

Thank you to the reviewer for the careful reading and helpful comments. We will address the points below as follows:

General comments: This paper provides a good dataset, for speed and glacier front position of 16 outlet glaciers located in all different geographical regions around the Greenland Ice sheet. Their data includes the periods before the warming and the rapid changes started (from the mid 1980s). Deriving records of air and sea surface temperature, they investigate the response of the outlet glaciers to warmer climate. It is a valuable paper but it needs somehow stronger argument for some of their discussion points and conclusions.

A better explanation of each glacier geometry and fjord geometry is needed while discussing the differences in behaviour of the glaciers in each section.

*The aim of the paper is to investigate the response to changing climate conditions with time rather than attempting to account for detailed individual responses to the forcings. However, we have now included more details on fjord shapes and have added glacier widths to Table 1.

Specific comments: Page 1642, line 24: Is sea temperature the same as sea surface temperature or is it ocean temperature? Needs better argument why they use sea surface temperature instead of deep ocean temperature. That may make a big difference for glacier with long floating tongue.

We agree that deep or subsurface ocean temperatures would be a better indicator of heat delivery to the glacier fronts but observations are only available of SSTs. We use SSTs as an indicator of changing ocean conditions and refer to the fact that they may be considered as proxies for subsurface temperatures in certain locations whereas in other places surface currents control SSTs.

Page 1642, line 26: A high number of coincident retrievals of speed and ice-front position also allows us to determine the strength of the relationship between retreat and acceleration by calculating for each glacier the statistical correlation between the two parameters. What is this statistical correlation between two parameters? Explain better.

We use Pearson's correlation coefficient as stated in the discussions and believe this to be a commonly understood and used statistic.

Page 1644, line 28: For the position of the glacier front: why not averaged front position, instead of one point on the centerline? I reckon the mean front position is more reliable indicator.

None of the glaciers analysed had unevenly retreating/advancing fronts and the centreline is a good representative of position. If we were making a quantitative estimate of ice loss then we agree it would be better to use the 'box' method.

Page 1645, line 9: For some of these outlet glaciers there are much higher resolution thickness data (bed topography) available (CReSIS data). Those data should be included.

The thickness data were used only to derive the gravitational driving stresses for the flowline model and for this purpose were required as a grid covering the whole ice sheet. The catchments derived using this method are used only to indicate relative sizes of the glaciers studied. Including the higher resolution data for the limited coverage of the lower portion of a few glaciers would make no significant difference to these calculations.

Page 1646, section 3.2: Is the flow speed, averaged summer speed or maximum speed?

Flow speeds were based on displacements over the period between images used for tracking, ie. 16, 32 or 35 days, as described in the methods section.

Page 1651, line 5: Major calving event of Petermann was in summer 2010 not 2011.

Will change this, thank you for the check.

For each sector add a plot, showing air temperature and sea surface temperature evolution in time.

We have added graphs of air temperature with time to Figure 3. For SSTs it is harder to choose a consistent location for a point that would be relevant for ocean temperatures affecting the glacier so we believe that adding this data would not improve the paper.

For some of their selected glaciers, they mention how many percentage of the Greenland discharge occurs through each glacier (e.g. Daugaard Jensen Glacier). Why not showing this for all of these 16 glaciers?

We include the catchment areas in Table 1 and have also now written this as a percentage.

It is better to include data from other studies for the part they are missing, e.g. front position of Petermann Glacier (Falkner et al., 2011) or velocity measurements of the recent years (Joughin et al., 2010 and Moon et al., 2012).

******We have now included some details of the other frontal positions for Petermann in the text. We also add an estimate for ice-front position following the recent calving event. For velocity measurements from Joughin it would mean judging the location on velocity maps and estimating the colour scale, this would be too inaccurate and not add more than 2 data points. Similarly for Moon et al. who present velocity change maps on for 2000-2005 and 2005-2010. We therefore do not agree that trying to add data from other papers would make this one better.

Discussion:

Page 1652, line 14: It is true that bed topography is unknown but there are other available data, which may help to understand the difference in behaviour of these glaciers, e.g. shape of the fjord (wide or narrow), existence of the sea ice or ice mélange, glacier front surface elevation (whether the front is close to flotation or not)!

Please see above *****.

Page 1652, line 21: "By 2002 the front retreated to a well defined, presumably grounded, linear ice-front, and calved much narrower icebergs. The lack of acceleration was presumably because the loss did not affect the stress balance as the ice removed was not bounded by fjord walls" First, figure 7 doesn't really show the velocity changes of the glacier after 2002, there is only one point! There might be an increase in glacier flow between 2002 and 2006! Can Joughin et al 2010 or Moon et al., 2012 show some additional velocity measurements to this? Second, if in 2002 it was grounded, then it should show changes in the stress balance (loss of basal resistance) even if the fjord walls were not supporting the front.

See above ****** for adding extra velocity points. We have now acknowledged in the text that there could be some unobserved velocity change between 2002 and 2006. We have changed the text as follows and now refer to loss of **floating** ice and believe that this will satisfy the point.

