Answers to Anonymous Referee #2

Thanks for your comments, which will help us to improve our manuscript. In the following, we will give answers to all major questions and comments. The corrections and comments which are not listed here will be fully adopted in the revised manuscript.

L19-L41: *I find the Introduction quite strange as it opens with a presentation of the results and study area, before providing any of the background or methods that would usually be expected in a paper. I therefore suggest moving the text from L19-L27 and Figure 1 to the Results, and the text from L28-L41 to a new section called 'Study Area' after the Introduction. The Introduction would then start on L42, although this first sentence might need to be modified.*

Response: We would like to start with attracting the reader by a first glance on the remarkable velocity variation patterns addressed by this study. (In fact, this was the starting point of our study.) The following paragraphs then provide a complete introduction in a conventional order. We would prefer to keep this principal structure. However, we will shorten the first paragraph to a minimum by shifting all background and explanation to the following paragraphs. Thus, our suggestion for the first and the 3rd paragraph would be as follows:

Paragraph 1:

"Based on optical and radar remote sensing data, we observed remarkable flow velocity variations of Harald Moltke Bræ, a marine-terminating outlet glacier in north-west Greenland. Figure 1 gives an impression of the variations in time, observed at a fixed position close to the terminus. Ice flow accelerated significantly in 1999/2000 and 2005/2006 and in 2013-2019. During the 2013-2019 phase, the dense temporal sampling reveals pronounced seasonal velocity variations, by one order of magnitude. At the end of 2019 velocities returned to a very low level that sustained at least until July 2020. This paper investigates in detail the spatio-temporal variations in glacier flow and geometry underlying this variation pattern."

Paragraph 3:

"Already prior to the era of satellite remote sensing, significant changes in the dynamic behaviour of Harald Moltke Bræ were reported. Wright (1939) observed an exceptional advance of the glacier front by about 2 km between 1926 and 1928 and inferred that the average surface flow velocity in this interval was at least 1000 m/year (2.7 m/day). Mock (1966) used the displacement of ice-surface features visible in aerial and terrestrial photographs to show that between 1954 and 1956 the average velocity was about 1 m/day, ten times higher than the average velocity between 1937 and 1938. Based on satellite remote sensing, the accelerated phases in 1999/2000 and 2005/2006 were previously documented by Joughin et al. (2010) and Rosenau (2014) and accelerated flow in 2013/2014 was reported by Hill et al. (2018)."

L44-45: *more recent papers and reviews suggest that the length of the active and quiescent phases of surge-type glaciers can be longer than what you state. For example, Jiskoot (2015) states that the quiescent phase lasts for 10s to 100s of years, while the active phase lasts for 10-15 years. See: Jiskoot H. (2011) Glacier Surging. In: Singh V.P., Singh P., Haritashya U.K. (eds) Encyclopedia of Snow, Ice and Glaciers. Encyclopedia of Earth Sciences Series, pp 415 428. Springer, Dordrecht. https://doi.org/10.1007/978-90-481-2642-2_559.*
Response: Thanks for mentioning this more recent publication. We will change our statement about the length of the quiescent and the active phases according to Jiskoot (2011). This reference will be added in the revised manuscript.

L51: *The study of Monacobreen by Murray et al. (2003) is one of the first to have reported an upglacier propagating surge, so I think that it should be referenced here.*
Response: We will include this reference.

L56: *you should also mention the large surge cluster in east Greenland, reported by studies such as Sevestre and Benn (2015) and others*
Response: We will include this information about clusters of surge glaciers in Greenland at line 56 as follows: "Some surge glaciers are also known in Greenland. For example, clusters of surge glaciers in central-west Greenland and central-east Greenland have been reported by Sevestre and Benn (2015). Apart from these clusters, also Hagen Brae in north-east Greenland is assumed to be a surge glacier (Solgaard et al., 2020)."

L61: *You need some words to introduce this sentence, such as: 'In mechanism (A), the base of a polythermal glacier: : :'. Similar to introduce (B) on L63*
Response: The suggested introduction of menachism (A) "In mechanism (A), the base of a polythermal glacier (…)" will be adopted in the revised manuscript."

L78: *I would delete 'extraordinary' as several other studies have previously documented surges initiated at the glacier terminus (e.g., see comment for L51)*
Response: With the word 'extraordinary' we meant to emphasize our findings about the pronounced seasonality with velocities decreasing to the level of the quiescent phase during the surge. However, as this expression could be misleading here, we propose to either remove it or use the word 'remarkably' instead.

L85: *I don't understand what 'suited' refers to here. Perhaps you mean 'suitable', but in that case you need to describe why the images would be suitable. In this section also make it clear that the black triangle in Fig. 2 is the point that all velocity time series were derived for – it took me a long time to spot this information in the figure caption.*
Response: "suited" is not important in this sentence and will be removed. We will add the following sentence in this section: "All velocity time series in this paper refer to the position indicated by the black triangle shown in Fig. 2."

