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Interactive comment on "Area, volume and mass changes of southeast Vatnajökull ice cap, Iceland, from the Little Ice Age maximum in the late 19th century to 2010" *by* HannesÃřóttir et al.

HannesÃřóttir et al.

hrafnha@hi.is

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Reviewer #2 – Hester Jiskoot

This manuscript presents a novel multi-temporal analysis of length, area and volume changes of a region of non-surge-type Icelandic glaciers over more than a century. The data are unique and there are some interesting findings in terms of different retreat rates, different glacier types, and different periods of potential climate forcing. Although the results seem substantial, it is hard to judge how well they stand due to a lack of proper error analysis, both in the construction of the glacier data and the analysis. Although the methodology appears extensive, much of the needed information to assess the quality of the data collection and error analysis are missing.

Answer: We have now better stressed one of the major result, i.e. the generation of a novel multi-temporal glacier inventory, and the discussion section is better structured. We do not agree with the reviewer that the mass loss data is “insufficient“ and that it should be only presented for the whole region, we have now detailed the method more clearly.

A. The paper is too long and lacks focus. Some of the major results are not stressed (e.g. that this research generated a novel multi-temporal glacier inventory) and other sections are not justifiable with the generalisations and/or the small sample of data (e.g. the volume-area scaling; mass loss).

Answer: The paper has been shortened, the section on Volume-Area scaling chapter has been omitted, and the discussion is now more focused.

B. The methodology is defective and poorly structured. Descriptions are mainly about what is done and not how it is done. A table of data types, sources, and errors for each of the DEMs, as well as the snowline MODIS imagery would be useful. The DEM of subglacial topography is unclear: what is the horizontal resolution, where were the transects taken and what was the interpolation technique? At what scale or zoom factor were the glacier outlines digitized and what was the human and digitizing error?

Answer: We have added a table that details the datasets used. The construction of the basal topography is not the subject of this paper and thus the corresponding papers are referred to for further details. In Table 2 the error estimate for the areal extent is provided.

C. Some of the methodology is questionable, in part due to the lack of information (A). In particular:

1) The mass change calculations are based on very rough generalisations, and should only be used to give an overall estimate in geodetic mass balance change, rather than

calculate changes over time, or between regions.

Answer: We present data on the basal topography and the surface DEMs at various times for 12 different outlet glaciers ranging in size and hypsometry, which warrant the detailed analysis. The glacier inventory provides both temporal (the whole post-LIA time period) and spatial (along the southeastern stretch of Vatnajökull) coverage. We also stress the importance of looking at several outlet glaciers, not just 1 or 2 when inferring the response to similar climate change (all glaciers descend from SE-Vatnajökull ice cap).

2) The different maps and DEMs should have been co-registered to perform a change analysis. If this was not done, the errors will be much larger than reported.

Answer: Maps and DEMs were co-registered, and this has now been stated more clearly in the methods section.

3) I derive from Fig 4 that the snowline elevations have similar or larger seasonal variability than interannual variability. Additionally, it is always necessary to give the exact dates of the MODIS images used for the snowline measurements, and to indicate how close this is to the end of the melt season. It is unclear how the snowline pixels were derived (e.g. by image classification, or thresholding?) and how their elevations were extracted (see e.g. Jiskoot et al., 2009 for two common methods giving quite different results).

Answer: The exact dates of the MODIS images have been added to the dataset table. The snowline was manually digitized, and this has been clarified in the methods section.

D. The error analysis is weak, and the total errors not calculated properly.

Answer: We have provided errors for areal extent, vertical accuracy and we calculated the error for the geodetic mass balance, by including the previously mentioned errors for area and volume. This is now better explained in the methods section.

E. The paper is too long for its findings, and poorly structured. Rewrite and remove all repetitions, and remove some of the non-essential self-references. Move the volume area scaling methodology and results from the discussion section to the results section (if it is concluded that this section should stay in the paper).

Answer: The volume-area scaling section has been removed from the paper. We find it important to refer to the studies carried out on other glaciers in Iceland for comparison. Only a small group of people are responsible for the glaciological research in Iceland, thus self-referencing is unavoidable.

F. The discussion is unfocussed and shallow, and it seems like the authors felt the need to discuss all the results. Pick the most important findings and focus the discussion around those.