We also note that Kong Oscar exhibits similar behaviour to Ingia Isbrae, Umiamakko and Jakobshavn Isbrae in terms of frontal retreat/loss of floating tongue; but unusually there is no detectable impact here on flow speeds although we only have measurements in 2002 and 2006. Prior to 2002 Kong Oscar ice front existed as a semi-coherent 5-10 km floating tongue extending beyond the coast as a conglomeration of partly connected tabular icebergs. Between 2002 and 2006 the front retreated to a well defined, presumably grounded, linear ice-front, and by 2006 was producing much narrower icebergs. The lack of detected acceleration was presumably because the loss of floating ice did not affect the stress balance as the ice removed was not bounded by fjord walls.

Page 1652, line 27: "The first two both experience major calving events on timescales of decades" When were the major calving events of Nioghalvfjærdsbrae? It should be marked on figure 7. Again, it would be much more helpful, if they include front position change or velocity from previous studies for the parts they are missing.

We add for Petermann that 'Within the time span of our flow speed record that Johannessen et al. (2011) observed large calving events in 1991 and 2001 in addition to the 2010 event. A further large calving event took place on 16/17 July 2012 leaving the ice front approximately 5.3 km further retreated than the last position plotted in Fig 6. This estimate is based on a MODIS image for 17 July 2012 downloaded from the NASA website (<http://visibleearth.nasa.gov/>) which has a spatial resolution of 250~m'

Have added to the text that the main Nioghalvfjærdsbrae calving front had a major calving event in 1997, the first since 1963, and we note that the narrower northern branch experienced a retreat and loss of about 36 km² of floating ice some time between 2006 and 2008. In order to add other data points to our time series we would need to estimate the common 'zero ' position read the datapoints from graphs in other publications. We do not believe it possible to do this with any degree of accuracy.

Page 1653, line 5: some explanation why it is stable. Move the first few sentences from page 1654 to here.

We believe that the suggested change would make the paper less easy to understand than more, in particular because the p-values, used in the first few sentences of page 1654 have not been defined until after line 5 on page 1653.

Page 1654, line19: Explain the geometry of the Gyldenlove and Kong Oscar, how long and wide is their floating tongue?

We have added 'For both these glaciers the proposed floating tongues would be about 3 km long.'

Conclusions:

Page 1655, line 11: Velocity data shown in figure 7, except for D.G., is not enough to make such a conclusion about any changes seasonality of these glaciers.

Have changed the sentence to read 'The major exceptions to these responses were Kong Oscar, Petermann, Nioghalvfjærdsbrae and Dagaard Jensen glaciers which showed neither acceleration nor any observable increase in seasonality.'

Page 1655, line 16: "The data presented here support the concept that under conditions of increasing atmospheric and/or oceanic temperatures, the loss of floating tongues or retreat of grounded ice-

fronts changes the balance of forces at the termini of tidewater glaciers resulting in rapid glacier acceleration and thinning.” Not for at least four of these glaciers!?

We have argued in the discussions that SSTs adjacent to Petermann and Nioghalvfjærdsbrae cooled during the period and hence these two are not ‘under conditions of increasing atmospheric and/or oceanic temperatures’. We also argue in the discussions that the remoteness of Daugaard Jensen from the ocean may limit rapid access of warm water to the front. For Kong Oscar, the floating tongue had not been bounded by fjord walls so we change the sentence to read –

“The data presented here support the concept that under conditions of increasing atmospheric and/or oceanic temperatures, the loss of fjord-bound floating tongues or retreat of grounded ice-fronts changes the balance of forces at the termini of tidewater glaciers resulting in rapid glacier acceleration and thinning.”

References:

Very long list of references. I suggest checking again whether they have been used for the right reason.

Page 1639, line 26: Nick et al. 2009 doesn’t discuss hydrofracturing of crevasses! That is discussed in Nick et al., 2010. And line 29, again Nick et al., 2012 investigate the importance of submarine melt for Petermann Glacier not 2009.

OK. Changed. We do not feel there are any references we could easily remove.

Table 1. Better to include the front thickness and width, ice discharge and geometry of the front, whether or not they have a floating tongue. Kong Oscar and 79fjærdsbrae are missing Location and CC.

We have added fjord widths to Table 1. Floating tongues are described or hypothesised in the text. Caption now includes why no CC for Kong Oscar or Nioghalvfjærdsbrae (no ice-front positions to test for a correlation). This similarly affects the specification of a location, the reader can refer to the Xs on the maps.

Figure 4 to 7, It helps a lot if they include a graph showing sea-surface temperature and air temperature changes in time.

We have added air temperature graphs to Figure 2. Point regarding SSTs already addressed above.

Page 1642, line 27: change “allows” to “allow”

Disagree – ‘A high number ... allows us...’

Page 1651, line 9: delete “in”

The end of this paragraph is changed now anyway.

Page 1655, line 27: remove “highly likely”

Have removed “highly” following other the suggestion of the other reviewer.