Response to Dr. Helmut Rott
We thank the reviewer sincerely for a very careful and thorough review. We appreciate the meticulous comments and the perspective of the reviewer as well. We have modified the text to incorporate some of the changes suggested. Below, you will find our responses in blue.

Naomi Ochwat, on the behalf of the coauthors

Comments on "Triggers of the 2022 Larsen B multi-year landfast sea ice break-out and initial glacier response" (revised version)
by N.E. Ochwat et al.

I wish to thank the authors for the careful considerations of the comments on the first version of the paper and the detailed response. The revisions address a main part of the issues raised in the review. However, there are still some items to be revisited, taking into account the issues explained below.

Main issues:
Volume and mass of the floating terminus of HGE glaciers:
The volume of the floating terminus of HGE glaciers is largely overestimated, contradicting mass continuity in view of the available mass for frontal advance. In L392/393 it is stated: "Hektoria Glacier had an extended thick (> 300 m) floating tongue that persisted until 12 to 17 March 2022". The joint HGE terminus area (formed by frontal advance after 2011) covered in January 2022 an area of 250 km2 (L243). Assuming a thickness of 300 m and density of 900 kg m-3 adds up to a total volume of 75 km3 and mass of 67.5 Gt. This is about two times the mass flux (MFL) supplied through the HGE gates located close to the 2011 glacier fronts. See numbers for 2011 to 2016 in Rott et al., 2018, and 2016 to 2021 computed for the same gates accounting for reduced velocities:

- **MFL 2011-2013: HG 5.73 Gt a-1, Evans 0.39 Gt a-1**
- **MFL 2013-2016: HG 3.39 Gt a-1, Evans 0.30 Gt a-1.**
- **MFL for July 2016 to Jan 2022 HG 2.24 Gt a-1, Evans 0.23 Gt a-1.**
- **Total HGE mass flux July 2011 to Jan 2022 to the frontal advance area: 36.9 Gt a-1.**

This implies a mean ice thickness of 148 m for an area of 250 km2 if no frontal calving at all would have taken place between 2011 and Jan 2022. In fact, there were many small calving events, in particular during the first years of frontal advance. In view of these numbers, the statements referring to ice thickness on the order of 300 m and more need to be corrected.

We appreciate your detailed analysis and calculations of the mass flux; however, the altimetry and DEM data indicate that the thickest part of the HGE tongue is at least 300-400 m thick (Figure S1 and S2). The shear margins are slightly thinner (Figure S1D) so not all of the 250 km^2 of the ice tongue is that thick, but the majority of it is (Figure S1E). There is some variation in the ice thickness, but not enough to constitute a deep discussion in this paper as the main focus of the paper is on the triggers of the loss of the fast ice and how the glaciers responded in its immediate aftermath.

Estimate of the grounding zone location:
The assumption of a partial grounding zone (GZ) within the advancing glacier terminus area and the inferred location of the grounding zones shown in Fig. 8 for HG and Crane glaciers are lacking traceability and are not in agreement with mass continuity (see point above). A much larger supply of ice mass to the frontal advance area would be needed than actually available. Fig. 8 (page 17) shows the inferred grounding zone (GZ) positions downstream (seaward) of the 2011 glacier fronts. By contrast, intensive thinning of the ice inland of the HG 2011 front, going on in subsequent years, implies further upstream shifts of the GZ after2011 (see the figure on HG elevation change below). Furthermore, the inferred GZ of Crane glacier in Fig. 8 shows a GZ seaward protrusion in the centre of the glacier which is located in a deep narrow canyon. In such a setting seaward extent of grounded ice has to be expected along the lateral slopes rather than in the centre.

