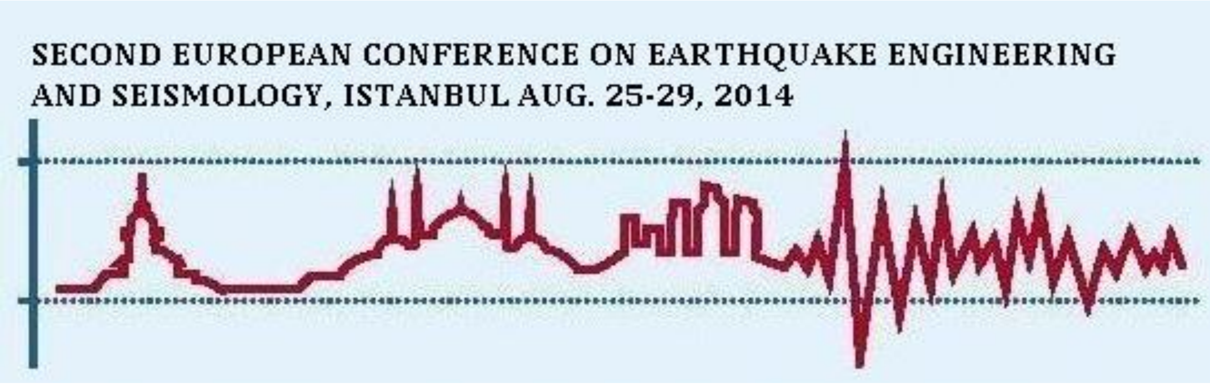


# THE ARGOSTOLI (CEPHALONIA, GREECE) EXPERIMENT

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The complexities of the effects of subsurface geometry on seismic ground motion, combined with the limitations of both geophysical investigation techniques and numerical simulation, made it impossible till now to include them in earthquake hazard assessment and risk mitigation policies. One of the goal of the JRA1 work package (Waveform modeling and site coefficients for basin response and topography) of the FP7 EU-NERA 2010-2014 project (Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation) was then to quantify the amplifications of ground-shaking produced by basin structures through experimental data and modeling, with the aim to establish scientifically solid and practically acceptable propositions to incorporate basin effects in seismic design (Bard et al., 2014).

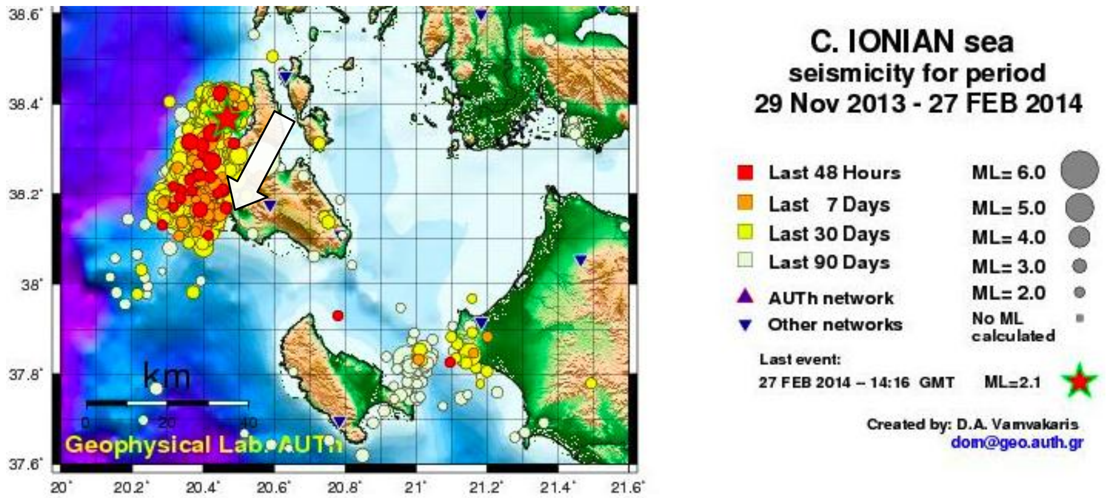


**Figure 1.** Seismicity of the broader area of Cephalonia island from November 29, 2013, to February 27, 2014. The plot shows the seismic sequence (January 26 to February 3, 2014) to the west part of the island. The arrow indicates the Koutavos-Argostoli experiment site.

