the whole ice column. How good is the assumption hold? Can you show the displacements of the internal layers? Maybe add a subplot in figure B1.

Thanks for raising this point. In the analysis of the data, we carefully checked if a constant strain is valid for all stations. At no station, the displacement distribution of the internal layers differ significantly from the fitted line.
We will add the vertical displacements of the stations pRES060 and pRES061 to another subfigure in figure B1. Since the vertical strain rate is low at this location as well as at many other stations, the displacements are close to zero.

Fig 3: Could the authors add the error bar to the melt rates?

There are error bars but the error is too small to see as the dot marking the pRES derived melt rate is of similar size than the error bar. We will update the sentence in the caption as follows:
"Uncertainties of the pRES derived melt rates are 0.03 cm and therefore too small to visualise."

L101, Fig 3: Could the authors add the ice draft measured by pRES e.g. by using two y-axis?

Thanks! Yes, we will add the ice draft to Fig. 3.

L104-108: It's not clear to me how the vertical gradients of the ice temperature influence the distribution of basal melt rates distribution. And how does it explain the melt rates distribution observed in this article?

The basal melt rate is determined by the energy balance at the ice-ocean interface. One term in this energy balance is the vertical temperature gradient, which is the heat flux at the ice side. The larger the temperature gradient, the lower the basal melting rate, as more energy is used to heat the ice.
Depending on the magnitude of the oceanic heat flux, the influence of the gradient of the ice temperature may be insignificant, or may contribute significantly. Ice streams often exhibit a cold core and this temperature distribution is altered over time and hence distance from the grounding line in flow direction, as also shown by Humbert (2010). Over distance, the temperature gradient in the ice is reduced as the temperature profile in case of basal melting is approaching a parabolic shape. With decreasing vertical gradients of the temperature in the ice, its influence is declining and less energy is needed to heat the ice. This favours higher melt rates.
In order to assess the influence in our study area, one would need vertical ice temperature profiles, which have not been measured as this requires drilling.

In the revised version we will add a discussion on the different mechanisms that affect the basal melt variation.

L111: What are the locations of the 18 pRES measurements? Can you show them in the map?

Yes, we will highlight the nearby station pairs in the map. Thanks!

L114: 'and' → 'an'?

Thanks! We will correct this.

L118: For Fig.3, again, it would be straight forward to demonstrate the potential influence of geometry if the authors could add the ice draft of these locations.

We will add the ice draft to Fig. 3, however, the change in ice draft of the pRES measurements will hardly be visible in Fig. B1, since the difference is small compared to the change over the entire central flow line.

For Fig. B1, the two signals in the inset plot (d) are not very similar visually. How well is the correlation?

The correlation is calculated for the basal segment ranging from -9 to +1 meter of the basal reflection (first maximum in amplitude after the strong increase). The correlation coefficient of the basal segment of pRES061 is 0.95. The correlation coefficient of the nearby station pRES060 is 0.96 and thus only slightly higher.

L119: The authors suggest that the higher melt of pRES061 is due to deeper ice draft and therefore higher thermal forcing. I hope the authors can discuss the impact of ocean dynamics to melt rates in this region, including thermal forcing, ocean circulation, and the influence of local boundary (depth of ice draft, slopes).

Thanks for raising this point. In the revised version, we will add a discussion on the contribution of the different oceanographic and glaciological mechanisms to the small scale spatial variability.

L120-122: Should this be a localized phenomenon? Will this conclusion hold at locations closer to the grounding line?

*We have only discrete measurements and our measurements are conducted at quite some distance to the grounding line due to a massive crevasse field further south. If a basal crevasse is the origin of the localised change in ice thickness, bending in the hinge zone has likely led frequently to formation of crevasses and it happens that we just by chance covered one of such features in our measurements. If this is the case or not can only be assessed by (a) having a continuous radargram from the grounding line northwards retrieved from an airborne campaign and (b) some more measurements in the vicinity of basal crevasses and (c) a more continuous profile of pRES measurements or (d) ApRES measurements spaced in 2[a]*v[m/a] distance, running over two years.*

Fig.5: With melt rates and vertical strain rate difference between pRES and remote sensing results, can you add another column of the differences caused by surface mass balance? This would make this figure more informative.

Thanks for raising this point. Unfortunately, the comparison of the surface mass balance is not possible as a separation between surface mass balance and densification is not possible from the pRES measurement, as only the sum of both is derived. However, the comparison of the pRES- and remote sensing-derived melt rates does not require this comparison. The starting point of the comparison is a product derived from the change in ice thickness and the correction of the surface mass balance and the snow and firn densification. Thus, this product represents the change in ice thickness in the ice column and it is shown in Fig. 5i and Fig. C2.

References:

Vaňková, I., Nicholls, K. W., Corr, H. F., Makinson, K., & Brennan, P. V. (2020). Observations of tidal melt and vertical strain at the Filchner-Ronne Ice Shelf, Antarctica. *Journal of Geophysical Research: Earth Surface*, *125*(1), e2019JF005280, https://doi.org/10.1029/2019JF005280.