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The Cryosphere Discussions

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Interactive Comment

Interactive comment on "Little Ice Age climate reconstruction from ensemble reanalysis of Alpine glacier fluctuations" *by* M. P. Lüthi

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The paper "Little Ice Age climate reconstruction from ensemble reanalysis of Alpine glacier fluctuations" by M Lüthi presents a climate reconstruction based on observed glacier length fluctuations of seven very well documented valley glaciers in the Alps. Glacier fluctuations provide evidence of past climate fluctuations that is independent of other proxy-based climate reconstructions. Therefore, this analysis of glacier fluctuations is a very welcome contribution. The author makes use of a simple glacier model, that models the evolution of glacier length and volume as a function of the equilibrium line altitude (ELA). With an optimalisation procedure one ELA history is derived that matches best with the observed glacier length records of all seven glaciers at the same time. This is a novel approach. It makes it possible to use the fragmentary and

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discontinuous information prior to 1600, such that the reconstruction is much longer than the existing reconstructions from glacier fluctuations.

The author presents ample discussion of the reconstruction and the possible roles of the different forcing components. Moreover, interesting comparisons with a large number of other climate reconstructions are given. All together, I found it a very interesting paper.

Apart from some specific comments below, I have one general question. There are several papers on the natural variability of glacier fluctuations (e.g. Oerlemans 2000, Roe 2011). Significant length fluctuations can result from the random noise in the climatic forcing of glacier systems - regardless of climate change. Therefore, we should be careful to explain every glacier fluctuation in terms of climatic change. It might be useful to include some comments on this in the paper. Can the methods of this study be used to quantify the likelyhood that the observed glacier fluctuations are the result of natural variability instead of the reconstructed climatic changes?

specific comments:

p 5148 line 22: Here and several times in the paper it is stated that glacier mass balance depends on summer temperature and radiation and on winter precipitation. This is not strictly true, although the mass balance is most sensitive to changes in temperature in summer. For example, Oerlemans and Reichert (2000) "Relating glacier mass balance to meteorological data by using a seasonal sensitivity characteristic" show for Hintereisferner that glaciers in the Alps are sensitive to temperature changes from March to October and sensitive to changes in precipitation in the entire year (without specific seasonality which can be explained by the high impact of summer snow events, e.g. Oerlemans and Klok 2004 "Effect of summer snowfall on glacier mass balance"). I think this should better specified in the paper. It might also have an impact on the comparison with the other climate reconstructions. As far as I know, tree-ring data are mostly correlated with, and calibrated on, June-July-August temperature anomalies, such that glaciers and tree rings do not represent the exact same temperature signal. This should be mentioned.

p 5152 line 5: Do the optimized values of Z0 and s of the model correspond to the actual values of the slope and altitude range for these 7 glaciers? Probably not, as the model has a constant width such that adjustments of the optimal Z and s will compensate for variations in the width of the real glaciers, but how large are the deviations?

p 5154 lines 6-10: To me, this seems a rather strange argument. It hints that the ELA altitudes are underestimated in the last decades, which would correspond to the results in Figure 2b. We have had the same problem in our temperature reconstruction from glacier length changes: the reconstructed temperature rise over the last decades in the Alps was smaller than the temperature rise in the instrumental record (Leclercq and Oerlemans 2012, Fig 5b). So, although I hoped that the two degrees of freedom LV-model would do a better job than our one degree of freedom L-model, this result not surprising. However, the response time is included in the LV-model, which models the dynamic response of glaciers. Because of this dynamic response, the glacier geometry is in general not in balance with the climate, but this is exactly what the glacier models try to capture. Therefore, the argument that the ELA might be even higher because the glacier geometries have not fully adjusted to the present-day climate seems silly. Moreover, if recent ELA changes are underestimated, why would this be different in earlier centuries?

p 5155 l 10: Fig 3c

p 5155 l 13-14: Why does a spatial average of temperature result in an increase in the sensitivity of ELA to temperature?

p 5155 line 7 - p 5156 line 1-2: I am not really convinced by the relation between volcanic eruptions and ELA. The high sulphate concentrations seem to coincide with, or be followed by, high and low ELA episodes more or less equally often.

p 5156 line 19: I have the feeling that "unaltered" refers to the smoothing done in the method used in Oerlemans 2005 and Leclercq&Oerlemans 2012 etc. The smoothing of the GLC in the inverse method of Oerlemans corresponds with accepting a mismatch between modelled and measured GLC in the forward approach, both using the same argument of lines 25-27.

p 5161 line 12-14: What do you mean with "the relative importance of different proxies in resulting GLCs"? Sentence is not clear to me. It seems to express that proxies, instead of climate variations themselves, cause glacier fluctuations, but that would be nonsense.

Table 2: Are the units of TSI correct? I would expect m3/W

Interactive comment on The Cryosphere Discuss., 7, 5147, 2013.