For such purposes, the (1.5 x 2.2) km$^2$ small-size shallow sedimentary basin of Argostoli (Cephalonia island, Greece) has been chosen as test site. The seismicity of the Cephalonia area is the

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highest in Europe: in 1953 Argostoli and the majority of the villages on the island was completely destroyed by a sequence of destructive shocks, the largest of which occurred on August 12 (M7.2) at an epicentral distance less than 20 km from Argostoli. Another large magnitude event (M7.0) occurred on January 17, 1983, at an epicentral distance of about 35 km, with low damage impact on the village. The most recent seismic sequence stroke the island with two major earthquakes of M6.1 and M6.0, on January 26 and February 3, 2014, respectively, having epicenters on the western part of the island and followed by an ongoing seismic sequence (Figure 1).

From September 2011 to April 2012, 62 seismological stations were deployed in the Koutavos-Argostoli basin, and 2 additional distant sites have been instrumented to improve the hypocentral locations of the earthquakes recorded during the experiment. Stations were distributed along two profiles (parallel and transversal to the major axis of the valley); the one crossing the basin had inter-station distance of about 50 meters, and included two very dense arrays (minimum inter-station distance of 5 meters) located close to the edge and in the center (Figure 2). Their continuous recordings have been loaded on the EIDA portal (www.orfeus-eu.org/eida/eida.html) and are nowadays restricted to the NERA partners. In addition, specific geophysical (single-station noise, passive and active surface waves measurements) and geological surveys have been performed to constrain the basin geometry and the wave-velocity structure. Other investigations have been performed within the SINAPS project (founded by French research Agency ANR) and their results were made available to NERA under a specific formal agreement. Finally, INGV and SINAPS teams installed 11 stations to record the ongoing seismic sequence following the two 2014 shocks in close cooperation with the NERA work package NA4 (Networking European rapid response networks).

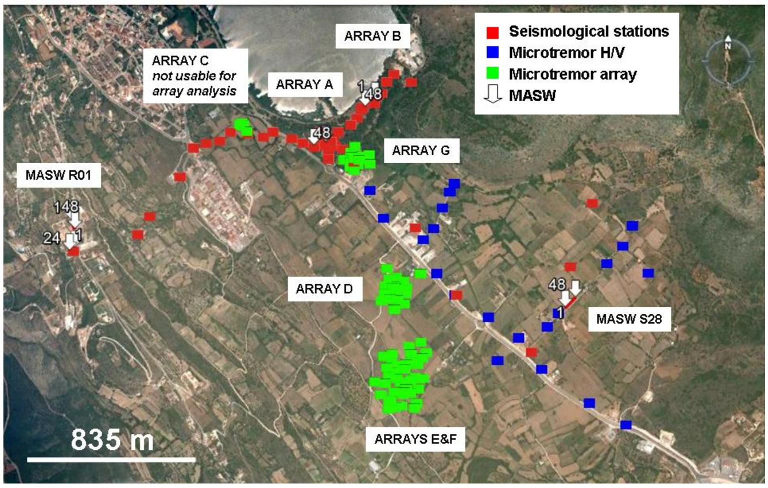


Figure 2. Experiment setting with stations and geophysical measurements location. A few (8) accelerometers has been collocated with velocimeters in selected stations.

More than 700 local, regional and teleseismic earthquakes have been recorded during the seven-month experiment, including large worldwide events ($M_w$ 7.2 Van earthquake on October 23, 2011; $M_w$ 7.4 Mexico earthquake on March 20, 2012; $M_w$ 8.6 and $M_w$ 8.0 Sumatra earthquakes on April 11, 2012): 461 of them have been re-localized using the local network and the local crustal velocity model. For the remaining 258 earthquakes, mainly regional and a few teleseismic, the best location solutions have been taken either from the Hellenic Unified Seismographic Network or from EMSC.

