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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.

Anonymous Referee #1

Received and published: 16 August 2012

Review of The Cryosphere Discussions Manuscript # tc-2012-76 entitled "Area change of glaciers in the Canadian Rocky Mountains, 1919 to 2006"

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.

Issues to be addressed:

page 2329 line 14: In the text "...volume is lost; this condition is likely..." it's not clear what "this condition" is referring to. Is it the initial increase in discharge due to mass wastage, or the subsequent decrease?

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?

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.

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, I'm not sure of they all can be called types. Maybe characteristics.

Page 2336 line 9: You refer to a "mean glacierized area per flowshed" of 1.7 \pm 0.2 km^2 is a "mean glacierized area per flowshed" the same as the "mean glacier area" you referred to in line 20 on page 2335.

Page 2336 line 27: These look like median rates of area change per glacier, is that correct? This doesn't seem clear to me from the text. Please clarify.

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?

Page 2337 eqs. 1 and 2: Although I can see understand the desire to express your equations in terms of A1919 the equation would be much more readable expressed in terms of log(A1919) such that the "guts" of the equation aren't in the superscript.

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 R2 adjusted for the greater number of degrees of freedom of your model. The statistical significance of the relationship didn't change, so I suspect that the adjusted R2 may also not justify the addition of a second explanatory variable. I would also surmise (and I think it's 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.

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 kmˆ2 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.

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.

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.

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

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.

Page 2339 Line 7: Where the correlations done on the mean temperature and precipitation or on the anomalies relative to the chosen climate normal period.

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..."

Page 2340 Line 9: Shouldn't you be able to directly compare your results for recent epochs to those of Jiskoot et al? My understanding is that your temporal coverage is almost identical to theirs.

Page 2340 Lines 25-29: Other explanations include the greater responsiveness of smaller glaciers, and greater susceptibility owing to a smaller elevation span.

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.

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.

Page 2343 Line 7: It doesn't seem surprising that the 1919-1985 anomalies are small when compared to your averaging period which isn't much longer.

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.

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.

Page 2344 Line 14: Change the second "most" to "greatest"

Page 2344 Line 15: Insert "that" into "suggesting local"

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.

Figure 1: 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.

Figure 6: This should be broken up into two figures – one for number and one for area for easier comparison.

Figure 7: It's not clear what the unlabelled tick mark is. Include intervening tick marks or somehow make this more clear.

Figure 8 and Figure 6 would look better with bounding boxes aligned with the plotting axes. This looks too much like raw R output.

Figure 10: As before, it's not clear how mm valued precipitation anomalies apply to the landscape. These would be more transferable as % anomalies.

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