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Glacier control and hazard prevention during de last eruptive period of Popocatépetl volcano (Mexico).

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Popocatépetl (19º03'N, 98º35'W; 5424 m) is one of the great active stratovolcanoes in the Trasmexican Volcanic Belt. A glacier located on its north side has undergone severe ablation since the volcano reinitiated eruptive activity in December 1994. The major pyroclastic events -falls in April 1995 and July 1997, and flows in January 2001- provoked rapid fusion of the glacier and triggered the formation of massive mud and block flows called lahars. These flows pose a serious threat to nearby settlements. Popocatepetl is only 70 km from Mexico City with a population of over 20 million inhabitants.

An important step in the prevention of catastrophes caused by lahars formed on Popocatepetl is the quantification of the variations in the glacier mass. Our study calculates the extent of the glacier recession and the loss in mass during the most recent period of eruptive activity (1994-2003). It offers new data and updates methods proposed by Huggel and Delgado (2000), Julio and Delgado (2003) and Tanarro, Zamorano and Palacios (2004 y 2005).

Direct control and monitoring of the glacier is impossible during periods of volcanic activity, so observations are made using aerial photographs of the volcano from the Secretariat of Communications and Transport (SCT) of the Mexican government. Digital and analytic treatment of the photographs assist in surveying the spatial-temporal changes in the glacier's surface and thickness.

Twenty photographs from the SCT collection were selected for the study. Two were taken before the eruptive phase, November 1982 and May 1989, and rest represent a range of dates selected according to availability, quality, distortion...: November 17, 1997; April 13, 1998; June 8, 1998; December 2 1998, January 2, 1999; June 20, 1999; October 14, 1999; November 4, 2000; January 20, 2001; March 15, 2001; April 6, 2001; August 20, 2001; June 17, 2002; September 17, 2002; December 2002, February 13, 2003; July 21, 2003; and August 25, 2003.

The terminus of the glacier was mapped for each of the dates using conventional photo interpretation. In order to compare all of the perimeters, however, geometric restitution of the photographs and maps was necessary, since the images were distorted and the scales varied. The ArcGis georeferencing tool provided accurate rectification of the x-y coordinates. Since access to the study area is prohibited when there is volcanic activity, we had no ground coordinates obtained from fieldwork, so we had to assign 13 UTM control points to known locations on an orthophoto published by the INEGI (1982), scale 1:20,000. The conversion was accomplished using a third order polynominal function that produced an average median standard deviation of 3-7 meters. To complete the procedure, measurements were taken of the areas covered by glacier, the extent of the glacier retreat and the rates of reduction in the glacier surface, for each date.

The images from aerial photographs dated November 17, 1997; December 2, 1998; June 20, 1999; November 4, 2000; March 15, 2001; June 17, 2002; December 2002; and February 13, 2, were clear enough to obtain information for 3-dimensional modeling. A Vexcel 5000 scanner reproduced a 21 micra resolution image for each photograph and *Photopol* software was used to complete the digital restitution. The overall process produced results within a 2 m margin of error.

Correction to a scale of 1:5,000 with 10 m equidistant contour lines was used to create TINs and DEMs in raster format. This information allowed us to determine volumetric changes for each pair of dates using *InRoads* and *SelectCAD (INTERGRAPH)* based on TINs; *TCP-IT* for *AutoCad* for contour gridding, TIN and transversal profile differences; and *ArcGis* from DEMs in raster format.

By using these procedures, we were able to monitor the existing glacier surface and the ice mass. It also provided easy access to information on the amount of water available if a laharic event were to take place. This information is very useful in calculating the magnitude of the largest of any lahars that might form.

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