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The Cryosphere
Discussions

Interactive comment on "The recent retreat of Mexican glaciers on Citlaltépetl Volcano detected using ASTER data" *by* J. Cortés-Ramos and H. Delgado-Granados

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Dear Dr. Andrew Klein,

The authors thank the anonymous referee for the useful comments to the present work. As it can be seen along this document, referee comments were useful to substantially improve this contribution. We find in his/her comments inspiration to pursue in the finding of the Equilibrium Line Altitude with a continuous effort from our working group.

Answers to specific comments and suggestions

1) "Glaciers of Citlaltépetl Volcano It would be important to specify if there is any in-

formation concerning the position of the Equilibrium Line Altitude (ELA) for this region. This information may be important if we consider that the value may have an important role in the interpretation of results."

A: The ELA in this region have not been studied in detail. Recently we are calculating the ELA by photogrammetric methods using air orthophotographs. However, it is difficult to decide the trace of an ELA on the glacier surface.

2) "3.2 Glacier mapping using ASTER P3155 L5-17 For the geometric correction of the ASTER images a SRTM Digital Elevation Model (90m resolution) was used. The horizontal Ground Control Points (GCP's) were obtained from panchromatic Landsat images (15m resolution) and 1:50000 scale maps. For this study the estimated horizontal error is Ìt' 40m. However it is not specified for this study if Digital Elevation Models were obtained from stereoscopic ASTER images (3N and 3B), in order to determine altitudinal position of the glacial front. If this is the case it would be important to specify what is the vertical error using this method. This is important taking into account that no elevation field measurements (DGPS) that have been undertaken. This may be relevant considering that the slopes of the study area are strong and that the base information for orthorectification incorporates an error source. The horizontal accuracy for SRTM model is 15m and vertical accuracy is 15-25 m (Toutin 2008)."

A: This study is based on the ASTER images as the main data for mapping and net radiation calculation. However, the thesis work of Cortés-Ramos (2009) shows how the ASTER DEM generated using the stereoscopy pairs from bands 3N and 3B have a strong distortion attributed to the topography of the volcano and the aspect of the surface to the satellite acquisition angle. The western and northern slopes are more affected for this geometry (see Cortés-Ramos, 2009). For this study we used a SRTM DEM for the orthorectification process however the altitude of the glacier front was calculated with a DEM at a scale 1:20,000, which could have altitude values every meter. All of above is referenced and short described into the new version of this paper tc-2012-69_new.pdf (supplements). The reference of Rabus et al. (2003) was also added in order to describe the accuracy of SRTM DEM.

3) "P3155 L8 Six images from 2001-2007 were geometrically corrected for the analysis, however it is not specified in which periods and dates the satellite images were obtained. This information can be important to note in order to evaluate if the images could be comparable or not."

A: Done (See Table 1 at supplementary material)

4) "P3155 L20-23 "The visual analysis can use other elements present in the image as textures, footprints, sites and locations, which are more difficult to classify in digital form" Considering a visual analysis can also be very useful to use ASTER stereoscopic capabilities applying photogrammetric techniques in order to visualize and to identify relief characteristics."

A: The ASTER stereoscopic pairs were obtained to generate the DEM at every scene. But the stereoscopic pairs were not used to delimiting the glacial cover. The ASTER scenes were chosen with a minimum snow cover and cloud free in order to ease the mapping of the ice bodies.

5) "3.3 Spatial distribution of the net radiation P3156 L24-25 If the accuracy of the method used is based on the geometric correction of images, it should be important take into account the comments section 3.2 (above). This information may be important if we consider that the value may have an important role in the interpretation of results."

A: The geometric corrections are based on the SRTM DEM and the Panchromatic Landsat image to get the ground control points for the orthorectification process. The effect of the estimated error in the two data sources is minimal as compared with the area and altitude changes. There should not be an effect on the areal distribution of the net radiation after the orthorectification process.

6) "4.1 Areal changes of Glaciar Norte P3159 L14-15 "Figure 2 shows the areal changes of the Glaciar Norte that extends, determined from ASTER images for 2001,

2003, 2005 and 2007." While years are mentioned, there are no specified dates for each ASTER images. Again, this information has to be verified to establish whether the images can be compared with each."

A: Done. (See Table 1 in the supplementary material)

7) "P3159 L22 – P3160 L8 According to Table 1 in the period between 2001 and 2007 (ASTER), the height difference of glacial front position is 85m. By averaging an annual change, regardless of the period 2002-2003 (3m), the variation is about 20m. According the observations mentioned in 3.2, errors and vertical accuracies obtained from the SRTM model and Digital Elevation Models from ASTER images can be several meters. Under this consideration, how realistic is it to make a comparison between heights considering that they were not used Ground Control Points with DGPS for the calibration? It would be important to specify in greater detail how these heights were obtained and what are the details in their estimation."

A: The altitudes of glacier fronts were obtained from the 1:20,000 DEM by photogrammetric methods using air photos. Then, the accuracy of this DEM (1m) is the support for this calculation. Snow sometimes is still present on the scenes, which could mask the real limits of the glacier, so there are variations on the glacier retreat as indicated in Table 2 for the period 2008-2010 (See Table 2 in supplements). In spite of that, our observations indicate that years such as 2010 have an increase of snow accumulation over the glacier surface provoking a possible advance of the glacier front.

