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Discussions

Interactive comment on "Record mass loss from Greenland's best-observed local glacier" *by* S. H. Mernild et al.

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Anonymous Referee #2

We thank the anonymous referee for the comments related to our paper in Discussion for TC.

Scope. First, but perhaps not the most vital point, the title of the paper is not providing much information about the major conclusions drawn in the paper, it sounds as a desperate attempt to attract attention. Mittivakkat may be the "best"-observed local glacier on Greenland but with very few studies done that does not say much. Record mass loss is of course sensational but such records are an effect of the length of the record, the longer the record the more significant are large aberrations in terms of their mean-

ing. I suggest the paper is provided with a reasonably balanced title that describes the scientific gains provided by the study; compare with your conclusions presented in the abstract. This point also reflects my next main issues with the paper, that it is not providing enough detail.

MERNILD: The title is changed.

I think that a contour map of the glacier and examples of the mass balance measurement setup would be very welcome additions. Such a map could also include equilibrium lines from different years and other useful information.

MERNILD: A contour map is added to the manuscript, including information as average ELA, stake location, and meteorological station location. Further, is added a figure illustrating net balance with elevation.

Glacier setting and history. I think it would be useful to get a more in-depth description of the climatological setting of the glacier. What are dominant weather patterns for summer and winter? This would provide further insights into how the glacier (which is on the coast of the north Atlantic) is affected by the general circulation.

MERNILD: The links between winter precipitation and winter balance (winter precipitation is dominant for the winter balance/winter accumulation) and summer temperature and summer balance (summer temperature is dominant for the summer balance/ablation) have been mentioned in the manuscript, and a reference to a previous study by Mernild et al. (2008) has been added, where these links have been described in detail.

The historical aspects of the glacier are also of interest. There are studies from the 1930s indicating a wide spread retreat of glaciers around the north Atlantic but none are referenced. I think it would be useful to know if there exist late maximum extent moraines, if they are dated and how large the glacier was at the Little Ice Age or whenever the moraines were formed. When discussing record melts and longer-term

retreat patterns it is use- ful to know what the base line was to which all comparisons are compared. The reason for bringing up this historical perspective is simply the inclusion of older front measurements in the paper, which in my opinion need to be put in some perspective. You have also included the longer temperature anomaly record that dates back to 1900. Therefore, an approximate extent of the max LIA or equivalent extent should be included in the map.

MERNILD: The position/location of the Little Ice Age (LIA) trimline is added to Figure 1d, and Mittivakkat Glacier terminus changes and Tasiilaq mean-annual-air-temperature anomaly for the intervals noted in Figure 1, are listed in Table 1. The year 1900 is related to the LIA trimline and moraine estimated from field observations (Hasholt et al. 2008; Humlum and Christiansen 2008). As illustrated by Figures 1d and 2, and Table 1 the glacier terminus has retreated by about 1600 m since the maximum LIA extension, and 1300 m since the first photo's from 1931, averaging $\sim$15 m yr-1 and $\sim$16 m yr-1, respectively. The variability in terminus retreat has been compared to changes air temperature observations in Table 1. What the reviewer is asking for has been addressed in the paper. Further, a historical mass-balance comparison is done, comparing the present Mittivakkat Glacier observations (1995–2010) with estimated Mitttivakkat net balance values (1900–2000, Mernild et al 2008), to illustrate if values (including the 2009/10 record value) for the observed period 1995–2010 is greater than the estimated net balance values for the early-twentieth-century warming period (1930s and 1940s).

Hasholt, B., Krüger, J., and Skjernaa, L. Landscape and sediment processes in a proglacial valley, the Mittivakkat Glacier area, Southeast Greenland. Geografisk Tidsskrift, 108(1), 97–110, 2008.

Humlum, O. and Christiansen, H. H. Geomorphology of the Ammassalik Island, SE Greenland. Geografisk Tidsskrift, 108(1), 5–20, 2008.

Figures. The paper lacks a figure that shows the glacier in map view with elevation

contours and where the local met station and the stake system is shown. Such a figure would greatly improve the understanding of the glacier and the experimental setup. It would also reduce the text describing the stake system. It is also possible to show a measured balance and the location of the ELA.

MERNILD: Such figures about elevation contours, location of average ELA, meteorological station location, and stakes from the observation program are added to the manuscript. Further, the location of the trimline from the Little Ice Age (LIA) is plotted (lower left corner) on the satellite image. The trimline and moraine is based on fieldwork observations, and has been estimated back to 1900 (Hasholt et al. 2008; Humlum and Christiansen 2008). Unfortunately, only parts of the trimline are shown at the new Figure 1d. In Table 1 the average glacier terminus retreat is shown since 1900 (anomaly for the intervals noted in Figure 1), and compared with temperature data from Station Tasiilaq, to put the retreat of the glacier in a long-term climate perspective. Also, a figure illustrating net balance with elevation is added to the manuscript.

