We thank the reviewers for their critical and constructive comments. We appreciate the recognition of the importance and usefulness of the Interprovincial Boundary Commission maps. We clarified terminology, measurements, and methods in a revised manuscript where suggested. Where applicable, we incorporated the comments into a revised manuscript or removed parts as suggested by the reviewers. While we were not able to incorporate all of the suggestions into the manuscript, primarily due to data constraints, we acknowledge their value and suggest that future research should investigate these matters. Our responses to the comments are given below. We already addressed M. Pelto's comments in a previous response, but we wish to address them again in light of the reviewer comments received after our initial response. The comments are in italics and our responses are in normal font.

1 M. Pelto

Tennant et al., (2012) provide a well written, thorough and valuable inventory of glacier change in the Canadian Rocky Mountains from 1919–2006. They provide a detailed and appropriate explanation of how glacier boundaries are derived from the various map and satellite image products. They further provide extensive statistical relationships with glacier properties and climate variables. This review focuses on three key issues.

2333-12: *There is an under representation of the smallest glacier class in the 1919 inventory (Fig. 6). Glaciers with an area of 0.05–0.1 km^2 certainly were not all shown in the 1919 map. This needs to be acknowledged more directly. This change in representation makes the comparison of relative area change less valid, unless only a portion of this class was used. You mention the missing glacier issue here. How did you deal with this smallest size classification in terms of comparison statistics given the underrepresentation?*
Response 2333-12: We thank the reviewer for their comment. The data in Fig. 6 are from the same set of glaciers. This figure shows the shift in glacier number and area as a result of glaciers from 1919, shrinking and falling into smaller size classes. However, for the analysis of glacier change, all glaciers were categorized into size classes based on their 1919 areas. These classes were held constant throughout subsequent years to ensure the same groups of glaciers were being compared. We replaced Fig. 6 with a more extensive area and number distribution of the glaciers (now Fig. 5) and found that the distributions are statistically similar (chi-squared test at 95 % confidence level). Also, we added the following sentence to the Results: Glacier properties section clarifying that size classes were based on the 1919 glacier area: 'We separated glaciers into six size classes based on their 1919 areas:...'

2336-6: *It is noted that 17 glaciers have disappeared. More details would be good. How many of the 17 disappeared by 1985 and since 1985? The size is noted, any other shared characteristics? Pelto (2010) noted that the glaciers that disappeared in the North Cascades lacked a persistent accumulation zone, which is evident in satellite imagery, and tends to occur more on slope glaciers with limited avalanching and height range. This is similar to the Jiskoot et al. (2009) class 4 glaciers. Jiskoot et al. (2009) were not focused on the smallest glaciers in terms of area, but the category descriptions still apply. How many would fall in this category?*
Response 2336-6: We added the following sentences to the Results: Glacier Properties section to provide more details about the glaciers that disappeared: 'Fifteen of the these 17 glaciers disappeared between 1919 and 1985; the remaining two disappeared between 2001 and 2006. Fourteen of the 17 glaciers that disappeared were smaller than 0.5 km^2. In 2006, glacier surface slopes ranged from 11° to 36°, with a mean of 20°. The mean elevation ranges of glaciers were between 96 m and 460 m. Mean and median elevations of the glaciers that disappeared prior to 2006 were below 2500 m a.s.l.' We do not have sufficient data to assess the persistence of the accumulation areas of the glaciers that disappeared and categorize them based on Jiskoot et al. (2009). The 15 glaciers that disappeared before 1985 only have 1919 extents and, unfortunately, no accumulation areas are identified on the maps. The two glaciers that disappeared between 2001 and 2006 did not have a persistent accumulation area. Also,

we do not have length measurements to properly classify the glaciers according to Jiskoot et al. (2009). However, these glaciers appear to fit within class 3 or 5 based on their slope.

2337-13: *The transition to the larger population representing a broader region needs to be either removed or better explained. Bolch et al. (2010) indicate a considerable difference in percentage of area lost between the BC and Alberta side of the range (11 % vs 25 %). Further they break the area loss percentage down by smaller regions, the changes from the central to the southern and the northern Rockies does indicate similar changes and that the extrapolation could be valid. With this variability in mind is it appropriate to say that Equation 1 can be applied to the broader region? If so demonstrate it with a bit more detail.*
Response 2337-13: The 11 % and 25 % difference between BC and Alberta glaciers (1985–2005) reported by Bolch et al. (2010) includes glaciers from all of BC, not just the Canadian Rocky Mountains. Looking at the Canadian Rocky Mountain regions only, their results for the southern and central Rockies are similar, at 18 % and 15 %, with the difference being less than the error term. At the suggestion of all the reviewers, we removed our original regression analysis and extrapolation to the entire central and southern Canadian Rocky Mountains. We determined that the area distribution by size class is similar between our study area and the whole central and southern Canadian Rocky Mountains. Therefore, we employed size class based scaling (Paul et al., 2004) to estimate area change of all glaciers in the two regions.

2341-6: *The assessment of non-climate controls is warranted. A further support reference would be Pelto (2010), which indicates that it is the glaciers without a persistent accumulation zone that will not survive, regardless of size. These typically are glaciers with low slope ranges and limited avalanching. Essentially these are the class 4 glaciers of Jiskoot et al. (2009) for those shrinking and class 3 for those that are not. Is this evident at all in your data set, or is it too difficult to assess at this point?*
Response 2341-6: We agree that a further assessment of non-climatic controls would be beneficial. However, at this point determining accumulation areas, avalanching glaciers, lengths, and slope ranges for all of the glaciers in our study area is not possible with our current data. Future research may be able to determine these properties for the years with imagery, but these properties cannot be determined from the 1919 maps. Instead, we included further analysis grouping relative area change of all glaciers and glaciers $<1\,\mathrm{km}^2$ with glacier attribute classes to determine the influences of non-climate controls.

2 Reviewer #1

Overall: This paper describes the use of historical, hard-copy maps to calculate glacier area change from the early 20th century to the early 21st. Such an approach provides useful context for the ongoing and sometimes rapid glacier wastage that is documented in many studies today using data from remote sensors. Furthermore, the study covers a fairly large area and includes glacierized regions with wide public appeal akin to the European Alps. This should provide a good template for providing perspective on present-day glacier change using historical maps which is useful groundwork for studies in ice covered regions world-wide. There are no major flaws in the paper that I can see but there are several places where the writing could be more clear or otherwise benefit from critical editing. I suggest that this paper be accepted with minor/major revisions.

Page 2329 line 14: *In the text '...volume is lost; this condition is likely...' its not clear what 'this condition' is referring to. Is it the initial increase in discharge due to mass wastage, or the subsequent decrease?*
Response page 2329 line 14: We were referring to the subsequent decrease. Sentence changed to: '...volume is lost; declining glacier runoff is likely now occurring in the Canadian Rocky Mountains...'.

Page 2330 lines 9–10: *Your range includes 4000 m even though Robson tops out below that. How about just saying that the relief is as much as 3000 m?*
Response Page 2330 lines 9–10: We removed the parenthetical expression: '(1000 to 4000 m above sea level, a.s.l.)' so the sentences now read as: '...recurrent alpine and continental glaciations, formed the high relief of the region (Heusser, 1956; Osborn et al., 2006). The two highest peaks in the Canadian Rocky Mountains are Mt. Robson (3954 m above sea level, a.s.l.) and Mt. Columbia (3747 m a.s.l.).'

