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Interactive comment on "Surges of Harald Moltke Bræ, north-west Greenland: Seasonal modulation and initiation at the terminus" *by* Lukas Müller et al.

Anonymous Referee #2

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This paper provides an interesting review of the surges of Harald Moltke Brae in NW Greenland, and their unique characteristics. In particular, the remote sensing data demonstrates that the glacier undergoes dramatic seasonal variability in motion during a surge (by up to an order of magnitude), and that the most recent surge lasted for 6 years, compared to a duration of 2 years for the two surges prior to it. The surges also initiate at the glacier terminus and propagate upglacier. Such strong seasonal variability in motion during a surge hasn't been reported for any glacier before, and there aren't many other reports of upglacier propagating surges. The results from this paper can therefore help advance general glaciological understanding of glacier surges, and the wide variability in their form and extent.

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The data is generally well presented, with lots of illustrative figures, although there are several places where some clarification of the methods and results, and improvements to the figures, would help. These are detailed below, together with other technical corrections. There are also several places where better referencing to existing literature would be useful. I find that the arguments in the Discussion and Conclusions concerning the causes of surges and their connections to basal shear stress and changes in the subglacial hydrological system are currently a bit weak, and would really be strengthened by modelling, but I expect that this modelling is beyond the scope of this paper.

L5: I would suggest saying 'annual velocity' or 'seasonal velocity' here to make it clear that this velocity variability occurred on an annual, repeating basis during the 6 year surge, rather than just once during it.

L8: I think that the wording is better as 'constitute a glacier surge', since you're talking about a singular surge each time

L10: 'involving' would be better worded as 'examining'

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.

L35: I would delete 'As another remarkable feature,', and start this sentence with 'A 3 km long and l km wide lake. . .', as I'm unclear as to how this lake is particularly remarkable in this part of the paper

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 ex-

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ample, 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.

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

L56: you should also mention the large surge cluster in east Greenland, reported by studies such as Sevestre and Benn (2015) and others

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

L78: I would delete 'extraordinary' as several other studies have previously documented surges initiated at the glacier terminus (e.g., see comment for L51)

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.

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. . .'

L99: You state that you use four different DEMs, but only list three

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

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L119-122: provide the resolution of your basal topography data

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.

L127: would be useful if you can show the location of this cross section on Fig. 2

L134: This seems to be the Results section, so it would be good to include that in the title

L136/7: would be better expressed as '. . .advance of the terminus which interrupted its long-term retreat'

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.

L172: change to 'compensate for the calving rate'

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.

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?

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 cross-section and the SMB.

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.

L227: change '230 km' to '230 m'

L251: change 'glaclier' to 'glacier'

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 crevassing, 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.

L266-273: here and elsewhere in this section it would be useful to make better reference to the figures

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?

L286: I think that you mean 'efficient drainage system' here, rather than 'effective'?

L301: change to ‘were modulated by a similar mechanism’

L322: can you provide the maximum velocity for the third pattern?

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.

L343: can you provide a reference to support the statement that ‘Surge looped moraines typically indicate a down-glacier surge propagation’?

L351: change to ‘opposite to down-glacier’

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.

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 poly-thermal conditions at this glacier or other nearby ones of a similar size?

L375: please describe what the ‘Kamb drainage-switching theory’ is for any readers who might not be familiar with it

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.

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)

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.

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

L450: change to 'enabled use of image pairs. . .'

Figure A1: there have been calls to stop using the terms 'slave-master' in remote sensing as they can be interpreted as colonial terms. Something such as 'reference' and 'secondary' is better. See, for example: https://earthenable.wordpress.com/2020/08/11/new-insar-terminology-coming-in-vogue-master-slave-to-reference-secondary/

Appendix E: text explanations in this section seem to be missing?

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