

Interactive comment on “Glacier dynamics over the last quarter of a century at Helheim, Kangerdlugssuaq and 14 other major Greenland outlet glaciers” by S. L. Bevan et al.

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General comments _____

This paper presents the derivation, analysis, and interpretation of new time-series data of ice velocity and calving front position for a number of large outlet glaciers, distributed over different geographic sectors of the Greenland ice sheet. These data extend the “period of measurement” for these glaciers back an additional ~7 years (to the mid 1980s), relative to the large-scale time-series datasets most often discussed in the current literature (which begin in the early to mid 1990s). In addition, observations and re-analysis based sea- and land-surface temperature datasets are derived and

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analyzed for the mid 1980s to the present. A correlation between increased sea- and land-surface temperatures, an increasing (temporal) trend in both, and increasing flow variability, discharge, and retreat of outlet glaciers is argued for, both qualitatively and statistically. The authors conclude that observed, dynamic outlet glacier behavior in Greenland since the mid 1990s is a response to these climate forcings.

Overall, this paper is well motivated, well organized, and well written. While I don't feel entirely qualified to judge the statistical methods employed, I assume they are standard (and that they are and are employed correctly here) and am largely convinced by the qualitative arguments and correlations proposed in the paper.

Some general comments/questions that apply to multiple sections of the paper are as follows:

Is there any reason for using units of meters per day when describing flow speeds rather than the more commonly used units of meters per year? Perhaps this is just personal preference, but I had a hard time putting the speeds in context, as I'm more used to thinking of Greenland outlet glaciers speeds in meters per year. Is the reason for using meters per day to distinguish velocity changes over shorter time periods than one year? If so, this should be made clear in the data and methods section.

Throughout the paper, the word “stable” is used to describe calving front positions. It would be good to expand on the metric for this somewhere early on so that the reader knows exactly what this means. Is it a qualitative or quantitative measure? Does it imply a change outside of what is expected in terms of seasonal calving front position change? If so, how is the seasonal range known?

A similar comment applies to the description of velocities (e.g. “none of the 5 outlets show . . . significant flow change other than that . . .”, line 5, p.1648). Do you have the measurement resolution here to define the seasonal velocity range for all of the glaciers in the study?

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Throughout the discussion and conclusions, the descriptors “early period” and “later period” are used. Suggest being more precise, e.g. “1st two decades of the study period” and “last two decades of the study period”.

Specific comments —————

Abstract —————

The abstract provides an appropriate and adequate summary of the paper. It might be useful to provide an indication for the metric used to define “most significant” w.r.t. outlet glacier (e.g. fastest? greatest mass flux?). A few additional suggested wording changes to improve the clarity are suggested below under “technical corrections”.

Introduction —————

The introduction is a good and mostly complete summary of related work to date, which provides context for the clearly stated goals of the present work. In the literature review section, suggest adding some discussion on recently published paper by Bjork et al. (Nat. Geosc., 5, p.427). Does the Bjork et al. work complement or conflict with any of the conclusions from this work?

p.1641, lines 5-7: “The mechanisms underlying the correlation between . . . are likely to include . . . from over the ocean.” This is awkwardly written. If the suggestion is that advection of warm air masses from the ocean onto the land surface is responsible for relatively more negative surface mass balance of the ice sheet, then I think it could be written more clearly and succinctly.

Additional minor wording changes to improve readability are suggested under “technical corrections.”

Data and Methods —————

Other than the comments below and the suggested minor technical corrections, the description of the data and methods used is largely adequate.

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In section 2.1, suggest making it explicit that these are re-analysis based data (e.g., for anyone not familiar w/ ERA products).

The first paragraph on 1644 contains a wealth of technical information that is a bit unclear to me. E.g., are “multi-looked” and “geocoding” standard terminology? It sounds like all images are resampled to a final pixel resolution of 40 m? If this is true, I think it could be stated more clearly.

1645, last part of 2.2: Is there a final combined error estimate used for all images or different values used for SAR vs. Landsat? For Landsat 7, clarify the final error value used.

Results —————

Other than the few items below, the majority of comments about the reporting of results are minor and are included under “technical corrections”.

1649, lines 13-17: “We see no evidence of a slowdown over this period . . .” In the figure, there does appear to be a small slowdown from ~1989-1992/93. Perhaps this points to the need for defining a threshold for velocity changes that are considered significant? “The 1985 measurement related to . . . of five SAR pairs.” Clarify if/that this sentence applies to the discussion of the Joughin data?

Discussion —————

As noted above, suggest some more precise terminology than “the earlier period” and “the later period” when discussing different parts of the data record being discussed.

1652, lines 8-10: “This 10 yr period of stability . . . , which ACCORDING TO OURS AND PREVIOUS WORK, experience and respond to changes in climate.”

1652, Lines 11-14: “The exceptions observed here are . . . in the southeast.” In this sentence you name what sounds like 6 of the 16 (nearly $\frac{1}{2}$) glaciers in your study. This makes it sound like there is no obvious majority in terms of observed glacier behaviors.

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Is that really what you mean here?

1653, lines: 10-15: Suggest giving some context for p-values reported here. E.g., remind the reader what a high vs. low p-value means. Also, the sentence "... and it should be noted that ... between glacier" seems awkwardly introduced here. It should go elsewhere or be made clear how/why it is relevant to the discussion in the first part of the sentence.

Conclusions —————

1655, lines 12-15: Clarify that what is stated here is still somewhat speculative, e.g. "We speculate that ...".