Page 2330 line 17: *You have characterized the climate of the region with a single mean temperature and an average total precipitation which is a meaningless metric. Furthermore, there is a precipitation gradient in the W–E direction and perhaps in the N–S direction as well making a single number even less meaningful. So, you may want to express the extremes or other statistics that indicate the precipitation variability of the region. For temperature, since you know where the glaciers are, you could extract the mean annual temperature of glaciers in the region. That would be better as a single number. Still, the lateral gradients are important.*
Response Page 2330 line 17: The values are the average mean annual temperature and total annual precipitation from the centre of all glaciers in the study area. As suggested by all reviewers, we determined a range of temperature and precipitation values instead. We changed this sentence to: 'Mean annual temperature ranges from −6.4°C to −0.2°C and total annual precipitation ranges from 733 mm to 1972 mm.'

Page 2330 line 23: *In your list of glacier types, it would be possible for a glacier to have more than one of those characteristics so, Im not sure [i]f they all can be called types. Maybe characteristics.*
Response Page 2330 line 23: We separated the main glacier types from the characteristics as suggested by multiple reviewers. We changed this sentence to: 'Types of glaciers include valley, cirque, and icefield outlet glaciers with a range of surface and frontal characteristics...'

Page 2336 line 9: *You refer to a "mean glacierized area per flowshed" of 1.7 ± 0.2 km^2. [I]s a "mean glacierized area per flowshed" the same as the "mean glacier area" you referred to in line 20 on page 2335.*
Response Page 2336 line 9: The two measurements both represent mean ice cover of the flowsheds. We agree that it may be unclear so we changed 'glacierized' to 'glacier' for consistency.

Page 2336 line 27: *These look like median rates of area change per glacier, is that correct? This doesnt seem clear to me from the text. Please clarify.*
Response Page 2336 line 27: These values are the median glacier area change rates for each period. To clarify, we changed the text to: 'The median absolute rates of glacier area change for the periods...' and 'Corresponding median relative rates of glacier area change for...'

Page 2337 lines 2–5: *Again, describe what these change rates are. It seems like these numbers are rates for the whole study area. Correct?*
Response Page 2337 lines 2–5: We clarify this by changing the text to: 'Total absolute and relative rates of glacier area change in the study area...'

Page 2337 eqs. 1 and 2: *Although I can understand the desire to express your equations in terms of A1919 the equation would be much more readable expressed in terms of* $log(A_{1919})$ *such that the "guts" of the equation arent in the superscript.*
Response Page 2337 eqs. 1 and 2: This is a good suggestion, but we decided to remove the equations and the regression analysis from the paper and use size class based scaling factors (Paul et al., 2004) to estimate the area change of the central and southern Canadian Rocky Mountains at the suggestion of F. Paul.

Page 2337 Line 27: *I agree that slope should be play a role in the area change of glaciers, so a model including slope does make physical sense. However, this is not the normal way of constructing*

regressions. Ideally you would start with many variables and remove the ones that do not improve the regression in terms of the statistical significance of the regression as well as the R^2 adjusted for the greater number of degrees of freedom of your model. The statistical significance of the relationship didnt change, so I suspect that the adjusted R^2 may also not justify the addition of a second explanatory variable. I would also surmise (and I think its mentioned in the text) that there is a substantial correlation between glacier area and slope. Including highly correlated variables as explanatory variables in a linear regression model is generally bad practice. You can see that including slope in the model increases the explained variance by only 3% whereas the residuals are correlated with slope at r = −0.39 which would suggest an ability for slope to explain 15% of the total variance. Because slope and 2006 glacier area are probably significantly correlated, the explanatory power of the variable is greatly decreased.
Response Page 2337 Line 27: We did not look into the dual correlation of slope with area and area change initially. We checked the slope-area correlation and found an r-value of −0.39. In light of this moderate correlation and at the suggestions of the reviewers, we removed Eq. 2 and the associated correlations and area estimations.

Page 2337: *I'm not sure these relationships for determining 1919 ice covered area are really all that useful in the end. The largest scatter in the relationships between 1919 and 2006 glacier area occurs for the smallest glacier classes with up to two orders of magnitude spread in 1919 area for a given 2006 area. And, while there is less scatter in the 1–5 km^2 class, there is a lot of ice covered area that falls in this class (30%) so any error here will have large impacts on your estimated 1919 ice covered area. The only foreseeable use of this relationship would be to calculate either 1919 glacier area or the area change of glaciers from 1919 to 2006. I can't imagine that the relationship described here is universal enough for it to applied in study areas that aren't like the Rockies. Consider deleting this section of the paper.*
Response Page 2337: The main purpose of the relation described by Eq. 1 was, as the reviewer mentioned, to determine the 1919 area for the remaining glaciers in the central and southern Rocky Mountains that were not mapped and to estimate the area change from 1919 to 2006. We did not mean to imply that it can be transferable to other regions outside of the Rockies. This may not have been clear in the paper. However, at the suggestion of all the reviewers, we removed this relationship and used the size class based scaling factor method described by Paul et al. (2004). This method may also reduce the error in the area change estimation as the scatter associated with some size classes will not be transmitted to other size classes.

Page 2338 Lines 16–17: *I think it goes without saying that the correlations for rates and the actual area change mirror each other because they are essentially the same numbers.*
Response Page 2338 Lines 16–17: Removed.

Page 2338 Line 20 and else where in the climate section: *What does "all minimum temperature anomalies" mean? I think you want to say the annual mean of daily minimum temperature. This or similarly unclear language occurs in a few places thereafter.*
Response Page 2338 Line 20 and else where in the climate section: We do not have daily temperatures. The data are mean monthly temperature and total monthly precipitation. The phrase 'all minimum temperature anomalies' refers to minimum temperature anomalies from the accumulation and ablation seasons and annually. We clarify this here and elsewhere by rewording the phrase to include the actual seasons.

Page 2338 Line 23 and onward: *Use "were" instead of "are" when talking about anomalies in past climates.*
Response Page 2338 Line 23 and onward: Changed.

Page 2338 Line 19: *The climate averaging period chosen is a bit strange. Although I can see why you would choose one to match your temporal coverage, you may get more interesting and comparable results if you choose one to match a more common era such as 1951–1980 which is commonly used in*

climate change studies and is roughly central to your temporal span.
Response Page 2338 Line 19: We thank the reviewer for their suggestion. We chose this period because it matches our temporal coverage and encompasses all the variations in the climate including the warm/dry climate between 1920 and 1950. We did not want to use a climate normal period as it could affect the results depending on what 30 year period we chose, whether it was 1951–1980, 1961–1990 or something else.

Page 2339 Line 7: *Were the correlations done on the mean temperature and precipitation or on the anomalies relative to the chosen climate normal period.*
Response Page 2339 Line 7: The correlations were done on the mean temperature and precipitation. We also tried correlating with the anomalies and produced similar results. However, at the suggestion of F. Paul, we removed the climate correlations.

Page 2339 second paragraph in section 5.1: *The first two sentences need to be rearranged. How about "We compared our results to those of Bolch et al. (2010) for the Southern and Central Canadian Rocky Mountains. A perfect comparison was not expected because we modified and edited the glacier extents and used a subset of their glacier inventory data. However, we found our area changes..."*
Response Page 2339 second paragraph in section 5.1: We thank the reviewer for their comment. We rearranged the sentences as suggested.

Page 2340 Line 9: *Shouldn't you be able to directly compare your results for recent epochs to those of Jiskoot et al. (2009)? My understanding is that your temporal coverage is almost identical to theirs.*
Response Page 2340 Line 9: We calculated the rate of area change for the Chaba Icefield region at $-7\,\mathrm{km}^2$ per decade, and found that it was closer to the Clemenceau Icefield rate stated in Jiskoot et al. (2009). Upon closer examination, the 1985 extents are from different sources. The 1985 Jiskoot et al. (2009) glaciers are more extensive and contain some glaciers that are not present in the Bolch et al. (2010). We added this information to the discussion.

