NERA

Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation

Report

[Array Measurements]

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Activity number:	*WP11, Task 11.4*
Deliverable:	*Array Measurements*
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Responsible activity leader:	*CNRS, P-Y. Bard*
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Seventh Framework Programme
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Summary

The aim of this Task is to present the seismological data and some preliminary empirical results related to two deployed specific arrays; (a) the Argostoli seismological array and (b) the Fucino seismological array. Both experiment arrays provided high quality data that along with corresponding geological and geophysical measurements may serve to critical evaluation of site effects and basin effects. In addition, work on modelling of basin effects may be significantly benefited by the observed acquired in both sites. Given that the analyses of the data obtained during the aforementioned experimental arrays will be performed in close link with activity of NERA-JRA3, the following goals are set:

- ✓ To investigate the link between ground motion spatial variability, strains, seismic wavefield and subsurface properties
- ✓ To compare numerical estimates of ground strain with actual measurements
- ✓ To investigate the capability of estimating ground strains from noise correlation studies.

In order to organize and accomplish the work according to the initial schedule, several meetings (actual or/and Skype) among the participants took place during the 2nd year of the NERA-JRA1 project. Minutes of these meetings are given in Appendices 1, 2, 3 and 4.

1. Introduction

During the last four decades the effects of surface and subsurface geometry on seismic ground motion have been clearly recognized and have been the topic of many instrumental and numerical investigations. In addition, their complexity, combined with the limitations of both geophysical investigation techniques and 2D/3D numerical simulation, made it impossible till now to include such effects in earthquake hazard assessment and risk mitigation policies. As a consequence, it is well known that the vast majority of building codes do not include any provision for basin and surface topography effects.

From experimental point of view, numerous instrumental recordings have been obtained in various valley and mountainous areas (especially Italy, Greece, Switzerland, France), with temporary as well as permanent instrumentations, while developments in data processing techniques now allow to recover experimental site transfer functions even without local reference stations. Special attention was dedicated also to dense array measurements and processing techniques giving rise to a detailed analysis of the wave-field and its evolution with time during earthquake recordings. However, such experimental sites including detailed geophysical and detailed geological work can be hardly found. To sufficiently cover this shortcoming it was decided during the first year of the NERA-JRA1 project (see Deliverable D11.1) to deploy special arrays in two European sites; one in Argostoli, Kefalonia-Greece and another in Fucino-Italy. In addition, for this two sites a series of geological and geophysical investigations was carried out (see Deliverable D11.3) to contribute to further data analyses.

In this report, the Argostoli and Fucino experiments, that took place during the period 15/9/2011 to 20/4/2012 and 24/4/2012-19/9/2012, respectively, are described. The data acquired during both experiments are presented, some preliminary data analysis is given and future work to be done is discussed.

2. Argostoli Array & Seismological Experiment

2.1. Introduction

The town of Argostoli is situated in the western Greece, on the Cephalonia island, in the Ionian sea (Figs. 1, 2). A relatively small size alluvium valley has been formed close by the town of Argostoli which was selected during the first year of the project as one possible test site for array deployment.

Fig. 1. The town of Argostoli, Cephalonia island, in western Greece.

