Replies to the short comment by Anonymous Reviewer#3

We thank the anonymous reviewer for his/her short comment posted in response to our initial response to referee comments. His/her specific comments (in blue) and our corresponding responses are given below.

The present study raises a serious question on mass balance results of debris-covered Hamtah Glacier derived from glaciological method conducted by Geological Survey of India (GSI). Authors compared these results with geodetic mass balance for this glacier performed by Vincent et al. (2013). Authors explained the discrepancy between values of glaciological and geodetic net mass balance for Hamtah Glacier using their flow line model. In simple words, authors believed that Vincent et al. (2013) and other studies by similar group (Wagnon et al, 2007; Azam et al. 2012) is absolutely correct and can be used as a reference data for comparison with glaciological method on Hamtah Glacier carried out by GSI.

Our estimate of net mass balance of Hamtah glacier is completely independent of the geodetic estimate of Vincent et al (2013), and is based on glaciological mass balance data of GSI, available velocity profile data and retreat data. We compare our result with that of Vincent et al as that is the only other independent measurement that is available for Hamtah glacier. We believe that consistency of these two independent estimates is significant and strengthen our claim of a missing avalanche contribution in the glaciological mass balance data. We also note that the geodetic estimate by Vincent et al agrees to the available glaciological data in neighbouring Chhota Shigri glacier as well.

In simple words, we do not start with any bias, either towards the geodetic method or the glaciological method. Our modelling shows that the mass balance measured by the glaciological method has a missing contribution since it results in a glacier of vanishing length. A variety of evidence points to the fact that this missing contribution could come from avalanches. When we model an avalanche contribution by increasing the specific mass balance in the accumulation area, we are able to reproduce the observed features of the glacier. We then find that the resultant increased mass balance approximately agrees with the one measured by the geodetic method.

1. The glaciological and geodetic net mass balance is two different methods and conducted by two different agencies. This is well known that geodetic

methods can differ significantly from estimates using direct glaciological field-based measurements (e.g. Krimmel, 1999; Ostrem and Haakensen, 1999; Cogley, 2009; Haug et al. 2009; Rolstad et al. 2009; Fischer 2011). Rolstad et al. (2009) reported the cumulative traditional mass balance was 22 m w.e in Engabreen drainage basin, Norway during 1970-2002 whereas the geodetic mass balance for the period 1968-85 was -2.1±1.2 m w.e., and from 1985 to 2002 it was -0.3±2.6 m w.e. The discrepancy between these results could be due to several reasons such as different assumptions for density of ice loss, wind effect in accumulation and number of stakes and pits measurement (Huss 2013) and different methodologies adopted for utilization of satellite data/Arial photographs for DEM generation (Fischer 2011; Zemp et al. 2013). Therefore, difference in mass balance of Hamtah Glacier by two different methods cannot justify with avalanches alone. Moreover, sometimes geodetic mass balance conducted by different research groups doesn't accord in similar region. The geodetic mass balance results in Everest Himalayan region by three different research groups doesn't match with each others (Bolch et al. 2011; Nuimura et al. 2012; Gardelle et al. 2013). The discrepancy between these results could be due to different methodology and datasets

The physical quantity of net mass balance must be independent of method and observer. Any inconsistency in independent measurement can only come from some systematic error which it should be possible to identify and estimate.

For example a closer look at the value of mass balance of Engabreen drainage basin quoted by referee reveals that the glaciological estimate of average net mass balance during 1970-2002 is -0.69 m w.e./yr (with unspecified errors) and the average geodetic net mass balance during 1968-2002 is -1.2 ± 1.9 m w.e./yr, so it *can not be concluded* that they are significantly different. Similarly as pointed out by Gardelle et al (2013) (sect. 5.3), the three quoted geodetic estimates of average mass balance of a set of ten glaciers in Khumbu region are all *consistent* within estimated uncertainties and there is no significant discrepancy among them.

On the other hand, in Hamtah glacier glaciological mass balance is 1.45 m w.e./yr (with unspecified uncertainty) and geodetic mass balance is 0.45±0.16 m w.e./yr. Clearly this is a significant difference. We have already discussed in our manuscript, in our initial response document, and in our reply to the anonymous reviewer referee comment, a host of other evidences that point to a missing contribution of avalanches as a resolution to this inconsistency.

There is need to describe the details of glaciological mass balance data collection procedures to understand the discrepancy in mass balance observations. What is the location of stakes and pits? What are the number of stakes and pits? What are the distribution of avalanches? What are the distribution of debris cover? The detailed map can explain all these issues. However, there is no map shown in study.