We selected 164 events that have been recorded by more than 20 stations of the experiment with good signal-to-noise ratio: they represent the initial data-set for the analysis on seismic ground motion. The objectives of the study are focused on the investigation of the complexity of the effects of subsurface geometry: i) site effect estimation from earthquake and noise measurements and link with underground structure; ii) study of the spatial variability in terms of seismic wave-field composition and spatial coherence, and their correlation with velocity structure and diffracted wave-field; iii) within event variability; iv) 2D-3D amplification model ("aggravation factor").

The horizontal spectral ratio (FFT on earthquake) with respect to the reference station (SSR) and to vertical component (HVSR) revealed large multidimensional site effects inside the basin (amplification from 5 to 10 over the 1.5-8 Hz frequency range) together with a large spatial variability of ground motion within few tens of meters (Figure 3). The first resonance frequency of SSR varies from 3-4 Hz at the basin edges to 1.8 Hz in the central part, where the maximum amplification is in the direction transverse to the axis valley (50°E-140°W); other peaks are present at 4 and 6 Hz. For HVSR only the first resonance frequency is visible and the maximum is found in the 160°E-20°W direction.

The Multiple Signal Characterization array analysis performed on the same data-set allowed the extraction of apparent phase velocity, back azimuth and polarization of Rayleigh and Love surface waves propagating through the central array (Imtiaz et al., 2014). Their results clearly indicate a significant scattering corresponding to 2D or 3D effects beyond the fundamental frequency (1.8 Hz) of the basin, coming primarily from the southwest of the basin. The scattered waves are mainly Rayleigh and Love waves, with a significantly higher proportion of Love waves contributing to the first resonance peak and Rayleigh waves for the other peaks.

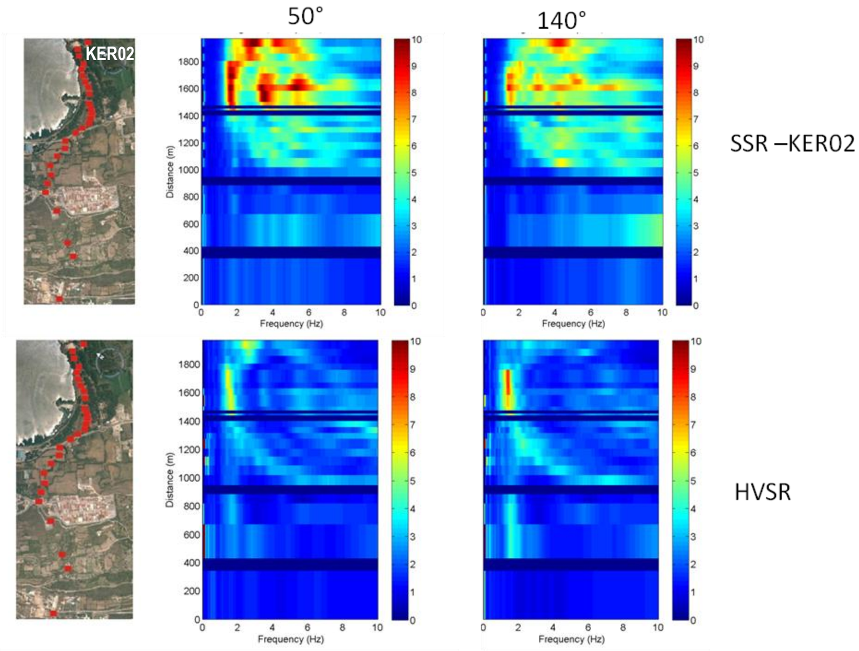


**Figure 3**. Mean SSR (respect to the reference station KER02) and HVSR along the transverse (N50°) and the parallel (N140°) directions to the valley. The average has been performed on a subset of 35 events, with homogeneous azimuth distribution in the local magnitude range of 2 to 5 and with epicentral distance < 200 km.

To link these findings to the local structure of the basin, a tentative characterization of its seismic properties has been performed using the results from the geological and geophysical surveys (Boxberger et al., 2014). The study of the relationship between wave-field composition and basin structure, together with the analysis of new recordings from the 2014 seismic sequence, will give further insights on the physics of the seismic propagation in the Koutavos-Argostoli basin.

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