The Cryosphere
Discussions

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

M. Pelto

mauri.pelto@nichols.edu

This paper provides a potentially important new approach to assessing glacier response time that does not rely on detailed observations of glacier mass balance or glacier velocity, key inputs to the most commonly used response time calculations (Jóhannesson et. al., 1989; Paterson, 1981). Thus, the method has the potential for much wider application. The reliance on geographic and climate based inputs also allows an assessment of the dynamic response versus static response of a glacier to a mass balance perturbation. By relying on the ELA and the balance gradient the authors are considering the mass balance of the entire glacier versus the mass balance of the

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

terminus region that had been used by Jóhannesson et. al., (1989). The potential of the method is highlighted by the close relationship observed between the median and the mid-point elevation of glaciers. The authors make a good case that the method allows median glacier altitude to be utilized as an accurate measure of the balance budget ELA. The model is applied only to glaciers with a symmetrical area elevation distribution around the ELA. This is a good constraint for initial model development. Importantly if further testing of this model indicates its merit, the model could be adapted for glaciers without a symmetric area elevation distribution. The length of the review is a reflection of the complexity of the problem for modeling glacier response time, and the potential of the proposed model to successfully address it.

The two main issues that need to be addressed are better acknowledgement of previous response time literature that can help clarify the importance of deriving a method not based on detailed glaciologic measurements and the importance of having a dynamic model. In general the suggested references below bolster the conclusions of the paper. The second issue is providing more testing of the response time model against existing published tests and in one case with respect to a particular step in the model development from this study. These two issues will be discussed in detail as each specific need arises in the course of the paper.

246-1: Reference must be made to the second response time method from Jóhannesson et. al., (1989), that uses a different approach. The second method relies on glacier length, observed terminus velocity and a shape factor f, the shape factor discussed by Paterson (1981). Jóhannesson et.al., (1989) and Schwitter and Raymond (1993) notes problems with this method due to the inconsistent and wide variability in terminus velocity response. Pelto and Hedlund (2001) found the method to be less accurate as well. That this method is not explored is fine, just acknowledge the existence and why it is not utilized.

247-10: An important point in support of the discussed method that needs to be discussed is the dynamic sensitivity versus static sensitivity (Jóhannesson, 1997). This

topic maybe better raised later in the paper. Previous response time models such as Jóhannesson (1989), Paterson (1981) and Oerlemans and Fortuin (1992) examined a glaciers static sensitivity to a climate change, whereas the proposed model allows for consideration of dynamic sensitivity, as did Wigley and Raper (1995). The dynamic approach considers the effects on glacier response due to ongoing glacier geometry changes and time dependent terminus changes. This point should be briefly discussed to distinguish how the model provides a dynamic sensitivity response.

248-6: The value of -0.66 m water/a for a +1K change needs better defense. Oerlemans and Fortuin (1992), Jóhannesson (1997), and Wigley and Raper (1995) use -0.5. This does not suggest it is a better estimate, just explain why the higher value is used.

249-17 That the top altitude for the glacier is fixed is not always realistic. Pelto (2006) and Paul et al., (2004) have noted marginal retreat at the head of the glacier. This has only been noted on glaciers that are experiencing a disequilibrium or non-steady state response to climate (Pelto, 2006; Paul et al., 2004). Such glaciers are rapidly downwasting and will not survive current climate. In your discussion of response time, this type of response should be noted, one where a glacier cannot retreat to a new point of equilibrium. Later in the paper you refer to your altitude-area range scaling factor as allowing for the change in surface elevation of the accumulation and ablation area, again suggesting that a fixed upper altitude may not always be realistic. In fact your model can accommodate such a change, in this instance of using the World Glacier Inventory it was simply convenient not to.

250-13: Terminus change altitude=2(ELA change). This is an assumption that can be put to a simple preliminary test using data from a few glaciers and must be supported by data.

254-7: Actual response time calculations need to be referenced here that can verify the model results, or indicate issues with the static sensitivity models used ie. (Jóhannesson, 1997; Chinn, 1999; Pelto and Hedlund, 2001; Joerin et.al., 2006).

255-29: Again Pelto (2006) and Paul et al., (2004) note this fact of accumulation zone thinning based on observations not modeling and this is an important advantage of the proposed model and must be emphasized with these citations.