Page 2340 Lines 25-29: *Other explanations include the greater responsiveness of smaller glaciers, and greater susceptibility owing to a smaller elevation span.*
Response Page 2340 Lines 25-29: We incorporated elevation range into the attributes influencing relative area change later in the discussion. Small glaciers do not necessarily have greater responsiveness as the local topography has a strong influence on how a glacier responds to climate.

Page 2341 Line 15: *Some of the increased variability seen for smaller glaciers is due to the methodology. If you assume that the buffer method represents the uncertainty in determining a glacier's area, then smaller glaciers will have a much larger relative uncertainty which propagates to the area change calculations.*
Response Page 2341 Line 15: We agree that small glaciers will have a larger relative uncertainty/error due to our method of calculating error. However, the variability we are discussing here is the wide range of area change values, not the uncertainty in those values. We replaced Fig. 7 at the suggestion of F. Paul with a scatterplot of relative area change vs glacier area. This plot shows the scatter in the smaller glacier better than the original plot.

Page 2342 Line 9: *It seems like you would be able to isolate the effects of having large numbers of glaciers on a given aspect by looking at the relative change for all glaciers within that aspect class.*
Response Page 2342 Line 9: At the reviewer's suggestion we looked at relative area change with aspect and found no preference with aspect. However, for small glaciers $<1\,\mathrm{km}^2$, we found high relative area changes with south to west facing glaciers.

Page 2343 Line 22: *It's not accurate or meaningful to state a precipitation anomaly in mm as is done here. It's also not clear what this anomaly is averaged over — is it the entire domain, or over the glaciers. Stating the anomaly as a percent of normal is more transferable — especially in mountainous*

terrain where precipitation varies greatly with elevation.
Response Page 2343 Line 22: We changed the precipitation anomalies to percentages of the averaged period 1919–2006. The anomaly is the approximate average of the annual, ablation and accumulation season median precipitation anomalies of the glaciers of the study area for the 2001–2006 period shown in Fig. 10. We stated in Data and Methods that precipitation and temperatures were extracted at each glacier.

Page 2343 paragraph including line 15: *It sounds to me that the snowy 2001 and 2002 Landsat imagery could explain both the lower rates in the preceding epoch and the higher rates in the subsequent epoch.*
Response Page 2343 paragraph including line 15: For the 2001 extents, snow cover was not on all scenes and only hindered the delineation of some small glaciers and high altitude extents accounting for an error of ±3 % as determined by Bolch et al. (2010). If the 2001 extent was decreased by 3 %, the 1985–2001 rate would still be similar (although slightly higher) to the 1919–1985 rate and the 2001–2006 rate would still be larger, just by a smaller margin. We added: 'A few of the 2000–2002 Landsat images have some late-lying snow that hindered delineation of some small glaciers and high elevation glacier extents. This late-lying snow only accounts for errors of ±3 % in the extents determined by Bolch et al. (2010), and is smaller than the error estimates (Table 2).'

Page 2344 Line 14: *Change the second 'most' to 'greatest'*
Response Page 2344 Line 14: Changed.

Page 2344 Line 15: *Insert 'that' into 'suggesting local'*
Response Page 2344 Line 15: Changed.

Figure 1: *I'm not sure of the national parks and provincial parks need to be shown on this map. The tend to distract from the map boundaries and other information.The flowsheds are hard to see. Given the diagonal trend of the border, maybe break this map into two panels to allow for more detail of what's important for your study area.*
Response Figure 1: We removed the parks and enlarged the map. We decided not to break the map up into two panels as the figure looked cluttered.

Figure 6: *This should be broken up into two figures — one for number and one for area for easier comparison.*
Response Figure 6: We replaced this figure with one showing area and number distributions for our data and Bolch et al. (2010) data. It is now Fig. 5. We took the reviewer's suggestion and separated percent area and percent number into two panels.

Figure 7: *It's not clear what the unlabelled tick mark is. Include intervening tick marks or somehow make this more clear.*
Response Figure 7: We replaced this figure with one of relative area change vs glacier area (now Fig. 6). We made sure that tick marks are labeled or easily identified.

Figure 8 and Figure 6: *Figure 8 and Figure 6 would look better with bounding boxes aligned with the plotting axes. This looks too much like raw R output.*
Response Figure 8 and Figure 6: We replaced Fig. 6 with the area and number distributions (now Fig. 5), but made sure bounding boxes are present. We removed Fig. 8 and placed the data in a table at the suggestion of F. Paul.

Figure 10: *As before, its not clear how mm valued precipitation anomalies apply to the landscape. These would be more transferable as % anomalies.*
Response Figure 10: We changed the precipitation anomalies to percentages (now Fig. 9).

3 H. Jiskoot

This paper by Tennant et al. presents the area change of many glaciers in the Canadian Rocky Mountains between 1919 and 2006, using a novel approach whereby the glacier extents were digitized from georeferenced historical maps. The research is original, the error analysis rigorous, the paper generally well-written and the presentation concise. The figures and tables are overall of good quality and appropriate, but some need improvement and some can be removed. I agree with the comments and suggestions made by Mauri Pelto and Reviewer #1, and will not repeat their remarks, but may expand on some major issues.
Most of my comments are minor corrections and requests for more clarity. The more substantial issues concern the statistical analysis of the correlation between glacier properties, climate, and retreat rates; the extrapolation of area losses over the entire Canadian Rocky Mountains region; and the potential bias in glacier characteristics and spatial distribution introduced by the location of the historical maps and by the removal of 'problematic' glaciers. I suggest that once the authors have address these concerns, the revised paper will be suitable for publication in The Cryosphere. The results will contribute to increasing the understanding of regional scale response of different types of glaciers to climate change, and the methodology to refining the use of historical map and photographic data to extend the study of regional glacier changes beyond the era of satellite remote sensing (e.g. Andreassen et al., 2002; Bjork et al. 2012).
Response: We improved and modified some of the figures as suggested in the SPECIFIC COMMENTS. The correlations between area changes and glacier properties were reduced and replaced with a different method of comparison involving grouping relative area changes by property classes and looking for patterns or trends. We completely removed the correlation between area change and climate variables at the suggestion of F. Paul, due to the poor correlations and lack of response time discussion. Extrapolation of area losses was also removed and replaced with a method described by Paul et al. (2004) as suggested by F. Paul. In this method area losses are scaled to the larger region based on size class scaling factors, relative area change. The potential bias was investigated by comparing our data used in the analyses with those of Bolch et al. (2010) for the central and southern Canadian Rocky Mountains. These issues are discussed further in the SPECIFIC COMMENTS.

SPECIFIC COMMENTS

Title and abstract: *Both need to be clear about the fact that area change was not measured for all glaciers in the Canadian Rockies: just 56% of the total number of glaciers on the IBCS maps were measured, and the maps were already a subset of the total glacierized area. Terminology such as 'Total glacierized area decreased by 590±100 km^2 (40±7 %)...' is somewhat misleading, as this is reduction of only a portion of the total glacierized area in the Canadian Rockies. Further, the extrapolation of the area loss rates through reconstruction of the 1919 area using the linear regressions should be clearly separated here and throughout the paper.*
Response Title and abstract: We clarified the area our values refer to in the abstract and throughout the paper by stating that the study area covers 50 % of the central and southern Canadian Rocky Mountain glacier coverage mapped by Bolch et al. (2010), and using the term 'study area' instead of or in conjunction with 'total' when referring to measurements. We kept the title as we don't use the terms 'all' or 'total'. We changed our approach to estimating area change for the entire central and southern Canadian Rocky Mountains as suggested by F. Paul, and clearly separated it here and throughout the paper.