1655, line 27: Suggest omitting the "highly" on "highly likely", as it starts to sound like you are making IPCC-like predictions with some kind of confidence intervals attached. Might also be good to add something like "Based on results from our study, we suggest that acceleration and retreat of Greenland's tidewater glaciers is ..."

Figures / Tables: —————

Table 1: Note in the caption why there are no values reported for the CC of some glaciers.

Figure 1: Unless the figure is made larger, it is difficult to see some of the "x's" marking the location of speed measurements. Make them darker, or larger or both?

Figure 2: Caption – because you report a difference, shouldn't the later time period be given first (e.g. "between 1996-2010 and 1982-1995.")?

In all of the figures w/ colorbars, it would help to note which colorbar goes with which dataset (i.e. land or ocean warming). It is not that easy to distinguish.

Figure 3 caption – note that 'grey' = not significant?

Figures 6 and 7: Kong Oscar is reported in the paper as belonging to the "western"

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group, but it is grouped with the "northern" glaciers in the plots. Suggest making consistent either in the text or figs?

Technical corrections —————

Abstract —————

Line 9: "SAR" – does this need to be defined? Change "Climate re-analysis" to "Climate re-analysis data".

Lines 11-12: "During the earlier period of climate consistency..." is a bit awkward. Suggest something more descriptive like, "During the period from XX-YY, when Greenland and the surrounding oceans were not warming, major tidewater outlet glaciers ... etc."

Lines 14-17: "Since the mid-1990s, glacier discharge ... and more variable. Together, these observations support the hypothesis that recently observed dynamic change is a response to climate forcing. Both air and ocean ... and will therefor likely drive further change in outlet glacier discharge."

Introduction —————

1639, line 7: "... based on flux-balance CALCULATIONS agree ..."

1639, lines 12-18: "...first Jak. Isbrae in the the west ..., followed by Helheim (refs) and Kanger. (refs) in the southeast in 2002 and 2004, respectively. The latter pair have since ... but their EARLIER behavior meant that, in the southeast, discharge dominated the TOTAL mass balance signal ..."

1640, line 1: "INCREASED submarine melt rates are likely to be the result of ... changes controlled IN PART by meltwater plumes." [I don't think we can confidently attribute all submarine melt changes to freshwater plume driven circulation.

1640, line 9: "The proposed connection between TERMINUS thinning, retreat, and ..."

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1640, line 15: “advance” → “re-advance” ??

1640, line 20: Consider adding Sole et al., (2008, Cryos., 2, 205-218) and Thomas et al. (2009, J. Glac. 55(189)) in addition to ref for Moon and Joughin (2008).

1640, line 24: “...although they have yet to ‘catch up’ ...”. This is a bit awkward. Suggest omitting or being more specific about what you mean here.

1641, line 21: “...the NAO has SWITCHED TO A MORE NEGATIVE (??) phase ...”

1642, last paragraph of intro, for clarity, suggest some wording changes and restructuring: “In this paper, we investigate ... leading up to and during the MOST RECENT period of ice loss, and test the evidence for a DYNAMIC ICE SHEET response by extending observations of flow speeds and terminus positions for 16 of Greenland’s major glaciers (Fig. 1), including Kang., Helheim, and Jak., back to 1985. In total, these glaciers drain approx. 25% of the GrIS. OUR NEW measurements extend the time series back 7 yrs PRIOR TO most published measurements to a TIME period when both ... and SSTs AROUND GREENLAND where not warming.”

Data and Methods —————

1642, line 21: “...and manual digitization of OUTLET GLACIER frontal positions ...”

1642, line 25: omit “some” in “... gain some insight ...”

1642, line 27: “...retrievals of ICE speed ...”

1643, lines 1-2: “... by calculating the statistical correlation between the two parameters for each glacier in our study.”

1643, line 5: “...covering Greenland and THE surrounding ocean ...”

1643, line 25: Assuming that the methods used are as described in the given refs., suggest omitting “intensity” in the description of feature tracking, as this detail just confuses the sentence.

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1644, line 3: Is the “d” abbreviation for “day” (e.g. “16 or 32 d”) standard for TC publications?

Results —————

1646, lines 13-15: “... sea-ice export through the Fram Strait (ref). THIS increase in freshwater may explain the ...”

1646, lines 24-26: Conceptually, it would make more sense to discuss the acceleration and retreat of outlet glaciers along with the acceleration in mass loss, rather than after you note that mass loss rates are now decreasing.

1647, line 4: Add ref to Howat et al. (Science, 315(1559), 2007) when discussing stabilization of Helheim and Kanger?

1648, lines 20-23: “Measurements for various locations ... (refs), AND new data here are limited to ... “

1649, line 5: “...and the ice TONGUE disintegrated. Between 2000 and 2010 ... Gt of GROUNDED? FLOATING? ice mass were lost ...”

1650, line 19: omit “but messy”

1651, line 15: “Lastly, DJ glacier, WHICH drains ... ice sheet, has a short ...”

Discussion —————

1652, line 23: “The lack of ... because the loss OF FLOATING ICE?? did not affect ...”

1653, line 8: “... measure the SIGNIFICANCE of this increase, ...”

1654, line 9: “... for all glaciers tested ...” Remove “tested”, as this makes it sound like not all of the glaciers in the study were tested (I assume they were?).

1654, lines 13-15: “Glacier with a less significant or weaker ...”. This is confusing. Above in the same paragraph it says that the correlations are significant for all glaciers

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tested, but this sentence sounds like it is saying something else? Please clarify.

Conclusions —————

1654, lines 25-26: "...constant flow speeds and STABLE ice-front positions. Following this period . . ., there were widespread . . ." (omit "then").

Interactive comment on The Cryosphere Discuss., 6, 1637, 2012.