Answer: The Discussion chapter has been focused and we have put special emphasis on the special conditions with the over-deepened basins of the SE outlet glaciers of Vatnajökull, the importance of proglacial lakes (and enhanced ablation) and the hypsometry of the different outlets.

G. Several figures and tables could be combined to strengthen the interpretation of these, and to focus the results and discussion.

Answer: Figures 2 and 7 have been combined.

H. Think critically about the usefulness of comparing relative area changes (in percentages of starting area) for different periods, given that the overall class sizes have changed over the reported years, and other regions have different glacier sizes. This difference (with often the smaller class size have the largest loss in relative area) is in part a scaling issue, rather than a result of climate forcing/response. Many glacier change studies (including my own) have really emphasized this relative (%) area change, but is it really that useful?

Answer: We are aware that % changes can be misleading, thus for example we show

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in Fig. 9 both absolute and relative area (and volume) changes for the whole post-LIA time period (1890-2010).

I. The use of English overall is quite good, but the use of verb tenses is confusing throughout the paper. In the manuscript the authors use the present perfect tense (has been) and past tense (was) interchangeably. I suggest using the past tense throughout, as the present perfect tense implies it still goes on. Wherever the past perfect tense (had been) is used it should imply that something was done (by other researchers) before the present study. Correct throughout and have a native English speaker check the verb tenses.

Answer: The verb tenses have been corrected as suggested.

Specific Comments Title is too long and detailed for the confidence in the data. Change to “Area and volume changes of southeast Vatnajökull, Iceland, between ∼1890 and 2010”.

Answer: The title has been shortened to: Changes of southeast Vatnajökull, Iceland, between ∼1890 and 2010.

P4682 Abstract Rewrite after the paper is updated, and tone down the second part where the wording is too strong given some of the uncertainties in the results. The ‘dynamic response’ of glaciers is usually separate from the mass balance response, and the term ‘indirect response’ may be more appropriate here. Apart from the retreat in proglacial lakes, the differences in response described in this paper are more related to the reaction time and response time, rather than dynamic factors. Rewrite and tone down the causal certainty that the changes are related to hypsometry, bedrock topo and proglacial lakes.

Answer: We have rewritten the abstract after reviewing the manuscript.

P4683 L4 ....sea level rise and water resources.

Answer: “water resources“ has been added according to the suggestion. L16-19:

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repetitive wording. Delete “is one of the most sensitive ice caps in the world” and reword accordingly.

Answer: The sentence has been structured as suggested and now reads: “Simulations with a coupled positive-degree-day and ice flow model reveal that the mass balance sensitivity of southern Vatnajökull is in the range of 0.8–1.3m w.e. a−1 C−1 (AÃřal-geirsdóttir et al., 2006), which is among the highest in the world (De Woul and Hock, 2005).“

L21-24: Don’t the glaciers and ice caps in the Canadian Arctic contribute too?

Answer: This sentence only expresses that the second highest input to the North Atlantic comes from the Icelandic glaciers, after Greenland, and as such does not exclude other sources of meltwater input (from Svalbard, the Canadian Arctic etc).

L27-7(next page): this section is repetitive within the intro. Move to section 2 (study area).

Answer: This section has been moved to the Study area chapter.

P4684

L3: delete ‘even’

Answer: The word “even“ has been deleted.

P4685

L2-5: How accurately is the bedrock topo known?

Answer: The results and details of the basal topography measurements have been published in the papers cited. We have changed the text in parenthesis to “for details see Björnsson 2009; Magnússon et al., 2012). “

L5: what is ‘alpine-like’?

Answer: “alpine-like“ has been deleted from the sentence.

L13: use the term ablations stakes, rather than survey stakes.

Answer: Survey stakes have been changed to ablation stakes.

L23-24: remove some references.

Answer: We do not agree, since we are referring to mass balance studies, modelling studies and satellite imagery, and these results are presented in the papers cited.

L 24: ..ELA was approximately...

Answer: the verb has been changed to “was“.

L26-29: Regular monitoring of annual frontal variations... Then remove ‘providing annual records of the advance and retreat of the glacier’.

Answer: This has been changed according to the suggestion and the sentence now reads: “Regular monitoring of annual frontal variations of the outlets of southeast Vatnajökull started in 1932 by Jón EyÃ¿órsson and were later carried out by volunteers of the Icelandic Glaciological society (references).“

P4686

L15-18: shorten this to one sentence: T and P were extended back to the end of the 19th century, following the methodology of A et al (2011).

