Reply to reviewer#3

This paper presents a thorough assessment of the products of the new Pléiades sensor for assessing glacier changes using photogrammetry at high spatial resolution. The authors test the performance of DEMs against in-situ field data for several glacier sites with strongly differing characteristics and provide conclusions on the accuracy with or without the availability of ground-control points. Whereas the paper is mainly focussed on the evaluation of the accuracy and the investigation of the potential of the new product for deriving glacier surface elevation changes at high spatial (and temporal) resolution, the authors also provide a few applications and demonstrate selected results of DEM differencing.

The present article convincingly shows the considerable potential of this new sensor for glaciological research. The paper is well written and addresses a wide range of open questions. Although there are a few issues – mainly related to possible limitations of the Pléiades DEMs – this study is highly welcome and should be accepted once the few critical points are answered.

General comments:

- The most important limitations of this sensor should be stated as prominently as the potential. For example, I consider the need for clear-sky conditions and the possible data voids in the accumulation area as critical factors that require more discussion.

> Our submitted MS did not clearly show the quality of the Pléiades DEM in the accumulation areas. This is now improved through two additional figures (see Fig. R4 and R5 at the end of our response to reviewer#1) and the revised text. So we do not consider this as a strong limitation of the sensor. Conversely, the need for clear sky condition is indeed a strong limitation. It is has been emphasized more clearly now, in the abstract and at the end of section 2.1 where Pléiades images are presented.

- Data voids can obviously not be avoided. But how are they treated if glacier-wide elevation changes are calculated? The authors should discuss their strategy (and the related uncertainties) for these applications as, in my understanding, a complete DEM is required to come up with a number for the volume change (be it seasonal or multiannual).

> Treatment of DEM data voids was indeed not addressed sufficiently in the submitted MS. Data voids in the DEMs are not filled by interpolation. Rather, and as in our previous studies (e.g., Berthier et al., 2010; Gardelle et al., 2012; Scambos et al., 2014), we made an hypsometric interpolation of the elevation changes. In other words, where no elevation change is available for a pixel, we assign to it the value of the mean elevation change of the altitude band it belongs to, in order to assess the mass balance over the whole glacier area. This assumption had only to be made for the 2003-2012 geodetic mass balance for the Mont-Blanc area as this is the only place where glacier-wide and region-wide averaging was performed. The MS has been amended to include those details.

- I do not have the impression that more results should be presented in the frame of this paper (as asked in one of the previous reviewer comments). It would blow up the content of

the paper too much. However, the results of the most relevant glaciological application (long-term mass change) should be validated also with other independent data sources. I know that this is a difficult task but at least for Argentière a mass balance monitoring programme exists (glaciological method) that covers the investigated period.

We agree about the need to keep the paper focused. Still, we added in Table 5 the geodetic mass balance for 10 selected glaciers in the Mont-Blanc area and the whole region. The cumulative glaciological mass balance for Argentière is also added in the Table for comparison, as requested. Discussing the glacier-to-glacier variability is however beyond the scope of this paper.

- Structure: I was troubled by the structure of section 2 which mixes up the presentation of in-situ field data for the individual study sites and the generation of Pléiades DEMs. It would be more logical to keep a clear separation between (1) field data, (2) DEM generation and (3) the comparison of the DEM products and the in-situ data (for georeferencing etc).

The structure of the paper has now been revised following the three reviewer suggestions.

Detailed comments:

- Page 4851, line 18: Surprisingly, the numbers for the mean mass balance of Mer de Glace and Argentière provided in the Abstract are more accurate than the results given in the body of the paper (see page 4865, line 28). The Results-section only yields a decimetre-accuracy and no specific value for each of the two glaciers.

In the abstract we now give the geodetic mass balance for the whole Mont-Blanc area. New table 5 lists the glacier-wide mass balances for the whole massif and for its 10 largest glaciers.

- Page 4854, line 8: This is an important statement which seems reasonable. However, can this advantage be shown / quantified / put into perspective somehow?

New Fig. R4 and R5 (see our response to reviewer#1) are here to confirm the quality of the DEM in the flat accumulation areas and the enlargement in Fig. R2 for Astrolabe Glacier is here to show that they are not texture-less at this sub-meter resolution. Regarding saturation we added a sentence to downplay our initial statement about no saturation. This is important for future users of Pléiades images: "*However, new Pléiades images acquired in northwest Himalaya in August 2014 contained a higher percentage of saturated pixels, sometimes over 10%. This is probably due to a high solar elevation angle in August at this relatively low latitude (~33°N). In such cases, specific acquisition parameters (i.e., lower number of TDI stages) may help to reduce the saturated areas*."

- Page 4858, line 12: It is assumed that the LiDAR DEM is 100% percent correct if GCPs are extracted directly from the LiDAR DEM. Is this true? If yes, it should be mentioned.

We mention now that errors in manually pointing a specific feature and in (x,y,z) positioning in the Lidar data affect the precision of the GCPs.

- Page 4860, line 6: How accurately can the "real" terrain elevation for a point location (GCP) be extracted from a DEM with 40m-resolution? I would assume considerable differences

between the grid cell elevation and a 1D-location just because of surface roughness within the cell.

Because of the coarse resolution of the SPOT5 DEM (40 m) we tried to select GCPs over flat terrain. But this is not always possible because flat areas have often also less prominent features. Thus it is true that the coarse resolution of the DEM and to a lesser extent of the image (2.5 m) is problematic. However, in this case we had no other alternative. Selecting a large number of GCPs (here 22) should somewhat help to minimize those resolution effects. The precision of the final Pléiades DEM (standard deviation of 1.02 m, see Table 4) is a confirmation that our procedure was successful. A short sentence was added in the MS: "*For Mera Glacier in Himalaya no accurate GCPs, i.e. measured in the field using static GNSS positioning, were available at the time of processing. Instead, a set of 22 GCPs was derived from a coarser resolution SPOT5 dataset (2.5-m ortho-image and 40-m DEM), previously co-registered to GNSS data acquired along the trails of the Everest base camp, outside of the Pléiades images (see Wagnon et al., 2013, for a complete description). Because of the coarse resolution of the DEM we tried as much as possible to select GCPs over flat terrain. The horizontal precision of these GCPs is limited by the SPOT5 pixel size (2.5 m) and their vertical precision is about ±5 m, the precision of the SPOT5 DEM*"

- Page 4863, line 8: firn compaction is probably less important in this case than snow compaction. It is mostly the winter snow (not yet to be called firn) that will be compacted over the summer season (with some contribution also from the underlying firn layers of course).

We agree with this comment. The importance of snow compaction (and, to a lesser extent, firn compaction) is now clarified.