Specific comments on content: P. 463, l. 15, you state that GIC can equilibrate to climate changes on time scales of a few decades. This to me seems unsubstantiated. First, I would argue it is too small and it would certainly be a function of the climate in which the glacier is located. You need to provide some references to back up this statement. I also like to see how you justify it for Mittivakkat.

MERNILD: In Table 1 the average glacier terminus retreat is shown since 1900 (anomaly for the intervals noted in Figure 1), and compared with temperature data from Station Tasiilaq. Based on the Mittivakkat Glacier data presented in Table 1, there seems to be a delay between periods with warm temperatures and fast glacier retreat, since the retreat of the MG terminus is highly influenced by: 1) the topography, going from valley to peak topography as further inland, away from the fjord, the MG terminus gets; 2) the shadow effect from the surrounding mountains; 3) the variability in climate; and 4) a delay in dynamic processes within MG. These issues have been mentioned within the paper.

P. 464, l. 23, you state that the observed mass balance is “considered” (by whom?) to be accurate to within ∼15%. First, you need to back this up with some hard data or point at some reference where this error estimate is evaluated. In short, the paper completely lacks an error discussion.

MERNILD: This statement is from one of the Mittivakkat Glacier observation paper by Knudsen and Hasholt. Here, is the reference: Knudsen, N. T., and Hasholt, B. Mass balance observations at Mittivakkat Glacier, southeast Greenland 1995–2002. Nordic Hydrology, 35: 381–390, 2004.

P. 464, l. 27-28, you need to be careful about the terminology of equilibrium line and ELA (as implicitly stated in the parenthesis). The equilibrium line is the “set of points on the surface of the glacier where the climatic mass balance is zero at a given moment”; ELA is “the spatially averaged altitude of the equilibrium line” and may be observed in the field but is commonly determined by fitting a curve to the mass balance curve established from measurements. Please correct the text to correctly state what it is you refer to. See (and correct) also your def on p. 467, l. 3-4. In addition, you seem to provide elementary definitions for a number of elementary textbook terms such as winter balance and nunatak. I suggest deleting these and as stated above some are not even completely accurate.

MERNILD: This is fixed and erased from the manuscript. And the mentioned definitions are used instead.

P 465, l. 6, “water equivalent” is abbreviated “w.e.”

MERNILD: This is changed through out the paper.

P. 465, l. 23-24, you state that high winter temperatures would decrease the “cold content of the snow and thereby increase the melt. I think that if you do the calculation you will see that this does not significantly affect the total balance of the glacier and I believe the end result is well within the errors of your measurements. Hence there is

an effect but it is not significant unless you can show it is on the order of 15% of the mass balance. Remember the difference in energy content of the latent heat of fusion of liquid to solid water and the heat capacity of ice (snow) of approx. 160:1.

MERNILD: The text is rewritten.

P. 465, l. 26-27, There are many excellent glaciological studies on the effects of albedo on melting so I do not see why you reference Douville et al. In general I find the paper lacking references to glaciological literature where applicable.

MERNILD: Additional references has been added to the manuscript.

P. 466, l. 5, I am curious to see how the measured precipitation correlates with winter balance for the years you have such measurements. I would expect some correlation but not necessarily a strong one. A plot would provide some additional perspective on your discussion of the data.

MERNILD: In 2003, 2004, 2007, 2009, and 2010 we didn’t went to the Mittivakkat Glacier to observe end-of-winter balance. Due to the missing values in the winter balance time series, we are in this paper only focusing on the net balance. In a previous paper by Mernild et al. 2008, a link between the end-of-winter Mittivakkat Glacier balance and Station Tasiilaq cumulative winter precipitation ($r^2=0.68$, $p<0.01$, where p is the level of significance), end-of-summer mass balance and cumulative summer positive degree days ($r^2=0.55$, $p<0.01$), and observed and calculated (calculated based on the links described) glacier net mass balance ($r^2=0.71$, $p<0.01$), were done. Lines, related to the Mernild et al. (2008) reference, have been added to the manuscript, illustrating the significant link between the climate and the glacier mass balances.

Mernild, S. H., D. L. Kane, B. U. Hansen, B. H. Jakobsen, B. Hasholt and N. T. Knudsen 2008. Climate, glacier mass balance and runoff (1993–2005) for the Mittivakkat Glacier catchment, Ammassalik Island, SE Greenland, and in a long term perspective (1898–1993). Hydrology Research, 39(4): 239–256.

P. 467, l. 9, you state that Aar is not related to ELA when ablation occurs over the entire glacier but surely you mean “net ablation” or negative mass balance over the entire glacier?

MERNILD: This has been changed in the manuscript.

Interactive comment on The Cryosphere Discuss., 5, 461, 2011.