Regarding the grounding line position, our determination of the grounding line was from a distinct change in calving style, as well as altimetry profile data, DEMs, and optical imagery glacier characteristics. We suggest that the discrepancy in our two grounding lines is due to the presence of an ice plain spanning the region between the two G.L. assessments. We infer that the ice plain may be ephemerally grounded with the tides (see Tuckett et al., 2020) or may have a tidally-paced oscillation in ice flow speed. In addition to your grounding line and our grounding line, we have now included Tuckett's grounding line on Figure 8. In the methods we explain the different possibilities of the grounding lines, the methodologies, uncertainties, and how the presence of an ice plain links it all together. We are also writing a follow-up paper that goes into greater detail on the grounding line.

Further issues:
L32: The calving of grounded ice was delayed by many months (not rapid).

According to Pfeffer 2007, "rapid" is defined as "retreat rates in excess of 200 m/yr". With this definition, the loss of grounded ice occurred within the year and was much greater than 200 m/yr. Other papers in the literature refer to "rapid" as 1000 m/yr for Columbia Glacier and Upsala Glacier East as well as 15 km over 8 years for Röhss Glacier (Pfeffer 2007; Warren et al., 1995; Glasser et al., 2011). This delay you mention may have existed in previously documented "rapid retreat" cases but due to the low temporal resolution of data at the time the delay may not have been obvious. To maintain a consistent terminology, we will continue to use "rapid".

L236/236: "During the 2011-2022 period of fast ice presence in the embayment, changes in the glacier extents suggests that the fast ice stabilized the Larsen B tributary glaciers" During 2011 to 2013 the losses of glacier mass were very high, and also in 2013 to 2016 the mass deficit was significant (Rott et al., 2018). This means there was no distinct

stabilization signal during the first years of the fast ice period, but a rather gradual transition.

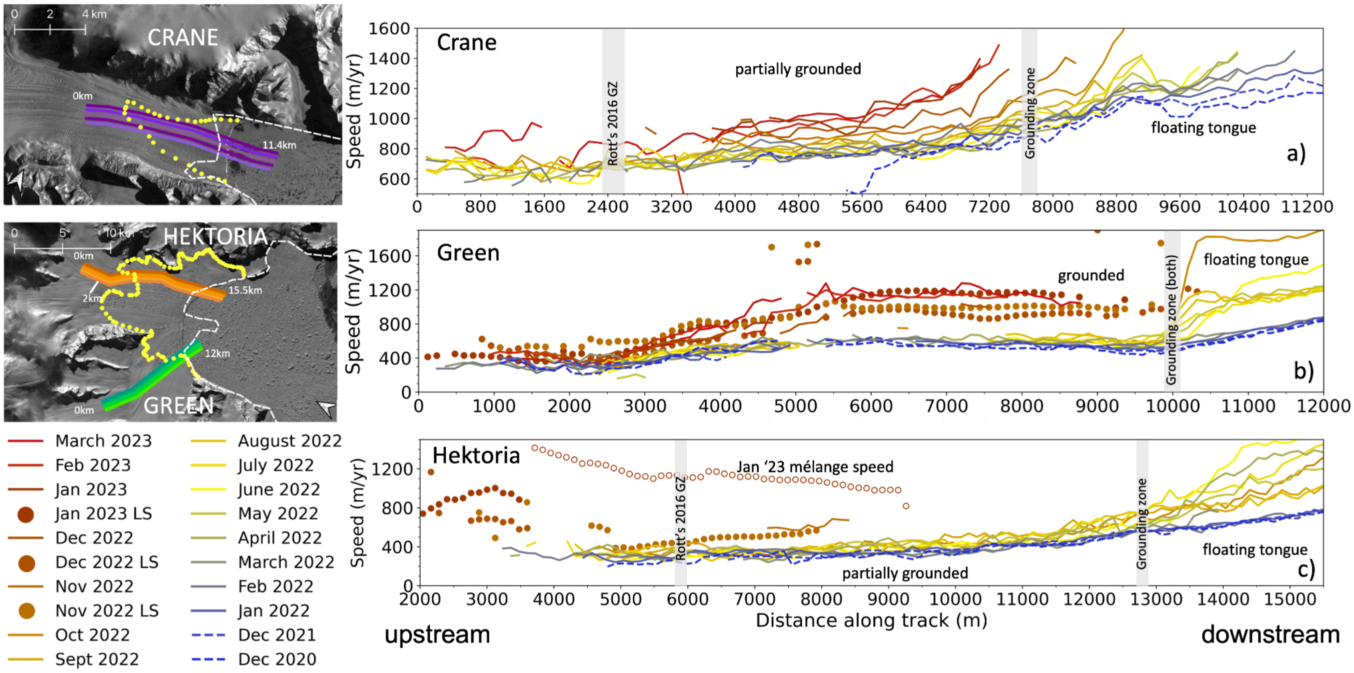
We have altered the sentence to say “During the 2011-2022 period of fast ice presence in the embayment, changes in the glacier extents and GNSS data suggests that the fast ice stabilized the Larsen B tributary glaciers and buttressed the Scar Inlet Ice Shelf, relative to the state prior to the fast ice occupation.”

