Dear Editor,

We basically agree with the comments made by the reviewers and M. Pelto. The most important change is that we have added a panel to figure 3, which explores the change in mass balance gradient over time in more detail. We have copied the relevant sections of the review report and reply to them below in red.

Regards,

Roderik van de Wal

M. Pelto

354-12: Why is Krabill et al. (2004) used and not more recent papers on the same topic by Zwally et al. (2011) or Sørensen et al. (2011)

The reason is that Krabill et al. 2004 was the first paper to our knowledge pointing out the difference between the marginal zone and the inland parts of the ice. We agree that it is useful to add the above mentioned references which show the increased thinning along the margin much more convincingly over the more recent years.

354-18: The observation that the balance gradient is increasing and this would increase climate sensitivity is a key point to this data set. Figure 4 does not present compelling support for this argument at present. The legend for Figure 4 needs to identify the individual years. Further to avoid confusion the years should be color shaded systematically, for example with all the 1990's shades of say blue and green and the 2000's shades of yellow-red. This would provide better visual evidence of the changing balance gradient and its robustness. The actual slope of each line for each year would be useful to report along with what the authors determine is a robust measure of the difference in mass balance with elevation. A quick comparison of Site 4 and Site 9 data indicate a difference less than 4 m in three years, all in the 1990's, and six years with difference greater than 4.5 m, all since 2000. This is not a very robust measure, but indicates the value of adding a figure or tabular data similar to Figure 2 that illustrates the differences between a measure of this nature such as (S4+S5+SHR) – (S8+S9). This may or may not be a more robust measure of mass balance change than the balance gradient.

We will improve the colors of figure 4 and we will present a panel b to figure 3 showing the change in the mass balance gradient over time to substantiate the statement of increased melt near the margin.

355-4: In terms of ELA on this section of the GIS, the ELA does not correspond to the altitude of the

transient snow line at the end of the melt season. However, the elevation of the transient snow line would have value, and can be recognized in the daily MODIS imagery with sufficient frequency for an end of the year elevation assessment (Pelto, 2011). Has this been done?

No we did not study MODIS imagery, we present our own observations.

If it has this would be useful to report as well as the ELA. If it has not I am not suggesting the authors include this analysis in this publication.

The data will hopefully be used by the reviewer or somebody to do this. We consider outside the scope of the paper.

Reviewer 1

A citation to current SMB work being carried out by the Geological
Survey of Denmark and Greenland in their PROMICE program would be appropriate
in the introduction.

We will do this

Specific comments, all minor:

P352, L10-14: I think the tense is unnatural in these first sentences. Consider rewriting to past perfect tense.

Changed first sentence

P352, L23: limited in length time wise, I presume? Perhaps "temporally" is better ot avoid confusion.

Changed

P353, L19-20: Which sites are you referring to as in the "lower region"?

S4,S5, SHR added info

P354, L11-14: This sentence is unclear to me. What is larger? The period? I think I understand, but can you please clarify.

Clarified

P354, L17-19: It is not clear to me if you're referring to your reproduction of the analysis using Krabill's periods in this statement. If so, it would be interesting to see a plot of the calculated SMB gradients for the four periods, since this is an important point.

We have considered this but the four partly very short periods do not warrant a figure to it. The

point made is that our data confirm what has been noted by Krabill and has been confirmed by several other studies more recently.

If you refer to the total time series (i.e., Fig. 3) I'm not sure how the increasing SMB gradient you imply is evident? The fit you've made is linear, which is a constant gradient, yes?

Indeed we do not aim to suggest that there is an acceleration in the ablation over time near the margin.

If, however, you by increasing gradient mean increasing spatially when moving towards the margin – which seems to be the case – this could be stated a bit clearer. Alternatively this discussion-like section could be shortened somewhat due to the scope of the journal.

We add an additional panel b to show the change of the mass balance gradient over time, which is in line with M. Pelto suggestion to clarify this statement.

