The Cryosphere Discuss., 7, C167–C171, 2013
www.the-cryosphere-discuss.net/7/C167/2013/

The Cryosphere Discussions

Interactive comment on "Uncertainties and re-analysis of glacier mass balance measurements" *by* M. Zemp et al.

M. Pelto (Referee)

mauri.pelto@nichols.edu

Received and published: 19 March 2013

Zemp et al (2013) provide a necessarily detailed examination of best practices for recalibrating glaciological and geodetic mass balance records on alpine glaciers. The paper is well written despite covering such a large topic. The paper will be an important contribution to the glacier mass balance community and those who utilize these records for climate assessment. I have three key comments, the first two must be addressed, the second I leave to the discretion of the authors whether further attention would be helpful or not add clarity.

1)In several locations within the paper the ELA and AAR are treated as solely derived elements from the mass balance record that can then be adjusted based upon mass balance recalibration. This is true in some cases, but in many cases the ELA and

AAR are directly determined from ground, aerial or satellite images. As such they are input to not output from the glaciologic method. If this is the case then they cannot be adjusted as part of the recalibration. Of the 12 glaciers that I submit Ba data on to the WGMS all six that have a reported ELA and all 12 with a reported AAR are based solely on direct observations.

2)The glaciologic method relies on extrapolation from index measurement sites across the glacier and requires an understanding of distribution of mass balance across the glacier determined from an initial detailed survey. With significant changes in glacier area and elevation this distribution may change. Ideally every decade or so, the distribution of mass balance would be reassessed using a detailed survey. This was the concept behind the USGS Benchmark glacier series that is discussed by Fountain et al (1997 and Van Beausekom et al (2010). This would help both identify and prevent bias. An example of this is on Lemon Creek Glacier in Alaska in 1961, 1984 and 1998 (Miller and Pelto, 1998).

3)The authors sketch the ideal situation where a DEM can be generated for the geodetic assessment of mass balance, which is appropriate. There is a second common data type used in geodetic assessment of elevation change that can be compared to mas balance aerial laser altimetry or ICESat imagery along specific profiles often the center line (Gardner et al, 2012; Sapiano et al, 1998). Given the comprehensive nature of this paper, it would be beneficial to have at least a comment on how such a data set should be utilized.

Specific Comments are below

794-10: Besides the measurement points often the observed ELA as an input to the mass balance and this is then not a single point.

795-4: ELA is often observed and not calculated. WGMS now asks for this observation in Ba data submission.

795-21: Pelto (2000) examined the impact of extrapolation on Columbia Glacier and Lemon Creek Glacier and found that reducing the number of data points from 300 to 40 on these glaciers did not lead to much higher error, but reduction from 10 to 40 did.

797-10: Better wording needed. Note that these are summer accumulation type glaciers where the main accumulation and ablation season coincide.

797-21: May not be the ideal location to address this. However, it must be stated, that an underlying principle of the glaciological method is that a few measurements can be used to extrapolate the mass balance distribution across a glacier once that distribution is determined with a detailed survey. A key to reducing errors in the long run for field mass balance programs on glaciers with changing surface areas is the periodic detailed reassessment of the mass balance distribution. This has been done on Lemon Creek Glacier where else?

798-3: This is a very comprehensive paper, and as such would be ideal to serve as the template for geodetic-glaciological mass balance comparison. A key method that has been used for geodetic mass balance assessment in Alaska and the Canadian Arctic is airborne laser altimetry of a center line profile (Gardner et al, 2012; Sapiano et al, 1998). It would be worth a brief note on how such a comparison should be utilized and tied into a DEM from a different time. Lemon Creek Glacier, Alaska (Miller and Pelto, 1999) is an example where laser profiling and a separate DEM provide verification for surface mass balance, albeit not in the rigorous and best practice scheme outlined here by Zemp et al (2013). In this case what would the ideal approach be for the best comparison?

799-25: The level of detail here for 3-D co-registration etc far exceeds that in other portions of the paper, should this section through page 800 be moved to Appendix B?

802-21: This statement is true only if the distribution of mass balance is known from detailed surveying so that the few measurement points can used appropriately.

812-10: This is not a correct assumption since ELA and AAR are often determined from aerial, ground or satellite imagery and are not output from the glaciological method. If they are not, they should be since they are both reliable indicators that can help in the homogenization process.

812-19: Nor does it change ELA or AAR measurements that were map based field or image observations.

817-16: separate- above described

818-10: What is the typical density per km2 of measurement points on the glacier.

820-12: A detailed mass balance distribution survey every decade would be just as crucial in an era of changing glacier area, elevation profile and climate, as is a geodetic survey. The geodetic survey checks the overall cumulative mass balance accuracy the former whether a bias is being introduced from assumptions that may no longer be valid. On Wolverine and Gulkana Glacier Van Beusekom et al (2010) noted that due to glacier retreat and ELA rise the need to re-define appropriate index sites through an expansion and upward migration of the site networks to readjust the original partitioning of the area represented by each stake. They also identified that the sensitivity of estimated balances to sparse input data further motivated deployment of expanded stake networks to better define the shape and stability of the balance gradient. This is an important and detailed reference examining recalibrating mass balance work that should be referenced.

Figure 2: In the caption separate elevation from distribution.

Table Appendix C: A better caption for this table is needed. I was not able to follow what each column represented.

References

Fountain, A.G., Krimmel, R.M. and D.C. Trabant, D.C.: A strategy for monitoring glaciers. USGS Circ., 1132. 1997.

Gardner, A., Moholdt, G., Arendt, A., and Wouters, B.: Accelerated contributions of Canada's Baffin and Bylot Island glaciers to sea level rise over the past half century, The Cryosphere, 6, 1103-1125, doi:10.5194/tc-6-1103-2012, 2012.

Miller, M. M. and Pelto, M.: Mass balance measurements on the Lemon Creek Glacier, Juneau Icefield, AK 1953–1998, Geografiska. Annaler, 81A, 671–681, 1999.

Pelto, M. S: The impact of sampling density on glacier mass balance determination. Hydrol. Process., 14: 3215–3225. doi: 10.1002/1099-1085(20001230)14:18, 2000.

Sapiano, J., Harrison, W., and Echelmeyer, K.: Elevation, volume and terminus changes of nine glaciers in North America, J. Glaciol., 44, 119–135, 1998.

Van Beusekom, A.E., et al: Re-analysis of Alaskan benchmark glacier mass-balance data using the index method: U.S. Geological Survey Scientific Investigations Report 2010–5247, 2010.

Interactive comment on The Cryosphere Discuss., 7, 789, 2013.