P2328-L13: *'Absolute area loss negatively correlates with slope and minimum elevation, and relative area change negatively correlates with mean and median elevations.' This is confusing if we dont know that an area loss is measured with a negative sign (see also P2338-L5-15). Clarify by restating: 'Absolute area loss is larger for glaciers with low slopes and minimum elevation, while relative area change is larger for small glaciers with lower mean and median elevations.'*
Response P2328-L13: We removed most of the correlations from the paper since they were weak

($-0.3 < r < 0.3$). Instead we grouped relative area change into attribute classes to determine influencing factors.

P2328-L21: *change 'form' to 'morphology'*
Response P2328-L21: We changed the structure of the introduction so this part has been removed.

P2329-L10: *Add a line including runoff contribution: e.g. Marshall et al (2011) quantify contribution from the eastern slopes glaciers, and Jost et al. (2011) and Jiskoot and Mueller (2012) from western slopes glaciers to the Upper Columbia River basin (approx. 25% the late melt season).*
Response P2329-L10: Added the sentence: 'Marshall et al. (2011) quantify contributions from glaciers in the Canadian Rocky Mountains east of the Continental Divide at 0.8 % to 7.4 % and Jost et al. (2011) and Jiskoot and Mueller (2012) estimate that the contribution from glaciers west of the Continental Divide to the upper Columbia River basin is ca. 25 %.'

P2329-L15: *Perhaps also add Moore and Demuth (2001) and Kienzle et al. (2012), as they present measurements.*
Response P2329-L15: Added.

P2330-L16-17: *Delete: at least some spatial variation should be given as the study region is large and contains both windward and leeward aspects of a continental divide. See also comments on figure 2.*
Response P2330-L16-17: We replaced this sentence with: 'Mean annual temperature ranges from -6.4°C to -0.2°C and total annual precipitation ranges from 733 mm to 1972 mm.' We calculated the mean annual temperature and total annual precipitation at the the centre of each glacier and determined the range over the study area. Also, we removed Fig. 2 at the suggestion of multiple reviewers.

P2330-L25: *Add Ommanney (2002) and Jiskoot et al. (2009) here.*
Response P2330-L25: Added.

P2331-L2: *Reference Ommanney (2002), as this is the only comprehensive review of the region's glaciers. Also, check the relative sizes of Columbia and Clemenceau icefields in the Bolch dataset: they may be very close in total area.*
Response P2331-L2: We checked the sizes of Columbia and Clemenceau icefields and agree with H. Jiskoot. We took out '(largest)' from the list of icefields. We don't cite Ommanney (2002) here since we are only stating the icefield names.

P2331-L7: *Add a URL for Library and Archives Canada.*
Response P2331-L7: Added.

P2331-L22: *Also report the error/accuracy of the source datasets?*
Response P2331-L22: We state the error of the glacier extents from the glacier inventory of Bolch et al. 2010 in the paper as 3–4%. We added error terms for the Landsat and BCTRIM data: '...from previously orthorectified Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) imagery with errors of ±15 m and ±50 m, respectively (Bolch et al., 2010). We also used a shaded relief model (hillshading) derived from the BC Terrain Resource Information Management (TRIM) digital elevation model (DEM; Table 1) with a horizontal error of ±10 m and a vertical error of ±5 m (Bolch et al., 2010).'

P2331-L23: *'..the features on the maps...' This is rather vague. List some examples in brackets.*
Response P2331-L23: We added a list of feature examples used in the visual check: 'We also visually checked the positions of peaks, ridges, and lakes on the maps against the BC TRIM hillshading and Landsat imagery.'

P2332-L2: *Change 'We digitized..' to 'We manually digitized...'*
Response P2332-L2: Changed.

P2332-L25: *'.....missing terminus of a large glacier'. This is Wales Glacier, an important glacier as it is fed by 3 icefields: Columbia, Chaba and Clemenceau (see also Jiskoot et al., 2009: Fig 1)*
Response P2332-L25: Sentence changed to: 'The terminus of Wales Glacier is missing from the IBCS map...'

P2332-L27: *beyond the limits (plural)*
Response P2332-L27: Corrected.

P2333-L16-18: *Only 56 % of the original 937 flowsheds could be analysed for area change. Mention what the removal of the 'problematic' glaciers meant for the potential bias in glacier size and spatial distribution? Also add what percentage of original area was removed (e.g. on the basis of the available post 1919 areas)? More problematic is perhaps that the original coverage of the 1919 maps was mostly limited to the crown of the BC-AB border and the eastern slopes of the Rockies. Report what the glacierized area NOT covered by the 1919 maps was: looking at Fig 1 it could be >25 %. Most of the glacierized regions missed by the 1919 maps are on the west to southwestern slopes (e.g. the entire Clemenceau Icefield (approx. 300 km^2: Jiskoot et al., 2009), which will certainly produce a bias in aspect and perhaps other glacier and climate properties (i.e. a more maritime climate). This makes the extrapolation of area loss (P2337-L8-29) problematic.*
Response P2333-L16-18: We looked at the distribution of glacier area across five properties — region (south vs central), divide (east vs west), basin (Columbia, Fraser, Nelson, and Mackenzie), aspect (N, NE, E, SE, S, SW, W, and NW) and size classes (0.05–0.1 km^2, 0.1–0.5 km^2, 0.5–1.0 km^2, 1.0–5.0 km^2, 5.0–10.0 km^2, and >10.0 km^2) — for both the glaciers used in the analysis (after the removal of the 'problematic' glaciers) and the glaciers of the central and southern Canadian Rocky Mountains in the glacier inventory by Bolch et al. (2010). The distributions were statistically the same (chi-squared test at 95% confidence level) for the basins, aspects, and size classes, but different among regions and from east to west. Therefore, there may be a bias between regions and east and west. Of the glaciers mapped in this study, 44% of the flowsheds and 17% of the glacier area were removed for reasons stated in the paper. We added the following sentence to Data and Methods: Error Analysis: 'Of the original 937 flowsheds, 414 were removed (44 % of the flowsheds or 17 % of the glacier area), leaving 523 flowsheds for analysis.' The glacier area used for analysis in this study accounts for 50% of the total glacier area in the central and southern Canadian Rockies. We added the following sentence to Study Area: 'In 2006, the area of glaciers in the study area was ca. 900 km^2, representing 50 % of the total glacier cover of the central and southern Canadian Rocky Mountains (Bolch et al., 2010).'. We removed the original extrapolation and used the method suggested by F. Paul (Paul et al., 2004) to estimate area change from 1919 to 2006 for the central and southern Canadian Rockies based on scaling factors for different size classes which showed similar glacier area distributions.

P2334-L5: *I assume you calculated the arithmetic mean based on the DEM. Give a reference for the techniques used for elevation, slope and (mean) aspect, as especially the last two can have different approaches (e.g. Schiefer et al., 2008; Paul et al., 2009).*
Response P2334-L5: We calculated the elevation, slope and aspect values from the DEM using zonal statistics. We added this to the sentence and referenced Paul et al. (2009): 'We determined the mean, median, and minimum elevations of glaciers within each flowshed, and derived the mean surface slope and aspect from the DEMs (Table 1) using zonal statistics (Paul et al., 2009).'