Figure 9c: Please check the Hektoria LS velocities for Nov. 2022, Dec 2022, Jan 2023. These numbers exceed the numbers derived from Sentinel-1 data and show a different trend along the flowline.

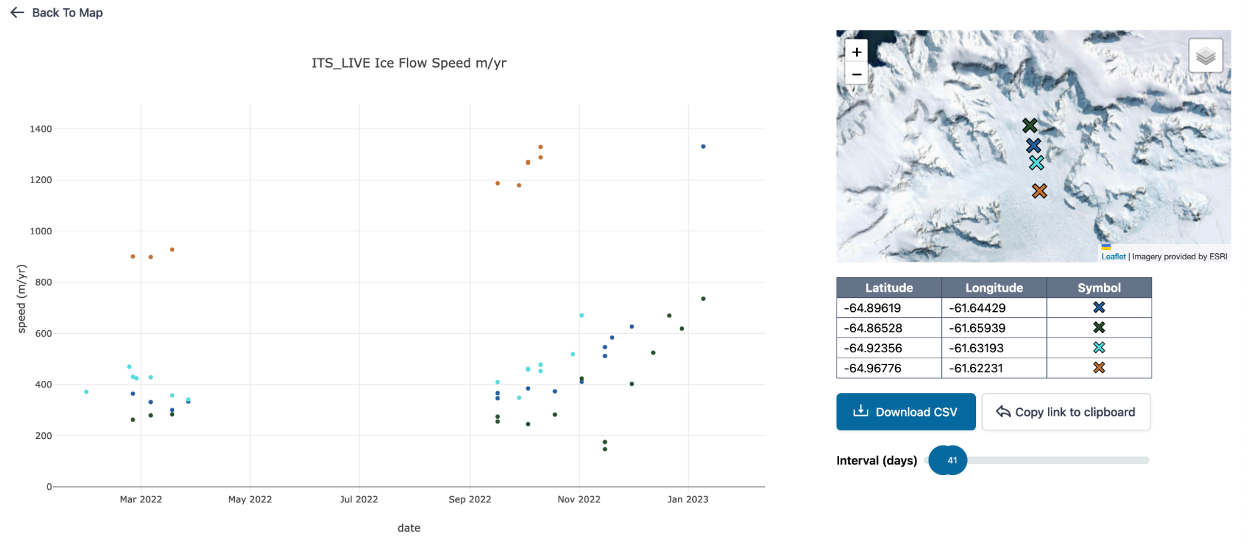
Thank you for bringing this to our attention. We noticed that one of the image pairs for November 2022 had only an 8-day separation, making the error range for the reported velocities very large. We have removed that image pair and replaced it with one spanning 22 November to 08 December, 2022. We have also adjusted the scatter plot to show the difference between grounded ice flow speeds (solid dots, as before) and melange flow (open circles) for January 2023. We have adjusted the manuscript text accordingly. This data is consistent with the ITS_LIVE data (see screenshot below), including the higher accelerations in the uppermost region of Hektoria in late 2022.