L89: *would be useful to provide some numbers here to define what you mean by 'spatial and temporal coverage as high as possible'. e.g., max resolution, max temporal coverage Table 1 caption: change 'Overview over …' to 'Overview of …'*
Response: "as high as possible" means here that the spatial and temporal coverage was adopted and varies strongly depending on the characteristics and availability of different

data sets. We will remove this part of the sentence "with a spatial (…)" as this does not affect our main message which is that we computed monthly velocity fields.

L99: *You state that you use four different DEMs, but only list three*
Response: Yes, it is true that only three DEMs ware used. This will be corrected.

L112: *it would be useful to provide a reference or two for the choice of 0.9 to convert the surface velocity to depth-average velocity. For example, Cuffey and Paterson (2010) provide a discussion of this: Cuffey, K.M. and Paterson, W.S.B., 2010. The Physics of Glaciers. Academic Press*
Response: The references for the value 0.9 are given one sentence later (Wu and Jezek, 2004). Nevertheless, we will additionally include the reference Cuffey and Paterson (2010) in line L112 as suggested.

L119-122: *provide the resolution of your basal topography data*
Response: We will add at the end the sentence in line 119 "(…) gridded format with a spatial resolution of 150 m".

L125: *in the caption for Fig. 4 it's stated that the SMB is calculated from the difference between precipitation and runoff (i.e., it's not calculated independently), so that should be made clear here. This also seems to implicitly assume that no mass is lost from calving at the terminus, but from Fig. 5 and 7c it looks as if this could be important. Can you therefore address whether this is accounted for, and what implications this has for your SMB data? This is partly discussed in Section 3.6, but it's unclear whether your SMB values are adjusted for the calving flux.*
Response: The note "difference between precipitation and runoff" intends to explain the SMB, but it does not mean that we computed it in this way. We will remove this statement in the brackets. In the entire paper, we always considered a fixed area of the glacier for computing the mass balance. We defined this area to be the part of the drainage basin above a cross section, which is located close to the glacier front, but remains behind the front over the entire study period. The amount of ice lost by calving is not considered in this paper. As we focused in our study on the glacier dynamics, we are mainly interested in the deviations from the balance ice flow and corresponding to that in the ice mass and volume changes within a fixed area. For the contribution of the glacier to the sea level for example, we would need to consider the mass-balance of the entire glacier, but this was not our intention here. To clarify this, we will add a sentence in the revised paper pointing out that we actually do not consider the mass-balance of the entire glacier, but only of sub-area with a fixed size.

L127: *would be useful if you can show the location of this cross section on Fig.* 2
Response: To show the exact location of this cross section, we will include a line in Figure 2. We chose this line such that it is located close to the glacier front, but remains behind the glacier front over the entire observation period.

L134: *This seems to be the Results section, so it would be good to include that in the title*
Response: We will change the title of section 3 to "Results" replacing this long title.

L152: *change 'exceptional' to 'exceptionally'. Can you also talk about whether this high precipitation fell as rain or snow, and what time during the year it fell? For example, high rainfall*

in the summer might have a different impact on dynamics compared to high snowfall in the winter.
Response: We considered here only the yearly averaged data. The changes of these climatic influences were, unfortunately, not examined with a higher temporal resolution in the scope of this paper.

Figures 4 & 6: *please use letters (a), (b) and (c) to label and refer to the different figure parts, consistent with the other figures. In the figure caption, the text '(Black triangle in Fig. 1)' should refer to Fig. 2. It would also be useful to see the surge periods labelled on these figures (e.g., by lightly shading the background), similar to what you show in Fig. 3, so that it's clear as to how their stated start and end times of the surges match up with the velocities and frontal positions.*
Response: Yes, it is true that the black triangle is in Fig. 2, not in Figure 1. The references in the captions of Figure 4 & 6 will be changed accordingly! We will use (a), (b), … to denote subfigures as suggested. Shadows marking the surge periods will be added to these Figures.

Figure 8a *seems to show the velocities at quite a bit higher temporal resolution than in Fig. 6. The better temporal resolution allows the variations to be more clearly seen, particularly for years such as 2014 and 2015, so can you plot the full high resolution dataset (and associated errors) in Fig. 6?*
Response: Besides the monthly velocities we also computed semi-monthly velocities which are shown in Figure 8 for instance. In view of the sparsely available data before 2013, we decided to show the entire time series from 1998 to 2020 with a resolution of one month, so that it is consistent over the entire time period. Figure 1 contains all available velocities. The time series in Figure 1 and the semi-monthly velocities in Figure 8 show that the major temporal variations are already contained in the monthly time series. Instead of changing the resolution we suggest to include an additional sentence in the paper referring to Figure 1 and stating that a higher resolution will not change our main conclusions.

