

## ***Interactive comment on “Glacier area and length changes in Norway from repeat inventories” by S. H. Winsvold et al.***

**H. Frey (Referee)**

holger.frey@geo.uzh.ch

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### GENERAL COMMENTS

The authors present a sound assessment of glacier area and length changes for Norway based on three to four (for the northernmost region) glacier inventories. Glacier inventories derived from topographic maps as well as from optical satellite data are used, covering about 50 years up the entire 20th century for the northernmost ice caps.

Although the potential for such analyses has outlined previously, it is one of the first studies performing such a detailed, multi-epoch assessment of glacier changes. Challenges related such comparisons of glacier data from varying dates and sources are

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addressed and tackled in appropriate manner, accompanied by clear descriptions and illustrative figures and tables.

Observed glacier changes are related to topographic and climatic characteristics of the study region. This is done only in a descriptive, qualitative way, i.e. in reference to other publications, although the data presented had the potential for quantitative analyses and testing of the supposed relations of glacier changes to these region-specific characteristics. However, this would probably go beyond the scope of this article.

This article provides a comprehensive overview of observed glacier changes in Norway in the past 50 to 100 years and it provides a valuable reference for scientist involved in glacier change assessments from modern glacier inventories. It therefore definitely deserves publication.

A few suggestions for minor changes are given below, followed by some detailed and technical comments and finally some annotations to the tables and figures.

### SUGGESTIONS FOR CHANGES

Explanations and calculations related to inventory dates and annual change require some more explanations and maybe some reconsiderations: The relatively large time ranges of the individual inventories are obvious and justified. However it is not exactly clear to me, how the numbers given in Table 1 are calculated. I assume they refer to glacier-specific time intervals. Nevertheless, it should be explained more clearly how the mean time span of 32 years for the full epoch is calculated. At first glance I thought this should be 36.5 a: 1966 (average of 1947 to 1985) to 2002/03 (average of 1999 to 2006). In addition, I suggest avoiding the expression ‘over the past 30 years’ when referring to the full epoch. In an article published in 2014, the ‘past 30 years’ are 1984 – 2014, not 1970 – 2000 (which is meant, I assume).

Related to the above point, I suggest avoiding average change rates (i.e. change per

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year), when referring to a baseline inventory that spans over 38 years, such annual change rates are not very significant and should only be applied to subsets of the analysis with consistent mapping dates. The number of '-11 km<sup>2</sup> a<sup>-1</sup>' should therefore be avoided in the abstract, text, and Tables 3 and 4. In Table 6 it is appropriate, because here the changes refer to equal time spans. The same applies to length change rates.

Sub-section 3.1.1 'Divisions of glacier' should be moved to after the description of the different inventories (i.e. after 3.4), or better still after 3.5 'Digital Elevation Model (DEM)'. The first sentence of 3.1.1 (P3074, L17/18) in my view belongs to the study region section; the rest of 3.1.1 is better placed after 3.5 (as section 3.6 or 3.5.1), since it uses the data described in these sub-sections.

On several occasions number of glacier or total glacier area is given without referring to a year or inventory (e.g. P3072, L21/22; P3073, L25; P3076, L25; P3082, L24). Please update.

#### DETAILED COMMENTS:

I suggest swapping Figures 5 and 6 as well as Tables 6 and 7: they are mentioned in reverse order in the text. In general, when describing ranges, the smaller value should be mentioned before the larger value. E.g. related to inventories (P3075, L9/10) or the band-ratio thresholds (P3077).

Please define the expression 'glacier unit'. In literature, often the terms 'individual glacier' and 'glacier complex' is used. From the context I assume glacier unit here refers to 'individual glacier', i.e. a glacier separated, but sharing common boundaries (drainage divides) with other individual glaciers. For instance, the two sentences on P3072, L21-23 are hardly understandable.

P3071, L6: The free availability of georeferenced and orthorectified scenes is another reason for the popularity of Landsat data. Although an individual orthorectification was performed here, this could be mentioned in the general introduction.

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P3072, L21: The bracket '(0.7% of the area)' belongs to the next sentence and should be mentioned after the glaciers.