Our velocity profile is aligned with the altimetry profiles from the IceBridge flights earlier in the 2000’s. This is to support later analyses that will look at the relationship between thinning and flow speed. Because the velocities extracted do not follow a central flow line, and because our extracted band to gather vectors for the profile is wide, there are some variations in the along-flow trend in speed relative to a true centerline of flow. Nevertheless, the graph provides a good representation of the general speed-up and loss of ice through the mapped period.

Please see the replacement figure:



And data from the ITS_LIVE interactive mapping tool:



Latitude	Longitude	Symbol
-64.89619	-61.64429	✖
-64.86528	-61.65939	✖
-64.92356	-61.63193	✖
-64.96776	-61.62231	✖

Velocity data generated using auto-RIFT (Gardner et al., 2018) and provided by the NASA MEaSUREs ITS_LIVE project (Gardner et al., 20XX).

https://mappin.itsliveiceflow.science/chart?lat=-64.89619&lon=-61.64429&c=ll&lat=-64.86528&lon=-61.65939&c=cpg&lat=-64.92356&lon=-61.63193&c=reb&lat=-64.96776&lon=-61.62231&c=c

Figure 12, chronology: In the context of processes leading to frontal advance after 2011 detailed data on glacier mass balance, mass fluxes and ice flow velocities (as reported by Rott et al., 2018) are of relevance. (not mentioned in the chronology)

We have now included reference to your 2018 paper in the chronology figure.

L592/593: “The calving regimes and dynamical changes of the Larsen B tributary glaciers are similar to their response after the 2002 Larsen B ice shelf.” This is statement is not well founded, considering that the ice shelf in 2002 was more than 200 m thick, the tributary glaciers were in balance, at least up to 1999, and the glacier tongues were several hundred metres thick, of compact ice and grounded. In contrast, in 2022 the glacier had newly formed floating glacier tongues of less than 150 m mean thickness with rugged surface topography (evident in ICESat-2 transects of Fig. S1), implying significant variations in ice thickness at small spatial scale and rheologically weak ice on account of this.

There are several aspects of the two events that are similar, as well as important differences to identify. The rest of the paragraph discusses this:

“The calving regimes and dynamical changes of the Larsen B tributary glaciers are similar to their response after the 2002 Larsen B ice shelf disintegration, suggesting that calving is an immediate response to stress perturbations (Hulbe et al. 2008). At first glance, the two events were quite different; for example, the tributary glaciers were stable prior to the 2002 event and though they were readvancing and stabilizing prior to the 2022 event they were still in an imbalanced state (Seehaus et al., 2023), additionally the ice shelf was old and thick whereas the fast ice was much younger and an order of magnitude thinner. However, despite these differences, the similarities in the tributary glacier response to the two events are important to identify.”

L623: High thinning rates were observed on Hektoria Glacier also in 2011 to 2013, amounting to 20 m a-1 on extended sections of grounded ice.

We acknowledge that Hektoria was still in a state of thinning from 2011-2013, but this section of the paper is discussing the immediate response of the glacier to the loss of the ice shelf in 2002-2003 and fast ice in 2022-2023; hence, we left out a more detailed examination of thinning rates over the last 20 years.

