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Morphological changes of the crater in the Tungurahua volcano, Ecuador, from 2002 to 2016: Implications for volcanic hazards

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Tungurahua (5023 m) is an active andesitic stratovolcano, located in the Eastern Cordillera of the Main Volcanic Arc of the Ecuadorian Andes. After eight decades of quiescence, this volcano started a new period of activity in 1999 and lasted until 2016. It was characterized by phases of inactivity and low-high explosive activity, as well as various eruptive styles, processes, and products. Its major eruption took place in August 2006 reaching a VEI 3 causing six deaths and major economical loses in the region. Throughout the recent eruptive period, this symmetrical stratovolcano which hosts a crater on its summit has suffered important morphological changes. By using aerial visual and thermal imaging acquired between 2002 and 2016 we focus our study on making a qualitative and quantitative analysis of possible spatio-temporal changes in the morphology of the crater and its thermal assembly during the different eruptive phases. All over this eruptive period, the crater showed a series of shape changes, modifications of its structure, and the development of an internal crater, a pyroclastic semi-cone and a volcanic terrace. The morphological changes observed in the crater are subjected to (1) pre-eruptive conditions (e.g. pre-existing topography), (2) constructive and destructive syn-eruptive mechanisms (e.g. eruption styles, dispersion and deposition of volcanic material, obstruction and release of the conduit, collapse or evacuation of material), and (3) post-eruptive weathering and erosion (e.g. gravitational landslides, erosion by water). Since decades ago, the initial geometry of the northwestern notch shape border of the external crater has channeled the emplacement of pyroclastic density currents towards the northern, northwestern, western and southwestern flanks of the volcano and potentially towards some populated areas. Only 3 lava flows were emitted toward the north-western flank. The involved risk has increased with the current configuration of the crater, which is characterized by an internal crater adhered to the north-western margin of the external crater, in which both craters share the same border. This configuration could facilitate the easy withdrawal and propagation of volcanic flows. On the other hand, the internal growth of the crater, where the pyroclasts were deposited and accumulated, mostly on the western side, could generate a non-uniform pressure distribution in the crater, higher on the western rim, threatening the stability of the edifice and thus increasing the possibility of a sectorial collapse. The results of this research show the importance of the use and applications given by thermal and visual images in geomorphology and volcanic monitoring, as well as its importance in the generation of useful information to improve the conceptual and numerical models in volcanology.