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Discussions

Interactive comment on "Relative effect of slope and equilibrium line altitude on the retreat of Himalayan glaciers" *by* T. N. Venkatesh et al.

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1. *Venkatesh et al (2011) provide a unique approach to assessing glacier terminus response in the Himalaya that utilizes the role of slope and ELA in quantifying recent terminus response. The approach merits further exploration by the authors and I look forward to this contribution examining more closely the glaciers in the Chenab, Parbati and Baspa regions.*

   We thank M. Pelto for the comments regarding our approach. Applying it to other basins would be the scope for future work.

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2. *The paper at present suffers from two key simpliïňĄcations that at this time prevent robust model results or validation.*

   The first issue is the opinion stated in the introduction that the different rates of retreat in the region over which the climatic conditions to do not change signiïňĄcantly is due to ice dynamics. The climatic conditions cannot be considered the same for the entire region discussed, from the Karakoram to Zemu Glacier in Sikkim. For the Chenab, Parbati and Baspa region the statement is true. One of the authors, Kulkarni, has an excellent data set for closer examination of this group.

   1) Climate differences: For the Karakoram, Hewitt (2005) notes that recent key climate changes include shifts in seasonal temperature, snowfall, and snow cover at high elevations. Further that the maximum precipitation occurs almost 2000 m higher than in the Nepal Himalaya. The glaciers are also not strictly summer accumulation type (Himalaya) or winter accumulation type but intermediate (Ageta 2001). Zemu Glacier is a summer accumulation type, but also has signiïňĄcant accumulation area between 6000 m and 8000 m and the Gangotri Glacier none above 6000 m. This leads to different climate conditions.

   We agree that climatic conditions are different in the western and eastern Himalayas. In this investigation, we wanted to show that if ELA changes are similar, glacier retreat will be different, depending upon geo-morphological parameters. Our premise is that on a long time-scale, to the first order, the ELA changes resulting from global climate change are of similar magnitude.

   A paragraph will be added in the revised manuscript to clarify this point.

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3. *The issue of terminus response time and longitudinal surface elevation proïňĄle also need more attention in order to control for their inïňĆuence.*

   2) Response Time: The method shows promise in the Parbati glaciers where the size, characteristics and climate of the glaciers are comparable. Glacier length is a key parameter to control for as response time is crucial to terminus behavior. One means to determine response time (Johannesson et al, 1989) is from terminus region velocity and glacier length. Pelto and Hedlund (2001) applying aforementioned method noted that the much different terminus response on small North Cascade glaciers during the 1950-1980 period resulted from different response times that were indeed partly dependent on glacier slope. This suggests that the response time issue cannot be ignored unless the glaciers are of similar length, slope and climate setting. Certainly the response time of a glacier is dependent on its longitudinal stress gradient that cannot be determined simply from a mean slope of a glacier, the mean slope can be far different from the slope of a signiïňĄcant region near the terminus (Adhikari and Marshall, 2011). The slope in the lower ablation zone is key to terminus response to ice dynamics in the short term to recent climate warming. Kulkarni et al (2007), note that the smaller glaciers in the Parbati, Chenab and Baspa region have retreated more rapidly possibly due to the shorter response time. This can be controlled for by comparing glaciers of similar length, and surface elevation proïňĄle. Table 1 indicates a group of glaciers with vastly different lengths.

   M. Pelto observes that our method is appropriate for glaciers in a basin with similar characteristics and states that the issue of response time is important for comparing glaciers of different lengths. While response time is important, it is our hypothesis that a major part of the glacier response, on a climatic time-scale can be explained in terms of the mean-slope, length and ELA change. The results for the glaciers considered (figure 12) support this view. Inclusion of other factors

   such as response time would be second order effects.

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4. *3) Longitudinal surface elevation proïňĄle example: In the case of Zemu Glacier and Gangotri Glacier both have low slope terminus reaches that are debris covered. Neither is likely to be sensitive at this time to the slope in the accumulation zone over the last few decades. For Zemu Glacier it is 18 km from the terminus at 4200 m to 5200 m along the main glacier trunk, still below the ELA, and 7 km from 5200 m to 8000 m at the glacier head. For Gangotri Glacier it is 19 km from 4000 m to 5000 m, still below the ELA, and then 13 km to the head of the glacier at 6800 meters. The slope difference is all in the accumulation zone, not the lower ablation zone. Changes in slope could be the controlling inïňĆuence if glacier proïňĄles were similar. Kulkarni et al (2005) Figure 6 is a key diagram of the change in slope with elevation on Parbati Glacier that should be utilized to control for this variable or at least deïňĄne it. Recent work by Raj (2011) on Milam Glacier is also worth referencing.*

   There is no doubt that using information about the change in slope with elevation would result in a better model. Our attempt was to come up with a simple model using the minimum set of parameters. Even using, just the mean-slope and length, we are able to explain the basic processes and predict different response of certain glaciers. Use of more geometric information such as i) accumulation zone slope and ablation zone slope or ii) slope-distribution could be an area for further work.

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We thank M. Pelto for these references.

Some of the relevant ones in this list will be added to the revised manuscript.

Interactive comment on The Cryosphere Discuss., 5, 2571, 2011.