256-10: Why is the method of non-linear regression of the range and area better?

257-19: How is Ro determined?

261-8 Schwitter and Raymond (1993) compare the change in surface altitude along a longitudinal profile in response to a climate change. They focus on the idea that at some distance upglacier from the terminus there is no change in surface elevation. This altitude was noted as in the vicinity of the ELA. Pelto (2006) notes considerable accumulation zone thinning on longitudinal profiles, supporting the idea in the proposed model that a response time model must allow for accumulation zone surface elevation change. Schwitter and Raymond (1993) and Jóhannesson, (1997), Paterson (1981) examine the shape factor (f), that relates this change in thinning with distance upglacier. A value of 1 would be equal thinning, they all found a value close to 0.3 works better, which argues for little thinning above the ELA. Your area altitude scaling factor is different, but seems related, based on the values it has, and the comments that with values above or below 0.5 you will either have or not have accumulation zone thinning. It is worth commenting on the potential relationship between the shape factor and scaling factor.

261-20 Continues on this point noting the advantage of your model that allows for the thinning in the accumulation zone, you have supporting references for this being required, use them.

Table 5: An additional table is needed that compares response times observations from other glaciers by other researchers with your calculations in Table 5. This will quickly address the point on 254-7. It is not realistic to test this model in detail in this paper, just some comparison is needed for perspective on relative reliability. In general I find the Jóhannesson et. al., (1989) calculations to be closer to the field observations

Interactive
Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

of response times of Swiss and North Cascade, Washignton glaciers, than the model results in Table 5. There is the issue of static sensitivity response times versus dynamic sensitivity response times that may explain this difference as well, with a static response being faster of course. There is also the difficulty of additional or ongoing climate change that impacts response time determined from field observations. The model presented has some clear cut advantages in relying on basic geographic and climate data and being dynamic. If the results are not quite as accurate as Jóhannesson et. al., (1989), this can be corrected later with model refinements.

References: Besides the references mentioned above, which provide essential information on the response time issue, one other paper should be referenced. Braithwaite (1984), makes a strong case for the "simple linear relation between the mean specific balance and the ELA, which is a key step in this model in assessing the mass balance of the entire glacier.

References

Braithwaite, R. 1984. Can the mass balance of a glacier be estimated from its equilibrium line altitude? Journal of Glaciology 30, 364-367

Chinn, T. 1999: New Zealand glacier response to climate change of the past 2 decades Global and Planetary Change, 22, 155-168.

Jóhannesson, T., Raymond, C. F., and Waddington, E. D.: Time-scale for adjustments of glaciers to changes in mass balance ,J. Glaciol., 35(121), 355–369, 1989b.

Jóhannesson, T. 1997: Glacier modeling for two Icelandic glaciers. J of Glaciol., 43, 321-327

Joerin, U, T. Stocker, and C.Schluchter 2006: Multicentury glacier fluctuations in the Swiss Alps during the Holocene. The Holocene, 16. 697-704.

Oerlemans, J. and Fortuin, J. P. F.: Sensitivity of glaciers and small ice caps to Greenhouse warming, Science, 258, 115–117, 1992.

Paul, F., Kääb, A., Maisch, M., Kellenberger, T.W. and W. Haeberli, 2004: Rapid disintegration of Alpine glaciers observed with satellite data. Geophys. Res. Lett., 31, L21402.

Pelto, M.S., 2006. The current disequilibrium of North Cascade glaciers. Hydrological Processes 20:769-779.

Pelto, M.S. and C. Hedlund, 2001: The terminus behavior and response time of North Cascade glaciers. Journal of Glaciology 47:497-506

Schwitter, M.P., and C. Raymond. 1993. Changes in the longitudinal profile of glaciers during advance and retreat. J. Glaciol, 39(133), 582-590.

Wigley,T.M. and S.C. Raper, 1995: An heuristic model for sea level rise due to the melting of small glaciers. Geophys. Res. Lett., 22, 2749-2752.

WGMS (2007): Glacier Mass Balance Bulletin No. 9 (2004-2005). Haeberli, W., Zemp, M. and Hoelzle, M. (eds.), ICSU (FAGS) / IUGG (IACS) / UNEP / UNESCO / WMO, World Glacier Monitoring Service, Zurich, Switzerland

Interactive comment on The Cryosphere Discuss., 3, 243, 2009.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper