Geophysical Research Abstracts
Vol. 18, EGU2016-8350, 2016
EGU General Assembly 2016

Insights into the dynamics of the Nyiragongo lava lake level

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Nyiragongo volcano, in North Kivu, Democratic Republic of Congo, is among the most active volcanoes in Africa and on Earth. Since the first European observations in the late 19th Century, its eruptive activity mostly concentrated into its main crater, with the presence of a persistent lava lake from at least 1928 to 1977 and since 2002. The size, shape and elevation of this lava lake have evolved through time, modifying the topography of the main crater. In January 1977 and 2002, the uppermost magmatic system of Nyiragongo, including the lava lake, was drained during flank eruptions. These flank events caused major disasters, mostly due to the exceptionally fast-moving lava flows and the presence of a dense population living at foot of this volcano. Despite a large scientific interest and societal concern, the study of the eruptive activity of Nyiragongo remains limited by climate and vegetation conditions that, most of the time, limit use of satellite remote sensing techniques, and recurrent armed conflicts in the Kivu region, which sometimes prevent field access to the main crater. Here we focus on the dynamics of the Nyiragongo lava lake level and its relationship with the volcanic plumbing system by describing the historical and recent lava lake activity and presenting new quantitative observations using close-range photogrammetry, a Stereographic Time-Lapse Camera (STLC) system and high-resolution satellite SAR and InSAR remote sensing. Results highlight that, contrary to the interpretation found in some recent publications, the lava lake drainages appear to be the consequence and not the cause of the 1977 and 2002 flank eruptions. Two types of short-term lava lake level variations are observed. The first one corresponds to cyclic metre-scale variations attributed to gas piston activity. The STLC data recorded in September 2011 show hour-scale gas piston cycles reaching up to 3.8 m, which are interpreted to be related to gas accumulation and release in the lava lake itself. The second type of variations corresponds to sporadic decametre-scale level rises or falls, which are related to major pressure changes in the upper magmatic system and may be responsible for topographic changes or ground deformation in the main crater. Such type of lava lake level variations was measured in June 2011, September-October 2011 and March 2012. Synchronously with the end of the large 2011-2012 eruption of the neighbouring Nyamulagira shield volcano, in March-April 2012, the long-term overall rise of the lava lake level since 2002 reverted to gradual drainage of the level continuing at least to July 2014. Since November 2014, a persistent lava lake also developed in the central caldera of Nyamulagira.