P2334-L21: *What lapse rate was used? If this was not a monthly variable lapse rate (which generally takes into account winter inversions, which may occur about 25 % of the time on the Eastern slopes of the Southern Canadian Rockies: Pigeon and Jiskoot, 2008) then this can result in large errors. See Shea et al. (2004) and Minder et al. (2010).*
Response P2334-L21: The wording may have been unclear, but the ClimateWNA program, not us,

applies a lapse rate to extract temperature and precipitation data at a specific elevation. Wang et al. (2006) discuss how lapse rates were calculates. We modified the sentence to: 'The program uses bilinear interpolation and monthly variable lapse-rate elevation adjustments to integrate the historical anomaly surfaces and the baseline grid and downscale the climate data at a specific location (Wang et al., 2006, 2012; Mbogga et al., 2009)'

P2335-L22-25: *Confusing phrasing 'glaciers <1.0 km^2 contained 49 %', in the context of glacier numbers (previous line) and area (next line). Mention that this contains 3 bins of glacier sizes <1.0km^2, and state if this is numbers or area.*
Response P2335-L22-25: Changed to: 'The three classes of glaciers smaller than 1.0 km^2 accounted for 49 % of the total number. Glaciers in the >10 km^2 class had the largest composite area (41 %).'

P2336-L2: *Report that this is in part the result of the location of the removed glaciers, which were mostly on the (south)western slopes.*
Response P2336-L2: We looked at the area and number distributions between our data and the entire central and southern Canadian Rockies data as mapped by Bolch et al. (2010). We found that they had the same distribution (chi-squared test at 95 % confidence level) across the different aspects.

P2337-L8-29: *I concur with Mauri Pelto and Referee #1 (C1195) that the regression analysis to extrapolate area losses to the entire region is problematic, especially since each term is considered separately and interaction terms are not considered. Moreover, the explanatory and response variables are not independent (e.g. area-slope, area- minimum elevation). Interaction terms between the explanatory variables should be considered: e.g. mean slope and lowest elevation are generally correlated because longer glaciers have lower slopes and descend further. Considering interactions may lead to better understanding of the sensitivity of particular glaciers to climate change. Additionally, there is a clear aspect bias in the omitted glaciers (many omitted glaciers are W and SW-facing: Fig. 1), and perhaps size/other biases, so the extrapolation of area loss may not be valid for these regions. Mauri Pelto's comment of comparing your 1985-2001 Chaba Icefield region with Jiskoot et al. (2009), and then comparing this with the Clemenceau Icefield region rates (omitted in yours) may provide an additional error estimate of this regional extrapolation through linear regression.*
Response P2337-L8-29: The interaction terms were not considered initially, but upon checking the correlations, we agree with the reviewers and removed the regression analysis as suggested. We checked the area distribution and did find a bias between regions and east versus west glaciers, but not in aspect. We did not find a bias in the area distribution of the size classes, so we used the method in Paul et al. (2004), suggested by F. Paul, to estimate the area change from 1919 to 2006 over the central and southern Canadian Rocky Mountain regions using size class specific scaling factors. We calculated the rate for the Chaba Icefield region at −7 km^2 per decade, and found that it was actually closer to the Clemenceau Icefield rate stated in Jiskoot et al. (2009). Upon closer examination, the 1985 extents are from different sources. The 1985 Jiskoot et al. (2009) glaciers are more extensive and contain some glaciers that are not present in the Bolch et al. (2010). We added this to the discussion: 'Jiskoot et al. (2009) determined rates of area change of −9 % per decade and −19 % per decade for the Clemenceau and Chaba icefields, respectively, from 1985 to 2001. Our rate of area change over the same period for the Chaba Icefield is −7 % per decade, which is closer to Jiskoot et al.'s (2009) rate of area change for the Clemenceau Icefield. The latter is not covered by the IBCS maps. However, Jiskoot et al. (2009) used different source data for the 1985 glacier extents with a larger extent of some glaciers of the Chaba Icefield than we used for our 1985 glacier extents.'

P2338-L5-15: *Write whether the correlations are positive or negative (additionally to strong/moderate, etc). Since you use the more negative rate as the larger loss I find this a little confusing to interpret. Also, I am a little surprised by the correlation of higher relative areal losses with lower median and average elevations. I would expect smaller glaciers to have higher mean and median elevations, but according to your results they are at lower elevations. Perhaps adding a scatterplot of glacier area versus the three elevations (E_{min}, E_{mean}, E_{med}) may clarify this area-elevation distribution.*

Response P2338-L5-15: We removed most of the correlations, but stated whether the remaining correlations are positive or negative and added explanations for what the correlations mean. Additional analysis comparing area change with attributes was conducted by grouping relative area change by glacier attributes to look for relations and trends. Using this method, we found similar results indicating higher relative area loss with lower median/mean elevations. We also looked at small glaciers $<1\,\text{km}^2$ and found that they are located across all median/mean elevations and not restricted to high elevations. Instead of additional scatterplots, we added a barplot of relative area change grouped by various attributes.

P2339-L14-15: *Make clear that this loss is for 56 % of the total glacier number. Also, change 'by' to 'in'.*
Response P2339-L14-15: Changed to: 'Total ice cover in our study area, decreased $590 \pm 100\,\text{km}^2$ ($40 \pm 7\,\%$) between 1919 and 2006.'

P2340-L4-5: *Jiskoot et al. (2009) is 1985–2001 so can be directly compared to your 1985–2000 and should be brought into the previous paragraph. Since their Chaba Icefield rates are comparable to yours, but not their Clemenceau Icefield group rates (not measured by you) this may be an argument for why your linear regression extrapolation of area losses into the unmeasured regions may not work as well as you argue (see also Mauri Peltos 2337-13 comment).*
Response P2340-L4-5: As mentioned in previous comments (P2333-L16-18 and P2337-L8-29), we calculated the rate for the Chaba Icefield region at $-7\,\text{km}^2$ per decade, and found that it was actually closer to the Clemenceau Icefield rate stated in Jiskoot et al. (2009). We added this information to the discussion. Also, we removed the original extrapolation and used the size class based scaling factor method to estimate area change of the Rockies.

P2340-L17-21: *There are measurements of glacier retreat since the LIA maximum for some individual glaciers in the Rockies (e.g. Stutfield and Cavell Glaciers). These could be compared, almost directly, to your retreat rates, assuming there is not much retreat before 1919.*
Response P2340-L17-21: There likely was some retreat between the LIA maximum and 1919 for some glaciers. Also, we do not report retreat rates as length was not measured and therefore cannot be compared with retreat rates from other studies. We explored length changes for the Columbia Icefield and compared them with early 1900 measurements of retreat rates in an upcoming paper currently under review.

P2340-L29: *Add reference that quantifies this effect from measurements or modelling (e.g. Jiskoot and Mueller (2012) on a Clemenceau Icefield outlet glacier).*
Response P2340-L29: Added.

P2341-Paragraph 5.2. *This discussion is quite superficial and needs to be updated once a more thorough regression analysis is done. Clearly separate absolute and relative area changes (be clear for the referenced regions too).*
Response P2341-Paragraph 5.2. We removed the original regression analysis and most correlations with glacier attributes. Instead we explored relative area change through attribute classes to determine influencing factors. We also expanded our analysis to factors influencing relative area change of small glaciers ($<1\,\text{km}^2$). Absolute and relative area changes are now clearly stated.

P2342-L18: *Figure 10 does not show how variable the climate was: See at Fig. 10 below.*
Response P2342-L18: By variability, we meant that the first period contained two main periods of differing climate, the warm and dry period, ca. 1920–1950 and the cool and wet period, ca. 1950–1980. The two extra periods (1919–1950 and 1950–1985) in Fig. 10 were shown to represent this. As it is not clear in the figure, we removed the reference to Fig. 10 and removed the extra periods form the figure.