We do appreciate the reviewer's concern about the unavailability of details of the mass balance measurement carried out by GSI. But as stated in our initial response, we work with whatever is freely available regarding the mass balance

measurements. We also agree that it would be good to have a detailed map of avalanche activities in Hamtah glacier which we are unable to provide. But, we feel that together with our quantitative model analysis, field photos, and the other indications like presence of steep, wide and relatively ice free headwall, avalanche cones, small AAR, relatively low ELA, extensive debris cover etc., we have enough evidences to make our case.

We also disagree with author's preliminary response to comments by the referees. They claimed that Page 2, line 30; "in neighboring Chhota Shigri Glacier, this kind of localised accumulation is not seen in the mass balance profile (Wagnon et al, 2007) as the topography there disallows such strong avalanche activity". But we found this kind of localised accumulation in neighboring Chhota Shigri Glacier in government report published by Ministry of Science and Technology, Indian Government (Ramanathan 2011). We believe authors overlooked the interesting facts about the Chhota Shigri Glacier mass balance as they referred this reference. At the almost same elevation (range 4800-5000m) one stake/pit of Chhota Shigri Glacier accumulated by 20cm (0.65 feet) firn w.e. during 2009-2010 whereas another stake/pit accumulated by 9 times more firn i.e. 180 cm (5.9 feet) w.e. (Ramanathan 2011, fig 2.7, page 41). The period of 2009-2010 is reported positive balance (+0.33 m w.e) (Ramanathan 2011; Azam et al. 2012). This could be due to avalanche or may be wind driven effect in accumulation zone. Similarly in years 2006-07 and 2007-08 data show single pit for accumulation and there is no pit measurements for accumulation in 2005-06. Since there is no pit measurements (2005-06; MB -1.4 m w.e) or single pit for accumulation those years show surprisingly high negative mass balance values (2006-07; MB -1.3 m w.e; 2007-08; MB -0.93 m w.e) (Ramanathan 2011, Table 2.6, page 40). Unfortunately, this detailed figure 2.7 has not published or mentioned by Wagnon et al, (2007) or Azam et al. (2012) or Vincent et al. (2013) and therefore significant observations were not come out in scientific community. This figure also raise question on Chhota Shigri Glacier positive balance years (e.g. 2009-2010) due to this localized accumulation and show serious biases in mass balance observations (2002-2010).

Wagnon and Ramanathan have clarified the issues raised here by the reviewer in their short comment to our discussion paper. They also state that strong avalanche activity or large wind redistribution effects may be unlikely in Chhota Shigri.

4. Authors used different assumed datasets for flow line model without any justifications. See page 646, line 24: bedrock with constant slope of 0.1 and the highest elevation of the bedrock is 4525m. Similarly, page 647, line 4: Ice thicknesses assumed as 100m. Authors tried to explain discrepancy in ground based and geodetic mass balance with flow line model which is based on assumed datasets.

We have already provided the justification for our choice of bedrock slope and the highest elevation in our initial response (sect 4.2) and these details would be included in the revised manuscript/ supplementary material. We have also dis-

cussed in our initial response document, the sensitivity of our results if various assumptions are relaxed/altered, which would be included in the supplementary material.

5. Most important issue is related with scientific ethics. Authors used hospitality and other facilities from the GSI. However, unfortunately authors presented this paper without considering and understanding of 10 years ground based mass balance data collection by GSI.

The implied accusation that we have violated scientific ethics leaves us completely bewildered. It is not clear to us how exactly we have been scientifically unethical. We clarify again that one of the authors (Argha Banerjee) is collaborating with GSI on Hamtah glacier, but does not have access to their raw mass balance data, and he is not part of their mass balance measurement program. He was hosted in 2013 Hamtah glacier camp of GSI and has sincerely acknowledged the same. So while we would have loved to be able to understand the mass balance data in depth, we are simply not in a position to do so as we only have access to the data in the public domain.

Therefore, in the light of above points we believe that proposal of this paper is inappropriate and conceptually incorrect. Also encourage anyone to raise questions on results of any study conducted by different groups in same region and can provide erroneous message to scientific community

We do not agree with the view of the anonymous reviewer that this work is "inappropriate and conceptually incorrect". We have already provided our detailed arguments in the replies and author comments to justify our view.

Further, we believe that it is absolutely essential in science to critically analyse independent measurements of any quantity (by same/ similar/ different groups) whenever they differ significantly. So we can not agree to the concluding remark of the reviewer.