RC1: 'Comment on egusphere-2024-1476', Anonymous Referee #1, 18 Jun 2024

This paper uses detailed GPS-based ice velocity records from near the terminus of Bowdoin Glacier, NW Greenland, to explore controls on the short term variability in ice motion along the lowermost 4 km of the glacier. This methodology is quite similar to that employed in previous studies of the dynamics of alpine glaciers and outlet glaciers from the Greenland Ice Sheet, and correspondingly some of the findings are quite familiar from earlier work. However, studies on the short term dynamics of tidewater glaciers remain comparatively uncommon, and this study thus adds value in demonstrating how far our understanding of glacier dynamics applies (and doesn't apply) in this context. The GPS data on which the paper is based is of high quality and the analysis and interpretation seem largely sound and well supported. I have no major concerns but just a few minor comments:

Thank you very much for reading our manuscript and providing helpful comments. Below (in red), we address the reviewer's comments and explain how we revise the manuscript.

L31. Can you be more quantitative on the relative contribution of these processes?

Yes, we will introduce the relative contributions reported in previous literature.

L33. I think it's overstating things to say that this is 'key' (implying it's the single most important factor) – it is one many topics that are important in understanding the current and future mass loss of the ice sheet.

We agree with this comment. The text will be revised.

L249. More so than simply the time taken for water to get to the bed, I think an important consideration here is what controls the timing of the diurnal peak in water pressure. Throughout the middle part of the day when melting is greatest, meltwater input to the glacier will exceed meltwater discharge from the glacier, causing water storage and pressure to increase (the opposite occurs during the remainder of the day). Thus the period of maximum pressure will not likely coincide with maximum melt rates, but rather will occur slightly later (towards the end of the higher melt period of the day), as you observe (see for example Cowton et al 2016).

We agree with the comment. The text will be revised by including the process controlling

water pressure.

L255-257. Could snow cover also be a factor here? I assume there was little in the study area at Bowdoin Glacier, but if the study area at Helheim extended 37 km from the terminus, then perhaps remaining snowpack could have played a role in slowing the runoff of meltwater.

Meltwater input from snow-covered upper regions is possible both in Helheim and Bowdoin Glaciers, but delay in runoff due to temporal retention in snowpack is expected to be longer than ~hours. It obscures diurnal ice speed variations, but it is unlikely to cause a "shift" in diurnal peaks. Further, Most of the GPS stations on Helheim Glacier was below 800 m a.s.l. (Stevens et al., 2021), which is well below the equilibrium line altitude. Therefore, the studied area was snow free during the mid and late summer survey period (July and August). Because of the reasons above, we excluded the influence of snowpack from the discussion here.

L282. Suggest 'The amount and…'

We correct the text as suggested.

L283. Suggest '…subglacial meltwater input on the basal water pressure…'

We correct the text as suggested.

L283. It's not totally clear whether Bartholomaus et al (2008) is being cited as an example of where glacier motion is or isn't a simple function of meltwater production.

The paper is referred to as an example of "not a simple function of surface meltwater production". We will move this citation to the next sentence to avoid confusion.

L283-285. I think you can see indications of this even within the short time windows in which data is available each year, with comparable temperature spikes appearing to generate a smaller velocity response later in each measurement period – this is particularly apparent in 2013 and 2019. Also, this sentence would benefit from one or more references – there are plenty to choose from on this topic.

In general, the response of the speed to meltwater input is smaller later in the season as commented by the reviewer. Although we should be careful about the influence of rain (e.g.

the first speed peak in 2013 is due to rain), speed becomes less sensitive to temperature in the later period. We describe this trend with citations, for example, the suggested Davison et al., 2019 paper.

L292. Suggest '…glacier acceleration has been documented…'

We correct the text as suggested.

L295-6. It would perhaps be fair to say that incidences of rain induced acceleration may be increasing in Greenland as the climate warms, but if the authors feel it is truly of 'critical importance' then it would be good to see some justification for this with respect to its contribution to ice discharge.

I agree that the sentence carries too much emphasis. We will revise the text to explain the increasing importance of rain-induced acceleration, but not to mislead the readers.

L311-313. It also looks like temperature is falling at this time, so it may be that the addition of rainfall is partially compensated by a reduction in meltwater.

Temperature decreases by several degrees from 21 to 22 July 2014 (Figure 6b). However, the temperature peak that almost coincided with the rain event on 21 July was still one of the highest during the measurement period. Therefore, we attribute the lack of acceleration to the basal hydrological efficiency rather than the temperature drop.

L316. Rather that saying the subglacial drainage system 'had already developed' (which implies the system can reach a specific 'developed' state beyond which it no longer changes), it might be more correct to say something like 'had already evolved to a more efficient state'.

We agree with the comment. The text will be revised as suggested.

L316-317. As for L311-313, it looks like temperature is dropping at this point too.

I understand that the reviewer is mentioning the temperature drop by several degrees in the evening of 10th July 2017 (Figure 6c), which was approximately 0.5 day after the initiation of the rain event. Considering the swift response of the ice speed to the rain events in 2013 and 2014, the lack of acceleration in 2017 cannot be attributed to the temperature change. The

temperature drop is reflected by progressive deceleration during the rest of the measurement period.

L399. It's also been previously observed (e.g. Cowton et al 2016) that there is a stronger correlation between horizontal velocity and the rate of surface uplift (i.e. the vertical velocity) – have you checked to see whether there is any correlation in this instance?

As far as they are compared with temporal scales of several days to a week, velocity is more correlated with the magnitude of the uplift rather than the uplift rate. Cowton et al. (2016) (as well as Sugiyama et al., 2003) reported a correlation between velocity and uplift rate, but they are compared in shorter temporal resolutions (hours to a day). By the way, I assume the reviewer is referring to another paper below by the same author in the same year.

Cowton, T. et al., 2016, Variability in ice motion at a land-terminating Greenlandic outlet glacier: the role of channelized and distributed drainage systems, J. Glaciol., 62, 451–466, https://doi.org/ 10.1017/jog.2016.36

Sugiyama, S. and Gudmundsson, G. H.: Short-term variations in glacier flow controlled by subglacial water pressure at Lauteraargletscher, Bernese Alps, Switzerland, J. Glaciol., 50, 353–362, https://doi.org/10.3189/172756504781829846,
2004.

L453-4. I've flagged this here as there is a specific reference to mountain glaciers in this sentence, but the comment applies more generally. It's great that earlier work on the hydrology and dynamics of mountain glaciers is cited – this forms the foundation of the topic and it's important that its contribution is recognized. There is however also a substantial body of literature on the hydrology and dynamics of land terminating glaciers in Greenland which builds on this work from mountain glaciers and develops it in a Greenlandic context. This is largely overlooked in the current manuscript, but it would seem appropriate to give this a little more reference, as it is the logical stepping stone between earlier work on alpine glaciers and the current study (and addresses many of the same themes as this manuscript). For a review, see Davison et al (2019).

We acknowledge the reviewer for pointing out the lack of citations. In revision, we refer to the suggested previous studies on land-terminating glaciers in Greenland.

References

Cowton, T., Sole, A., Nienow, P., Slater, D., Wilton, D., & Hanna, E. (2016). Controls on the transport of oceanic heat to Kangerdlugssuaq Glacier, east Greenland. Journal of Glaciology, 62(236), 1167-1180.

Davison, B. J., Sole, A. J., Livingstone, S. J., Cowton, T. R., & Nienow, P. W. (2019). The influence of hydrology on the dynamics of land-terminating sectors of the Greenland ice sheet. Frontiers in Earth Science, 7, 10.