P2343-L1-24: *This discussion is quite vague and could be improved in several ways once Fig. 10 is* *updated. Further, the correlation between temperature and precipitation with PDO will need to include some more detail, with a cautionary note about the length of the last period (2001–2006). Line 20 should not be stated with such certainty since you have just argued that the 2000–01 area extent might have been overestimated. Estimated response times of the different glacier sizes/types may also help strengthening this discussion.*

Response P2343-L1-24: We decided to keep our version of Fig. 10 (now Fig. 9) with the removal of the extra periods as it can be visually compared with the area change rates in Fig. 8 (now Fig. 7). We removed the link with the PDO, but included a note on the length of the periods: 'However, the first period (1919-1985) spans more than six decades and includes shorter intervals with different rates of loss, whereas the last period (2001–2006) is a half decade long and may be a period characterized by high rates of loss.' For the 2001 extents, snow cover was not on all scenes and only hindered the delineation of some small glaciers and high altitude extents accounting for an error of ±3 % as determined by Bolch et al. (2010). If the 2001 extent was decreased by 3 %, the 2001–2006 rate would still be larger, just by a smaller margin. We added: 'A few of the 2000–2002 Landsat images have some late-lying snow that hindered delineation of some small glaciers and high elevation glacier extents. This late-lying snow only accounts for errors of ±3 % in the extents determined by Bolch et al. (2010), and is smaller than the error estimates (Table 2).' We have not estimated response times for the variety of glaciers, but we removed the climate correlations for which the response times would need to be considered. We do briefly mention response times in the discussion on climate: 'Area change is not an immediate response to a change in climate. The response time of a glacier depends on its size, attributes, and topography.'

REFERENCES

Delete the page numbers of this manuscript after each reference.

Response: The page numbers were not included by us. We believe they are a result of the production of the online discussion paper. They are probably added to make it easier to find the instances of the references within the paper. We assume they will not be included in the final paper.

TABLES and FIGURES

Table 3: *I assume that the correlation was done with negative rate (the faster the change the more negative the rate). Mention this in the caption for clarity.*

Response Table 3: We removed the correlations from the table and replaced Table 3 with a table of area changes for glacier size classes as suggested by F. Paul.

Fig 1: *Change Fraser to 'Fraser River Basin' and Columbia to 'Columbia River Basin'. Note in the caption or legend what year the blue glacier outlines are from. Are the parks (especially the provincial) really necessary? Especially the bright green takes away from the focus on the glacier outlines.*

Response Fig 1: We changed the basin names and added the year of the glacier extents to the legend. We removed the parks as suggested.

Fig 2: *Not sure if this is such a useful/necessary figure in this paper. Taking the average over all glaciers does not say much over such a large area including both sides of a continental divide. Further, the snowfall amount frequency is not clear at all (snow pillow data may be better). Delete the figure, and the text does not depend on it.*

Response Fig 2: We removed Fig. 2 at the suggestion of the reviewers.

Fig 5: *It may be helpful to provide centrepoint latitude and longitudes and/or glacier names, for all 6 panel locations in the figure caption. Also, panels a, c, and e have black outlines, but b, d and f not.*

Response Fig 5: We do not think latitude and longitudes and/or glacier names are necessary as the images are just examples of errors/uncertainty and will clutter the figure. We added black outlines to all panels. This is now Fig. 4 in the revised manuscript.

Fig 7: *I assume the disintegrated glaciers' area in 2006 are the sum of the fragmented parts. It may be interesting to do a statistical analysis of the difference in retreat rate between fragmented and non-fragmented glaciers (c.f. Jiskoot et al., 2009)*
Response Fig 7: We cannot do an analysis on retreat rates as we did not measure lengths. However, we quickly calculated the relative area change for disappearing glaciers, disintegrating glaciers, and glaciers with the same number of ice masses. The values are, respectively, −50.5 %, −52.8 %, and −55.8 %.

Fig 10: *Update: this figure does not show how variable the climate was. It is also statistically confusing for the box plot periods to have different lengths. Instead, plot the seasonal accumulation/ablation season temperatures and precipitation as a line graph, and add a horizontal line for the average per studied period of area change.*
Response Fig 10: We thank the reviewer for their suggestion, but we do not think the line graphs would be able to show all of the different temperature and precipitation anomalies without appearing cluttered. However, we removed the periods with the smaller widths, and removed the reference to this figure in relation to climate variability (now Fig. 9).

Figs 6-10: *This may be a personal preference, but I think it is clearer when the numbers on the y-axes read horizontally.*
Response Figs 6-10: We thank the reviewer for their comment, but we decided to keep the numbers vertical on the y-axes.

4 F. Paul

General Comments

The study by Tennant et al. presents an assessment of glacier area changes in a part of the Canadian Rocky Mountains (British Columbia) where glacier inventories from earlier studies and change assessment already existed. The important step forward in this study is the temporal extension to the period 1903–1924 (median 1919) from digitizing glacier extents on topographic maps of this period after proper coregistration with the other datasets. The observed changes are then analysed in regard to potential influential factors such as topographic properties of the respective glaciers and downsampled climate data. Though I found the change analysis interesting and carefully performed, the attempt to correlate this with climate data is in my opinion very weak. This is largely due to the missing consideration of glacier response times and the high degree of generalization found in some statements, basically discussing area changes as they were elevation changes. I also wonder why changes in glacier length are not discussed in more detail? Actually this is the parameter where numerous measurements exist far back into the past and where at least some process understanding for the 'climate change - glacier response' relation exist from numerical modelling.
It is not explained or motivated in the introduction why there should be a relation between climatic parameters (or trends) and glacier area change? Of course, glaciers adjust their size in response to climate change as their extent is a result of the balance between mass gain and loss. But this is a very glacier specific reaction (e.g. depending on glacier slope/mass flux or the area-elevation distribution). My point is: why should there be a relation under this circumstances? The entire argumentation (section 5.3) comes back to the link of climate with mass balance (P2343, L12/3): 'increased precipitation may have offset some area loss due to the warmer temperatures'. As there is no direct link between area change and climate (as stated correctly 5 lines later), this is not how it works (by the way, temperatures can only be higher). As a way forward, I suggest to skip the entire climate relation analysis in a revised version of the ms. This part currently makes the ms unacceptable in my opinion as it violates some basic and well known glaciological principles. I have listed below some more specific comments to this

and other parts of the ms that I hope are helpful in revising it.
Response: We initially conducted the correlation between area change and climate under the assumption that the period we were correlating over was longer than most dynamic response times of glaciers. However, this may only be the case for the whole study period (1919–2006) and the first period (1919–1985), but would not hold true for the shorter periods. We further investigated the correlation of area change with climate data in response to your concerns. We lagged the climate variable anomalies by up to 20 years and correlated them with area change for each period to address the issue of response times. We found that the correlations with the shorter periods were more variable over the different lag lengths. However, the strength of the correlations remained low. Based on these results, we agree with the reviewer that the correlation is weak and that other glacier specific factors play a strong role in area change. Therefore, we removed the area change-climate variable correlation as well as the discussion implying direct response of area change to climate change from the paper. Length changes were not measured for this study and could not be discussed, but are included in an upcoming paper on glacier change of the Columbia Icefield, currently in review. These issues are discussed further under the specific and detailed comments.

Specific Comments

Introduction–2328: *The introduction reads like a conglomerate of unconnected statements that provide little information on the background of this study. Mass balance is not investigated here, neither is run-off, glacier volume or its future changes. What should be clearly explained instead is the additional insight that is gained by extending the time series to the 1920s and taking the effort of digitizing the historic maps. As these changes provide only a mean over a very long period, it should be clarified how potentially available front variation measurements help to clarify what has happened in-between. This is actually the key to an integrated glacier monitoring strategy: creating overall assessments from glacier inventories at decadal time scales and complementing these with more sparse, but higher temporal resolution ground measurements. I also wonder why Little Ice Age extents of the glaciers have not been mapped from trimlines? It should be shortly explained why this was not an option for the study region.*
Response Introduction–2328: We adjusted the introduction to focus more on glacier extents and the historic maps. We do not discuss glacier lengths as they were not the focus of this study, but we explore length changes of the Columbia Icefield in a future paper that is currently in review. Little Ice Age extents are not currently mapped for this region and were not included in the study. Our current research focuses on mapping these extents.

