Point by point reply (in red) to Mauri Pelto by Azam et al.

Major Comments:

Azam et al (2014) construct an energy balance model that is calibrated with limited but the best available field meteorological and surface mass balance data in a region of the Himalaya that lack such studies. Given that Chhota Shigri Glacier has the best field data this is the ideal location for better understanding the specific climate sensitivity of the glacier. This is an essential step forward in our understanding of the energy balance and climate sensitivity and how they vary significantly in the high mountains of Asia. A key observation is the importance of winter precipitation for this particular glacier. Three challenges that remain: 1) Explaining why October 1 is used as the end of the hydrologic year, since it is not the balance minimum. This would include better defining ablation during the at least the start of the post monsoon season. 2) The validation is based primarily on results from a single elevation, a single stake. This could be expanded using the transient snowline if no other field data exists. 3) Identify the key conditions that have led to either high ELA above 5100 m or low ELA below 4950 m. The trend of recent higher ELA's is worth a brief comment.

We would like to thank Prof. Mauri Pelto for his constructive comments on the manuscript. Here is the point by point reply of each comment.

1. Why October 1 is used as the end of the hydrologic year?

The least amount of precipitations in the months of October and November at base camp as well as at the nearest Valley Station at Bhuntar meteorological station (Fig. 4 in the manuscript) suggests that October and November are the driest months in this area in agreement with Datt et al. (2008) and Prasad and Roy (2005). Besides, Fig. A (below) shows the mean annual mass balance cycle at daily and monthly time-steps (data from 1969 to 2013 averaged every day or month) derived from the temperature-index model and an accumulation model described in Azam et al. (2014). From Fig. A, we observe almost balance conditions of mass balance in October and November months indicating that the ablation is very limited in these months. We agree that October 1 is not the balance minimum of hydrological year as there are some specific years when the glacier may experience a little ablation for some days in October (Azam et al., 2014). Thus starting of hydrological year from 1st November would be more appropriate. But the access to the glacier is not possible after 15th October as the access road crossing Rohtang Pass is closed by the government. In this situation and given almost balance conditions in October month, selecting 1 October as the start of hydrological year seems to be the best available option.

This point has now been discussed specifically in the revised manuscript in section 2.1:

"On Chhota Shigri Glacier, the hydrological year is defined from 1 October to 30 September of the following year (Wagnon et al., 2007). Since, the glacier sometimes experiences some melting even in October, it would have been more appropriate to start the hydrological year at the beginning of November. Nevertheless, for practical reasons (access to the glacier is impossible after mid-October) and in view of the fact that both October and November are usually characterized by a non-significant mass balance, starting the hydrological year at the beginning of October does not change the results."

