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Interactive
Comment

Interactive comment on "Reconstructing the glacier contribution to sea-level rise back to 1850" *by* J. Oerlemans et al.

J. Oerlemans et al.

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Comment to Cogley's report

We acknowledge Cogley's statement that our study is the first attempt to synthesize data on direct mass-balance measurements and glacier length (although, in a way, Meier (1984) worked along the same line but with a very limited dataset and a different methodology). We agree that the model we use is really a minimal model, and that refinements can be made in the future. However, it is timely to publish our estimate about the contribution of glaciers to past sea-level rise, because the question keeps coming from the climate research community. We think a simple approach is justified as long as the procedure is transparent and anyone can judge the merits.

Although we did not report on this in any detail, the dependence of retreat reates on

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glacier size, characteristic slope, latitude, etc. was studied. However, this did not bring out results that could be used directly to refine our procedure. In the simplest glacier model, in which there are no variations in width or bed slope s, the sensitivity of glacier length to a change in the equilibrium-line altitude is given by -2/s, i.e. independent on glacier length (Oerlemans, 2001; p. 60-61). In practice this implies that larger glaciers are more sensitive, because on average they have smaller slopes. It also means that the choice of reference length is not as important as it may seem at first sight. Altogether we do not share Cogley's view that large glaciers must be less sensitive to climate change. Numerical model studies have also revealed that the average glacier slope is the most important factor. Connected to this is the issue of response time. It is widely believed that large glaciers have larger response times than small glaciers ("a truck accelerates slower than a motor bike"). However, many modelling studies (analytical, scaling, numerical) show that this is not true. Long glaciers have a larger mass turnover and higher ice velocities, and this allows them to respond relatively fast (see also the comments to Pelto's review). In the end, if large glaciers would be less sensitive and slower, it would be impossible to understand what we actually observe !

We agree with Cogley that glacier length is not a very well-defined quantity (as compared with area and volume), because it involves the identification of a flowline. In future work more accurate estimates of the reference glacier length can be included, of course. However, we do not think that this will affect the final result in a significant way.

Volume and mass: the issue is not so relevant because the proxy for ice volume (or mass) is directly calibrated against the sea-level contribution as assessed by Dyurgerov and Meier (2004).

Comments to Pelto's report

The Meier (1984) study: pioneering work, but we are not able to reproduce the result from his Science paper. We also think that there is a mistake, which, however, does not affect his result too much.

We have studied the papers on glaciers in Alaska (most of them were known to us) but we think it needs quite a bit of work to convert the information given into useful glacier length records. There are many ad hoc statements about glacier changes, sometimes in terms of area, sometimes in terminus position since a not well-dated maximum stand, etc. Useful material, but not yet in a form that makes it appropriate for our analysis. We will pay attention to this in future work.

We do not agree with Pelto's theoretical ideas on glacier response to climate change. First of all, we stress that sensitivity and response time are fundamentally different concepts. Sensitivity describes how large the difference in equilibrium glacier geometry is for different climatic states, response time tells how fast the transition to another state is achieved. Secondly, we do not see how Johannesson's time scale predicts larger response times for longer glaciers. His estimate is essentially given by a characteristic ice thickness H divided by the balance rate b at the terminus: H/-b. For a longer glacier H increases roughly with sqrt(L), whereas -b increases linearly with L if the slope would not change and the balance gradient is constant. The result is that the response time changes in proportion to 1/sqrt(L), i.e. decreases with L ! We also note that the whole issue of sensitivity and response times is not so crucial for the present study, because we directly use glacier length records to estimate mass loss without investigating the reasons for the glacier retreat (interesting, but not the subject of our study).

Calving glaciers is a difficult issue. A lot of glaciers in Alaska are calving glaciers, but there are many glaciers around the world which were not calving glaciers, but have formed proglacial lakes in which they now calve. For sure, the issue of calving glaciers versus non-calving glaciers should be taken up in future work.

We think our description and referencing to the scaling issue is adequate. We do not think that the Schwitter and Raymond paper (1993) is as central as suggested by Pelto. Looking in more detail at one or two glaciers really does not prove anything, and for the present approach it is better to rely on the robust elements of existing theory (e.g. that glacier thickness increases roughly with the square root of the horizontal length scale).

Comments to Klein's report

We agree that the discussion on possible errors and a comparison with earlier estimates should be strengthened. One of the things to point out more explicitly is that in the Zuo and Oerlemans (1997) estimate only temperature forcing was considered, whereas in using glacier length records directly, all other affects are implicitly included (although we still think that the temperature effect is most important). We also plan to look more carefully at the apparent sea-level low (as far as the glacier contribution is concerned) around 1850 and report on that in a revised version. At the same time, one should note that the number of records before 1850 is really small.

Altogether, there is much room for improvement in future work, but we think it is important now to supply the climate research community with a simple first-order estimate of the glacier contribution to sea-level rise. As witnessed by the sea-level discussion in the lastest IPCC Report, too little work on this has been done in recent years.

References: Dyurgerov M B and M F Meier (2005): Glaciers and the changing earth system: a 2004 snapshot. Occasional Paper No. 58, INSTAAR, University of Colorado, 117 pp. Meier M F (1984): Contribution of small glaciers to global sea-level. Science 226, 1418-1421. Oerlemans J (2001): Glaciers and Climate Change. A.A. Balkema Publishers, 148 pp. ISBN 9026518137. Zuo Z and J Oerlemans (1997): Contribution of glacier melt to sea-level rise since AD 1865: a regionally differentiated calculation. Climate Dynamics 13, 835-845.

Interactive comment on The Cryosphere Discuss., 1, 77, 2007.