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Site-specific characteristics of the observed ground motions are considered important for the estimation of seismic design parameters in engineering applications. Seismological observations have indicated that effects of surface geology and geometry (e.g. sedimentary valleys, topography) significantly contribute to ground-motion amplification and variability. These effects are generally associated with a substantial proportion of surface waves in the seismic wave field, largely caused by lateral variation of material properties of the site. Among them, the surface waves diffracted by the basin edges contribute significantly to ground-motion amplification and variability. Understanding of the seismic wave field crossing the site, hence, is the key aspect to characterize and quantify these effects. However, this task remains technically challenging due to the complexity of such effects as well as the limitations of geophysical investigations, especially in case of small-size sedimentary valleys.

Studies investigating the properties of the wave field have shown that seismic arrays are very useful to characterize the fine-scale structure of Earth’s interior and the variations of the material properties. A single seismometer is unable to determine both velocity and direction of the incident seismic waves while arrays of seismic sensors enable us to study the phase delays that normally cannot be identified in seismograms of single stations. Yet, a one-dimensional (1D) seismic array can only determine the component of the wave vector, which lies in the array direction. Therefore, two-dimensional (2D) arrays are needed to retrieve the back-azimuth and velocity of the incoming waves.

This study presents the results obtained from the analysis of the seismic wavefield composition of two 2D dense seismic arrays, deployed during the seismological experiment held at the small-size, shallow alluvial valley of Koutavos-Argostoli in the Cephalonia Island of Greece, under the framework of 2010-2014 FP7 EU-NERA (Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation) project (Imtiaz, 2015; Imtiaz et al., 2017). The principal dense array was positioned close to the center of the valley and consisted of 21 velocimeters in concentric circles with radii of 5 m, 15 m, 40 m and 80 m around the reference station. Another smaller array (Array B) was deployed near the one edge and consisted of 10 velocimeters with interstation distances ranging from 5 to 60 meters. A set of 46 earthquakes, with magnitude 2 to 5 and epicentral distance up to 200 km was analyzed.

Among the various available array techniques, the MUSIQUE algorithm (Hobiger et al., 2012) was used to analyze the selected events. It combines the MUSIC (MUltiple SIgnal Characterization) (Schmidt, 1986) and quaternion-MUSIC (Miron et al., 2006) algorithms and offers an advanced three-component (3C) seismic array processing technique. In addition to the estimation of the apparent velocity and direction of the dominant incoming waves, MUSIQUE allows identification of Love and Rayleigh waves, and estimation of the polarization parameters (i.e., ellipticity and sense of rotation) of the Rayleigh wave particle motion.

The results clearly indicate a predominance of scattered surface waves (40-60% of total energy), mainly from the closest edges, beyond the fundamental frequency (~1.5 Hz) of the valley. Love waves dominate the low-frequency wave field (1.5 - 3 Hz) while Rayleigh waves strongly dominate only in relatively narrow bands at higher frequencies. Within particular frequency bands, an excellent consistency was observed among the dominance of the identified surface wave type, group velocities estimated from the ground velocity structure, and site amplification in terms of the Standard Spectral Ratio. For both arrays, amplification observed between 1 and 2.5 Hz, 3 and 6 Hz frequencies could be associated, respectively, with the diffracted Love and Rayleigh waves. The findings provide an exciting opportunity to advance our knowledge in understanding the physical causes lying behind the spatial variation of earthquake ground motion and multi-dimensional site effects.

References

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