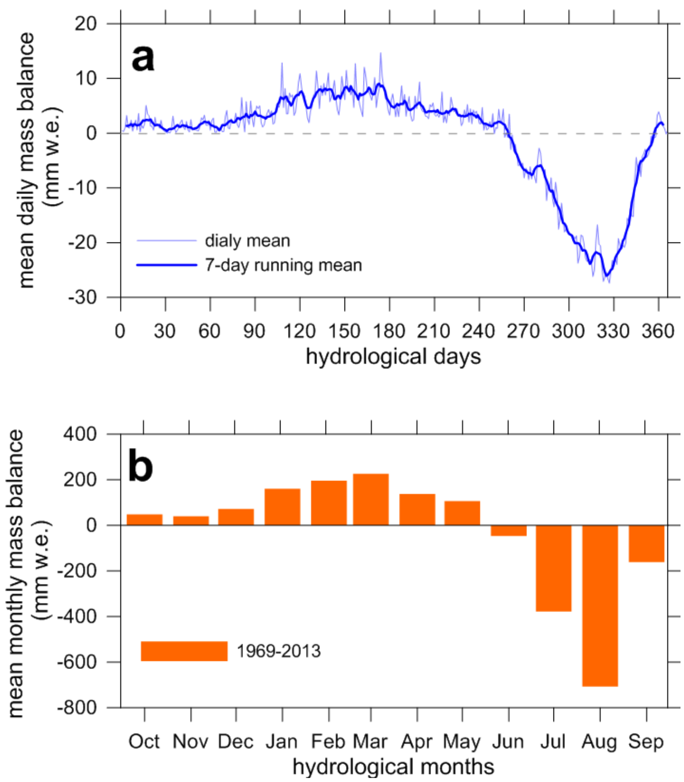
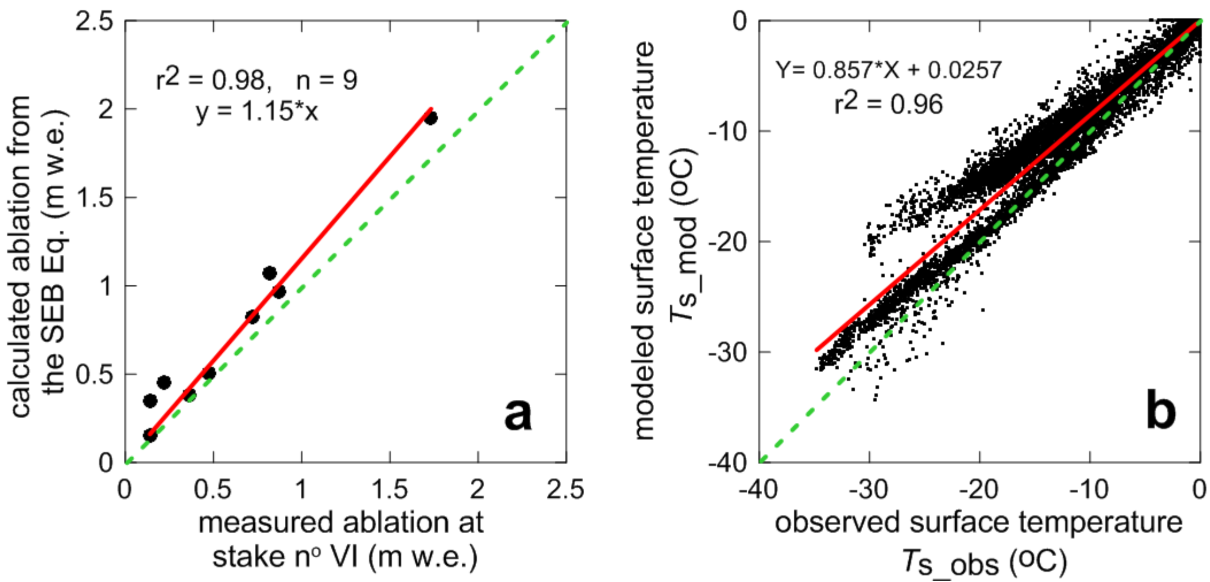


Fig. A mean annual mass balance cycle at daily (a) and monthly (b) time-steps (data from 1969 to 2013 averaged every day (a) or month (b)). Hydrological year is defined between 1st October (0 day on x-axis) and 30th September.

2. Model validation:

We agree with the comment no "2889-2" (below) saying that the model validation using the stake ablation data is weak. However, this is the standard method and widely used in several studies (e.g., Favier et al, 2004, Nicholson et al., 2013; Giesen et al., 2014) but often supported by other methods which was not the case in our previous manuscript. In our revised manuscript, we have now extended this validation by comparing computed and observed surface temperatures (See below fig. 11b). For more details, we invite Prof. Mauri Pelto to read the replies to Referees 1 or 2 major comments.

If we had performed a spatially distributed energy-balance study, validating our results against the migration of the transient snow line over the glacier along the year would have been strongly recommended. However, since our study is a point study, such a validation makes less sense especially because the error range in estimating this line is high (Mernild et al, 2013). Consequently, we preferred not to perform any validation using this line.



(Revised) Fig. 11. Comparison between ablation computed from the SEB Eq. and measured at stake n° VI (a) during several few-day to few-week periods of 2012 and 2013 summers where field measurements are available. (b) Comparison between half-hourly modeled (T_{s_mod}) and observed (T_{s_obs}) surface temperatures over the whole simulation period. Also shown are the 1:1 line (dashed line) and the regression line (solid line).

3. The key conditions for different ELAs:

Discussing the ELA variations with respect to the climate and finding the key conditions for high and low ELA on Chhota Shigri Glacier is surely an issue to be dealt with. But according to the framework of this present study it seems beyond the scope. We are preparing another manuscript dealing with annual and seasonal mass-balances, ELA, AAR and their relationship with meteorological conditions, in the light of findings from this present work. Consequently the proposed point will be discussed later in this new manuscript. Thanks for pointing out this issue here.

Minor Comments:

2869-26 to 2870-5: Remove unneeded reference section.

We feel it is worth providing here a quick review of the status of the energy balance studies world-wide to highlight the importance of such kind of studies in High Asia Mountains. We therefore preferred to keep this reference section here.