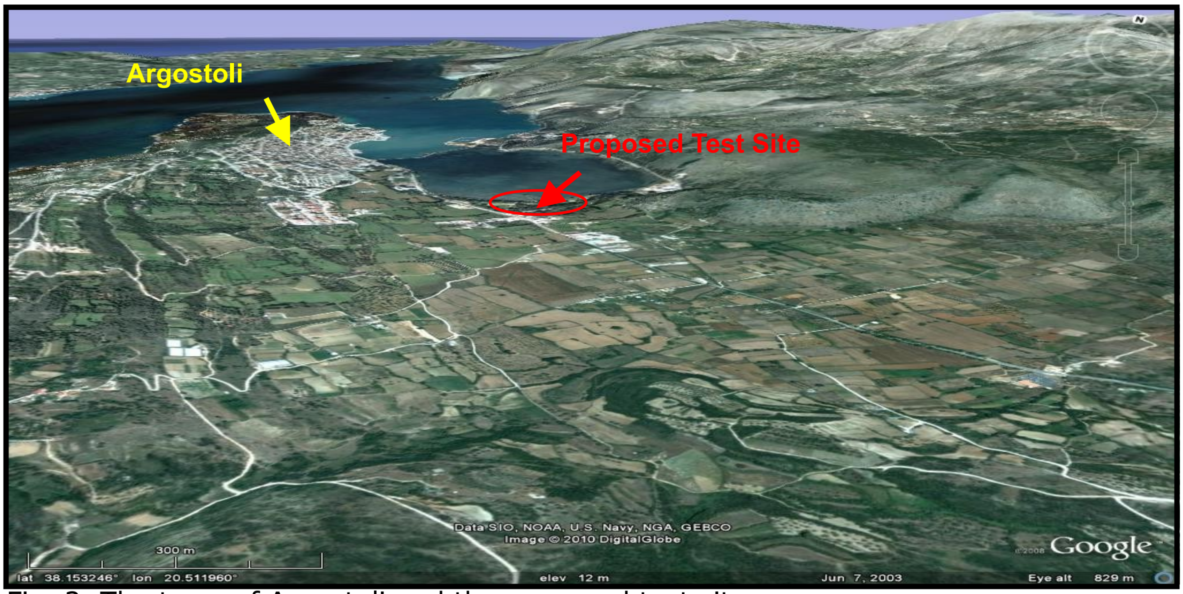


Fig. 2. The town of Argostoli and the proposed test site.

2.2. Seismotectonic Information

Argostoli was completely destroyed by a sequence of destructive shocks, the largest of which occurred on 12 August 1953 with M7.2, at an epicentral distance less than 20km from the town. Another large magnitude event, M7.0, occurred on 17 January 1983, at an epicentral distance of about 30km, with low damage impact on Argostoli.

The island of Cephalonia, falls in the northwesternmost boundary of the Aegean plate that is dominated by the Cephalonia Transform Fault (CTF in Fig. 3) (Scordilis et l., 1985). The slip direction of the CTF, N213°, is in agreement with a southwestwards motion of the Aegean. The rate of seismic slip in the CTF is ~3cm/year, the highest observed in the whole Aegean area (Papazachos and Kiratzi, 1996).

