Comment on 'Integrated monitoring of mountain glaciers as key indicators of global climate change: the European Alps' by Haeberli and others

The paper by Haeberli and others (2007; *Annals of Glaciology*, vol. 46) contains misconceptions and unacceptable recommendations which cannot be left unanswered. On p. 151 the authors write 'Long-term observations at isolated index stakes without repeated mapping of the entire glacier are not recommended, because they cannot easily be related to other components of the integrated monitoring strategy and may even be confusing for a wider public.'

Net glacier mass balance is a local quantity and can only be measured locally at single stakes. The question is not how useful single stake measurements are, but how many stake measurements are needed to represent average net balance of a given glacier in a statistically significant way. If, however, the interest is to assess climate change over a long time period (say the 20th century), the most important 'monitoring strategy' is a separate record of winter and summer mass balances at the same location, independent of the number of stakes required to obtain an average net balance with a prescribed precision. In that sense, every time series of stake measurements is useful, and its value increases with the length of the measurement period.

The argumentation continues (p. 151), 'the long series of isolated local seasonal balance (accumulation) observations at two sites on Claridenfirn[, Switzerland,] (starting in 1917) must be disregarded in this respect, as Claridenfirn is mostly an accumulation area with ice avalanches constituting the main ablation process, prohibiting geometric changes and, hence, making realistic mass-balance determinations impossible for simple topographic reasons.'

Contrary to the authors' claim, it is the stable geometric setting of Claridenfirn that makes it an exceptionally valuable long-term record of seasonal mass balance in the Alps. There are only two data series of winter and summer mass-balance records in the Alps that cover more than 50 years: Claridenfirn (since 1914; Müller and Kappenberger, 1991) and Glacier de Sarennes, France (since 1949; Vincent and Vallon, 1997). Recent analysis of these time series showed that (1) the annual mass balance is primarily driven by the summer balance term and (2) melting-rate variations with time are similar for both glaciers located 290 km apart (Vincent and others, 2004; Ohmura and others, 2007). So we cannot put enough emphasis on the requirement to encourage recording winter and net balance separately at single stakes, and to report these raw mass-balance data in publications like the *Mass Balance Bulletin* of the World Glacier Monitoring Service (WGMS).

We find it irresponsible that the director of WGMS publicly discourages mass-balance measurements on a glacier, even more so considering that this unique record is due to the continued work of unpaid volunteers for 93 years! If field measurements do not fit into a certain monitoring strategy, that does not necessarily mean that the measurements should be discarded (as implied by the authors), but might indicate that the strategy needs revision.

We cannot address all the other aspects of the paper we do not agree with, but confine ourselves to the most blatant misconceptions. The authors claim (p. 152) that 'the balance at the terminus (in steady-state condition) tends towards zero with slope decreasing towards zero'. Net balance is usually most negative at the glacier terminus, irrespective of slope. Maybe they are confused by the fact that average net balance tends to zero in a steady state?

On p. 154 the authors write that 'the often-used volume/area scaling (Bahr and others, 1997) is problematic, as it correlates a statistical variable (area) with itself (area in volume)'. The volume/area scaling $V \propto S^{\gamma}$ is still the best method to estimate ice volumes in remote mountain areas where no measurements of ice thickness are available. Such a relationship facilitates the approximate calculation of ice-volume change from measured glacier area change. The power-law relationship between area and volume is not purely empirical, but has its roots in ice dynamics (Bahr and others, 1997). To alleviate the perceived problem of relating 'area with itself', the scaling relation can be rewritten in terms of area and mean ice thickness, and replacing γ (greater than 1) by $\gamma - 1$. A problem exists only if area and volume were proportional, resulting in a constant mean ice thickness. Exactly this is claimed with the following statement (p. 154):

> 'An even simpler and astonishingly elegant consideration assumes that relative volume change is closely comparable to relative area change, because mean glacier thickness (averaged for the changing glacier area) tends to remain constant (even with pronounced overall changes in glacier mass!): by calculating total volume loss from mass-balance time series and mean area during the investigated time interval, and by assuming that percentages in area loss correspond to percentages in volume loss, total volume can be directly approximated.'

If 'correspond' in the above sentence means 'are proportional', the described 'astonishingly elegant' method can be written as

$$\frac{\mathrm{d}V}{V} = \gamma \frac{\mathrm{d}S}{S},$$

which after integration is identical to the power-law relationship which was discarded in the beginning. The seemingly constant mean ice thickness is a consequence of a scaling exponent close to one. For example, the mean ice thickness of Rhonegletscher, Swiss Alps, changed from 125 m to 120 m between 1874 and 2000, with a scaling exponent $\gamma = 1.11$ (Zahno, 2004; Bauder and others, 2007).

As a final remark, sources should be cited correctly. The authors, all working for WGMS, are doing that important institution a disservice in citing the data in Figures 1–3 as 'from WGMS'. Even if it is true that the data are compiled and archived by WGMS, the institutions that provided the resources to collect, homogenize and publish the data measured by many individual and academic volunteers should be referenced (data for the Swiss glaciers appear in Glaciological Reports, 1881–2002.

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