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Comment on tc-2022-157

Kay Helfricht (Referee)

Referee comment on "Constraining regional glacier reconstructions using past ice thickness of deglaciating areas – a case study in the European Alps" by Christian Sommer et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2022-157-RC1, 2022

In their manuscript „ Constraining regional glacier reconstructions using past ice thickness of deglaciating areas – a case study in the European Alps" C. Sommer et al. present a method to assimilate spatially distributed data of observed ice thickness loss at glacier tongues into regional calibration of ice thickness models.

Ice thickness observations in deglaciating areas are not necessarily representative for the state of the entire glacier. In particular at times of negative glacier disequilibrium, a direct assimilation for model calibration would lead to underestimation of the glacier volumes. Thus, they developed an empirical relationship between the ice viscosity at locations with in-situ observations and observations from DEM-differencing at the glacier margins to overcome this bias.

They authors combine ice thickness data sets, remote sensing products and modelling for glaciers cross the European Alps. With respect to data availability, the calibrated model is able to reproduce regional glacier volumes, but larger uncertainties remain at a local scale.

Nevertheless, the presented approach might be advantageous for improved estimation of glacier volumes if applied to regions where no direct measurements of glacier ice thickness exist.

However, the period of interest is in the manuscript comprises both states of glacier disequilibrium, with increasing glacier volumes in the 1970s and 80s, followed by years of strong negative glacier mass balances. This might be a challenging process to be considered in the discussion of the results.

In general, the manuscript is well written. The extensive introduction is followed by a well-structured data and methods section. The results are discussed in the light of existing literature and conclusions contains the outlook for application of the presented method to glacierized mountain regions worldwide. Figures and Tables good are balanced with the results in the main text.

General Comments

As mentioned in L185, changes in glacier area and volume were very small in the 1970s and 1980s. This may have been more valid for smaller glaciers, such as those in the eastern Alps, than on large valley glaciers in the western part of the Alps. For the Swiss Alps, the volume change between 1970 and 2003 is about 20.9 km^3, which corresponds to the values of 22.51 ± 1.76 km^3 presented by e.g. Fischer et al. (2015). However, the volume change calculated from the total glacier volume presented for Austria (1970: 28.7±7.3km^3; 2003: 13.3±3.8km^3) is more than half of the original 1970 glacier volume. In comparison, Lambrecht et al. 2007 found a volume of 22.8 km3 for 1969 (GI 1) and 17.7 km3 for 1998 (GI 2), corresponding to a loss of 22%. Helfricht et al. (2019) presented a glacier volume loss of 6.4 km^3 or 29% of the original volume from 1969 to 2006 (1969: 22.3 km^3, 2006 15.9km3). The distinctly higher volume loss presented in this study results in part from the high volume in 1970. This should be discussed by the authors, especially based with respect to different glacier sizes.

Despite the regional differences in glacier volume, the local differences due to the different methods are obvious in figure 7. At Pasterze, for example, the highest estimate results from the presented method using retreat observations. However, the glacier appears to have a fairly thick tongue fed by a broad but relatively shallow upper cirque known from GPR measurements. The overestimation of ice thickness at higher elevations of the glacier causes a range of ice volume estimates by almost a factor of two, with the approach of this study at the upper end. Possibly, this is also true for other glaciers with similar topographic features (Rhone, Findel, ...). The same is shown in Figure 6 g vs. i, where bluish colors dominate the upper and lower parts of the Pasterze. But also, smaller glaciers southwest of the Pasterze show maximum ice thicknesses of up to 150 m in Figure 6g. A higher ice thickness and thus a higher ice volume also seems to be modelled for the Aletsch glacier region when comparing the presented approach (Fig. 6b) and the estimate constrained to measured ice thickness (Fig. 6d). It can be concluded that an overestimation of glacier volume may be calculated for regions where most of the ice thickness change data for calibration come from still thick glacier tongues of typical valley glaciers.

The more general question is whether the scaling parameters and its thresholds, which are derived primarily from low-lying glacier tongues, are universally applicable to entire mountain regions with different assambling of glacier types. Please include this in more detail in your discussion.

Specific comments

L164 Please provide information on which resampling method was used.

L170 Please present a value of the uncertainty per year relative to the mean annual ice thickness change (or relation of the total values for the 50y-period).

L204 and L214 Please present in addition the relative value to the mean of the measured ice thickness

L276 Eq. 5 With respect to the slope threshold, this equation may need a validity indication. For slopes smaller the threshold, the result may become negative else?!

L295 Eq.6 Same like in Eq. 5, a range of validity should be given ($h \geq h_{tres}$?)

L273 to L293 Please consider to move the two equations to Chapt. 2.2

Figure 2: Please increase the font used in the legend.

Figure 6: Partly it is hard to see the main differences apart the big blue Aletsch glacier. One option would be to present difference maps between b/g and the other calculations in c/d/e and h/i/j using a different colour grading differentiating negative and positive differences.

Figure 7: Please add the axis title for ice thickness.

References

Fischer, M., Huss, M., and Hoelzle, M.: Surface elevation and mass changes of all Swiss glaciers 1980–2010, The Cryosphere, 9, 525–540, https://doi.org/10.5194/tc-9-525-2015, 2015.

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