The Cryosphere Discuss., 4, C1479–C1486, 2011
www.the-cryosphere-discuss.net/4/C1479/2011/

The Cryosphere Discussions

TCD

4, C1479–C1486, 2011

Interactive Comment

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

C. VINCENT (Referee)

vincent@lgge.obs.ujf-grenoble.fr

Received and published: 10 January 2011

Review on : Comment on Âń 100-year mass changes in the Swiss Alps linked to the Atlantic multidecadal Oscillation" by Matthias Huss et al.(2010), P. W. Leclercq et al. Christian Vincent

The paper of Huss et al. (2010) deals with the relationships between multidecadal climate variations and glacier mass balance changes. Glacier mass balances are determined for 30 swiss glaciers for the period 1908 to 2008 using temperature and precipitation as input variables and using a mass balance model. In situ measurements, discharge data and ice volume change measurements are used for calibration. The main conclusion of this paper is relative to the relationship between the mass balance variations and the Atlantic Multidecadal Oscillation (AMO) index with a period of 65 years.

Leclercq et al. assert that the influence of the AMO on glacier behaviour is overestimated by Huss et al. For their study, Huss et al. used the glacier wide mass balance of glaciers. Leclercq et al. argue that the glacier wide mass balance of glaciers is not the appropriate measure to interpret climate changes for the following reason: the glacier wide balances of glaciers depends on surface area changes which depend on a long term dynamic response. It means that a part of a long term climate change is not visible in the mass balance. For this reason, Leclercq et al. propose to use the "reference-surface mass balance" (constant glacier surface area) (Elsberg et al., 2001; Harrison et al., 2009) which does not depend on the effects relative to surface change. The reference-surface mass balance is directly related to climate fluctuations.

Leclercq et al. estimate the difference db between the conventionnal mass balance and the reference-surface mass balance for 12 swiss glaciers over the last century. They calculate, from a very simple method, the loss of ablation area using the observed length changes. These calculations do not take into account the effect of the surface lowering. They found an average db of –0.36 m.w.e a-1 (according to these very simple calculations, db for different glaciers varies between –0.15 and –3 m.w.e a-1).

Leclercq conclude that the negative trend in mass balance over the last century is underestimated. Consequently, they conclude that the influence of the AMO on glacier behaviour is overestimated by Huss et al.

1) I believe that Leclercq et al. are right when they assert that the reference surface mass balance is a good parameter (better than the mass balance) to study the climate fluctuations. As shown by Harrison et al. (2009), the dynamic effects can complicate the relationships between climate and mass balance. In this way, with constant surface area, the reference surface mass balance is more negative. In order to do some nu-

merical experiments, I used mass balance data from Saint Sorlin glacier to calculate the differences between these two mass balance (Fig. 1). The mass balances of this glacier have been measured since 1957 and have been reconstructed using meteorological parameters since 1907 (Vincent, 2002). For Saint Sorlin, db is -0.18 m w.e. a-1 over the last decade. The difference db found for Saint Sorlin glacier shows that rough values found by Leclercq et al. (with an average of -0.36 m w.e. a-1) are realistic, although they do not take into account the effect of the surface lowering.

Therefore, I agree that the long term climate variability inferred from mass balance is underestimated.

2) However, I believe that the fact that Huss et al. did not use reference mass balance to quantify the influence of the AMO on the last-decade mass balance has little influence. Leclercq et al. overestimate largely this effect for the following reasons:

Leclercq et al. find an average db of –0.36 m w.e. a-1.Consequently, they assert that the reference surface mass balance decade for the last decade is –1.23 m w.e. a-1 (i.e. –0.87 - 0.36 w.e. a-1). From this result and using the amplitude (-0.41) of the sine function shown in Fig.3c (Huss et al., 2010), they conclude that 33% (=-0.41/-1.23) of the recent glacier wastage only is due to natural multidecadal climate variations (and not 50 % as reported by Huss et al.).

I believe that Leclercq et al. forgot that Huss et al. used the mass balance anomalies (and not the mass balance) for their study. In fact, they used the deviations (centered mass balance) from the 1908-2008 average (Huss et al., 2010, Fig.3c).

Consequently, assuming that the value of –0.36 m w.e. a-1 given by Leclercq is correct, the difference dbeta between mass balance anomaly calculated from mass balance and from reference surface mass balance is reduced to –0.36/2 w.e. a-1 over the last decade (assuming that the surface change is roughly linear over the century). These differences between mass balance anomalies can be seen easily in Figure 2: the red dots are above the blue dots (anomaly with constant surface area) at the beginning of

TCD
4, C1479–C1486, 2011

the 20th century and below the blue dots for the last decade.

For the sake of clarity, I reported the mass balance anomalies calculated from both method using Saint Sorlin data (Fig.2). As mentionned before, the difference db is -0.18 m w.e. a-1 over the last decade. The difference dbeta is 0.10 w.e. a-1 in the case of Saint Sorlin glacier (and not 0.18/2 exactly because the surface decrease is not constant over the last century).

