Open and closed system eruptive dynamics at Tungurahua volcano constrained by SO2 emission rate and seismo-acoustic intensity measurements

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The current eruptive period of Tungurahua volcano (Ecuador) began in 1999 with multiple episodes of explosive activity that have threatened the local population. The monitoring network has been continuously improved in order to better understand the eruptive behavior of Tungurahua and eventually provide early warning to the population. We obtain SO2 gas emission measurements from a network of four permanent NOVAC stations located between 7 and 11 km from the volcano, covering the preferential directions of winds in the area. Seismic and acoustic energies were calculated for explosions using a seismo-acoustic network composed of five broad band seismic stations coupled to infrasonic sensors installed at distances between 5-7 km from the vent. Furthermore, we derive tremor amplitudes from a short period seismic station, situated at about 2 km from the crater.

Since December 2009, five well-defined eruptive phases lasting from 21 to 70 days and following 82 to 181 days of quiescence have been recognized. Besides, between November 2011 and September 2012 a succession of short explosive and/or ash emission phases also took place. Activity is characterized by strombolian and vulcanian eruptive styles. In five occasions, pyroclastic flows were generated by sustained lava fountains or triggered by discrete explosive events. Ash fallouts were common to these eruptions and had low to significant impact on the nearby populations, depending on the duration and intensity of the eruptions.

During the eruptive phases no clear correlations were found between observed SO2 mass emission rates, seismic and acoustic energy of the explosions and the tremor amplitude. However, in a few cases some patterns related to different eruptive dynamics can be identified. We identify and characterize two end-members, which correspond to open and closed system degassing. In the first case, observed SO2 emission rates increase a few days before any significant change in tremor amplitude and any explosive activity appear. A clear example of this behavior is the eruptive period between December 2009 and March 2010, where the SO2 measurements increased 4 days before a change was evident in the seismic amplitude of tremor and 9 days before the occurrence of the first explosions. This suggests open system dynamics where gases are easily released throughout the entire eruptive phase. In the closed-system end member, the increase in SO2 degassing occurs simultaneously with the increase of tremor and/or explosive activity. An example of this activity took place in May 2010, when almost no SO2 was detected by the DOAS stations before a vulcanian explosion, with associated pyroclastic flows, partially opened the system allowing gas escape.

In this work, we present observational evidence of these mechanisms which are used to identify possible patterns of evolution of the activity, contributing to a more effective volcanic hazard assessment.