Study Area–2330: *For the study area section I recommend shortly explaining the potential influence of the climatic conditions (e.g. a precip. gradient) on glacier distribution and characteristics, and to not mix up a glaciers primary classification (valley, mountain, icefield) with its surface and frontal characteristics. If an analysis of the area change for land and lake-terminating glaciers is added in the later sections, the percentage of the two classes should be given. The mentioned main icefields should be shown in Fig. 1, in particular when a regionally differentiated analysis of the changes make sense.*
Response Study Area: We added a brief sentence on glacier distribution and climate: 'Shea et al. (2004) suggest spring precipitation, annual temperatures, and winter precipitation are the main factors influencing glacier distribution within the Canadian Rocky Mountains.' We separated the glacier classification from the characteristics, changing the sentence to: 'Types of glaciers include valley, cirque, and icefield outlet glaciers with a range of surface and frontal characteristics...'. Also, we added the mentioned icefields to Fig. 1. We did not conduct an analysis on land vs. lake-terminating glaciers so no percentages are given.

Data–2331: *In the data section I suggest to better justify the use of 1919 as a median date for all regions (e.g. show a histogram of the map dates), and the different interpretation of glaciers / perennial snow fields by cartographers vs. glaciologist might also be worth a short discussion. As explained in the general comments, I would remove the climate data section (3.5) completely. Though this is likely a very valuable dataset for many applications, it makes no sense to correlate these data with glacier* *changes without considering glacier specific response times. It is even worse for glacier area changes as these show a much higher variability (i.e. they are close to random for small glaciers). I think stating that glaciers shrink when temperatures increase is fine and pointing out that temperatures have increased recently as well. But this influences glacier mass balance and only in a much longer term (involving glacier dynamics) length or size. In this regard most valuable would be to collect from the here analysed datasets changes in length for all glaciers.*

Response Data: The 1919 value is the median year of all glaciers mapped from the IBCS maps. Most of the maps were from 1916 to 1924 with a few maps from 1903, 1906, and 1913. The subsequent years of glacier extents were also given a median value (1985, 2001, and 2006) calculated by the same method. While the rates of area change of the entire study area were calculated using the median values, the individual rates of area change were determined using the actual years of the glacier extents, not the median years, which we clarified: 'We used the median year of the glacier coverage (1919, 1985, 2001, and 2006) to define approximate acquisition dates for the glacier data as a whole, although individual area change and rates are based on the actual acquisition year for a given flowshed.' We removed the correlation part of the climate data section for reasons stated in the general comments, but kept the anomaly analysis. While direct comparisons are not possible, we think it is important to include the data for showing the temperatures and precipitation over the periods. We did not collect length changes for this study as it was focused on area change, and we will not be collecting them for the whole region at this time. We agree that length changes would be valuable to investigate and have done so for the Columbia Icefield in an upcoming paper currently under review.

Results–2335: *For the results section I first suggest to show all values of the change analysis in a table (per size class, in total, and for all epochs in absolute and relative terms). The text for section 4.1 and 4.2 can then focus on the interesting details rather than just listing all values. It would be nice to add a scatter plot showing mean (or median) elevation vs. mean glacier aspect and maybe also the change in minimum elevation vs the change in mean elevation. Additional to Figs. 7 and 8, I would suggest to also show the relative area changes versus glacier size for at least one of the periods. The double logarithmic plot in Fig. 7 strongly suppress the scatter and might imply that it is a good idea to create a regression through the data points (see your equations on page 2337). But Fig. 8a (and to some extent also 8b) indicates that a simple regression is not a good idea. Previous studies (e.g. Paul et al., 2004) have used size class specific mean changes to extrapolate change rates to other samples. I suggest applying this method here as well (instead of the regression).*

Please also be aware that there is some correlation between glacier size and slope / minimum elevation. So correlations between area change and slope or minimum elevation (described in section 4.3) come back to the dependence of the area change on glacier size. For one moment I would also step back from the simple presentation of correlation coefficients and their significance. Please add (at least in the discussion) what these numbers mean. Is there any physical reasoning behind them? Maybe it would be helpful to also show some scatter plots and not only the correlation values. This might much better illustrate the mutual relationships. And, as already said above, I do not see the glaciological relation between area change and climate parameters without considering response times, so section 4.4 should be removed in my opinion. Please consider to discuss or show a regionally differentiated change analysis.

Response Results: We created a table as suggested with the total and size class area change values in both absolute and relative terms. The data in the table is similar to the data to shown in Fig. 8 so we removed Fig. 8. We decided not to add the extra scatterplots suggested, but mentioned the mean elevation vs aspect relation: '...glaciers with the highest mean elevations had northern aspects.' We modified Fig. 7 (now Fig. 6) to address the concerns and changed it to a relative area change (1919–2006) vs 1919 area scatterplot, but kept the glacier categories (disintegrating, disappearing, and same). We found that the size class area distributions between 1919 and 2006 were similar, so we applied the method in Paul et al. (2004) to estimate area change for the central and southern Canadian Rocky Mountains. We removed most of correlations between area change and attributes as they were mostly weak and as the reviewers mentioned, there is a correlation between glacier size and slope/minimum elevation, which we now mentioned in the paper: 'This result indicates that, glaciers with lower minimum elevations and slopes lost more absolute area. These two properties, however, are also moderately correlated with glacier area ($r = -0.51$ and $r = -0.39$, respectively). Therefore, large glaciers tend to have the lowest minimum elevations and slopes and lost the most area.' We also briefly discussed the meaning of the correlations still used in the paper. Since we removed most of the correlations, we decided against showing additional scatterplots. We removed the correlation analysis between area change and climate variables as described in the general comments, but kept the observations of temperature and precipitation anomalies across the periods. The relative area change between regions was similar, so we only added a brief mention of this: 'There did not appear to be any trends in relative area change with other glacier attributes including insolation, aspect, region, basin, or position relative to the Continental Divide.'

Discussion–2335: *In the discussion section I read that small glaciers should shrink faster (P2340-L26/27). Why? Small glaciers are found at all elevations, cover a wide range of slope values and are often located in special topographic conditions. So in this generalized form the statement is not really valid. As a wide range of topographic attributes have been calculated in this study (incl. potential solar radiation), it would be nice to analyse the area changes in regard to these parameters for distinct size classes (e.g. smaller than 1 km2). Is there a stronger dependence of the area change for certain topographic parameters in this case? On page 2341 (L4-9) this issue is discussed, with reference to conclusions from other studies. But why it is not investigated here? This would really be an improvement compared to the published literature. In regard to the calculated change rates, please mention somewhere that the first period is much longer than the other two and short-term variations are simply averaged out (but might have occurred). In the same direction I would also mention that for the very short last period, short term effects might have an influence.*
The statement on P2341 (L26/27) is too generalized. As it reads now, it refers to elevation changes / mass balance and not to area changes. For normal a glacier is rather thick where it is flat, so even high melt rates in these flat regions do not change the size substantially. As explained above, the area change with climate is not convincing. The description of the climatic development is fine in itself, but the physical link with the observed area changes is not given without considering response times (and even then it will be challenging). I suggest to skip this section and extend the topographic analysis instead.
Response Discussion: The statement that 'small glaciers should shrink faster' was in relation to large glaciers while under the same ablation rate as the rest of the sentence stated and was a theoretical situation. We realize that this is not the case in reality. As the revierwer suggested, we investigated relative area change in regard to the attributes for all glaciers as well as small glaciers. We added our findings to the results section. We added the following sentence to address the length of the periods: 'However, the first period (1919-1985) spans more than six decades and includes shorter intervals with different rates of loss, whereas the last period (2001–2006) is a half decade long and may be a period characterized by high rates of loss.' We removed the sentence on P2341 L26/27. We removed our climate correlation discussion for reasons stated in the general comments. However, we kept the description of observed climate change and our general observations on rates of area change.