Consequently, the calculation performed by Leclercq et al. is overestimated by a factor $\sim$2.

3) In addition, Huss et al. fitted a sine function using these anomalies values. From the differences obtained between the mass balance anomalies (over the last decade) and the sine function, they concluded that about half of the mass loss since 2000 can be attributed to the oscillating behavior. Providing that the sine function has been obtained from data, the sine function depends on data. Consequently, the difference between anomalies and the sine function are more or less similar for both methods.

Again, in order to support the demonstration, I used the mass balance anomalies of Saint Sorlin glacier from both methods (constant glacier surface area and real surface area) to calculate sine functions (Fig. 2).

In the case of Saint Sorlin, the averaged differences (over the last decade) between the annual values coming from the sine function and the annual anomalies are 0.55 and 0.53 m w.e. a-1 for both methods (Fig.2).

Consequently, both methods lead to very similar results (because the sine function is based on the anomalies) and the conclusions found by Huss et al. remain unchanged.

A related topic is to decide whether if it is reasonnable to draw such conclusions (relative to the AMO influence) from these results, given the very short period (9 years for the last decade) but it is beyond the scope of this comment. . .

4) The reference surface mass balance is certainly an appropriate measure to study

the climate fluctuations. However, I believe that the best way to investigate the climate variations from mass balance measurements is to use directly the point surface mass balance in order to extract the centered mass balance which accounts for the temporal variability and is free of effects related to the geometry and the dynamics of the glacier (see for instance Lliboutry, 1974; Rasmussen and Andreassen, 2005; Thibert et al., 2008).

In conclusion, I believe that Leclercq et al. are right when they assert that the influence of the AMO on glacier behaviour is overestimated by Huss et al. However, the calculations of Leclercq et al. are largely overestimated. First, they forgot that Huss et al. used the mass balance anomalies for their analysis and, therefore, missed a factor $\frac{1}{2}$ in their assessment. Second, the sine function is related to observations and the differences between anomalies and the sine function are very similar for the both methods. Consequently, both methods lead to very similar results and the conclusions found by Huss et al. remain unchanged. However, I am not convinced by the conclusions of Huss et al. related to the influence of AMO on glacier behaviour over the last decade, given the very short period, but it is beyond the scope of this comment.

References

Lliboutry, L. 1974. Multivariate statistical analysis of glacier annual balances. Journal of Glaciology, 13 (69), 371-392.

Rasmussen, L.A. and L. M. Andreassen. 2005. Seasonal mass balance gradients in Norway. Journal of Glaciology, 51 (175), 601-606.

Thibert E., R. Blanc, C. Vincent, N. Eckert. Glaciological and volumetric mass balance measurements: error analysis over 51 years for Glacier de Sarennes, French Alps. (2008). Journal of Glaciology, 54 (186), 522-532.

Vincent C. 2002. Influence of climate change over the 20th Century on four French glacier mass balances. J. of Geophysical Research, Vol.107, D19, ACL 4, 1-12.

Captions:

Figure 1: Cumulative mass balance of Saint Sorlin glacier

Figure 2: Mass balance anomaly for Saint Sorlin glacier.

Interactive comment on The Cryosphere Discuss., 4, 2475, 2010.

TCD

4, C1479–C1486, 2011

Interactive Comment

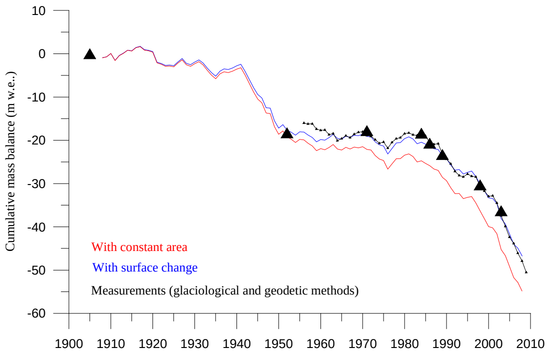
Cumulative mass balance (m w.e.)
10
0
-10
-20
-30
-40
-50
-60
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
With constant area
With surface change
Measurements (glaciological and geodetic methods)

Fig. 1.

TCD
4, C1479–C1486, 2011

Interactive Comment

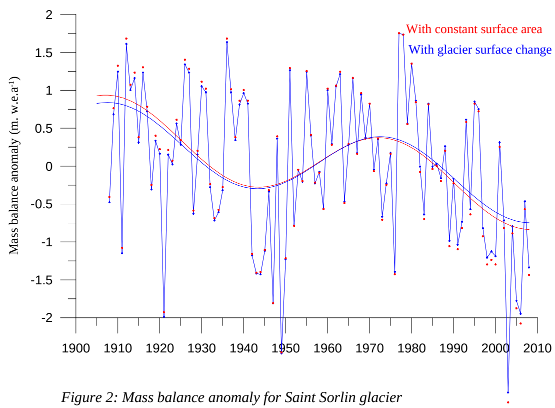

Figure 2: Mass balance anomaly for Saint Sorlin glacier

Fig. 2.

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper