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# *Interactive comment on* "A comparison of different methods of evaluating glacier response characteristics: application to glacier AX010, Nepal Himalaya" *by* S. Adhikari et al.

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In this paper the authors are investigating the response behaviour of a small Himalayan valley glacier by calculating the reaction time (length time lag) and the volume and length response time with different methods. The methods used are several analytical methods and numerical methods. The ice-flow model used for the numerical method has been discussed in a recent paper by two of the authors (Adhikari and Huybrechts, 2009).

**General comments**

The investigation of the reaction time would be a very significant contribution as it is important to know how long a glacier takes to react to changes in mass balance in order to make any useful interpretations about changes in climatic conditions from measured glacier length changes. However there are some problems with the used methods.

The authors investigate the reaction time in two ways: 1) estimating the reaction time by a visual comparison of the temperature and the measured glacier extend and calculating it by a cross-correlation analysis between time series of temperature and measured glacier extend; and 2) modelling the glacier extend for mass balance perturbations with different amplitudes. This would have been an useful investigation however their results are limited for method 1) by the coarse sampling rate of the length changes (9 data points over approx. 26 years) and for method 2) by the grid size of the model.

On page 771 the authors state that the temperature increase from 1976 might have caused the rapid retreat in 1989. However between 1978/79 and 1989 are no other length measurements available. Therefore it is difficult to judge if the glacier hasn't reacted earlier to the measured changes in temperature. I am not sure how this gap in data affects the cross-correlation analysis.

The problem with the grid size is that for the shown periodic mass balance perturbation (Fig. 7a) the model only advances and retreats one grid point. As the horizontal resolution of the grid is not high enough we do not see the evolution of the glacier for the advance or the retreat. Therefore conclusions about reaction times of the glacier cannot be made. The authors mention the pro blem with the grid size on page 780 (lines 8-12) but not in section 5 where they determine the reaction time for different temperature forcing. For such a short and not very steep glacier (mean slope inferred from Figure 3 in Adhikari and Huybrechts, 2009) a larger amplitude or period in mass balance forcing or, for the same forcing, a much smaller horizontal grid should be chosen to model the reaction of the glacier.

The major part of the paper is the investigation of the response time of this small Himalayan valley glacier, which has been done by the authors in some considerable detail. They calculated the response times, for volume and length, by means of different methods and did a thorough comparison study. The used methods are: 1) four analytical methods by Nye (1960), J'ohannesson and others (1989b), J'ohannesson and others (1989a), Harrison and others (2001), 2) a numerical ice-flow model (shallow ice) (e.g. Oerlemans, 2001) and 3) a linear inverse model (Oerlemans, 2001). This gives an useful idea of which method in general and which analytical method in particular is most suitable to calculate the response times for this glacier.

A similar, more general investigation of the response time exists by Leysinger Vieli and Gudmundsson (2004), where they used three different sized alpine glaciers (with the length of the smallest of the three investigated glaciers comparable to AX010 but with a much steeper mean slope) and compare their numerical response times with two of the above mentioned analytical response times (Jóhannesson and others, 1989b; Harrison and others, 2001). The numerical response times were obtained by two different models: i) the shallow ice approximation (SIA) model and ii) a full-system glacier flow model (solving full Stokes equations) using finite elements (FE) and a moving-mesh technique, which allows the position of the snout to be determined with high accuracy. This research has not been mentioned in the current paper but is highly relevant here. Findings such as e.g. shorter volume response times $\tau_V$ than length response times $\tau_L$ have been discussed in this earlier paper (e.g. Table 3 and page 9 of Leysinger Vieli and Gudmundsson, 2004).

Although this paper presents some potentially interesting investigations on the reaction time and a thorough comparison of methods to calculate the response time of such a glacier to climatic changes it can, in my view, not be accepted in it's current form. The two main reasons are: 1) the problematic calculations of the reaction time (as discussed above: grid size, sampling rate) and 2) that the discussion of the response time should be put into context with results obtained by similar means from existing literature.

**Additional comments**

p.780: Discussing the values from Figure 5a should be consistent with the ones in the figure: $\tau_L$ should be 55-86 years, and $\tau_V$ should be 48-63 years.

p.803: The two different solid lines in Figure 6a are not very clearly different to each other.

**Additional references (all others are found in the reviewed paper)**

Leysinger Vieli, G. J.-M. C., and G. H. Gudmundsson (2004), On estimating length fluctuations of glaciers caused by changes in climatic forcing, J. Geophys. Res., 109, F01007, doi:10.1029/2003JF000027.

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