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Ground deformation and lava accumulation measurements in volcanic craters using UAS image acquisitions and 4D photogrammetry

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Unmanned Aerial Systems for image acquisition have revolutionized the study and monitoring of volcanic activity where field access is complex or impossible. Through a series of 3 examples in the Virunga Volcanic Province (Eastern Democratic Republic of Congo), the present work shows how times-series of photogrammetric products (i.e. point clouds, digital elevation models and orthophotos) allow the detection, quantification and interpretation of topographic changes associated with ground deformation, lava accumulation and erosion processes in volcanic craters. All these case studies of applied 4D photogrammetry also illustrate the solutions found to compensate the lack of ground control points and adapt the image acquisition strategies to the complexity of such a tropical volcanic environment.

The two first examples focus on the summit crater of Nyiragongo. (1) The low level of the Nyiragongo's persistent lava lake observed during the 2012-2015 period was accompanied with the subsidence of the surrounding platform and the appearance of ring fissures. This subsidence was also detected using SAR interferometry. The modelling of that subsidence points towards a shallow source associated with the 2002-2012 accumulation of lava in the crater due to lava lake overflows. (2) On February 29, 2016, at the same time as the rise of the lava lake level, a new eruptive vent developed east of the lava lake, producing lava flows that accumulated in the crater and, for some of them, felt into the lava lake. From March 2016 to March 2018, at least 10.5 106 m3 of lava accumulated in the Nyiragongo crater, according to the comparison of digital elevation models. This volume corresponds to half of the lava flow volume emitted during the last disastrous flank eruption of the volcano, in January 2002.

The final example concerns Nyamulagira volcano, where the collapse and enlargement of the pit crater located in the summit caldera was followed by the appearance of lava fountains in April and June-September 2014, and the development of a new intermittent lava lake activity starting from November 2014. From June 2014 to October 2018, about 19 106 m3 of lava accumulated in the pit crater. This summit activity at Nyamulagira seems to have inhibited the occurrence of flank eruptions, which used to occur every 1-4 years between 1938 and 2012.