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Quantitative analysis of Very-Long-Period (VLP) seismicity at Etna during summer 2005

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Very Long Period (VLP) and Long-Period (LP) signals are commonly observed on active volcanoes, and reflect the elastic response of the plumbing system to pressure perturbations associated with mass transport processes. Their detection and analysis represents therefore a crucial step toward the quantification of mass budget during either quiescent or eruptive stages. In this work we present results from a detailed analysis of VLP recordings obtained at Etna Volcano, Italy, during the Summer 2005. Our data include stations from both the permanent, broadband monitoring network, and a temporary array which was specifically deployed with the purpose of tightening the coverage of the summit volcano area. During the analysed time interval, the most characteristic seismicity was associated with (i) weak VLP ($T \sim 20$ s) pulses, dominated by rectilinear motion radially oriented toward the source; and (ii) LP ($T{\sim}0.5$ s) signals, depicting a complex polarisation pattern dominated by either radial or transverse motion. Both classes of signals occurred at a sustained rate of 4-10 events/hour. We began our analyses by applying an automatic signal detection procedure based upon STA/LTA triggering of the time series of the 3-component principal eigenvalue. Repetition of this procedure over different frequency bands allowed discrimination of VLP, LP and Volcano-Tectonic (VT) signals. For this dataset, we found that VLP pulses generally occur in association with LP signals, according to a delay time of maximum $\pm$ 20 s and an amplitude ratio of about 1:20. Using back-projection of the polarisation vectors estimated at the summit stations, we locate the VLP source some 1000 m beneath the summit (Bocca Grande - Voragine) craters. For this position, we calculate the

Green's functions at the stations of both the permanent and temporary networks using a three-dimensional discrete elastic lattice method. We then performed a Moment Tensor decomposition of the VLP source using a frequency-domain, full-waveform inversion of the broad-band ground displacement recordings. The error affecting the source time function derived from the inversion are estimated by calculating the variance of the observed spectra using different noise recordings. The amplitude ratios of the principal axes of the moment tensor derived from these latter measurements are 1:1.1:2.4. Assuming a Poisson ratio n = 1/3 at the source, then Lamè's elastic parameters satisfy the relationship $\lambda = 2\mu$, and our results may thus be viewed as approximating those for a crack. Under this hypothesis, and assuming μ in the 7-10 Gpa range, then the volumetric change associated with our VLP events is on the order of 460-660 m^3. In agreement with previous studies on VLP activity at basaltic volcanoes, these data are interpreted in terms of the volumetric changes of the conduit walls in response to the ascent of a slug of gas. Together with the volumetric source are single forces with a magnitude of $1*10^8$ N, which can be interpreted in terms of pressure fluctuations associated with the migration of a slug of gas in the conduit. Note that a single-force component must have an amplitude of approximately 10^{-3} N to excite signals whose amplitudes are comparable to the signals excited by a moment-tensor component of 1 Nm. Since the seismic moment associated with the maximum peak-to-trough amplitudes is on the order of about $4*10^{12}$Nm, then the force observed contributes roughly 2.5% of the signal amplitude relative to the contribution from the moment tensor. The time histories of the single forces depict however an asynchronous behaviour, which is at present difficult to interpret. Although further tests are needed to better elucidate stability and robustness of our inversions, this study represents the first attempt of quantitative analysis of VLP source at Etna, and opens the way to the establishment of automatic procedures aiming at the real-time evaluation of volumetric changes due to unstable mass flow throughout the shallow plumbing system.