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The Cryosphere Discussions

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

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In this paper the authors present a characterisation and analysis of the dynamics of Harald Moltke Brae, a marine terminating glacier in north-west Greenland which experiences multi-year periods of accelerated glacier flow (surging). They use a variety of optical and radar remote sensing products from 1998 onwards to deduct surface velocities and surface elevation models using well established and cited methods, as well as to observe ice front positions and hydrological features. Several patterns of seasonal velocity variation and spatial flow distribution are identified and used in describing and interpreting the observed behaviour.

The strong seasonal flow modulation observed during the most recent surge is consistent with possible hydrological controls which have been discussed in existing literature (i.e. acceleration with meltwater onset and rapid deceleration with the switch from an inefficient to an efficient subglacial drainage system at around meltwater peak). Surges are reported to initiate at the terminus and ice flow acceleration propagates up-glacier, and possible mechanisms for this are discussed. The analysis of whether the most recent surge was significantly different to past surges is somewhat unclear and could be expanded on. It will naturally be very interesting to see how the situation evolves into the future.

This paper is well written and will surely be of interest to readers of the Cryosphere, in particular those interested in the phenomenon of glacier surging. It presents a thorough and detailed picture of the dynamical behaviour of Harald Moltke Brae since 1998, bringing together a lot of observational data and contributing an interesting discussion. I have a number of specific comments and questions which follow below.

SPECIFIC COMMENTS:

L 6-7: From the results presented it doesn't seem like there is enough evidence to state that there is similar seasonality during the quiescent phases. As you say in L261, there could potentially be seasonality present during the quiescent phases, but it could not be identified due to the limited accuracy of the Landsat velocity fields.

L 7: The choice of the word 'peculiar' suggests to me that the seasonal amplitude during surging is something observed only at Harald Moltke Brae, which is not the case – perhaps 'significant', 'noteworthy', 'interesting' or something along those lines would avoid this potential misunderstanding.

L 26-27 and Figure 1: It is stated that velocity remained low from the end of 2019 to the beginning of 2020 but from Figure 1 it looks like the low velocities extend to mid/late 2020 although it is hard to see for sure when the last data point is. Could the text be updated to state when (which month) in 2020 the data extends until? It would be

interesting to know whether the velocity remained low over the summer 2020.

L 89: Is it possible that the Sentinel and TerraSAR-X data can be used to get velocity fields with temporal resolution finer than monthly, given that the time basis and temporal resolution is less than a month? If this is the case, the use of a monthly averaged dataset could mean temporal resolution is being lost. I think that the use of a monthly combined velocity dataset is reasonable, but have you analysed the individual datasets to make sure you are not losing potentially valuable information on a finer temporal scale, particularly around the rapid summer decelerations? When looking at the surge of Kyagar Glacier (doi:10.5194/tc-11-723-2017) we used TerraSAR-X data to compare velocities over consecutive 11 day periods to identify similar rapid summer decelerations.

Table 1: Could you provide a specific range of days for the Landsat temporal resolution rather than 'few days'?

L 99: It states that 4 DEMs are used but only three seem to be referred to – the ActicDEM and two interferometric DEMs from January 2011 and Dec/Jan 2013/2014. Is there something missing, or is the fourth DEM referring to the computed ice-height change rates?

Figure 3: The shading representing the most recent surge seems to cover less than the six years of reported surging. Is there a reason for this or is it an oversight? Additionally, I think it might be clearer to remove the black line joining the observed front position points, to better represent the discontinuous nature of the historical dataset.

Figure 6: Is there a reason not to include 2019 or even 2020 in this figure considering that the surge continued through 2019? It would give a more complete picture of this very recent surge if the data extended as far as possible, including termination of the surge in late 2019 or in 2020. I also recommend repeating the description of parameters shown on panels rather than refer back to Figure 4 – this allows Figure 6 to be understood in isolation.

Figure 7: The colours in the flow velocity profile plots are difficult to distinguish, especially 2013-09 and 2013-12. Please consider using a range with more contrast in these types of figures (e.g. also Figure 14, 15) or perhaps even different line patterns.

Figure 8: The year 2018 is almost impossible to detect in the bottom panel. Could you find a way to make it visible or if it is hidden behind one of the other years perhaps make a note of this in the caption.

L 209: I assume this is referring to a lack of significant year-to-year changes in the lake, however it could be useful to provide a brief description of the seasonal patterns observed (lake formation in summer). In section 4.2 it is noted that large meltwater lakes form at the beginning of summer so it would be useful to make note of that here in the results section.

Figure 11: I suggest considering switching the axes in this figure i.e. stacking the years vertically, to make it easier to compare the timing of events between the years (as described from L 206 onwards).

Figure 14: It would be helpful to show a horizontal line at 0 to make it easier to distinguish between positive/negative height gain (especially for the earlier dates for where the difference is more subtle). The same applies to Figure 15.

L 275: It would be nice to briefly summarise the glacier types 2 and 3 identified by Moon et al. here.

L 282: The observation of seasonal meltwater lakes was not noted in the results and should perhaps be included in section 3.5 too.

L 307: Regarding the low velocities at the beginning of 2020 – when is the latest available velocity data, i.e. from which month in 2020 and in particular do they extend into the spring/summer?

L 310: The summary sentence here seems a bit subjective and also contradicts the statement in the abstract that the most recent surge 'lasted significantly longer' than

previously observed surges or the passage from L 74-76. If not in terms of maximum velocity then at least in terms of surge duration the most recent surge does seem (in my subjective opinion) significantly different to at least the two well observed surges before it. The various arguments presented in section 4.3 mostly relate to limitations in the data (e.g. lack of data pre 2013, greater smoothing on velocity maxima in the earlier Landsat data). So in summary, it would be more correct to say there is insufficient evidence (historical data) to conclude whether the surge behaviour has changed since 2000.

L 319: The example of September 2013 doesn't show the moderately higher velocities further upstream which is described for pattern A, but rather seems to show velocity decreases up the glacier. Is it just the high velocity at the terminus which is the defining feature of pattern B?

L 326: I like this concept of categorising the various flow profles but the difference between C and D isn't very clearly defined – both of these patterns show high velocities with the maximum at the glacier front. Is the difference that with C the velocities high up the glacier are lower and hence the overall profile steeper, or that velocities are higher overall for D? Also it might be helpful to add that while pattern D reverses A, the timescales will be quite different because of the difference in the magnitude of velocity between these two patterns.

TECHNICAL CORRECTIONS:

L 227: There is a typo on the stated depth of 230 km (should be m). L 251: Typo 'glaclier' rather than glacier.

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