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The Cryosphere
Discussions

Interactive comment on "Area change of glaciers in the Canadian Rocky Mountains, 1919 to 2006" *by* C. Tennant et al.

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We thank M. Pelto for his comments as they highlight some interesting points of discussion. Although we cannot address all of them in our paper, they provide areas that future research can expand upon. Below are our responses to individual comments.

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:

Thank you for your comment. The data in Figure 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 added the following phrases to the Results, Glacier Properties and Area Change sections clarifying that area change by size class was based on the 1919 glacier area:

"These classes are also used for area change comparisons in the following section."

"For glacier size classes, which are based on the 1919 glacier area,..."

The 0.05–0.1 km^2 class for 1919 contains all of the glaciers on the map that were not removed due to the errors and uncertainties mentioned in the paper (70 glaciers or 17 % of the removed glaciers). Many of the small glaciers from the 1919 maps were not mapped in subsequent years, so either they disappeared or were incorrectly mapped snow patches. Where this distinction was uncertain, we removed the glaciers. For future investigations, data from the 1950s and perhaps the 1919 terrestrial photographs, would help determine which glaciers mapped in 1919 are actual glaciers.

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:

"Between 1919 and 1985, 15 of the glaciers had disappeared, and the remaining two disappeared between 2001 and 2006."

"Slopes of the 17 glaciers ranged from 11° to 36°, with a mean slope of 20°. Elevation ranges were below average, between 96 m and 460 m."

We do not have sufficient data to assess the persistence of the accumuluation 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:

Thank you for your suggestion. 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 Mountian 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. Our study area focuses on glaciers mapped in 1919 located in the central and southern Canadian Rocky Mountains. From our results, glaciers west of the Rockies lost 58 % for the period 1919–2006, and 55 % for glaciers east of the Rockies. Breaking it down by river basin, glacier area loss was 56 %, 61 %, 55 %, and 55 % for the Mackenzie, Fraser, Nelson, and Columbia basins, respectively. Equation 1 is based on all 506 glaciers analyzed that are present in both 1919 and 2006. We believe our application of Eq. 1 is appropriate because we are only applying it to the rest of the glaciers in the central and southern Rocky Mountains that were beyond the 1919 map extent. We have added the following details to the Results, Area Change section to better explain our reasoning and application of Eq. 1, as you have suggested:

“Glaciers on the western side of the Canadian Rocky Mountains lost 58 % of their area between 1919 and 2006, and on the eastern side, glaciers lost 55 % of their area. Examining glacier area change by river basin, glaciers in the Mackenzie, Fraser, Nelson, and Columbia basins respectively lost 56 %, 61 %, 55 %, and 55 % of their area."

"Due to the similar percentage of area loss between the river basins and the eastern and western sides of the Canadian Rocky Mountains, Eq. 1 can thus be used to estimate the remaining glacier extents in the Canadian Rocky Mountains not covered by the IBCS."

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.

Interactive comment on The Cryosphere Discuss., 6, 2327, 2012.

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