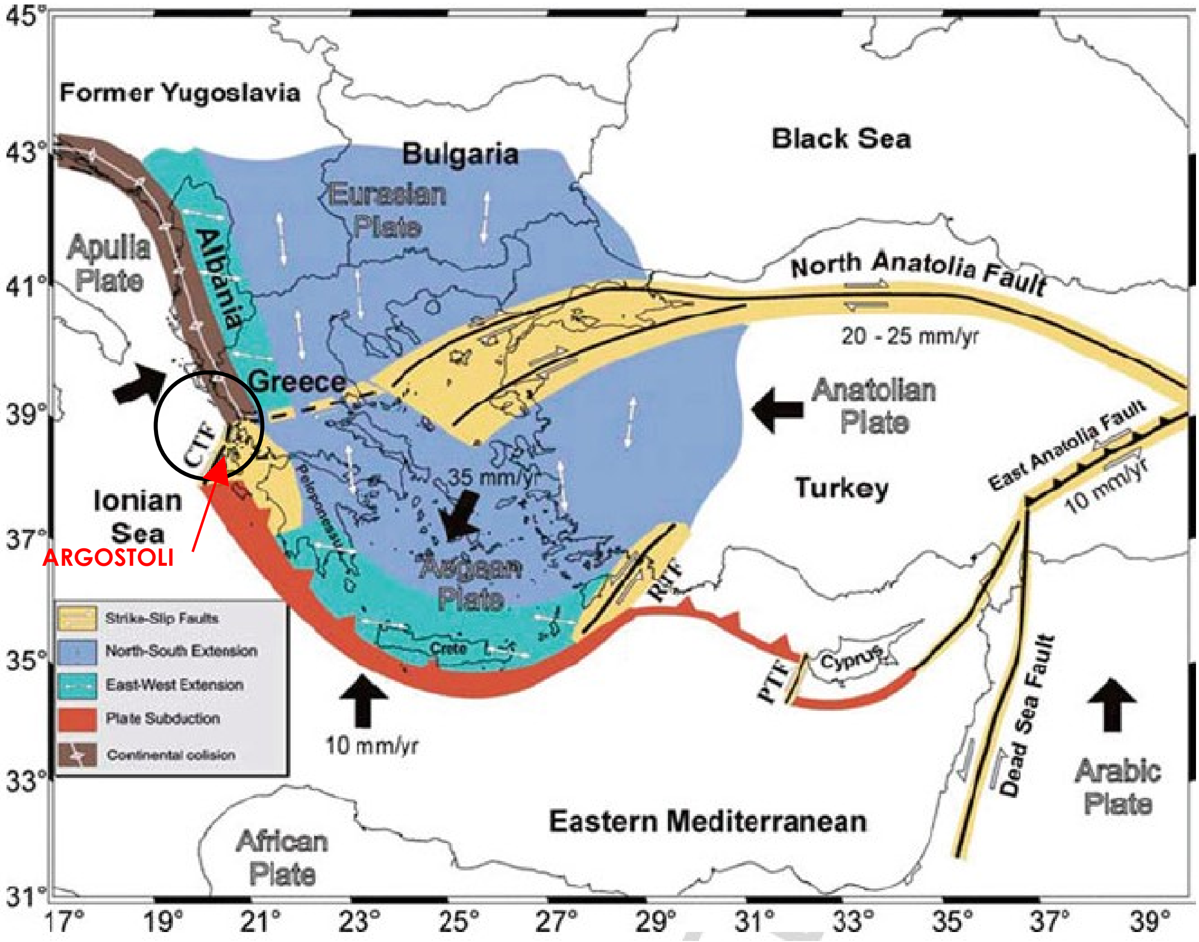


Fig. 3. Plate motions that affect active tectonics in the Aegean and surrounding area (Papazachos et al., 1997).

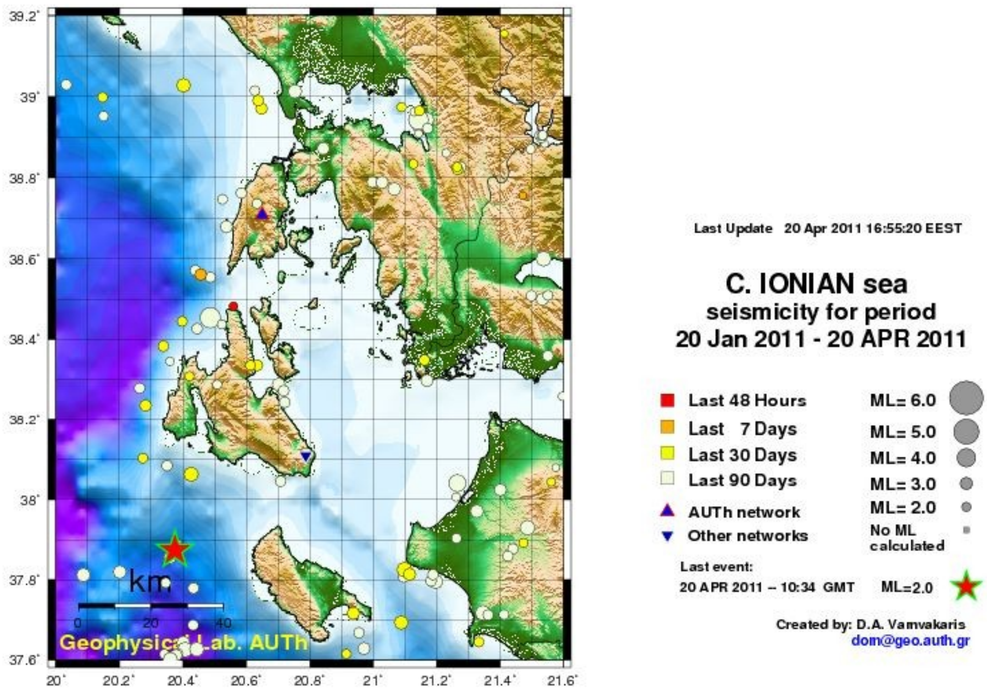


Fig. 4. Seismicity of Greece (preliminary location of epicentres) during 3 months in the vicinity of Argostoli, Kefalonia, Ionian Sea.

The seismicity of the broader Argostoli, Cephalonia area is the highest in Greece. In Figure 4 a preliminary 3 months seismicity map before the set up of the experiment, is given.

2.3. Array of Argostoli and Data Acquired

2.3.1. Past Relevant Work

In late 1990's a project coordinated by National Technical University of Athens was set up by installing in the center of the Argostoli valley a 3D borehole array. This array was operated by NTU for several years and led –among others – to the work of Protopapa et al. (1998). A proposed NE-SW cross section of the valley is presented in Fig. 5.