Answer: This has been changed according to the suggestion and the sentence now reads: “The temperature and precipitation records were extended back to the end of the 19th century, following the methodology of AÃřalgeirsdóttir et al. (2011).“

P4687

The subsections are too short to warrant subheaders, and the glacier geometry in sections 3.2-3.2.2 is poorly explaind. What was the resolution and scale of the datasets, were they georeferenced to each other, what scale was the outline digitized, etc.

Answer: 3.2 is only to introduce the following sub-chapters as stated. We provide the

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vertical and horizontal accuracy for the LiDAR DEM in chapter 3.2.1 and refer to a paper on that. The LIA DEM is detailed in the paper cited, and as such we do not go into detail on that in this paper. L20: do you mean nunataks rather than erratics?

Answer: No "glacier erratics", left by the LIA glacier, in some places leaving a lateral trace of

P4688

L6-14: express as the percentage of total area not mapped.

Answer: The sentence starting in L9 has been changed to: "The 1904 maps do not cover all outlets glaciers up to their ice divides. The Öræfajökull outlets have a complete coverage except Skaftafellsjökull and Morsárjökull, leaving 28% of the total area of the Öræfajökull outlets of this study unmapped. Three of the eastern outlets (Skálafellsjökull, Heinabergsjökull and Fláajökull) were mapped in 1904, but most of the accumulation area was unmapped, resulting in 67% of their area unmapped."

L28: Need an error analysis of the influence of snow cover on the accuracy of the mapping of glacier outlines from the nunataks.

Answer: The variable snow cover around the nunataks (as seen in Fig. 4) is integrated in our error assessment for our method of recreating the glacier surface DEM in the accumulation area.

P4689

L1: explain ehf.

Answer: This has been clarified: "of the company Loftmyndir ehf."

3.2.4 Explain the resolution and sampling of the RES: was this along flowlines or other transects or a grid? What was the horizontal spacing of the bedrock topo, and how much of that was through interpolation techniques?

Answer: As mentioned previously, results of the radio echo sounding measurements of the basal topography are referred to in the text and we do not agree with detailing the resolution and sampling since this was not part of our study. We have added in the parenthesis: “for details see. . .“

Section 4.1: Separate the methodology clearly into DEM reconstruction and DEM differencing. Need a much more precise explanation of the georectification (any co-registration?), GCP orthorectification, and error analysis and quantify the errors better. Rewrite entire section into the past tense.

Answer: We have rewritten this chapter in past tense. The vertical error for each DEM is provided in Table 3. We have added a sentence on the coregistration and goereferencing: “The various DEMs were coregistered and georeferenced to be merged into a common dataset, where the LiDAR data provided the reference DEM.“

L19-24: move to results

Answer: This is one of the prerequisites for the method, i.e. since little changes in the surface geometry (only elevation changes) are observed in the areas mentioned or studies referred to, we feel confident in this approach.

P4690

L11: which kriging methods?

Answer: “point kriging“ has been added to the sentence.

L20: ice divide shift importance is relative to the glacier size: both ST glaciers are large, but did it do something to the smaller outlets: express as a function of area.

Answer: Only a limited number of the studied outlets are adjacent to the surging glaciers as shown in Fig. 1, and since there are no exact measurements of the area affected during the surge, thus we will not express this as a function of the area. We have exchanged the sentence with the following: “ Even though there have been surges in the larger outlets of Vatnajökull (Björnsson et al., 2003), they have not affected the studied SE-outlet glaciers during the study period.“

P4691

L6: is the 1890 DEM explained in H et al, 2014?

Answer: We have added in the parenthesis: “(see Hannesdóttir et al., 2014 for details of the method).“

L6: delete ‘shape of the’ Answer: L8 (not L6): We have deleted “shape of the“

L12: how was this adjusted?

Answer: This has been clarified: “and their shape was adjusted to resemble the more accurate contour lines of the AMS 1945 maps.“

P4692

L6: Explain how it was ‘reassessed’.

Answer: This has been clarified: “The glacier outline was also revised by digitizing the glacier margin from the original aerial images in areas of misinterpretation, as on the 1945 images.“

L20: need to know the dates of the Landsat images, and the potential errors associated with these.

Answer: The date of the Landsat image used to digitize the glacier margin of the eastern outlet glaciers is 28th of July 1999, with a horizontal resolution of 30 m. This information has been added to the dataset table.