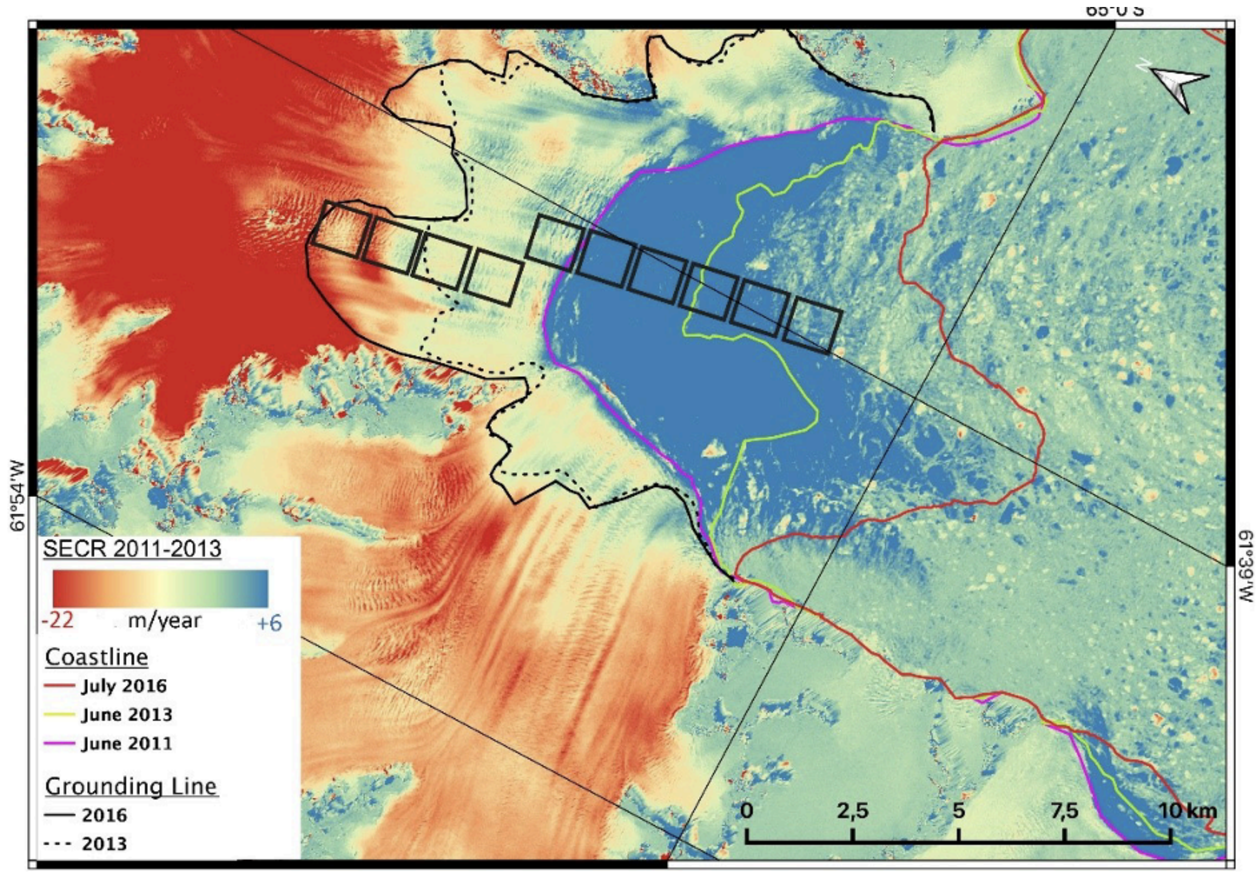


Figure 1: Map of rate of surface elevation change (dh/dt, m/year) from June 2011 to June 2013 based on the elevation difference in TanDEM-X DEMs. Background: TanDEM-X amplitude image of Hektoria and Green glacier terminus, 2011-06-25. Colour code dh/dt from -22 m/yr to +6 m/yr. According to mass continuity the transition from dh/dt on the order of -20m/year to much smaller numbers is a clear indication for the transition from grounded to floating ice. Further details in Rott et al., 2018 and 2020.

Given this graphic, it is evident the area of the hypothesized ice plain thinned up to ~8 m/yr in some areas during this time. If that was floating ice in hydrostatic equilibrium that would be more than 60 m of thinning in one year, which is clearly not likely given the ocean conditions of this region (Nicholls, Pudsey, and Morris 2004). This kind of transition is possible when going from a steep glacier to a flat ice plain, furthering our interpretation of the presence of a partially grounded ice plain. As mentioned previously, we will be evaluating the grounding lines and ice plain feature in greater detail in our follow-up paper.