The Cryosphere Discuss., 5, C1607–C1615, 2011
www.the-cryosphere-discuss.net/5/C1607/2011/

The Cryosphere Discussions

Interactive comment on "Changes in the marine-terminating glaciers of central east Greenland and potential connections to ocean circulation, 2000–2010" *by* K. M. Walsh et al.

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Received and published: 16 December 2011

GENERAL COMMENTS

The paper by Walsh et al. presents frontal positions, thinning and ice speed of 38 marine terminating glaciers in East Greenland using remote sensing observations from Landsat 7 and ASTER scenes. The data are new, and aim to cover the transition zone between the fast retreating glaciers in southeast Greenland and the mostly unchanged glaciers in northeast Greenland in more detail than previous studies (e.g. Pritchard et al., 2009; Joughin et al., 2010). The paper is well-written and the methods are reasonably well explained, but the discussion is weak and in places incomplete or even

incorrect. Overall, the scientific significance of the manuscript is good, but the scientific and presentation quality need improvement. I feel that the paper needs some more work to consolidate the findings and improve the discussion. Some of the figures also need improvement, and better error estimates are needed (see below). I recommend the paper to be published in TC after (moderate) major corrections are made.

SPECIFIC COMMENTS

The largest drawback of this paper is the treatment of glacier surging. The authors mention surging in the Blosseville Coast and Geikie Plateau region, and present a very general paragraph (4.1), but apart from Sortebrae, do not directly link the behaviour of surging to the distribution of glacier retreat rates. Further, section 4.1 has many mistakes (glacier surges generally last between months and a few years for temperate glaciers, and several years for polythermal glaciers, while the quiescent phases are decades). Instead, the authors could do quite a nice analysis by integrating the frontal fluctuation results in this paper with the occurrence of surges: using an overlap between Fig 1 in Jiskoot et al. (2003) would be useful. Additionally Jiskoot et al. (in press) investigate the relationship between surging and frontal dynamics (both in surge and quiescence) and found that surge behaviour (both surge and quiescence) is the main control on the magnitude of frontal variations in the Blosseville Kyst and Geikie Plateau region. It could well be that all 8 glaciers with retreat of 1-5 km along Blosseville Coast (Fig 2) are in their quiescence phase, so these may experience faster retreat and depletion, and lower flow speeds, than non-surge-type glaciers (e.g. Yde and Paasche, 2010).

Overall the discussion of the results in this paper should be expanded and strengthened. The role of the Irminger Current in the behaviour of East Greenland glaciers could be set into a better context by including papers with direct recent and past measurements (e.g. Christoffersen et al., (TC, 2011) and references in Jiskoot et al. (in press)). The discussion would also benefit from a closer comparison Joughin et al. (2010) and Pritchard et al. (2009 + supplement), and by addressing for individual

glaciers the influence of surging behaviour, the margin width (e.g. have Scoresby Sund and Kangerdlugssuaq fjord glaciers narrower tidewater margins than those along the Blosseville Kyst and/or Kong Christian IV land?), and the (near) fragmentation of confluent tidewater margins (e.g. Fig 6-7). It would further be beneficial to differentiate between outlets from the Greenland ice sheet and glaciers peripheral to the ice sheet (some of which are outlets from Geikie Plateau ice cap or icefields around the Watkins Bjerge, and many are valley glaciers, especially along the Blosseville Coast).

Jiskoot et al. (in press) investigate this region in more detail and suggest a number of different controls (e.g. surface mass balance: see also TC discussion comment by Pelto), surging behaviour, glacier type, location, etc). It is also clear from Kargel et al. (TCD, 2011) that several land-based glaciers of different sizes inland of Blosseville Coast are retreating significantly, so the potential direct role of a warming ocean in the retreat of glaciers north of Kangerdlugssuaq fjord is probably at least aided by a regional long-term negative surface mass balance.

Some inferences in this paper are made without strong arguments, and I feel the authors can get more out of their data than they present. For example, i) a graph of surface speed versus retreat rate may elucidate dynamic thinning (4.2), ii) an approximation of volume change can be made from frontal retreat and thinning, assuming an average glacier width and thickness of calving front. The SST data presented in this paper (A-D) are taken quite far off the coast, and information on the methods is a little sparse (exact timing and potential role of sea ice?). Improve this and present SST measurements closer to the coast (at least quite far onto the continental shelf). Major SST results should be presented in the Results (new section 3.4.4), rather than in the discussion.

Adding a Table with the individual glaciers, their general properties (lat-lon, area, terminus length, coastal or inland, confluent or not), frontal variation, thinning and speed, will be helpful.

