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The Cryosphere Discussions

Comment on "100-year mass changes in the Swiss Alps linked to the Atlantic Multidecadal Oscillation" by Matthias Huss et al. (2010)

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Abstract

The paper by Huss et al. (2010) presents a comprehensive set of 100-year specific mass balance series for 30 Swiss glaciers. In the second part of the paper, the authors relate the fluctuations in alpine glacier specific mass balance to climatic changes attributed to the Atlantic Multidecadal Oscillation (AMO). We believe that the specific mass balance is not the appropriate measure to interpret climatic fluctuations. Due to the dynamic response of glaciers to changes in their climatic forcing, the importance of short-term climatic oscillations is overestimated. Taking the changes in glacier geometry into account, the AMO related climate variations are far less important to the recent mass loss than the trend caused by the gradual warming over the past century.

1 Introduction

Huss et al. (2010) base the modeled mass balance series for the 100-year period 1908–2008 on in-situ measurements and ice volume changes derived from sequential Digital Elevation Models (DEMs) of the studied glaciers (with a total of 3 to 9 DEMs per glacier). These measurements constrain a degree-day mass balance model that is used to compute daily mass balance values for the studied glaciers on a 25×25 m grid. For each year Huss et al. (2010) calculate the specific mass balance by dividing the total mass balance of the glacier surface by the glacier area of that year. They show that the specific mass balance of the Swiss glaciers was mostly negative for the last century, leading to a total volume loss of 14 km^3 for the 30 glaciers from 1908 to 2008.

In the second part of the paper, the authors link the specific mass balance anomalies to climatic fluctuations and show a statistical correspondence between the AMO and the mean mass balance anomalies of the 30 glaciers. They fit a combination of a sinusoidal and a linear trend to the specific mass balance anomaly and conclude that about half of the loss of ice mass over the most recent decade can be attributed to the 65-year period variation that is superimposed on the negative linear trend.

2 Climatic interpretation of mass balance

The specific mass balance calculated by Huss et al. (2010) is the measure of the actual ice volume change in a year. This mass balance is not only dependent on the climate but also on the changing configuration of the glacier surface. Hence the variations in the mass balance do not only reflect climate variations (e.g. Oerlemans, 2008, Section 3.4). To use the variations in mass balance for a climatic interpretation, the mass balance should be calculated for a constant glacier surface, the so-called reference-surface mass balance (Elsberg et al., 2001; Harrison et al., 2009). Over the last century, the glaciers used in the study of Huss et al. (2010) have significantly retreated, losing part of their ablation area (Zemp et al., 2006). Loss of ablation area leads to a more positive mass balance, bringing a glacier closer to equilibrium (see Fig. 1). A part of the climate change over the last century is thus not visible in the mass balance but hidden in the change of glacier geometry (e.g. Nemec et al., 2009; Paul, 2010).

The change of glacier geometry as a consequence of changes in climate is a slow process with a response time of typically a few decades (e.g. Adhikari and Huybrechts, 2009; Brugger, 2007; Oerlemans, 1997; Jóhannesson et al., 1989). Therefore short-term climate variations are less damped by geometric adjustment of the glacier than long-term climate variations (Fig. 1). To estimate the relative importance of short-term climate variability on the state of glaciers, variations of the reference-surface mass balance should be used.

3 Reference-surface vs. specific mass balance

We have estimated the present day mean reference-surface mass balance of the 30 Swiss glaciers to be $-1.23\,\mathrm{m\,w.e.a^{-1}}$ instead of $-0.87\,\mathrm{m\,w.e.a^{-1}}$, as presented by Huss et al. (2010). This estimate is based on a simple calculation using the results of Huss et al. (2010) and measured glacier length changes (see Supplement). In a recent article, Paul (2010) quantified the influence of changes in glacier extent on the mass balance of a part of the Swiss Alps, but for a different period (1850–1970/'80). He performed experiments with a physical mass balance model (Machgut et al., 2006; Paul et al., 2009) and measured or reconstructed glacier surface topographies of the Great Aletschglacier region in Switzerland. Based on these calculations Paul (2010) concluded that only 30–50% of the climate change over the period 1850–1970/80 can be observed in the specific mass balance and 70–50% of the climate change is "hidden" in the geometrical change of the glacier surface. A similar strong effect of the geometrical change on the mass balance (nearly 50%) has been found by Nemec et al. (2009) for the Morteratsch glacier, also located in Switzerland.