P354, L22: Surely a question of convention/semantics, but you say the mass balance decreases when changing from e.g. -6 to -1. One could also say it increases.

We agree

P354, L23: In *an* absolute sense [..]

We agree

P355, L4-5: How did you derive the small correction?

We added a sentence to explain this detail

P355, L16: [..] melt extent, both important [..]

We agree

Table 1: Perhaps add a horizontal line above the row of mean values to improve readability

We agree

Fig. 1: Good, clear map. Perhaps state the source of the satellite image?

We agree

Fig. 3: Use "Time" on x axis label to be consistent with figure 2.

We agree

Please explain more clearly which sites are represented by the different line-types. Adding labels like you already have on SHR, S5 and S4 would be fine.

We agree

Fig. 4: Please add a legend so each year can be distinguished.

We agree

Fig. 5 (b): Unit on Y-axis should be Cumulative SMB (m w.e./yr)?

We agree

Reviewer 2

Main substantive issue

The paper states that data always represent one mass balance season. A bit of clarification would help in terms of what this means. For example, if you visit a site once a year in August (e.g. Aug 2009 and 2010) and there is subsequent melt in Sept 2009 of the first year, what year is that loss attributed to? Presumably it cannot be distinguished from the majority of melt in the following summer of 2010? This issue may not be important for the general mass balance trend over 21 years but does have implications for comparisons with other data sets (e.g. summer melt estimates from regional climate models) and inter-annual variability (as late August/September melt may be considerable). This is not a criticism of the paper but I think needs clarification so that other workers do not use the data incorrectly.

We agree that this is an issue for the season 2010. As we do have whether station data including Sonic Height ranger data we know that there is in general not significant melt, though there is even melt in winter occasionally near the margin. For this reason we have corrected the data of the season 2009-2010 such that the Autumn 2010 melt is assigned to the mass balance season 2009-2010. We clarify this point now in the paper.

Specific issues and suggested edits

Abstract - would help to add elevation of the highest of the 3 sites that experiences a significant increasing trend in ablation

Done

P352, L10 - add a comma after “10yr,” P352, L10 – of the Greenland ice sheet HAS improved. . ..

Done

P352, L11-14 – this is awkward as written currently. Perhaps change to “The analysis of gravity field, radar altimetry and inferometry data combined with regional climate models has contributed to this”

Done

P352, L 15-19 – suggest editing to “Figure 1 shows the K-transect where 21 years ago, IMAU (Institute for Marine and Atmospheric research Utrecht) started mass balance observations, GPS measurements. . ..”

Done

P353, L8 – might as well say that the record from the highest site is 4 years shorter as opposed to “a few”

Done

L14-15 – suggest merging the two sentences “....except at the highest site where snow and firn is at the surface and density measurements are carried out.”

Done

Figure 3 – the yellow data (site 7?) is almost invisible and all the dotted lines could be made bolder

Done

Figure 3 only appears to plot data up to the very negative 2009-10 year. Why isn’t the 2010-11 year also included in Fig 3 as it is in Fig 2 and in Table 1?

Omission changed

Figure 3 caption – add “ with no STATISTICALLY significant trend. . .”

Done

P354, L22 - I think that to state that “we can conclude that on average the mass balance decreases linearly

with elevation" is rather too simplistic. There is a certainly a 'general' decrease and it looks approximately linear but the wording currently seems rather loose. This is especially the case since no statistics are applied to test whether the best fit lines are indeed linear throughout the period.

We have added r=0.996 and the average gradient to be more precise

Figure 4 – it would help to clarify trends in mass balance gradient if there was a gradation in the colour scale from the start to the end of the time series

We have improved this

P354/355 – suggest editing to "The highest ablation took place during the 2009–10 season while the lowest ablation was recorded during the 1991-92 season".

Done

P355 L3 – ". . . and site 10 WHERE available"

Done

P355L 4 – 6 – it would be helpful to have a little more information on how this height correction was applied as it is not clear from this summary.

Done