L23-26: What date was the lidar and what error? Not sure if I understand the methods here.

Answer: The details of the LiDAR are found in section 3.2.1., including dates and resolution, and for further detail we provide references. The method of reconstructing a DEM from the profiles is clarified in the following sentences: “The DEM is obtained by construcing new contour lines from each contour line of the LiDAR DEM; the new contour has the elevation of the LiDAR plus an amount dh. The intersection point of the new contour with the valley wall is found by moving the old point up or down the wall by a vertical amount dh along a line drawn between the old intersection points on the opposite sides of the valley (see e.g. Echelmeyer et al., 1996) for details of reconstructing surface DEM from survey profiles).“

P4693

L2: explain what error analysis you used. For each pairwise comparison (e.e. DEMa and DEMb) of the error should be calculated as E=$\sqrt{}$E_a^2+ E_b^2.

Answer: This is now stated in the section. For each DEM we provide the vertical accuracy, and when subtracting two DEMs from each other, to calculate the geodetic mass balance, we use the square root of the sum of the two errors associated with each DEM as detailed by the reviewer.

L7: and glacier dynamics (e.g. surging: see Jiskoot et el., 2001).

Answer: “and glacier dynamics“ has been added to the sentence, as well as the reference as suggested.

L8-9: irrelevant: remove sentence and Lliboutry reference.

Answer: We think it is important to refer to the pioneering work of Ahlmann, and have included a reference to his paper from 1943 together with the reference of Furbish and Andrews, 1984.

L10: were these normalized curves?

Answer: The curves were not normalized.

L15-17: Long before ‘recent’ the ELA or snowline was estimated from aerial photography: see World Glacier Inventory (wgms.org). This was common practice in appr.

1950s-1980s.

Answer: We have removed “in recent years“ from the sentence.

L21: Give years and resolution for the MODIS used for the snowline. Any problem detecting the snowline different dates? What method did you use: manual, supervised classification, thresholding? See also Jiskoot et al., 2009: Shea et al. 2013.

Answer: A table has been added with information about dates and resolution of all the MODIS images used. To clarify the sentence it now reads: "The visible snowline was digitized manually . . .“

P4694

Reverse order of equation 1 and 2.

Answer: Equations 1 and 2 have been reversed.

L9: Remove ‘Sorge’s Law’. Also, 900 kg/m3 is a very rough estimation of the average density of ice. See Cuffey and Paterson (2010) for a better range for the Iceland glaciers, and calculate associated errors in volume.

Answer: In order to facilitate the comparison with other geodetic mass balance estimates of glaciers in Iceland we decided to use the same value for ice density, 900 kg m-3 (GuÃřmundsson et al., 2011; Pálsson et al., 2012; Jóhannesson et al., 2013).We have added the following sentence: “The error estimate of the geodetic mass balance takes into account the estimated error of the DEMs and the glacier areas.“

We have calculated the geodetic mass balance of the outlet glaciers using 850 kg m−3 for ice as recommended by Huss (2013), which is valid for periods longer than 5 years, for glaciers with stable mass balance gradients, the presence of a firn area and volume changes significantly different from zero. The difference in mass change by using 850 or 900 kg m-3 is much smaller than the associated errors of the DEMs and area. Sorge′s law has been removed as suggested.

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L23: bring to methods.

Answer: A similar description of the average ELA and the standard deviation has been added to the methods section, but we keep the sentence here as it is referring to the results shown in Fig. 4.

P4695

L1-14: confusion between the term snowline and ELA

Answer: We explain in the methods section that the snowline on the MODIS images is used as a proxy for the ELA. We have changed the title of the section: “5.1.: Spatial and temporal variability of the MODIS derived ELA.“

L15-28: Poor phrasing throughout. Answer: This section has been rephrased and shortened.

L24: debris cover will introduce and additional error in the ice extent delineation. Was this the only glacier with some debris cover, and can you give an estimate of the associate error?

Answer: Yes, this was the only glacier, and to avoid confusion we have omitted this specific sentence on Hrútárjökull.

L25: Be more specific than ‘in the following few decades’ Answer: This has been clarified, and now reads: “in the 1960′s to the 1990′s.“

P4696

L6: is this rate for ‘relative’ (%) or absolute area loss?

Answer: We have added "high rate of absolute area loss“ for clarification.