4 Conclusions

As stated by Huss et al. (2010), the specific mass balance is mainly and increasingly negative over the period 1908–2008, despite the geometric adjustment of the glaciers. This implies that there is a strong negative trend in the reference-surface mass balance, the mass balance that truly reflects climatic change. Using the specific mass balance this trend is underestimated: by a factor 1.5 according to the simplified minimum estimate presented in the supplement, and by up to a factor 3 by detailed calculations (Paul, 2010; Nemec et al., 2009). The underestimate of this negative trend goes together with an overestimate of the importance of the short-term climate variability visible in the specific mass balance anomaly. It is this short-term variability that is related to the AMO in Fig. 3 of Huss et al. (2010). Thus the influence of the AMO on glacier behaviour is overestimated by Huss et al. (2010). In addition is the phase difference between the sinusoidal fitted to the mass balance and the sinusoidal fitted to the AMO such, that the causal relation between AMO and mass balance anomaly is opposite at first sight. This further indicates that the significance of the AMO with respect to glacier shrinkage in the Swiss Alps over the past century is small compared to the gradual warming over this period. The 100-year mass changes in the Swiss Alps are governed by the long-term trend rather than the AMO.

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Supplementary material related to this article is available online at: http://www.the-cryosphere-discuss.net/4/2475/2010/tcd-4-2475-2010-supplement.pdf.

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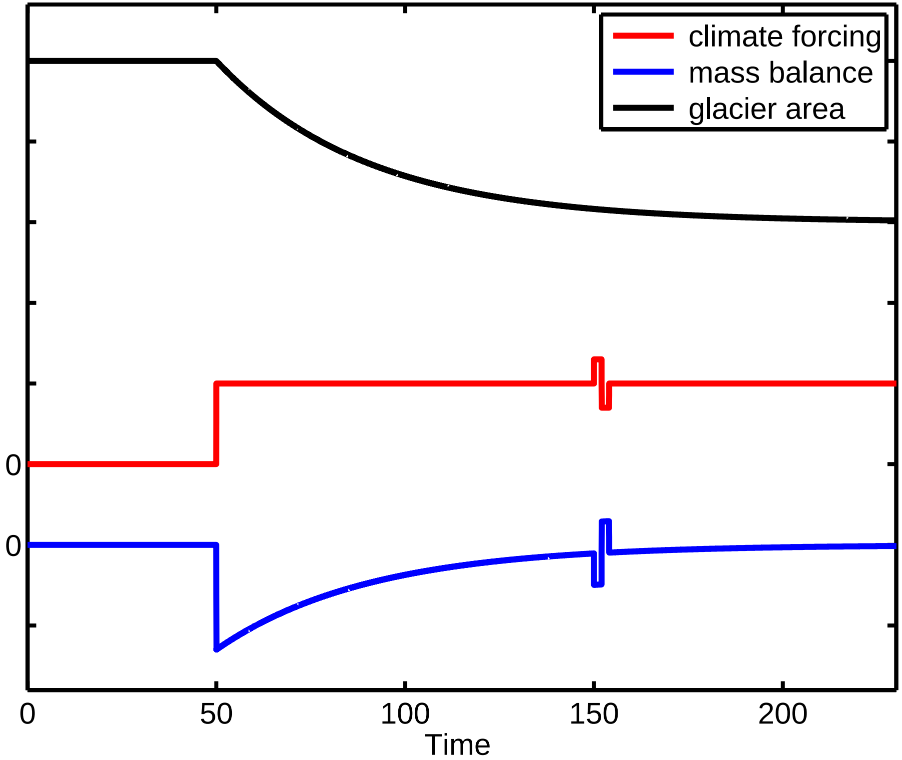

Fig. 1. Schematic response of the mass balance (blue) and glacier area (black) to an idealized climate change (red). Due to the slow change in glacier area the mass balance acts as a high-pass filter (cf. Oerlemans, 2001, Section 9.7).