Review to Florentine et al. (2018): *Local topography increasingly influences the mass balance of a retreating cirque glacier*, submitted to The Cryosphere.

General

The authors present a study of glaciological and geodetic mass balance estimates from Sperry Glacier, a small cirque glacier in Glacier National Park, Montana, USA. Modelling of past surface mass balances applying a statistical model, which was calibrated with recent mass balance observations, yields a bias between the modelled surface mass balance and observed geodetic mass balances. The authors interpret this bias as an increased control of local climatic mass balance drivers and a decreased regional climatic influence.

The study is a decent example of the climate proxy potential of small glaciers and is therefore a valuable contribution to the journal. However, the key findings do not completely exclude alternative interpretations and thus, I'd like to address three concerns, which may sum up to a major revision.

1. Quality of SWE data (section 3.5.1): Mount Allen SWE measurements serve as input to the regression model. Hence the data quality is decisive for interpreting model results. From visual analysis Figure 5b suggests a step change of peak SWE on Mount Allen in the mid 1970s. Does this change also appear in the other SWE observations listed in Table S3 or is it a local effect or an inhomogeneity of the data series?
2. Kalispell air temperature data: Assuming one climate station in ~50 km distance to the glacier representing the regional climate needs more justification. How do the summer temperatures compare to e.g. the NCEP North American Regional Reanalysis (to the closest grid point to Sperry Glacier or to Kalispell climate station)?
   Why is the ablation season confined to the summer months JAS? Degree-day approaches are based on the correlation of ablation to positive air temperature sums (parametrizing the available energy for melt) over the whole ablation season or even the whole year (e.g. Hock, 2003). How would the results of the mass balance regression change using air temperatures for the whole year or at least for the months MJJAS instead of JAS?
3. Discussion of the mass balance regression and the interpretation of the increase of local topography to the mass balance: The regression model is based on two proportionality factors (m_s, m_w). The discussion implicitly presumes both factors constant over time, but this needs to be addressed more comprehensively.
   - Winter proportionality factors might be variable (Galos et al., 2017; Huss et al., 2008), causing random errors, but systematic errors due to changes in large and meso scale atmospheric flow patterns (Huss et al., 2010) will alter the mass balance regression and weaken the argument of the increasing influence local topography to the mass balance. Can the authors exclude systematic changes of m_w?
   - Degree-day factors (i.e. the summer proportionality factor) are not constant over time, if the glacier surface area is largely changing. The major reason for this systematic change of the degree-day factor is the albedo feedback (e.g. Naegeli and Huss, 2017). An approximation to this feedback is the change of accumulation area ratio (AAR). Results of the geodetic survey show a thickening of the accumulation area and a concurrent glacier retreat, which means that the accumulation area remained rather constant, while the glacier lost wide parts of its ablation area. Hence, in relation to the total glacier area the AAR increased, resulting in higher mean albedo of the glacier and thus a lower degree-day

factor. This effect would indeed strengthen the finding of the increasing influence local topography to the mass balance. (Interestingly, in all studies I'm aware of, the albedo feedback increases melt because the glaciers generally lose their accumulation areas due to rising equilibrium line altitudes.)

Introduction

This chapter must more elaborate on the peculiarities and the definition of a small glacier, which in the manuscript seems to be synonymous to a cirque glacier and a very small glacier. Whatever classification is used, the important message in this study is that the local topography has a high influence on the accumulation regime of the Sperry Glacier. In the last paragraph the authors describe briefly the areal change of Sperry Glacier and formulate their research question. At this point I suggest introducing the term accumulation area ratio (AAR) (Cogley et al., 2011) as it (i) presumably describes that the glacier lost its ablation area while the accumulation area almost remained constant and (ii) this fact is crucial to interpret the findings later in the manuscript.

Methods

I suggest adding a paragraph that the two mass balance methods used (geodetic and glaciological) consider different processes of mass change (e.g. Klug et al., 2018; Zemp et al., 2013). In this study the differences will presumably be smaller than the given errors. The exclusion of methodological differences will support the discussion of the regression model later in the manuscript.

In Eq. 1 the authors derive the geodetic mass balance based on the initial glacier area. By convention (Cogley et al., 2011), the mean area between initial and final state is used (Andreassen et al., 2016; Klug et al., 2018; Lang and Patzelt, 1971; Zemp et al., 2013 etc.), thus a recalculation of the geodetic mass balance is required.

Results

Section 4.3 supports the albedo feedback mentioned above.

Figures & Tables

Figure 1a: Explain HCN.

Figure 1b: Give exact date of the aerial image. Add the location of the mass balance stakes and the meteorological station.

Figure 4b: Indicate source of the peak SWE data.

Figure 6: Add the glaciological mass balance values.

Figure 10: Add labels a-d.

Figure S2: What is the added value of this Figure? The grey line is hardly visible.

Figures 5, 6, S2: Figures do not depict continuous data as suggested by the x-axis. Use a bar chart instead of a line graph.

Table 1: Add columns of ELA and AAR.

Table 2 and S2: As glacier hypsometry is generally not normally distributed the median elevation is preferable to the mean elevation.

Table S3: Explain m_w in the table capture.

Specific comments

P 1, L 15 and elsewhere in the manuscript: Are negative mass loss rates a mass gain? This is pedantic but I suggest using neutral formulations that do not compete with the sign of the corresponding value.
Glaciologists traditionally use m w.e. as mass balance unit. Let's convert to kg/m² (≡ mm w.e.), because this is the SI unit and outside the glaciological community nobody understands w.e.

P 2, L 20: relative to what?

P 6, L 26: The air temperature lapse rate must be a negative value.

P 6, L 27: Rephrase the sentence. 7 years ago is not recently.

P 7, L 1: Was the glacier surface on average 35 m lower in elevation or just the terminus?

P 7, L 4: Change the units to °C and maybe rephrase the last part to "..., and cumulatively -24°C and -14°C changes to PDD."

P 9, L 5+6: Replace million and billion by 10^6 and 10^9, respectively.

P 9, L 9: Link to Table 3?

P 9, L 28: Rephrase the sentence beginning with "Enough years are positive…"

P 10, L 4: Explain how you derived this number.

P 11, L 1: Explain the meaning of uniform mass balance gradients. Gradients in the ablation area are usually different from those in the accumulation area, mainly because of the higher albedo in the latter (Kaser et al., 1996; Kuhn et al., 1999).

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