Conclusion–2335: *In the conclusions section there is only one sentence about the area change - climate relationship,confirming my point that the study would not really lose anything when skipping this analysis. For small glaciers, it might be the case that the non-climatic factors not only modulate the response (L16), but largely decouple them from climate change. This is also the reason why their changes should be excluded from glacier change - climate change analysis. I wonder if this can be shown in this study with a more detailed analysis of the topographic parameters?*
Response Conclusion: As mentioned in our response to the general comments, we removed the area change-climate correlations from the paper. We focused more on the topographic analysis in the conclusion. We do not believe we can show that small glaciers are decoupled from the climate with our current analysis as we have largely removed the climate analysis from the paper at your suggestion. However, the data collected in this study may be of use in future analysis on this matter.

Detailed Comments

2328-L18/19: *Please skip this remark on temp/precip. It is difficult to understand in this short form.*
Response 2328-L18/19: Removed.

2328-L21: *Better: Glacier adjust their extent in response to a change in climate. And: Please add a connecting sentence between this sentence and the next one, otherwise the jump from the extent change to the mass balance is unclear.*
Response 2328-L21: Changed.

2328-L26: *I think these studies have not made any quantitative statement about area change and climate change (apart from the fact that glaciers shrink / adjust their size when temperatures increase / change).*
2328-L26: We did not intend to imply that these studies quantitatively linked area change and climate. We changed the structure of the introduction and rearranged this sentence to avoid the confusion.

2329-L3: *What does 'can be less labour intensive' mean? Of course they are when they are derived (automatically) from satellite data. In regard to long records, I would add here a few words on length changes and why the existing data have not been used in this study.*
Response 2329-L3: We meant that deriving extents from satellite imagery can require less work than field measurements. This sentence was removed from the introduction and replaced by the following: 'Satellite imagery provides a means for comprehensive, uniform, and frequent monitoring of glacier coverage globally...'. As mentioned in the Specific Comments (Introduction), we did not explore length changes for this study, but have in a upcoming paper currently in review.

2330-L16/17: *To which regions do these values apply (elevation, lat/lon)? Consider showing a map with the spatial distribution of precipitation (instead of Fig. 2).*
Response 2330-L16/17: The values are the average mean annual temperature and total annual precipitation from the centre of all glaciers in the study area. We changed this sentence to the following at the suggestion of all reviewers: 'Mean annual temperature ranges from $-6.4°$C to $-0.2°$C and total annual precipitation ranges from 733 mm to 1972 mm.' Also, we removed Fig. 2, but decided not to replace it with a distribution map.

2330-L17: *For which region (coordinates, elevation) do these values apply?*
Response 2330-L17: See previous comment

2331-L7/8: *Maybe show a histogram of the map dates to better justify the median year 1919?*
Response 2331-L7/8: We thank the reviewer for his suggestion, but we believe we explained our reasoning for using the median year as stated in the Specific Comments (Data), without the need of a histogram.

2331-L12: *previously orthorectified ...*
Response 2331-L12: Corrected.

2331-L24: *What was the result of this visual check?*
Response 2331-L24: We used the visual check to look for offsets with features such as ridges and peaks. If offsets were found, we adjusted the GCPs to minimize the offsets. We changed the sentence to: 'We also visually checked the positions of features (e.g. peaks, ridges, and lakes) on the maps against the BC TRIM hillshading and Landsat imagery. If there were noticeable offsets, we adjusted the GCPs to minimize the offsets.'

2334-L25: *I dont know the term water year, do you mean hydrologic year?*
Response 2334-L25: Changed to 'hydrologic year'.

2337-L10: *When you find a dependence of the area change on the size class, it might be beneficial to use size class specific scaling factors rather than one overall regression for all glaciers.*
Response 2337-L10: We thank the reviewer for this suggestion. We decided to remove the regression analysis and use the method in Paul et al. (2004) based on size class specific scaling factors.

2337-L18: *Most variability seen in Fig. 7 ...*
Response 2337-L18: We changed Fig. 7 and rearranged the sentence. It now reads: 'Relative area change becomes increasingly variable with smaller glaciers (Fig. 6)

2340-L17: *Paul (2002) only analyzes a small sample of glaciers. Please consider to cite Paul et al. (2004) instead (the study also analysis the 1850-1973 period).*
Response 2340-L17: Changed.

2343-L23: *from the higher temperatures*
Response 2343-L23: Removed.

2344-L16: *of these glaciers to climate change. ...*
Response 2344-L16: Changed.

Figures

1: *Please indicate where the 11 main icefields are (at least when they are referred to later in the study).*
Response 1: We added most of the icefields to the figure and removed the ones not on the figure from the text.

2: *What do I learn from this graph? I would suggest to show a colour-coded map with the mean annual precipitation amounts as derived from PRISM and an overlay of glacier extents instead. This would much better visualize the climatic regime of the glaciers in the region.*
Response 2: We removed Fig. 2 at the suggestion of the reviewers. We decided to just state a temperature and precipitation range in the text and not use a figure.

7: *I suggest to replace this graph with the relative area change vs. area plot. The regression line is not convincing (double logarithmic plot suppress the scatter) and I would suggest to use another method for extrapolation (see above).*
Response 7: We replaced this figure with relative area change 1919–2006 vs. 1919 area as the reviewer suggested (now Fig. 6 in the revised manuscript). Also, we used the method in Paul et al. (2004) to estimate glacier area for the rest of the region as suggest in previous comments.

9: *Maybe key values of this plot can also be shown in a table?*
Response 9: These values (median rates) are stated in the text: 'The median absolute rates of glacier area change for the periods 1919–1985 and 1985–2001 are similar, $-0.0065 \pm 0.0009\,\mathrm{km}^2\,\mathrm{yr}^{-1}$ and $-0.0047 \pm 0.0005\,\mathrm{km}^2\,\mathrm{yr}^{-1}$, respectively (Fig. 7). Corresponding median relative rates of glacier area change for these two periods are $-0.50 \pm 0.07\,\%\,\mathrm{yr}^{-1}$ and $-0.45 \pm 0.04\,\%\,\mathrm{yr}^{-1}$, respectively. The absolute median rate of area change for the period 2001–2006 is significantly higher, $-0.0200 \pm 0.0025\,\mathrm{km}^2\,\mathrm{yr}^{-1}$; the relative median rate is $-1.67 \pm 0.21\,\%\,\mathrm{yr}^{-1}$.' The rates for total area change of the study area are now listed in Table 3.

10: *This figure might be removed when climate data are no longer used to 'explain' the area changes.*
Response 10: We left this figure in the paper with the modifications suggested by other reviewers (now Fig. 9). We believe it is still useful to show the changing climate over the periods even if it is not used to 'explain' area changes.

References (Excl. those in the Discussion paper and reviewer comments)
Paul, F., Kääb, A., Maisch, M., Kellenberger, T. W. and Haeberli, W. (2004): Rapid disintegration of Alpine glaciers observed with satellite data. Geophysical Research Letters, 31, L21402.

Wang, T., Hamann, A., Spittlehouse, D. L., and Aitken, S. N. (2006): Development of scale-free climate data for western Canada for use in resource management. International Journal of Climatology, 26, 383-397.