P3074, L13-15: A reference should be added.

P3075, L25: Reword 'an accuracy of less than ...'. It sounds like a lower accuracy, but it actually denotes a higher accuracy.

Section 3.2: Is no filtering (i.e. a median filter to eliminate isolated pixels) applied? Is a minimum glacier area threshold applied? Please specify if yes. (I do not assume that every single pixel classified as glacier ice is considered in the inventory).

P3077, L14-23: This section is hard to follow: I do not see why threshold changes from 2.8 to 2.4 (should be 2.4 to 2.8, see above) are treated separately from variations between 2.0 to 2.4, when the findings are the same for both ranges. What means 'mixed ice and terrain pixels' (P3077, L16)? Please reword.

P3079, L18/19: It is not clear whether 4 transformations (spline, adjust, second order polynomial, and third order polynomial) or 3 methods (spline adjust, and second and third order polynomial transformations) were tested for the georeferencing.

P3080, L17-20: The last sentence of the DEM section should be moved upwards, to around P3080 L4: The acquisition date of the DEM should be mentioned already here because it is relevant for the content following from P3080 L5 onwards.

P3082, L21-23: The last sentence of this paragraph is not clear to me: Why are snow fields included in the analysis? Because they are assumed to be the remnants of glaciers included in the older inventories? Further explanations are needed.

P3088, L18: '... because they [the ice caps in northern Norway] are located in a maritime climate ...'. But on P3073, L3/4 it says that precipitation decreases from south to north. This is contradicting. The following discussion on differing sensitivities to ELA changes for steep and flat glaciers and ice caps is convincing, but I cannot follow the argument given in the sentence on P3088, L16-19.

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#### TYPOS AND WORDING:

P3070, L16: 'glacier sub-regions' instead of 'glacier regions'

P3075, L1: 'glacier regions' (instead of glaciers regions)

P3077, L19: Insert 'threshold' (' The TM3/TM5 threshold should be...')

P3079, L24: Remove 'from the applied method'.

P3083, L10/11: '... change in the mean area change value ...' sounds unfavorable. Replace by 'variation' or 'difference' or similar.

P3086, L5: Remove 'the' after 'although'. Maybe also move 'the deviation' to right after 'although'.

P3986, L14: December 2013

#### TABLES:

Table 1: Please give more info in the caption on how these time spans are calculated. I assume they refer to individual glaciers. But is the mean for instance area weighted or not?

Table 2: The second sentence can be deleted, this is obvious. In the third sentence, add that this statement refers to GI2000 (I assume), and add 'threshold' to TM1.

Tables 3 and 4: As mentioned in the general comments, I suggest eliminating the last rows (average annual change rate) due to the difference in time spans.

Table 5: Closing bracket is missing at the end of the caption.

Table 6: How does it come that the value of the decadal length change for the whole period (-158) is not equal to the sum of the values for the three epochs (-150)?

#### FIGURES:

The figures in general are of high quality. However, when printed it is challenging to

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read some of the figures. When zooming in in the digital version, the details become visible, so this is fine for me. Nevertheless, avoiding fine and dotted lines might improve readability (e.g. in Figures 6, 7, and 9).

Figure 2: Mention in the caption that the location of 2a is indicated by the black rectangle in 2b.

Figure 3: A zoom in 3b/3c would be illustrative. Or choosing a smaller glacier. Currently, not much details are visible (my first impression was, that I had a bad printing quality, only by taking a closer look I saw the differences).

Figure 5: Maybe include 'central and northern Norway' in the legend besides mentioning it in the caption? This would be more consistent with the text and Figures 6 and 7.

Figure 6: Move the last sentence of the caption ('Only glaciers > 0.5 km<sup>2</sup> are included in (a)') upwards, to the description of (a), before (b).

Figures 6 and 7: Expand the line (glacier IDs) in (c) down to the last glacier. Copy the text from this line given in Fig. 7 ('Glacier IDs (1 = north, 3143 = south)') also to Figure 6c.

Figure 8: Change the color of either GI<sub>n</sub>50 or GI<sub>n</sub>1900, it is currently hard to discriminate in the digital version and impossible in my printed version.

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