

## ***Interactive comment on “Mass gain of glaciers in Lahaul and Spiti region (North India) during the nineties revealed by in-situ and satellite geodetic measurements” by C. Vincent et al.***

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Vincent et al (2012) provide a rather cursory model of the Chhota Shigri Glacier mass balance for the 1990's and extend the results to the entire Spiti and Lahaul region. This paper adds little value to the fine study of this group (Azam et al, 2012). The author's title makes a key assertion that is not even supported in the abstract. The study does not utilize the majority of other area glacier studies, does not properly defend basic assumptions, discounts previous results without support and extrapolates without verification or well established procedure. The shortcomings are detailed below.

3734-7: The title of the paper states there is a mass gain of glacier in the Spiti and

C1961

Lahaul region in the 1990's. The abstracts notes that the gain for Chhota Shigri is deduced, not observed. The gain is -1.1 m, which is small enough to be in the error range cited of -1.5 m. The hypothesis of the title is not supported by this sentence.

3734-11: This sentence states that the observations indicate no large scale mass wastage until the last decade. This is not the same as a mass gain from the previous decade. Again the title belies the results.

3735-1: Why is there a generic list of global data references and not to the specific references that abound for glaciers in the area? See extensive list below.

3735-4: There are studies in the very study area that should be cited. See extensive list below.

3739-7: A uniform thinning of 5 m to 8 m at 91 points besides the very end of the glacier tongue is noted. How does this end up with a net thinning of 3.8 m? Why given this consistency is it assumed that there would be little or no change at higher elevations?

3739-17: The thickening here at the lowest 1% of the glacier does not seem to agree with either the recession observed or the photographs of the terminus from Kulkarni et al, (2007). How is this significant disparity accounted for?

3739-26: Is no change above 5100 m realistic? This might be correct but Bolch et al (2011) noted a significant thinning in the accumulation zone in the Khumbu Region.

3740-13: The noted error is -1.5 m greater than the net potential gain for the 1990's.

3741-6: The thickness changes are quite large across many glaciers in Figure 4. These changes are likely not due to just ablation during the interval of 1999-2010, and likely also reflect longer term dynamic changes, that have been underway. What is the case that dynamic thinning due to reduced flux was not underway prior to 1999 as is suggested by the terminus response, downwasting and area extent losses in the region, note Figure 6 (Bhambri and Bolch, 2009). Figure 4 does not allow an inference to be drawn about mass loss in the 1990's for the region.

C1962

3742-3: What are these studies?

3742-25: The inferred mass balance loss is not confirmed by the Azam et al (2012) change in state. It may be suggestive but given the response time of glacier flow to climate change a reduction in velocity at the various transects across the glacier would not have likely occurred rapidly do to a mass balance change in state that occurred after 1999. It is more likely that a change in velocity would be the result of a longer term trend in mass balance.

3743-13: Where is the evidence that Chhota Shigri is similar to the mass balance of other glaciers in the area? If it is a thinning pattern, where is the data on this? The range between glaciers and elevations needs to be examined.

3743-25: On what basis do you assume that the mass balance on the Hamtah, Dokriani and Dunagiri glacier do not adequately address the accumulation zone? This is a substantial assertion that cannot be made without documentation. It is worth noting that Chhota Shigri there are not measurements above 5100 meters either.

3427-28: The authors assert based on their geodetic measurements, which have large assumptions and substantial errors, that the rest of field based measurements in the region document mass balance losses that are too large. This maybe the case, but where is the detailed evidence that this is the case. The evidence must be able to explain discrepancy that exists.

3744-10: Figure 5 does not illustrate any kind of a strong agreement between the mass balance of area glaciers and Chhota Shigri. This graph does show that whenever we have mass balance series the cumulative record in every decade for are negative. This parallel the records of area extent losses and terminus change for the region, they are all consistently trending downward as well, note references below. The only exception is the deduced trend for Chhota Shigri. There is just not support for the statement

3744-13: The debris cover would reduce the speed of response of a glacier terminus

C1963

reach to climate change. Since Chhota Shigri has limited debris cover this would tend to make its response faster, yet it has been noted as the glacier responding the least to climate change (Bajracharya et al, 2008). The Parbati, Samudra Tapu and Bara Shigri are more heavily debris covered and are all noted as retreating faster than Chhota Shigri.

