Review of the TCD ms by Tennant et al.

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.

Specific comments

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.

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.

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.

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.

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 km^2). 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.

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?

Detailed comments

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

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.

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).

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).

2329-L3ff
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.

2330-L17
For which region (coordinates, elevation) do these values apply?

2331-L7/8
Maybe show a histogram of the map dates to better justify the median year 1919?

2331-L12
previously orthorectified ...

2331-L24
What was the result of this visual check?

2334-L25
I don't know the term water year, do you mean 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.

2337-L18
Most variability seen in Fig. 7 ...

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).

2343-L23
from the higher temperatures

2344-L16
of these glaciers to climate change. ...

Figures

1: Please indicate where the 11 main icefields are (at least when they are referred to later in the study).

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.

7: I suggest to replace this graph with the relative area change vs. area plot. The regression line is not convincing (double logaritmic plot suppress the scatter) and I would suggest to use another method for extrapolation (see above).

9: Maybe key values of this plot can also be shown in a table?

10: This figure might be removed when climate data are no longer used to 'explain' the area changes.

Cited literature

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.