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Fibre optic Distributed Acoustic Sensing of volcanic events at Mt Etna

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We explore a unique dataset collected by Distributed Acoustic Sensing (DAS) technology at the summit of Etna volcano in September 2018. We set-up an iDAS interrogator (Silixa) inside the Observatory Pizzi Deneri to record strain rate signals along a 1.3 km-long fibre optic cable deployed in Piano delle Concazze. This area is affected by several North-South trending faults and fractures, that are originated to accommodate the extension of the nearby North-East Rift zone, where magmatic intrusions often occur. The field evidence of the segments of these faults and fractures is hidden by lava flows and volcano-clastic deposits (e.g. scoria and lapilli) produced by the effusive and explosive activity of Etna volcano.

We propose a new technological and methodological framework to validate, identify and characterize volcano-related dynamic strain changes at an unprecedented high spatial (2 m) and temporal (1 kHz) sampling over a broad frequency range. The DAS record analysis and the validation of the iDAS response is performed through comparisons with measurements from a dense network of conventional sensors (comprising 5 broadband seismometers, 15 short-period geophone and two arrays of 3 infrasound sensors) deployed along the fibre optic cable. Comparisons between iDAS signals and dynamic strain changes estimated from the broadband seismic array shows an excellent agreement, thus demonstrating for the first time the capability of DAS technology in sensing seismic waves generated by volcanic events.

The frequent and diverse Etna activity during the acquisition period (30 August - 16 September 2018) offers the great opportunity to record a wide variety of signals and, hence, to test the response of iDAS to several volcanic processes (e.g. volcanic tremor, explosions, strombolian activity, local seismic events). Here, we focus the analysis on the signals recorded during a small explosive event on 5 September 2018 from the New South-East Crater (NSEC). This explosive event generated both seismic waves (recorded by the seismometers) propagating in the ground, and acoustic pressure signals (recorded by the infra-sound arrays) propagating in the atmosphere. We show that the DAS records catch both, as confirmed by the conventional sensors records.

Spectrogram analyses of the DAS signals reveal that the frequency content is confined in two distinctive frequency bands in the ranges 0.5-10 Hz and 18-25 Hz, for the seismic and acoustic

wave, respectively. The amplitude and frequency response of the ground to the arrival and propagation of the seismo-acoustic wave along the fibre reveal spatial characteristic patterns that reflect local geological structures. For example, the finer spatial sampling of the iDAS records allows catching details of the variability of dynamic strain amplitudes along the fibre. Amplified signals are found at localized narrow regions matching fracture zones and faults. There, a decrease in the propagation velocity of the seismo-acoustic waves is also clearly pinpointed.

These preliminary findings demonstrate the DAS potentiality to revolutionize the study of volcanic process by discovering new signal features undetectable with traditional sensors and methodologies.