MINOR ISSUES AND TECHNICAL CORRECTIONS

Title: According to the official regional division, the regions discussed in this paper are southern East Greenland and central East Greenland (Weidick, 1995: Fig 1). I suggest changing 'central east Greenland' to "southern and central East Greenland".

Throughout paper:

The way the specific subregions in this paper are described is confusing: It is very clear what the Blosseville Coast region is, and it is superfluous add 'southern Geikie Plateau' to that (e.g. 2867, 29). See more specific suggestions in the page, line numbered comments below.

Remove space between number and degrees symbol.

The order of references between a set of brackets needs to be chronological.

Differentiate between Kangerdlugssuaq fjord and Kangerdlugssuaq glacier and give full names of glaciers throughout the paper (e.g. Midgard glacier, Daugaard-Jensen Gletscher).

2866, 17: remove 'unpredicted'.

2867, 27-29: the location description here is confusing: the range of latitude in degrees is sufficient.

2867, 10: Box et al., 2009

2868, 7: delete 'these'

2869, 1-19: Need some more detail about the satellite image data. LS7: were the scenes orthorectified, was the panchromatic (14/5 m resolution) band used, ASTER: state the level (AST14DEM?) and resolution, MODIS: are the data used twice daily, daily or monthly, what resolution (250 m?), how does sea ice affect the accuracy of SST measurement?

2870, 3: delete ‘arbitrary’: the centreline point is not arbitrary.

2870, 7. Need a spatial resolution of the frontal position and an error margin (including human error).

2870, 15. You assume sea level is at 0 m asl, but what is the tidal range in this part of the world? (This will give you an additional error margin for the elevation).

2870, 19-27. Need to add information on the time periods used to calculate the surface speed.

2870, 23. Delete ‘more’ and ‘is found’

2870, 24. Be more precise than ‘near the front’ (e.g. give a range of distance from the front in m or km).

2871, 7-9: The location is overly complicated and not entirely correct (e.g. the southern part of Blosseville Kyst is not draining from Geikie Plateau). Rewrite: “...glaciers terminating along the Blosseville Coast and Kong Christian IX Land coast (see Fig 1).....”.

2871,11: Rewrite: “.....glaciers along Scoresby Sund.”

2871, 16. I agree with reviewer Jacob Yde that Gåsegletscher is hardly a tidewater glacier and should be removed.

2871, 18-19: replace with: “...is found along the Blosseville Kyst and Kong Christian IV Land coastline,....”

2872, 4: replace with: “..into Scoresby Sound and Gåsefjord (inner Scoresby Sund).

2873,6-10. Mention here is all glaciers are outlets from the Greenland Ice Sheet and what the range of terminus widths is.

2873, 27-28: Since Midgard Glacier retreated >5.5 km between 2000-10, the measurement location was 5 km up-glacier in 2010, but $\sim$10.5 km in 2000. Part of the

speed-up may therefore be because it is closer to a terminus at flotation. It would be interesting to mention the speed $\sim$5 km up-glacier from the 2000 front and compare it to this reported one, and see if there is still speed-up.

2874, 1. This title (3.4.2) could simply be ‘Blosseville Coast’.

2874, 18: Are both Howat et al. references necessary?

2874, 7: Change to “....into Kangerdlugssuaq fjord.”

2875, 8-9: There are many more glaciers presented in this study that are of surge type (see Jiskoot et al. (2003) Figure 1). It would be useful to identify more of these and relate the tidewater margin behaviour possibly to surge-type behaviour (see also Jiskoot et al (in press) and Kargel et al. (2011))

2875, 9-12. This general sentence about surging is out of place and incomplete: this only described the surge mechanism of temperate glaciers (‘Alaskan-type’: see Murray et al., (2003).

2875, 9-13. ‘Jiskoot et al. (2001)’ is missing from the list of references.

2875, 20. Change header to ‘Scoresby Sound and Gåsefjord’

2875, 26. Daugaard-Jensen Gletscher

2876, 25: Glacier surges last months to years, not days to weeks, and not all surging glaciers advance (but they all speed up).

2877, 1-4: Releases of trapped subglacial water coincide with the termination of a surge and not with the speed-up. Quiescent period are decades to centuries. Read up on surging in Murray et al (2003) and Jiskoot (2011).

2877, 10-15: This section is repeated from 2875, 15-20, where the maximum surface speed is given as 3 m d-1 instead of 2 m d-1 in this section. Clean up both sections and avoid overlapping information.

2877, 16: There are at least 7 glaciers in East Greenland observed surging e.g. Sortebrae, Sermeq peqippoq and a tributary of Bredegletscher (both north of Geikie Plateau), and several glaciers in the Stauninger Alps region (see details in Jiskoot et al., 2003; Jiskoot and Juhlin, 2009; Jiskoot et al., in press).

