The Cryosphere Discuss., 6, C490–C497, 2012
www.the-cryosphere-discuss.net/6/C490/2012/

The Cryosphere Discussions

Interactive comment on "Observations of widespread accelerated thinning in the upper reaches of Svalbard glaciers" *by* T. D. James et al.

Anonymous Referee #2

Received and published: 8 May 2012

Overview

James and others provide a very detailed picture of elevation changes of 6 glaciers around Svalbard through mainly 2 time periods. The results are achieved through DEM differencing of high quality LIDAR DEMs and re-constructed DEMs from aerial photography using the LIDAR as control. The generation of elevation changes in 2 distinct time periods provides a temporal analysis of change rates for the studied glaciers, which lead the authors to conclude that these particular glaciers are (mostly) thinning at larger rates more recently than previously, and that most of this enhanced thinning is occurring at the upper reaches of these glaciers. In general, the paper is well written and the technical aspects are sufficient. The results of the study are clear though a

larger discussion in the variability of the elevation change measurements between the glaciers is required. The discussion is weak. Overall, I recommend publication to The Cryosphere after major revisions.

1 General Comments

I think the title needs to be revised since 6 (rather small) glaciers totaling $\approx$ 160 km^2 in Svalbard is certainly not widespread given the $\approx$ 36000 km^2 of ice (Hagen et al., 1993). A more detailed methodological description would increase the reproducibility of the study. My major criticisms towards the study involve the rather long leap between the results of the elevation changes and the interpretations provided (the discussion). Much text is used to discuss meteorological settings, mainly using a time series from only one station. The results of this analysis in combination with the elevation changes is that regional variability exists which contradicts the setup of the analysis in the first place. If such regional variability exists, why provide an analysis from only one location which may not represent the climate where the glaciers are. Further, a detailed discussion on the spatial variability of the observed elevation changes is lacking. In terms of the description of the albedo feedback, although significant and important, there is very little evidence provided in this study (I think it would require additional data such as those presented in Greuell et al. (2007) or Rotschky et al. (2011)) that can clearly connect high elevation thinning with albedo, though it may be suggested and in that case, the text considerably shortened. Last, the extrapolation of the results to all of Svalbard is weak, and not all assumptions are considered. I think there is a misconception between elevation changes and mass balance. In particular, the measurements of this study do not sample any calving glaciers which biases any extrapolation for a regionally integrated Svalbard mass balance.

Specific Comments

- **Title**
  The title needs to be revised.
  Suggestion: "Observations of high elevation thinning of 5 Svalbard glaciers"

- **Section 2.1**
  - A more detailed methodological description would benefit the reproducibility of the study.
  - Were all DEMs re-created using LIDAR GCPs (i.e. did you create DEMs from 1990 images)? What is the resolution of the DEMs? How were they re-sampled and differenced? etc...
  - Did you use the image correlation mask to filter and further assess DEM quality? (Pg1091, L21)
  - How large is your off-ice test site and is this test site only the airport? Is there only 1 test site for all DEMs (glaciers), or 1-Test site per DEM (glacier)? The former would (should) have to be replaced by the latter method. Why not use all terrain outside of glaciers? Is your data corrected for any biases (in the vertical)?. There seems to be some variation in the vertical ($\pm 2m$) as derived by summing the values provided in Table 4. To this studies benefit, these residuals all fall within or are just outside the provided error bars.

- **Section 2.2**
  - Ln 18-20: Yes, extrapolation is not needed. However, a comment is required that these upper regions contain the smallest elevation changes and the most insecure using photogrammetry due to a lack of visible contrast. It would be interesting to know the correlation values from image matching in these upper reaches.

- **Section 3**
  - All glaciers in this study do not experience similar significant increase in thinning (Table 4). There is also considerable variability within the 6 glaciers (i.e. the mean elevation change rates for either pre- or post- 1990 vary over 300% between the glaciers). These results of your data suggest significant heterogeneity in mean elevation change and requires explanation rather than simply stating increasing thinning for all glaciers. Any suggestions on what may be the cause of this heterogeneity? Other studies such as Hagen et al. (2003b) and Bamber et al. (2005) describe similar regional variations, especially in northeast Spitzbergen/Svalbard.
  - Pg 1094 Ln 6-8: "occurred in areas of former snow accumulation". Are you sure? I doubt the glaciers in your study area all do not have accumulation anymore. If this statement was true, then your density assumption later on for conversion into mass balance is wrong.
  - Last sentence: I am not yet convinced by this since the quality (precision) of your photogrammetric measurements in the accumulation area are rather low (more discussion into the correlations in the accumulation area and possibly plotting the variation of changes per elevation in Figure 5)), and since the smallest rates of change are experienced here.
  - Mention/discuss the lack of high elevation data on Albrechtbreen and Gullfaksebreen (Table 1).

- **Section 4.1**
  - Two important references are missing in this section, Førland and Hanssen-Bauer (2000) and Hanssen-Bauer (2002). These references describe temporal trends from the Svalbard Airport time series, and further describe the problems with precipitation trends and the effect of measurement bias on these trends with a proposed correction. This is particularly important for the trends derived on Pg 1095 Ln 19-26.

- The analysis of the PDDs is noteworthy. Do the statistics change if you use maximum daily temperature for PDDs instead of the average daily temperature?
- It seems in general that your conclusions are that regional variation exists in Svalbard, yet this whole analysis relies on the assumption that Longyearbyen is representative for all the glaciers in your analysis. Contradicting results...
- Last sentence unclear. What do you mean? The accumulation rate may drive the albedo feedback described below.