8) "4.2 Surface: Distribution of net radiation P3161 L19-20 "The net radiation values for 2007 are in agreement with the values measured on the same day of the year by the Glaciar AWS" Where can we see this relationship?"

A: Done. (See tc-2012-69_new.pdf at supplements)

9) "5 Discussion P3162 L1-2 In order to get a better estimate of the year of disappearance of the glacier, Is there some information on the thickness of the glacier and the

rate of loss of thickness? It is recommended seeing (Ramirez et al. 2001)."

A: Thickness allows visualization of ice mass loss. According to Ramirez et al. (2001), the calculated volume from ice thickness and its variability with time allows to establish the ice loss pattern of the glacier. However, those measurements are not available. The physical parameters that can give an idea of the retreat pattern are the surface-area changes and the variation in altitude of the glacier front. Here, we determine a possible date for Glaciar Norte disappearance, but it is only based on the tendency of the glacial area and length changes.

10) "P3162 L24 – P3163 L1; P3163 L28 –P3164 L8 The strong ablation on the glacier surface is located principally at zones of low altitudes where the temperature effects are more visible. However it would be important evaluate the influence of precipitation according to the direction origin. It is recommended to see for example (Soruco et al. 2009) showing the effect of mean altitude, exposure and source of precipitation."

A: An evaluation on the use of NARR data is under way but cannot be included in this study because it has not been completed. By now, we thank the recommendation about the work of Soruco et al., 2009 that is useful for further work analyses.

11) "P3163 L19-22, "The ablation processes occur along the year, however in this work is not possible to conclude if ablation is more prevalent in one season than another." The glacier retreat depends largely on the mass balance for the analyzed period. Therefore this can also be a relevant factor in terms of their accumulation and the Equilibrium Line Altitude (ELA) position. In small glaciers at lower altitudes, in certain years, the ELA can rise causing an imbalance in the glacier causing strong ablation (Vuille et al. 2008)."

A: Our observations indicate that the glacier's surface is an ablation surface most of the year. The driest season determined by Ontiveros-González (2007) is characterized by low cloudiness, low temperatures and incidence of strong radiation on the surface. Also, observations show that melting is present in spite of low temperatures during this

season. During the rainy season melting can be present. It is needed mass balance data in order to determine the role of ablation. Unfortunately, mass balance data for Glaciar Norte and ELA position are not available so far.

12) "6 Conclusions P3165 L13-15 At this point is emphasized again the need to determine the ELA. Considering that studied glacier currently has an area less than 1 km2 it can be very sensitive. In some years, depending on the position of the ELA, the glacier may experience an imbalance."

A: See the answer for 1)

13) "Figures Figure 1 can be improved. It is recommended to focus the upper figure in order to obtain a better balanced figure as a whole. It would be desirable also to show the current glacier contour to get a visual idea of surface change occurred."

A: Done. (See Figure 1 attached)

Figure 1. Location of Citlaltépetl volcano and extent of its glaciers as documented in 1958 (Lorenzo, 1964; grey area) and 2007 (this work; contour in blue). Shaded relief of 1:20,000 DEM from SIGSA (Sistemas de Información Geográfica S. A.). MC: Mexico City; C: Citlaltépetl Volcano.

14) "Figure 2 can probably be improved by maintaining a single reference window where the peak of the volcano is centered. It could be used for example the window of Figure e). It is recommended to standardize the position of the graphic scale of the figure a) with the rest of the figures. For the figure 2, the figure caption should specify the exact date of each image acquisition."

A: Done. Also, see Figure 3.

Figure 2. Ice-coverage changes of Glaciar Norte between 2001 and 2007 obtained from ASTER images. Figure 2e shows changes of the glacier boundaries through that period. The ellipses make evident the glacial shrinkage. a) 20 October 2001; b) 3 February 2003; c) 23 November 2005; d) 18 March 2007.

Figure 3. Glacial shrinkage on Citlaltépetl Volcano from 1973 to 2010. Outlines from 1973, 1989, 1999, 2000, 2006, 2009 and 2010 were delimited using Landsat data of the sensors MSS and ETM+. The rest of the outlines are from ASTER data (Figure 2).

15) "It is recommended as a complementary reference (Sicart et al. 2008)"

A: Done.