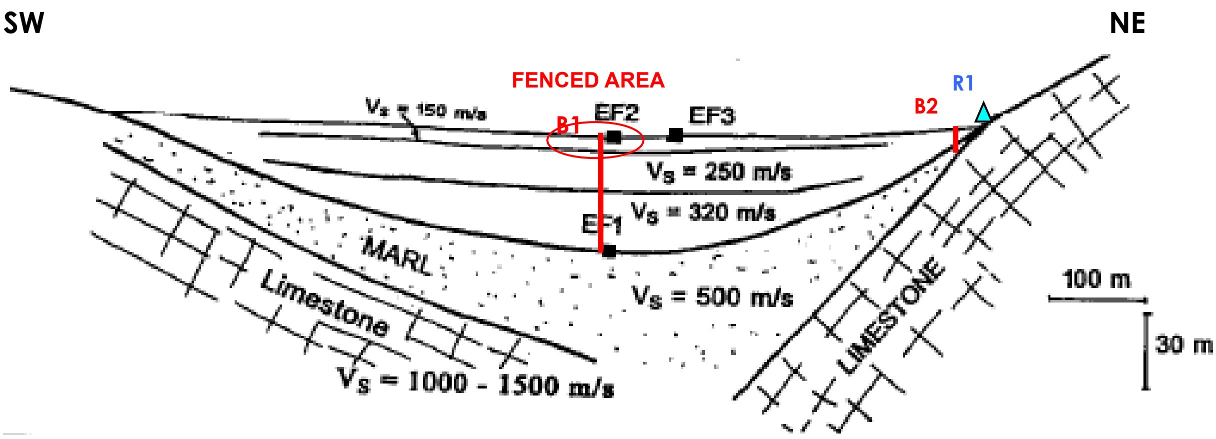


Fig. 5. Proposed cross section 2D model of the Argostoli valley (Protopapa et al. 1998)

In the center of the valley (point B1 of Fig. 5), before the set up of the recent array experiment several hours of ambient noise measurements was performed and the Horizontal to Vertical Spectral Ratio, H/V, was estimated. This H/V spectral ratio showed a clear peak at 1.8Hz with an amplitude around 5. Thus, the fundamental frequency of the valley can be considered to be around 1.8Hz and the H/V spectral ratio showed a high stability in time (Fig. 6).

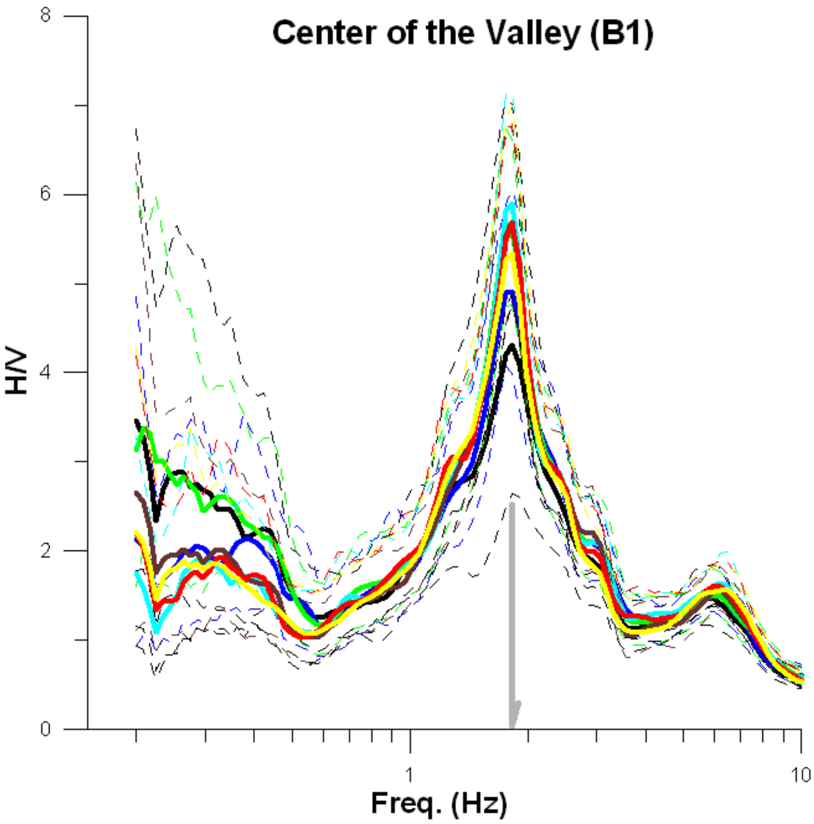


Fig. 6. H/V average spectral ratios (±1sd) at the center of the valley based on ambient noise recording of about 6 continuous hours.

2.3.2. Array Deployment and Data

In Figs. 7 and 8, a plan view of the Argostoli basin test area where the seismological array was deployed is shown.

The equipment and manpower provided by each Institute for the experiment was as following:

ITSAK: 12 CMG-6TD 30s sensors , 4 persons, 10 solar panels.
ISTERRE: 25 Taurus with CMG-40, 30s sensors, 5 persons, all station with solar panel.
INGV: 12 Quantera (6 channels Le5s, episensors), 6 persons, all station with solar panel.
GFZ: 10 EarthData EDL with Mark 1Hz sensors, 4 persons, all station with solar Panel & 5 K2 with episensors.