L10: But the lack of downwasting seems a function of you forcing this above a certain elevation. If you first force it not to change and then conclude it did not change then there is no real process interpretation possible. Also, the shape of advancing and

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retreating glaciers has been extensively discussed and is in part due to the interplay between dynamics and ablation (see Schwitter and Raymond, 1993: JGlac 39 (133)). Use this in the discussion.

Answer: Here we are referring to available data shown in Fig. 11a, from which negligible surface lowering in the elevation range specified is evident; hence we are not forcing the lack of downwasting. A reference to Schwitter and Raymond (1993) has been added to the discussion.

L15-21: Need to know the topography of the nunataks (steep or shallow slopes) and the variability of the snow around it. See Answers in methodology too.

Answer: We agree, this is now discussed and clarified in the methods section.

L23 and further: Be careful concluding too much from comparing rates for different length of periods.

Answer: The rate of volume loss is presented as annual changes, so the comparison should be viable.

P4697

L4-5: delete: this is obvious.

Answer: We keep this sentence, since we come back to the importance of increasing the temporal resolution of the data set in the Discussion/Conclusion.

L7-25: Simplify and perhaps only use a rough estimate for the entire region, due to large errors assuming that the density is a constant for the different glaciers and at the different elevations. Also, use a good error estimation, where the error is a function of the error in the elevation, in the area, as well as in the ice density. Answer: We do not agree that the data do not allow the detailed analysis and we provide the geodetic mass balance changes for each outlet glacier. We have also provided a more precise definition of the error estimate in the text.

P4698

L1-14: Use the proper and accepted terminology of top-heavy, equidimensional and bottom-heavy. What are the exact boundaries of the classes, or was this just done visually? De Angelis et al (2014) use the Hypsometric Index classification proposed by Jiskoot et al. (2000 and 2009). Also, the top-heavy class (B) is typical for ice caps, so it is not a surprise that the ice caps of iceland mostly fall into that category.

Answer: We think it is useful to compare the different classes of glaciers, since the 12 outlets of SE-Vatnajökull have different area distribution with altitude (as shown in Fig. 13). The different geometry of the Öræfajökull outlets vs. the outlets of eastern Vatnajökull is also worth to compare. The categorization into the 5 hypsometric classes was done visually, and this has been clarified in the methods section. We did follow the five idealized classes as presented by Furbish and Andrews (1984) and more recently by De Angelis (2014). The terminology presented by De Angelis (2014) we found to fit better with our data than the classes suggested by Jiskoot et al. (2009), which do not include the bimodal hypsometric curve (class E) nor the glaciers where bulk of the area lies at the ELA (class D).

L14: why 'in its greatest extent?'

Answer: We have added the year at the end of the sentence "in its greatest extent ~1890.", the hypsometric curve in 1890 and 2010 is very different as shown in Fig. 13.

L17-22: A discussion of general response time is missing.

Answer: A discussion on the response time is found later in the discussion (P4702) and we have now reorganize and focused the Discussion chapter.

P4699

L12: The geodetic mass balance of - xx m. w.e. (specify)

Answer: This now reads: " geodetic mass balance of -1.38 to -1.51 m w.e. a-1 of the eastern outlets (apart from Heinabergsjökull) during the time period 2002-2010 is in line with . . . “

L17-29: Be clear about what you discuss: this material can be deleted, as it is not new for Iceland or the world. This information is now better incorporated in the text as a comparison of our records with other data worldwide – the glaciers of this study were not included in the data base presented in the latest IPCC report. And as a response to the comment on L3-L8 on page 4700, we focus the attention on the factors that are unique for this setting, the maritime glaciers with overdeepenings, thus we find this comparison with other glaciers around the world valid.

P4700

L1: from the ‘non-surging’ outlets

Answer: “non-surging“ has been added to the sentence.

L3-8: The interesting comparison here would be a difference in maritime glacier mass balance curves and the response, relative to other more continental regions. Additionally, iceland glaciers may have wider tongues and flatter topography due to the lack of (or very little) constraining surrounding topography, relative to higher alpine regions (I include Svalbard and East Greenland). Additionally, the reverse bed slope and overdeepening give rise to a larger marginal region of recent proglacial lakes, and if neighbours surge the both water and mass piracy may occur. The combination of these factors is rather unique for Iceland and should be included in any discussion.