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Please also note the supplement to this comment:
http://www.the-cryosphere-discuss.net/6/C2033/2012/tcd-6-C2033-2012-supplement.zip

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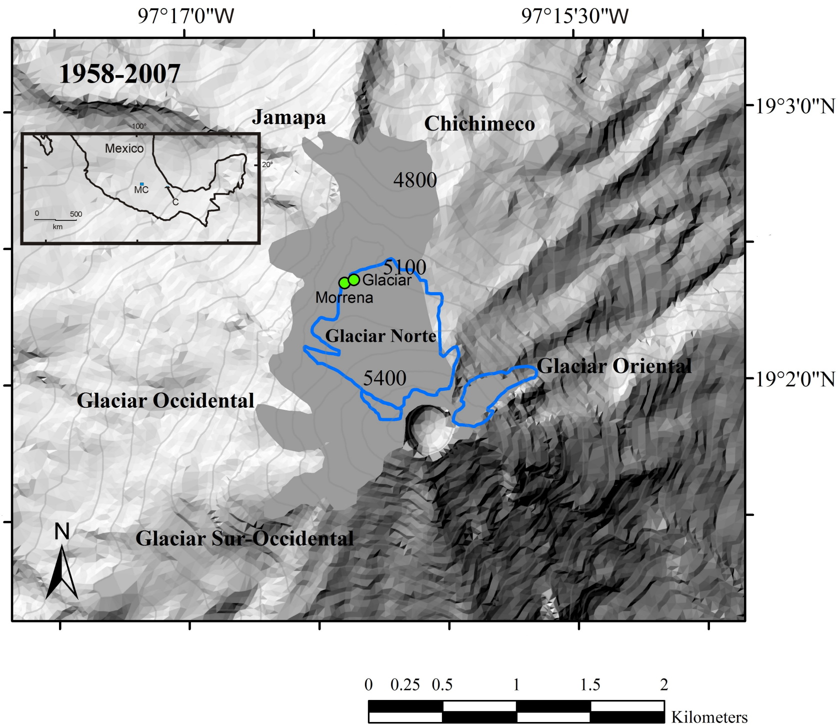
Interactive comment on The Cryosphere Discuss., 6, 3149, 2012.



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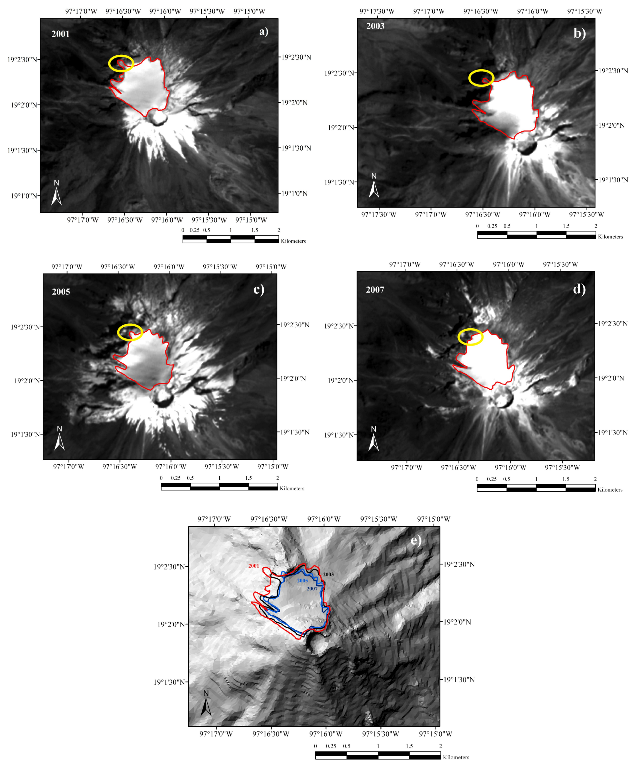

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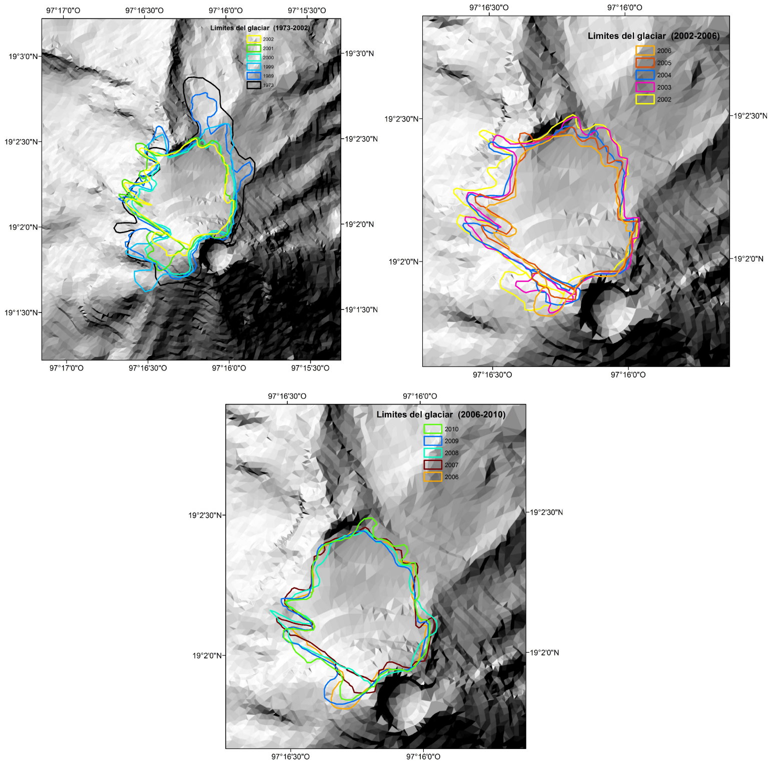

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