2870-20: Why not mention the 1986-1988 period of observation too?
Done and added in the revised version. A sentence *"The first mass balance measurement on this glacier was performed in 1987. Unfortunately, it was abandoned in 1989 and restarted in 2002 (Ramanathan, 2011)."*

2875-16: Given that the winter season starts in December, and that the post Monsoon season typically features significant ablation why is October 1 the start of the hydrologic year? It is fine to do so, but the rationale should be stated. Note the comments below on this topic too. There is not a simple solution since October 1 is typically not the minimum balance date. Figure 2 highlights this fact as well. Datt et al(2008) observed that winter precipitation is dominant at Dhundi field station of Snow and Avalanche Study Establishment, which lies in Pir Panjal range, and that snowfall did not usually accumulate until November. Prasad and Roy (2005) using a snowmelt model in the Beas River basin observed that October had the minimum snow covered area fraction for the elevation band from 3000-5000 m. Negi et al (2009) note a lack of snowcover in the Beas River basin in October. The Beas is not the same basin, but the same feature can be seen in satellite imagery for the post monsoon season.

Please see reply of major comment 1.

2877-18: Worth contrasting this percentage of summer and winter precipitation to Mera and Pokalde Glacier, Nepal.
Yes, the precipitation percentage in winter and summer on Mera and Pokalde glaciers, Nepal is in contrast to that at Chhota Shigri Glacier as stated in Introduction (2870 13-18)
"*For example, glaciers in Nepal receive almost all their annual precipitation from the Indian summer monsoon (ISM), thus these are summer-accumulation type glaciers (Ageta and Higuchi, 1984; Wagnon et al., 2013). Besides, Chhota Shigri and other glaciers in Western Himalaya receive precipitation both from the ISM in summer and from mid-latitude westerlies (MLW) in winter (Shekhar et al., 2010)."*

2889-2: The validation of the model using the limited stake data from one elevation is weak. This is hard to overcome at this point. One solution worth exploring is to use the transient snowline that can be visibly observed. If the model can correctly predict its elevation for specific dates observed by satellite imagery or in the field, than each of these dates represents a validating measure too. If snowpack depth in the area above the snowline is available then the ablation rate can be determined as the transient snowline rises (Mernild et al, 2013).

Please see reply of major comment 2.

2892-9: It is noted here the occurrence of mid-September snow storms near the end of the summer monsoon and their ability to reduce melting for a short period. What needs further attention is the fact that in this region snowcover is typically less in October than in September. The ablation may not be high but in satellite imagery it is quite apparent in the fall of 2011, 2012 and 2013 that mid-Sept. snowcover is greater than mid to late October snowcover. That ablation does occur is implied by the authors noting role that such snow events can have on ablation. This also suggests the problem with having October 1 as the end of the hydrologic year, since it is typically not the balance minimum.
Please see reply of major comment 1.

2893-12: The authors indicate that ablation typically ends in mid-October, confirming the above for many years. The references noted above all indicate that minimum snowcover in the region occurs in October, which makes October 1 problematic as the end of the hydrologic year. I do not suggest the authors need to make this change at this point just acknowledge the issue.

We agree that there may be ablation up to mid-October for some years especially when the glacier doesn't receive summer-monsoon snow falls but this ablation is very limited. For more details please refer to reply of major comment 1 (above). This issue has now been acknowledged in the revised Manuscript, by including new sentences about this point in section 2.1.

"On Chhota Shigri Glacier, the hydrological year is defined from 1 October to 30 September of the following year (Wagnon et al., 2007). Since the glacier sometimes experiences some melting even in October, it would have been more appropriate to start the hydrological year at the beginning of November. Nevertheless, for practical reasons (access to the glacier is impossible after mid-October) and because both months of October and November are usually characterized by a non-significant mass balance, starting the hydrological year at the beginning of October does not change the results."

2893: There should be reference to the difference in climate during the years with the ELA above 5100 m such as 2003, 2004, 2006, 2007 and 2008 versus those with the ELA below 4950 m such as 1986, 1987, 1988, 2005 and 2010. Maybe 2010 can be compared to the higher ELA of 2013.
Please see reply of major comment 3.

Figure 14: Does not add value beyond what can be stated in the text.

In this figure 14, the reader can visualize the large annual variability of this relationship between MB and summer snow events. We thus believe that it brings substantial information, and since there is no space limitation in "The Cryosphere", we prefer to keep it.

References:

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