- **Section 4.3**
- Pg 1097, Ln 13-15: This is clearly a misconception. Figure 7 shows elevation changes and glacier thickness losses do not necessarily imply no accumulation area. Individual elevation changes are a combined effect of surface mass balance and dynamic fluxes (Cuffey and Paterson, 2010) whereas the ELA is purely a surface mass balance phenomenon. See Cogley et al. (2011) for details.
- Considering the significant variability in the mean elevation change of the 6 glaciers, how can you justify averaging all thinning rates and applying it to one hypsometry? (Also, more details about this are required so that it is reproducible). It is also questionable how representative your 6 small glaciers (all less than 50 km^2) is for the all of Svalbard. In particular, elevation changes in this study of non-calving glaciers certainly does not represent or sample elevation changes of calving glaciers and therefore it would be meaningless to up-scale these estimates for sea-level contributions. Nonetheless, it may be feasible to estimate *surface* mass balance from this data for each individual glacier by assuming that the dynamic components cancel through integration of the elevation changes over the glacier area. The larger step for extrapolating this to all of Svalbard requires a much more detailed methodology and deeper investigation into viability and assumptions of trying to upscale geodetically derived surface mass balances. Hagen et al. (2003b) and Hagen et al. (2003a) present the variability in estimates using either 13 or 1 surface mass balance curve for all of Svalbard.

- Last, comparisons to GRACE seem also meaningless since the variability of these estimates is so large (also see Jacob et al., 2012) and the time frame of your results and that of GRACE are different...

- **Section 5**
Conclusions require revisions after the previous considerations have been accounted for.

Technical Corrections

- Pg 1089
- Ln 18: delete "a number of factors including"

- Pg 1090
- Ln2-4 : Confusing. What do you mean "methods employed here cannot account for mass losses from tidewater calving"? Volume changes derived from elevation changes include both the *surface* mass balance and dynamic changes, i.e. from losses through calving.
- Ln 28: "average" or standard deviation?

- Pg 1091
- Ln 17: Why "autocorrelation"? I think you mean correlation?

- Pg 1092
- Ln 12: "However, photographs from 1977 were"...
- Ln 25: "we extracted Svalbard's.."

- Pg 1093
- Ln 17: "have been experiencing significant..."
- Ln 21, How was the averaging done?

- Pg 1096
  - Ln 8: You mean "decrease" here, correct?
- Fig. 2e
  - What are the linear N-S and E-W features in the middle of the glaciers. Looks like artifacts from stitching of photogrammetric blocks?
- Fig. 4
  - Would be useful to see the glacier hypsometry on these plots.

References

Bamber, J. L., Krabill, W., Raper, V., Dowdeswell, J. A., and Oerlemans, J.: Elevation changes measured on Svalbard glaciers and ice caps from airborne laser data, Annals of Glaciology, 42, 202–208, http://dx.doi.org/10.3189/172756405781813131, 2005.

Cogley, J., Hock, R., Rasmussen, L., Arendt, A., Bauder, A., Braithwaite, R., Jansson, P., Kaser, G., Möller, M., Nicholson, L., and Zemp, M.: Glossary of Glacier Mass Balance and Related Terms, IHP-VII Technical Documents in Hydrology No. 86„ Tech. rep., IACS Contribution No. 2, UNESCO-IHP, Paris., 2011.

Cuffey, K. and Paterson, W.: The Physics of Glaciers, Elsevier, Inc., fourth edn., 2010.

Førland, E. J. and Hanssen-Bauer, I.: Increased Precipitation in the Norwegian Arctic: True or False?, Climatic Change, 46, 485–509, http://dx.doi.org/10.1023/A:1005613304674, 10.1023/A:1005613304674, 2000.

Greuell, W., Kohler, J., Obleitner, F., Glowacki, P., Melvold, K., Bernsen, E., and Oerlemans, J.: Assessment of interannual variations in the surface mass balance of 18 Svalbard glaciers from the Moderate Resolution Imaging Spectroradiometer/Terra albedo product, Journal of Geophysical Research-Atmospheres, 112, 2007.

Hagen, J. O., Liestøl, O., Roland, E., and Jørgensen., T.: Glacier atlas of Svalbard and Jan Mayen, Oslo, 1993.

Hagen, J. O., Kohler, J., Melvold, K., and Winther, J. G.: Glaciers in Svalbard: mass balance, runoff and freshwater flux, Polar Research, 22, 145–159, http://dx.doi.org/10.1111/j.1751-8369.2003.tb00104.x, 2003a.

Hagen, J. O., Melvold, K., Pinglot, F., and Dowdeswell, J. A.: On the net mass balance of the glaciers and ice caps in Svalbard, Norwegian Arctic, Arctic Antarctic and Alpine Research, 35, 264–270, http://dx.doi.org/10.1657/1523-0430(2003)035[0264:OTNMBO]2.0.CO;2, 2003b.

Hanssen-Bauer, I.: Temperature and precipitation in Svalbard 1912-1950: measurements and scenarios, Polar Record, 38 (206), 225–232, 2002.

Jacob, T., Wahr, J., Pfeffer, W. T., and Swenson, S.: Recent contributions of glaciers and ice caps to sea level rise, Nature, 482, 514–518, http://dx.doi.org/10.1038/nature10847, 2012.

Rotschky, G., Schuler, T. V., Haarpaintner, J., Kohler, J., and Isaksson, E.: Spatio-temporal variability of snowmelt across Svalbard during the period 2000-08 derived from QuikSCAT/SeaWinds scatterometry, Polar Research, http://www.polarresearch.net/index.php/polar/article/view/5963, 2011.