Answer: The SE-outlet glaciers are maritime and very different from the majority of the flatter more gently sloping larger outlet glaciers of western and northern Vatnajökull, and the outlets of the other major ice caps in Iceland (including Langjökull and Hofsjökull). They are constrained by valley walls and most of them have a narrow tongue. The surging glaciers of Vatnajökull are not affecting the studied outlets as now clarified in the reviewed version.

L9-29: very repetitive.

Answer: L13-L17 have been deleted (indicated by the strike-through). "In situ mass balance measurements of glaciers in Iceland and degree-day mass balance models of selected glaciers indicate that the mass balance is governed by variation in summer ablation (which is strongly correlated with temperature), rather than winter accumulation (Björnsson and Pálsson, 2008; GuÃřmundsson et al., 2009, 2011; Pálsson et al., 2012; Björnsson et al., 2013). Higher than average winter precipitation at the meteorological stations south of Vatnajökull, is not correlated with more positive geodetic mass balances of the southeast outlets. However, a strong correlation (r = 0.94–0.98) is found between the geodetic mass balance and the average summer temperature (Table 4).

L17-21: So here is a hint why the Iceland glacier retreat faster? Elaborate and include if it is mb curve or in part dynamic.

Answer: The maritime glaciers are sensitive to climate change and respond fast, we will refer to other previously published papers on this subject (e.g. Björnsson et al., 2013), which discuss the increased ablation in the last decade, which is not attributed to changes in the dynamic response of the glaciers.

L22-29: delete.

Answer: There is no reason provided by the reviewer for deleting this paragraph, and we think it is important to comment on the rise of the ELA in the post-LIA time period; it sheds light on the variable response of the outlets, as the hypsometry (among other factors) affects the volume loss. This paragraph has been moved to the following subchapter on “Different response to similar climate forcing“.

P4701-03

6.2 is a particularly general, disorganised and weak discussion. The authors have the opportunity to focus on overdeepening, proglacial lakes, and differences in flow velocity here, but do not apart from a short mention in the last sentence (P4703, L8-10). I suggest to focus and elaborate on those factors which make Icelandic glaciers unusual, and from which we can learn about process-response.

The discussion about the influence of hypsometry (and Fig. 13) should include a scatterplot figure that groups the glaciers with similar hypsometries, and contrasts their length or area change, so that it becomes clear if this is a strong patters or merely a suggestion.

Answer: A scatterplot figure with the hypsometric classes and the total volume loss was included in the manuscript in an earlier version, but when cutting down the number of figures it was omitted- as it did not add much to the discussion – the information in this type of figure can be read from the tables and the text itself. Scatterplots of the volume loss (and mass balance) vs. the average slope of the outlets did not show a strong correlation – the average slope is not very descriptive, since many of the glaciers have flat accumulation and ablation areas connected by a steeper area (as can be seen in Fig. 8. The discussion is now more focused and includes a more thorough analysis of the variable factors influencing the volume loss of the outlet glaciers, including hypsometry, proglacial lakes and the basal topography/overdeepenings.

L11-12: these class B glaciers are the larger ones, so the % loss is size related, and thus not particularly informing.

Answer: There are other glaciers than the larger eastern ones which belong to shape class B, including Morsárjökull and Skaftafellsjökull. L19-24: These glaciers have different size and slope (which is not mentioned) thus the different response is not surprising and can be explained with response time theory. Answer: The average slope of Skaftafellsjökull and of Svínafellsjökull is 4° and 9° respectively, and does not explain the difference in their retreat or volume loss, as the steeper and smaller glacier (Svínafellsjökull) would be expected to respond faster than Skaftafellsjökull, but it is the other way around.

P4703-05

6.3 I suggest removing this entire section from the paper.Volume-area scaling should be in the methodology and results, and be properly presented and discussed. The number of glaciers may be too small (as you state later), and scaling laws are generally used to estimate volume from a population of glaciers, not individual glaciers.. Additionally, most of your glaciers are ice caps or outlets and should have different parameters (see e.g. Hagen et al., 1993: Glacier Atlas of Svalbard and Jan Mayen). Also, some recent effort have not surpassed this general scaling (e.g. Adhikari and marshall; Farinotti and Huss several papers).

Answer: We have removed the chapter on Area-Volume scaling from the paper.

P4705

7 Conclusions: be much more specific and give a summary of the major findings. Really focus on your own results.

Answer: The Conclusions have been rewritten, is now more specific and focuses on our findings.

