Acquisition of seismic noise at Solfatara Volcano for the determination of the shallow crustal structure

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In the period 2-6 April 2007 a seismic survey was carried out at Solfatara Volcano, with the aim of inferring the shallow structure and evaluating local site effects. Seismic noise was recorded by five circular seismic arrays deployed in different areas of the crater. The geometry was designed in order to obtain also a sub-configuration consisting of two profiles oriented in the N-S and E-W directions. An other seismic station was installed at the crater outer rim for a hardrock reference.
Surface wave dispersion will be obtained by using array techniques, such as the spatial correlation method (SPAC) of Aki (1957) and its recent modifications (MSPAC, Bettig et al, 2001; CCA, Cho et al., 2004). The shear-wave velocity models will be inferred for each array from the inversion of the dispersion curves. Moreover experimental site transfer functions will be evaluated for each station, both using Nakamura's technique and reference site spectral ratio method.
The high density of the deployment and the large number of the sampled sites will allow to obtain a detailed shallow velocity structure and to map resonance frequencies and amplifications values in different areas of the crater.

The deployment

One seismic station (TSFT) was installed on the crater outer rim and set in continuous acquisition mode, while five circular seismic arrays (A, B, C, D and E) were deployed in the Solfatara crater. Each array consisted of 4 sensors, 3 of them evenly spaced (120°) around the circumference and the fourth placed at its center. Arrays A, B and D were designed with radii of 5, 10, 25, 50 and 100 m. Arrays C and E had radii of 5, 10, 25 m. Moreover, some stations of the arrays shaped two orthogonal profiles of about 250-m-length, roughly oriented in the N-S and E-W directions. About 1-hour of seismic noise was recorded for each circular configuration with fixed radius.

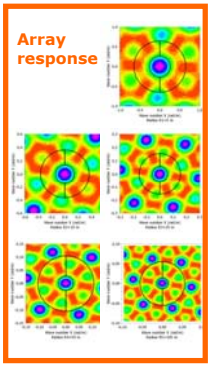
The instruments

5 sesimic stations Lennartz MarsLite
5 three-component 1-Hz Mark LE3Dlite seismometers
2 GeoXT Trimble GPS receivers
The most part of the seismometers was buried in approximately 20 cm deep holes. The sensors DR51 and AR52, located near the fumarolic field, and all the geophones of the array B were not buried due to the high temperature reached by the soil in those areas. The coordinates were measured using GPS positioning.

The methodologies

The particular geometry of the deployment was chosen to apply the spatial autocorrelation technique (Aki, 1957) and its modifications (Bettig et al., 2001, Cho et al., 2004), to the data recorded by each array, in order to estimate surface wave dispersion curves and to infer shear-wave velocity models for different areas of the crater. Further information about the shallow structure will come from the application of Nakamura's technique (1989) to microtremor recorded at each sampled site. The two orthogonal profiles oriented N-S and E-W will be useful to map possible variations of the resonance frequencies and amplification values, along the two main directions cutting the crater.
The level of the local seismic noise will be evaluated comparing the array recordings with those of the reference station TSFT, located outside the crater. This station will also be used as reference station in the application of the spectral ratio technique.

