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Shallow crustal structure of Solfatara volcano from seismic noise analysis

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We combined results from several methodologies applied to seismological, volcanological and structural data from in-situ measurements with the aim to extract as much information as possible for the detailed definition of the shallow crustal structure of Solfatara crater.
First we analyzed background microtremor data recorded by 5 seismic circular arrays, sampling different areas of the crater volcano, in April 2007 during a seismic survey.
The frequency peaks of the H/V curves were found analysing the 1-hour-long samples of seismic noise daily recorded by 5 representative stations. A map of the resonance frequencies and peak amplitudes was obtained by using an inverse-distance-to-a-power gridding method that interpolates the H/V data. Frequency values relative to the different sampled sites range from 3.6 to 7 Hz.
We used three different methods to estimate the dispersion curves of Rayleigh waves propagating through the arrays: the Frequency–Wavenumber (f-k) technique, the Spatial Autocorrelation (SPAC) technique and the Modified Spatial Autocorrelation (MSPAC) technique. The dispersion curves obtained from the 3 methods are comparable. The phase velocity ranges from 100 m/s at high frequency to about 1000 m/s at frequency of 2 Hz. Since the MSPAC curves are affected by smaller errors, they were chosen to be inverted for the S-wave velocity model, jointly with the corresponding H/V peak frequency. We used the neighborhood algorithm carried out by Wathelet et al. (2008) to obtained 1-D velocity model underneath each array. To check the robustness of the obtained models we analyzed the influence of the number of layers and of the half space depth on the inversion procedure. By applying a Montecarlo algorithm, we checked the significance of the superficial depth differences and then we used the 5 obtained S-waves velocity models to infer a 3-D model for the Solfatara volcano. We applied a kriging gridding method to combine the velocity values in the volume below the 5 arrays and organized a velocity map for all the velocity discontinuities encountered.
With the aim to reconstruct the structure of the Solfarata edifice and hence to constrain the geophysical interpretation of the 3-D velocity model, a volcanological and structural survey was carried out in October 2009. It was preceded by a photo aerial analysis and interpretation. We measured a total of 330 attitudes of fault planes and fractures in 7 sites, both inside and outside the Solfatara crater, in different lithotypes at variable stratigraphic height.
The high density of the seismic deployment, the large number of the sampled sites and the joint interpretation of the results with data from the meso-structural survey, and with the geological information available for the volcano allowed us to obtain a realistic 3-D shallow crustal structure.
Finally we took inspiration from the recent observation of Rigano et al. (2008) that the direction of microtremor polarization is somewhat controlled by the presence of faults (although the influence of the faults on the polarization of earthquake ground motion has been found by many authors and has been explained in term of a waveguide mechanism) and investigated the polarization properties of the seismic noise. We applied the covariance matrix method and estimated the following parameters: rectilinearity, azimuth of the polarization vector and incidence angle. Finally me investigated the possible correlation with the orientation of the faults cutting the volcano.