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Array analysis of volcanic tremor during the July-August 2011 lava fountain activities occurred on Etna Volcano.

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This work focuses on the analysis of volcanic tremor recorded at Etna between July and August 2011, when a succession of six paroxysmal episodes occurred from a new vent opened at the base of the South East Crater (SEC).
The volcanic tremor has become a key tool for volcanic surveillance at Etna. Remarkable increments in the amplitude of tremor were observed during the paroxysmal phases of the July-August 2011 activity, namely Strombolian activity and lava fountains. During July and August 2011, a small-aperture (ca. 100-150 m), broadband seismic antenna was deployed on the South flanks of the volcano, at distances of about 1 km SW of the South East Crater. We first conducted spectral and coherence analyses on the data from the array, in order to identify the most significant frequency bands for the subsequent filtering procedures. These analyses indicate that significant wavefield coherence is maintained throughout a tremor frequency band spanning the 0.5-1.5 Hz range. For this particular frequency band, the propagation azimuth and apparent velocity of the incoming wavefronts were retrieved by inverting the inter-station delay times for the two cartesian components of the slowness vector, under a plane-wave approximation.
We performed the analysis over short (10 s) data windows spanning the complete set of tremor recordings and thus obtaining continuously 44-day-long time-series of propagation parameters for tremor waves recorded by the array. Throughout the analysed time interval, the distribution of the propagation parameters changes significantly in correspondence of the lava fountaining episodes. In particular, the propagation azimuth, which is clustered over the 160°-180° angular range during the quiescent periods between the paroxysmal phases, turns anticlockwise 2/4 hours before the volcanic tremor amplitude increases, pointing to the South East Crater zone (around 200°-220°). The paroxysmal phase of each fountaining episode is marked by a further widening of the range of propagation azimuths, which evidences the contribution in the wavefield of the eruptive fracture located at the base of the South East Crater (around 230°).
The most representative values of ray parameter are in the 0.6-1 s/km range, corresponding to apparent velocities between 1 and 1.6 km/s; these values are consistent with a wavefield composed by both surface and body-waves impinging at the array with shallow incidence angles.
While the depth of the tremor source remain stable throughout the quiescent time intervals when the amplitude of the volcanic tremor increases, at the beginning of the volcanic activity, the source get progressively shallower. Afterwards, since the onset of paroxysmal phase of the lava fountain activity, the tremor source deepens again, until it returns to the level it was during the quiescent period.
These results evidence the ability of the multi-channel techniques to track precisely the location of active magmatic fluids, thus offering a valuable support to volcano monitoring activities.