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Interactive comment on "Glacier volume response time and its links to climate and topography based on a conceptual model of glacier hypsometry" *by* S. C. B. Raper and R. J. Braithwaite

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We thank Mauri Pelto for his comments. Although broadly favourable, he suggests a number of places where we should insert extra references. If permitted to revise this discussion paper, we will certainly add these references.

Our model includes both thickness and area changes over the whole glacier (except at the maximum altitude of the glacier). It was clear to us that such changes do occur, e.g. as shown on some of the remarkable maps on glacier changes that have been given away with Fluctuations of Glaciers. In our review of previous work, we overlooked the shape factor (f) used by Jóhannesson et al. (1989b) to describe elevation changes in

the accumulation area and we will add the suggested references. However, the shape factor (f) is not easily related to our scaling factor (eta) as our model is formulated in altitude-area space while the model of Jóhannesson et al. (1989b) is formulated in cross-section.

Mauri Pelto raises the issue of static versus dynamic sensitivity of glacier mass balance. This is explained in the first paragraph of our paper with five references to the literature. Our conceptual model (lines 19-24 and Figure 1) combines static and dynamic sensitivity. The mass balance of the whole glacier is suddenly perturbed by Δb (the static sensitivity) and then slowly returns to zero balance as the glacier area adjusts to the perturbation, as long as the perturbed ELA is below the maximum elevation of the glacier. The changing mass balance during this adjustment period, i.e. from Δb to zero, is the dynamic response described by the volume response time. We claim that our conceptual model is a convenient way to calculate this dynamic response.

The mass balance sensitivity of -0.66 m water/a is only used to construct Figure 1 as an illustration of principles. We were wrong to ascribe this value to a "typical alpine glacier" and we will rephrase in a revised version: it is more appropriate for a glacier in the drier parts of the Alps. The modelled mass balance sensitivities for the seven regions (mean and standard deviation) are shown in Figure 2. The average for the Alps is 0.87 m water/a. We cite several references (Braithwaite and Raper, 2007: De Woul and Hock, 2005: Oerlemans and Fortuin, 1992: Oerlemans, 1992) to work on static mass balance sensitivity. These studies agree in showing wide variations in mass balance sensitivity between regions with higher values in wetter regions as first claimed by Oerlemans and Fortuin (1992). We apply our model to seven regions where mass balance sensitivity varies by about one order of magnitude. The mass balance sensitivity of -0.5 quoted by Mauri Pelto was probably never more than a "ball park figure" that has been superseded by more recent work.

The main purpose of our paper is to show that glacier volume response times vary between regions governed by different climatic and topographic settings. We make some restrictive assumptions to arrive at an analytic solution, so our response time formula cannot expect to capture the details of individual glaciers that will undoubtedly influence their response time. The main application of our model is to regional and global changes in glacier mass balance, e.g. for the glacier melt contribution to sea level rise (Raper and Braithwaite, 2006). However, we agree with Mauri Pelto that it would be interesting to relax some of these restrictions in the model to better capture the response time of individual glaciers. For example, in future work, we could try to introduce the asymmetric glacier hypsometry that may occur with strong advance or retreat. Another future problem is to assess the prevalence of "downwasting" that literally implies that glaciers can get thinner without reductions in their areas, i.e. in violation of volume-area scaling.

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