L214-220: *this discussion only refers to mass lost by flow through the cross-section close to the glacier front. However, mass is also lost by retreat of the glacier terminus (and mass gained when it advances), so this should also be accounted for when presenting the mass numbers and balancing them against the flux through the crosssection and the SMB.*
Response: Here, we consider only the mass balance of the glacier area above this cross section (see also the more detailed response to the comment of line 125).

Figure 11: *there is insufficient information provided in the figure caption or methods to understand what exactly was measured for these visual features, and how a distinction is made between 'moderate' and 'strong' conditions. The methods refer to Appendix E, but this simply consists of three satellite images without any description. Please provide more information so that the reader can understand what was done, and what was measured.*
Response: We will include an explanation of the classification of the features in Appendix E based on examples in the selected Landsat scenes. We well refer to Appendix E in the Figure caption.

L252: *at the start of this section I would like to see a few sentences to describe exactly how you defined a surge, including its start and end date. For example, is this just based on velocity variations, or also on things such as changes in terminus position, calving rate, surface cre-*

vassing, etc.? This is needed to put the remainder of this section in perspective, particularly because the 2013-19 surge was so much longer than the previous two surges.
Response: We will add the following sentence at the beginning of this section: "In this context as the main criterion for the surge the strong change of flow velocity is used, as discussed in the introduction."

L266-273: *here and elsewhere in this section it would be useful to make better reference to the figures*
Response: We agree that references to the figures are missing in this section. The statements are mainly based on Figure 8. We will add the references to this figure.

L283: *please provide some more detail about the large meltwater lakes. E.g., are these supraglacial? Ice marginal? Where on the glacier do they form?*
Response: We will mention in the text, that we refer to the supraglacial lakes here. As an example of these supraglacial lakes we will refer to Appendix E.

L322: *can you provide the maximum velocity for the third pattern?*
Response: The maximum velocities will be included in the explanation as follows: "… with a maximum of about 6 - 10 m/yr… "

L316-337: *I find it a bit hard to follow and visualize the flow patterns based on the text descriptions here. To make them easier to understand, could you add a schematic or cartoon that shows the velocities and surface elevation changes associated with each pattern (A, B, C, D), and the sequence that occurs during surge initiation (A-B-C-D) and after surge initiation (A-D)? This will also help with the description of upglacier propagation vs uniform acceleration described in Section 4.5*
Response: We will add an additional Figure showing schematically one ideal profile for each of the flow velocity patterns and the 4 corresponding patterns of the ice height change.

L343: *can you provide a reference to support the statement that 'Surge looped moraines typically indicate a down-glacier surge propagation'?*
Response: This is actually an assumption for which we do not have any reference. We will remove this statement, if we cannot find and reference for it.

L353: *would also be useful to make comparisons with other up-glacier propagating surges, as well as the findings of this paper (particularly for Section 4.7): Thøgersen, K. et al. 2019. Rate-and-state friction explains glacier surge propagation. Nature Communications, 10, 2823.*
Response: We actually made some comparisons with an up-glacier spreading of a surge in Svalbard observed by (Sevestre et al. 2018). However, Thøgersen, K. et al. (2019) will be included as an additional reference.

L366: *can you provide more information about this? E.g., what are the mean annual temperatures here? Have there been any direct measurements or evidence of polythermal conditions at this glacier or other nearby ones of a similar size?*
Response: We decided to delete the description and arguments of the polythermal glacier in the lines 366-368 as we do not have enough evidence for that. Instead, we will begin with the hydrological argument, and after that shortly explain why a thermal mechanism is unlikely.

L375: *please describe what the 'Kamb drainage-switching theory' is for any readers who might not be familiar with it.*
Response: We will delete the sentence with the Kamb drainage switch theory as this theory is not that relevant for our studies at Harald-Moltke-Brae.

L389-394: *do you have any observations of crevasse formation at Harald Moltke Brae from the remote sensing imagery that provide support for the statements made here? It could be useful to add them as a visual feature to Fig. 11*
Response: The resolution of the applied Landsat images is too low for a detailed analysis of the crevasses.

L421: *it would be useful to provide some numbers here for the mass imbalance, including the mass due to terminus retreat (related to comment for L214-220)*
Response: Our mass balance considerations refer always to fixed area (see explanations for L214-220).

L431: *was any change in crevasse formation actually observed (similar comment to L389-394)? It could also be useful to refer to the visual indicators from Fig. 11 here or elsewhere in the Conclusions to help back up your statements.*
Response: see answer to comment for lines 389-394.

L450: *I don't understand the reference to improvement in spatial resolution here, when both Landsat 7 and 8 have a multispectral resolution of 30 m and panchromatic resolution of 15 m*
Response: The resolution refers here to the computed velocity fields (Rosenau, 2014). This statement will be added in the text for clarification.

Appendix E: *text explanations in this section seem to be missing?*
Response: Some more explanation will be added here describing how we distinguish between low, moderate and strong occurrence of a feature based on these example images.