Array response

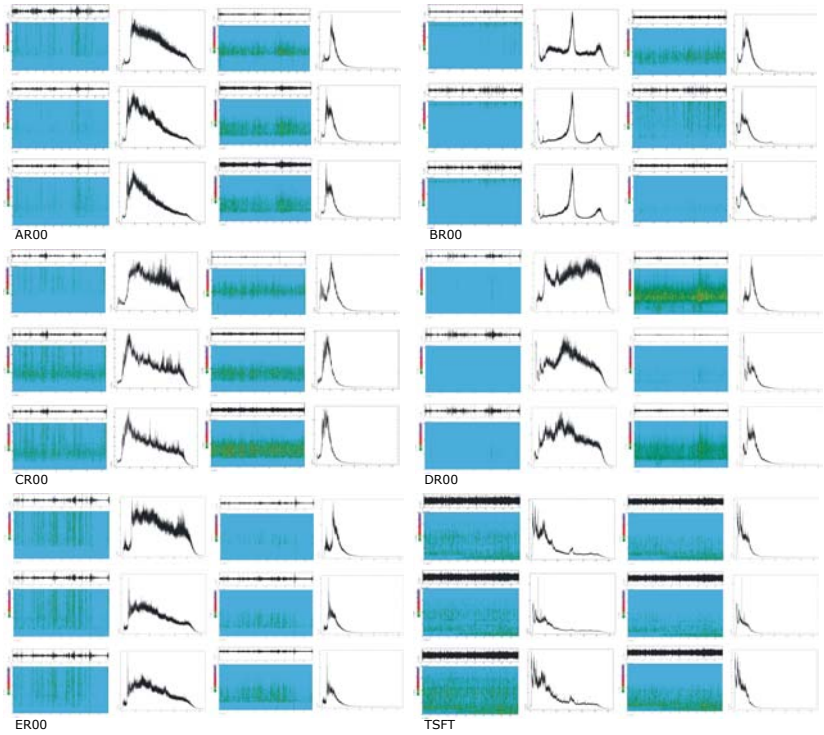


Preliminary data analysis

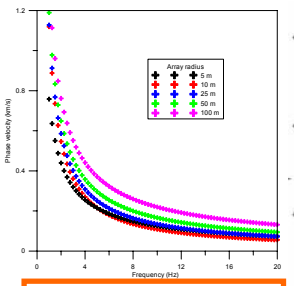
A preliminary spectral analysis was performed on about 1-hour of microtremor recorded by the central stations of each array and for the reference station TSFT.
The spectra evidence some high frequency noise (> 10 Hz) due to the presence of the numerous tourists walking in the field. Moreover, recordings of the array B are affected by a low frequency peak (< 1 Hz) due to the strong wind occurred during that day, and a high frequency peak at about 28 Hz probably due to the wind-induced vibrations of some nearby objects. Seismic noise recorded by the station TSFT, which thanks to its position was not affected by the noise produced by nearby walking people, is characterized by a lower spectral content, mainly comprised in the 1-10 Hz frequency range. Spectral analysis was repeated after filtering the seismograms below 10 Hz, to further investigate the spectral properties in the frequency range that will be used for the seismological analysis. The filtered signals recorded at the station AR00 installed approximately at the center of the crater, show a spectral peak on the vertical component at about 8 Hz and a maximum at about 5 Hz on the horizontal components. The same pattern is observed at the station BR00, located in the area of the mud-pool. The station CR00, located in the Northern area, shows a slightly higher frequency content, being the main spectral peak on the vertical component at 10 Hz, while peaks on the horizontal components appear between 5 and 10 Hz. In the Eastern part, near the fumarolic field, spectral peaks at 2 and 8 Hz are observed in the seismic noise recorded by the station DR00. Finally the station ER00, located at the West, shows amplitude peaks spread in the 5-10 Hz band. The spectral content of the 10-Hz-low-pass filtered microtremor recorded at the stations located in the crater are quite different from those observed at the reference station TSFT, installed on the outer rim. Actually, TSTF spectra evidence a lower frequency content, with main peaks at a 2.5 and 1 Hz.

The spatial autocorrelation technique (SPAC) was applied to the data recorded by the array A and the preliminary phase velocity dispersion curves were obtained for each radius. The results indicates phase velocities ranging from 1.2 to 0.2 km/s in the 1-20 frequency band.

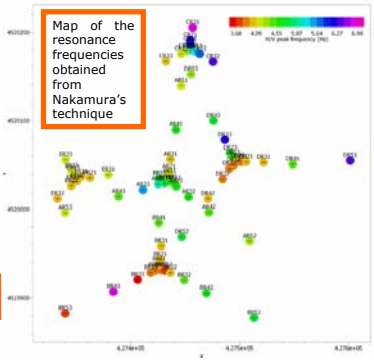
Finally, the preliminary results obtained from the application of Nakamura spectral ratio technique show some differences in the resonance frequency values. In particular, higher values are observed for those stations (CR11, CR21, CR31, CR32, DR51) located closer to the crater border.



Spectral analysis of the seismic noise recorded at the central stations of each array and at the reference station TSFT. In each plot, from the top to the bottom: vertical, N-S and E-W component. From the left to the right: unfiltered spectrogram, unfiltered spectrum, filtered spectrogram and filtered spectrum.



Dispersion curves obtained from SPAC technique applied to the array A.



Map of the resonance frequencies obtained from Nakamura's technique

Conclusions

The results of the preliminary analyses of some samples of seismic noise recorded at Solfatara Volcano suggest to get more insights in the wavefield properties in order to exclude external disturbances due both to the antropic activity and to the unfavourable weather condition. However, these first results are already indicative of differences both in the spectral content of the microtremor and in the resonance frequencies in different areas of the crater. These differences could be due both to the presence of horizontal velocity contrasts and to variations of the thicknesses of the shallower layers.
Both array and single station techniques will be applied to the whole data set in order to better define the crustal structure of the volcano, to investigate about the presence (or not) of lateral heterogeneities and to estimate local site effects.
The results of this new experiment will also be interpreted in terms of some unsolved issues concerning the Solfatara site transfer function (Petrosino et al., 2006).

References

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