3744-27: The following studies in the Himachal Pradesh indicate that this sentence is not well supported by other data. The average rate of the Chhota Shigri Glacier snout recession increased from  $-7.5 \text{ m a}^{-1}$  from 1970-1989 to  $-27 \text{ m a}^{-1}$  during the 1989-2000. A comparative analysis of the Chhota Shigri Glacier between 1988 geomorphological and the 2000 Landsat image indicated a 12% glacier coverage decrease in the 13-year interval (Vohra, 2010). This is at odds with Vincent et al (2012) findings. For the Spiti Basin as a whole of the 337 glacier inventoried, 169 retreated during the 1962-2001 period with a 16% area loss, the area loss rate increased in the 2001-2007 period with 13% loss (Ramesh, 2011). The adjacent Sara Umaga Glacier has retreated at a rate of 44 meters/year from 1989-2004 (Kulkarni, 2005). The Hamtah Glacier, 10 km west lacks a debris cover and with its noted negative balance was been retreating at 17 m/year during the late 20th century. The Beas Kund Glacier 40 m west retreated 19 m/year during the late 20th century (Bahmbri and Bolch, 2009). The Malana Glacier 10 km southwest is a similar size and the terminus is relatively debris free, it has retreated at approximately 50 m/year (Pelto, 2012). The Samudra Tapu Glacier 30 km northeast had a total recession of 742 m with an average rate of 19.5 m/yr from 1962-2005. The glacier extent is reduced from 73 to 65 km<sup>2</sup> between 1962 and 2000, an overall deglaciation of 11% (Dhar et al, 2010). The Parbati glacier in the Parbati river basin, Kullu district, Himachal Pradesh is almost 52 m per year (Kulkarni et al., 2005). Kulkarni et al (2007) identify an areal extent loss of 21% in the Himachal Pradesh basins of Parbati, Baspa and Chenab overlapping the time period of the Vincent et al (2012) study. The fact that it is not just the termini that are retreating and downwasting is indicated by the number of glaciers separating, tributaries pulling away from valley tongues at elevations well above the terminus. Kulkarni et al. (2007) fur-

C1964

ther noted that the retreat was greatest for the smallest glaciers. This observation was also made by Bhambri and Bolch (2009) using Nagpo Tokpo Glacier as an example. This point is emphasized by Bajracharya et al (2008) for other regions of the Himalaya. The observation of significant downwastage of glacier termini and glacier area loss was consistent from Chhota Shigri, Patsio and Samudra Tapu Glaciers (Kulkarni et al, 2006).

In the nearby Garwahl region Dokriani Glacier between 1962 and 1995 was reduced by 20% in glacier volume and terminus retreat was 16.5 m/year (Dobhal et al., 2004). The cumulative mass balance of Dokriani Glacier during the 1990's was -2.5 m. Glaciers in the Saraswati/Alaknanda basin and upper Bhagirathi basin lost 5.7% and (3.3% of their area respectively, from 1968 to 2006 (Bhambri and Bolch, 2009). The Staopanth Glacier retreated 22.88 m from 1962-2006 and Bhagirathi Kharak 7.42 m (Kulkarni et al, 2007). These are both heavily debris covered glaciers that should respond to climate more slowly.

The largest glaciers in the region have been consistently retreating though at rates less than smaller glaciers. The area extent losses have been greater for smaller glaciers. In the Split and Lahaul area what do the authors offer as a rationale that Chhota Shigri Glacier response would be the same as that for the smaller glaciers?

Given the above there is a consistent signal of ongoing retreat and downwasting in the region, that does not support the author's conclusions. This does not mean that Chhota Shigri did not have a positive balance in the decade. However, there was no evidence presented that the retreat, volume and areal extent losses in the region halted during the 1990's, beyond Chhota Shigri. Further the Chhota Shigri data for the 1990's at least does not appear robust given other observations of the glacier in other studies.

Most of the area observations are of not of mass balance. Mass balance is not the same as terminus behavior or area loss. The terminus behavior and area losses typically lag the mass balance due to the response time or debris cover. However, on a

C1965

glacier the size of Chhota Shigri the mass balance over the span of a couple of decades is largely determinative of terminus behavior and area change. Terminus behavior and areal extent changes are driven by cumulative mass balance changes, and this signal is particularly clear on small glaciers lacking debris cover in this region. These glaciers in particular have been in rapid retreat and experienced rapid area loss. An examination of terminus behavior and areal extent changes in the region does not paint a supportive picture for the conclusions of Vincent et al (2012). This does not mean they are incorrect, rather it indicates much stronger evidence is required to address the other studies that indicate ongoing glacier losses in the 1990's regardless of the variable assessed.

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C1966

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