The Cryosphere Discuss., 5, C217–C223, 2011
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The Cryosphere Discussions

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

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Received and published: 31 March 2011

Anonymous Referee #2

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 meaning. 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

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providing enough detail.

MERNILD: The title has been changed.

Structure. The paper suffers from its current organization. It seems to follow the short contribution format of GRL or some similar journal. Since TC does not have such extreme limitations, the paper can and should be expanded to better explain and present the data and their interpretation. The methods and results chapter should be split into three chapters. Methods: present the methods used for new data presented in this study; Results: present the new data introduced in this study; and a general "Mittivakkat Glacier" chapter that presents earlier studies and older published data included in this study. Such a division also provides an additional benefit in that the glacier is properly described and existing data presented for readers.

MERNILD: We agree that a change of organization is warranted. We decided to split the methods and results section into two sections: "Methods and historical data" and "Results". We considered having separate short sections on "Methods" and "Historical data", but we thought the flow was better when these sections were combined.

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 has been added to the manuscript, including average equilibrium line, stake location, and meteorological station location. Also, we 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: A discussion of links between winter precipitation and winter balance,

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and between summer temperature and summer balance, has been added to the manuscript, with a reference to a previous study by Mernild et al. (2008).

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 useful 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 has been added to Figure 2. Also, Mittivakkat Glacier terminus changes and Tasiilaq mean-annual-air-temperature anomaly for the intervals noted in Figure 1 have been 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 2 and 3 and Table 1, the glacier terminus has retreated by about 1600 m since the maximum LIA extension, and 1300 m since the first photos from 1931. The variability in terminus retreat has been compared to air temperature anomalies in Table 1. Further, a historical mass-balance comparison is done, comparing the present Mittivakkat Glacier observations (1995–2010) with estimated Mittivakkat net balance values (1900–2000, Mernild et al. 2008), to illustrate that mass losses (including the 2009/10 record loss) for 1995–2010 are likely greater than the estimated net balance values for the early-twentieth-century warming period.

Hasholt, B., Krüger, J., and Skjernaa, L. Landscape and sediment processes in a proglacial valley, the Mittivakkat Glacier area, Southeast Greenland. Geografisk

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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: A figure showing elevation contours, equilibrium line, meteorological station location, and stakes from the observation program has been 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 a small part of the trimline is shown in the new Figure 2. 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 Tasiilaq, to put the retreat of the glacier in a long-term climate perspective. Also, a figure illustrating net balance with elevation has been added.

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: This statement has been modified to state that the response times of GIC are shorter than those of ice sheets. Also, we added a discussion of the various factors contributing to the rate of terminus retreat.

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 based on a paper by Knudsen and Hasholt (2004). The reference has been added. 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: We have corrected the ELA/equilibrium-line terminology in the manuscript and removed definitions of elementary terms.

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

MERNILD: This is changed throughout 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

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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 has been rewritten to state that the relation between winter temperature and mass balance has not been shown to be significant.

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 have 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, the end-of-winter mass balance was not observed. Due to the missing values, we have focused on the net balance. In a previous paper by Mernild et al. (2008), we documented links between the end-of-winter Mittivakkat Glacier balance and Station Tasiilaq cumulative winter precipitation ($r^2=0.68$, $p<0.01$), end-of-summer mass balance and cumulative summer positive degree days ($r^2=0.55$, $p<0.01$), and observed and calculated glacier net mass balance ($r^2=0.71$, $p<0.01$). Text related to the Mernild et al. (2008) reference has been added to the manuscript.

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: Yes. The text has been changed.

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