2877, 20-28: this general discussion on the propensity of surging is beyond the scope of this paper. It also contains several misinterpretations. I suggest deleting this paragraph.

2878, 1: 4.3 mechanisms for glacier thinning. The authors only talk about dynamic thinning and do not really explain the physical mechanisms of thinning. Replace title with “Glacier thinning”.

2878, 18: refer to a Fig 4 here.

2878, 20: why smaller glaciers? As compared to thinning of the ice sheet? Are these glaciers peripheral to the ice sheet or outlets?

2879, 7-16: This section on Jacobshavn Isbrae has too much detail that is irrelevant to this paper. One simple sentence discussing the possible influence of the warmer ocean T on the retreat of this glacier should be sufficient.

2879, 16-20: add a reference for this statement.

2879, 20-30 and 2880, 1: This description of SST data should be in the results section (3.4.4?). The discussion that follows needs some more critical work, and include concrete findings from other studies in this region. See also references in the discussion on this topic in Jiskoot et al (in press).

2880, 17-20. The difference in glacier behaviour between these regions may also be because of the large proportion of surge-type glaciers in the region north of Kangerdlugssuaq fjord, and possibly also because the glaciers south of K-fjord are more uniform in size and mostly outlets from the Greenland ice sheet.

2881, 1-16: This section is quite long and has many vague suggestions for further research. Tidy it up and only mention concrete new ideas for further research that came forth from this research.

2881, 20: Mass loss is not really quantified in this paper (but could be: see Major Issues), and even referring to the exact measured amount of GRACE loss will strengthen this statement.

2881, 2028-30: Many of the glaciers studied in this paper are local glaciers (peripheral and separate to the Greenland ice sheet), especially some of the extreme glacier changes of Sortebrae. Adjust this last sentence accordingly.

2886, 7: Surging glaciers (nor suring), and Undersøgelse (not Undersøglese)

FIGURES

Fig 1: The location map is quite confusing and some of the names (e.g. Geikie Plateau) are in the wrong location. I also suggest the coast and fjord names are placed on the sea side rather than on land. The map on the right could be bigger, and the Greenland image on the left should be a small inset. Daugaard-Jensen needs a hyphen. There is also an East Greenland Coastal Current, which starts around K-fjord (e.g. Christoffersen, 2011). Reference the chosen location of the Currents (Why are the Current line locations different in Fig 1, 2, 3 and 5? It looks like a scaling or shifting error occurred)

Fig 2: legend should read: Terminus retreat.

Fig 3: State in the figure heading whether 15 km from glacier front is for the year 2000 or 2010.

Fig 4: It would be useful if error bars (e.g. at one location close to the front) could be added to this figure, including the DEM error, manual error, and tidal variation.

Fig 5: Legend should read: ‘Average surface speed.’ Caption should read “Average surface speed (m d-1) for 38 marine-terminating glaciers.

Fig 6 and 7: Lat-lon would be useful. Small location maps are hard to read, and can be deleted (Fig 1 already gives location).

Fig 8: Is this monthly SST? The minimum rather than the maximum seem to vary more and over longer periods, so the 'spike in 2003' could be rather described as a 2003-05 high winter T. What is the influence of sea ice on these measurements? Fig caption: delete "site SST-A. . ...furthest north" and replace with: "See Fig 1 for SST locations".

References:

Christoffersen, P., and 7 others. 2011. Warming of waters in an East Greenland fjord prior to glacier retreat: mechanisms and connection to large-scale atmospheric conditions. The Cryosphere 5, 701-714, doi:10.5194/tc-5-701-2011.

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Jiskoot, H, D Juhlin, M Citterio & H St.Pierre, in press. Tidewater glacier fluctuations in central East Greenland coastal and fjord regions (1980s-2005). Annals of Glaciology 50 (53).

Kargel, JS, and 13 others: Brief Communication: Greenland's shrinking ice cover: "fast times" but not that fast, The Cryosphere Discuss., 5, 3207-3219, doi:10.5194/tcd-5-3207-2011, 2011.

Weidick, A, 1995: Greenland. In: Williams, R.S. Jr. & Ferrigno, J.G. (eds): Satellite image atlas of glaciers of the world. U.S. Geological Survey Professional Paper 1386-C, 141 pp.

Yde, JC, Paasche, Ø, 2010. Reconstructing climate change: Not all glaciers suitable, Eos Transactions AGU, 91(21): 189–190.

Interactive comment on The Cryosphere Discuss., 5, 2865, 2011.