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Conduit pressurization pulses at Stromboli volcano revealed by the ground-based InSAR monitoring system

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At Stromboli volcano (Southern Italy), only few minor precursors (gas output) have been identified for 'major' Strombolian explosions. We use ground-based interferometric synthetic aperture radar (GBInSAR) technology to monitor the displacement rate of the summit area of Stromboli. We analysed the 2009–2011 period. We analysed three major explosion-dominated periods: March–May 2009, November 2009–January 2010 and June–September 2011.

The analysis of the displacement rate has been performed by dividing the summit zone monitored by the GBInSAR into three regions, corresponding to the edge of the craters area (1 and 2), and to the slope of the NE crater (3, Figs 1b and 3). Sector 3 is generally decorrelated in interferograms spanning more than 12 h due to the fast accumulation and remobilization of ejecta. During the three analysed anomalous periods, sector 3 is characterized by higher coherence and hence the increase in the displacement rate has been measured. Short-term interferograms (11 min) are used to measure the syn-explosive displacement and also to locate fast lava flows in sector 3, which are easily visible due to the high loss of coherence compared with the surrounding area. The ability of InSAR to measure volcano deformation depends on the persistence of phase coherence over appropriate time intervals on various types of volcanic deposits. Loss in coherence depends on chaotic ground movements (e.g. debris avalanches) while higher coherence is related to coherent displacements.

An increase in the displacement of sector 3 has been observed since 20 March 2009, when the deformation pattern changed and the coherence of the radar image of that zone increased from low values (rolling of incoherent material on the cone slope) to values higher than >0.8 (coherence threshold). The deforming area was very localized and stable in its extent, involving approximately 15 × 103 m2 of the NE cone base. The maximum displacement rate was reached on the 27 March 2009 (0.35 mm h–1), 2 days before the lava outflow from the summit craters (29 March), but the displacement rate of the summit area remained high for the following 2 months, with peaks on 3 April (0.27 mm h–1), 14 April (0.3 mm h–1), 3 May (0.25 mm h–1) and 22 May (0.23 mm h–1). The peak of 3 May corresponds to the displacement related to the major explosion that also was observed in sectors 1 and 2.

Displacement rates during the November 2009–January 2010 period were subject to a higher degree of variation than March–May 2009, with some peaks in correspondence with the major explosions and others, which occurred some days before them. In particular, an increase in displacement rate was observed starting from 2 November 2009 (0.56 mm h–1) that ended with the explosion of 8 November (0.6 mm h–1). Similar trends have been observed in the periods between (i) 19 and 23 November (0.25–0.3 mm h–1), (ii) 20 and 28 December (0.25–0.29 mm h–1), (iii) 6 and 9 January (0.24–0.29 mm h–1) and finally, (iv) 16 and 20 January 2010 (0.2–0.3 mm h–1). The GBInSAR revealed that displacements in sectors 1 and 2 occurred only during the 8 November 2009, 24 November 2009 and 21 January 2010 major explosions.

Analysing the data before 20 June 2011, an increase in the displacement rate has been detected in sector 3 in the period 9–18 May. Displacements have been observed during the night between 8 and 9 May, with an increase in the displacement rate at the base of the NE crater area up to 0.38 mm h–1. The displacement rate reached its peak during the early morning of 10 May and then gradually decreased. The GBInSAR revealed displacements in the crater area (sectors 1 and 2) only during the 20 June and 5 July explosions. The occurrence of the 1–2 August 2011 lava flow from the NE cone on the SdF and its subsequent remobilization, promoting small-scale instability on the SdF, has also been recognized.

Pulses of rapid expansion of sector 3, of variable duration and amplitude, appear in coincidence with periods of intense activity that include lava flows and major explosions. We associate this expansion with the pressurization of the magma column that is recharged by deep-derived gas, promoting the onset of 'major explosion-dominated' activity.