P4707

References: Quite a plethora of references, and many are only used once or in conjuction with other similar references. Thin out a bit. Why are the page numbers after the references?

Answer: We have omitted the page numbers after each references and removed a few references.

TABLES

Table 1: List what year(s) are these data based on? The ELA description is vague, and should have some standard deviation.

Answer: Table 1: The caption now reads: “Characteristics of the southeast outlet glaciers in 2010. Some glaciers have gently sloping accumulation and ablation areas, which are connected by ice falls, thus the mean slope is not representative for the entire profile. The ELA is presented as the average of the years 2007-2011 with the standard deviation. Average ice thickness and terminus elevation is presented in 2010 and 1890. The retreat is from 1890 to 2010.“

Tables 2 and 3: I think it would be more effective to have the numbers in a figure, such as for length (Fig 7). Perhaps make Fig 7 underneath each other a (length), b (area), and c (volume). With error bars.

Answer: Tables 2 and 3: In our opinion the data needs to be in a table, the exact numbers can not be read from a figure, and the figure would be too crowded if the % were included, which values that are referred to in the text. Figs. 2 and 7 are recommended to be combined, and we agree on that, which would not make a good fit if the area and volume data would be included in the same figure, too chaotic in our opinion.

Table 4: Delete. I doubt if the method warrants the detail per glacier. Just give the overall geodetic mass balance for the entire region as a fogure in the text. Additionaly, the average T does not say much if the time periods are for different lengths (not taking into account the NAO and AMO).

Answer: We disagree that the method is not robust enough to warrant the geodetic mass balance to be calculated for each glacier. We omit the correlation between T and geodetic mass balance in the last column (as in the text).

Table 5: delete, or go into much more detail and group per hypsometric class.

Answer: Table 5 has been deleted.

FIGURES

Fig 2 and 7 should be combined or at least underneath each other with the same scale so that patterns can more easily be discerned. Indicate starting year on x-axis.

Answer: Figs 2 and 7 are now combined, and the starting year indicated on the x-axis.

Fig 3: Add a scale-bar, and overlay and align the four panelsbetter. This image suggests that the snow cover may cause a larger error in the glacier outline than suggested in the text. Also, the snowline delineation appears to be problematic.

Answer: A scale bar has been added. Since the different sources of aerial images vary in their extent/limits, this alignment is the best possible. The possible errors associated with snowline delineation are included in the error estimate.

Fig 4: This figure suggests that interseasonal variability is higher than interannual variability and trend. Use that in the text to calculate a netter error estimate.

Answer: In the case where there are two available MODIS images from the same year, we see that the variability in the elevation of the snowline is in the range of $\pm$50 m.

Figs 5 and 6: nice and clear figures

Fig 7: I wonder if there are any significant volcanic eruptions that can be indicated in this figure, which may have affected the glacier mb for a year or two. The figure caption is quite wordy. An 'unbroken line' is a solid line. The Lambatungnajökull dotted line should at least have msymbols on the line for the years for which the remote sensing or mapped data is available.

Answer: The effect of the eruptions is very short lived (see e.g. Björnsson et al., 2013) and would presumably not show up in the frontal variations of these oulets. There are no volcanic eruption in this area since 1727, which had local affects in Öræfajökull. The caption has been shortened and solid line used instead of "unbroken line". The data points of Lambatungnajökull have been added.

Fig 8: This figure nicely show the scale and extent of overdeepenings in Iceland. Try to explain some of the retreat patterns in Fig 7 from the margin position in the overdeepenings and the formation of proglacial lakes.

Answer: The importance of the variable basal topography and the retreat patterns is now discussed in more detail, and compared with the data shown in Fig. 7 (now Fig. 2c) and the volume loss. We have also indicated in Table 2 when lakes formed in front of the studied outlets.

Fig 9: caption: 'in geographical order': do you mean 'from west to east'?

Answer: We have changed this to: glaciers "represented from west to east" – instead of ′geographical order′.

Fig 12: As stated before, the assumptions for the mass calculations are so general that this figure is perhaps useful when the average for each zone is given, rather than each individual glacier.

Answer: We do not agree, our results indicate that the different glaciers undergo variable area and volume loss in the last 120 years, and in order to interpret and discuss the possible mechanisms it is wortwhile to calculate the geodetic mass balance for each glacier.

Interactive comment on The Cryosphere Discuss., 8, 4681, 2014.