Information about the stations deployed in Argostoli basin are given in Table 1.

Table 1. Information about stations of the array deployed in Argostoli basin.

Original name	Station code	Station name	Longitude	Latitude	Altitude
(station name during the experiment)	*(proposed station code for ISC)*	*(short description to identify site location)*	*φ [deg]*	*λ [deg]*	*m*
A00(TAU)	KeA00	A00-Koutavos park	20.505548790	38.163316710	0
A01(TAU)	KeA01	A01-Koutavos park	20.505583395	38.163350640	0
A02(TAU)	KeA02	A02-Koutavos park	20.505518610	38.163355485	0
A03(TAU)	KeA03	A03-Koutavos park	20.505492297	38.163303115	0
A04(TAU)	KeA04	A04-Koutavos park	20.505545310	38.163270890	0
A05(TAU)	KeA05	A05-Koutavos park	20.505602523	38.163300564	0
A06(TAU)	KeA06	A06-Koutavos park	20.505653842	38.163421575	0
A07(TAU)	KeA07	A07-Koutavos park	20.505457210	38.163431830	0
A08(TAU)	KeA08	A08-Koutavos park	20.505381660	38.163281493	0
A09(TAU)	KeA09	A09-Koutavos park	20.505541254	38.163181723	0
A10(TAU)	KeA10	A10-Koutavos park	20.505708430	38.163265920	0
A11=S10(TAU)	KeA11	A11-Koutavos park	20.505832996	38.163596083	0
A12(TAU)	KeA12	A12-Koutavos park	20.505298941	38.163621014	0
A13(TAU)	KeA13	A13-Koutavos park	20.505109227	38.163222426	0
A14(TAU)	KeA14	A14-Koutavos park	20.505528778	38.162955083	0
A15(TAU)	KeA15	A15-Koutavos park	20.505973477	38.163184700	0
A16=S09(TAU)	KeA16	A16-Koutavos park	20.506111273	38.163883663	0
A17(TAU)	KeA17	A17-Koutavos park	20.505060201	38.163924558	0
A18=S12(TAU)	KeA18	A18-Koutavos park	20.504655765	38.163129133	0
A19(TAU)	KeA19	A19-Koutavos park	20.505508902	38.162595717	0
A20(TAU)	KeA20	A20-Koutavos park	20.506396022	38.163052042	0
B01 (EDL)	KeB01	B01-Koutavos park	20.50801377	38.16548164	0
B02 (EDL)	KeB02	B02-Koutavos park	20.50783735	38.16565457	0
B03 (EDL)	KeB03	B03-Koutavos park	20.50801773	38.16553964	0
B04 (EDL)	KeB04	B04-Koutavos park	20.50824945	38.16562022	0
B05 (EDL)	KeB05	B05-Koutavos park	20.50846693	38.16561596	0
B06 (EDL)	KeB06	B06-Koutavos park	20.50829131	38.16522486	0
B07 (EDL)	KeB07	B07-Koutavos park	20.50756826	38.16506705	0
B08 (EDL)	KeB08	B08-Koutavos park	20.50804746	38.16544558	0
B09 (EDL)	KeB09	B09-Koutavos park	20.50779486	38.16533694	0
B10 (EDL)	KeB10	B10-Koutavos park	20.50793286	38.16548057	0
R01(CMG)	KeR01	R01-Spilia V. Vassiliki	20.490460	38.158240	120
R02(QUA)	KeR02	R2-Water pump area	20.510493924	38.166274543	13
S01(TAU)	KeS01	S01-Koutavos park	20.509435959	38.166647511	0
S02(QUA)	KeS02	S02-Kouvatos park	20.509021749	38.166293426	0
S03(TAU)	KeS03	S03-Koutavos park	20.508704503	38.165739637	0
S04(QUA)	KeS04	S04-Kouvatos park	20.508212417	38.165618575	0
S05(TAU)	KeS05	S05-Koutavos park	20.507790214	38.165317735	0
S06QUA)	KeS06	S06-Kouvatos park	20.507494657	38.164937440	0
S07(TAU)	KeS07	S07-Koutavos park	20.507255174	38.164537044	0
S08(QUA)	KeS08	S08-Kouvatos park	20.506839817	38.164225938	0
A16=S09(TAU)	KeS09	DOUBLE	20.506111273	38.163883663	0
A11=S10(TAU)	KeS10	DOUBLE	20.505832996	38.163596083	0
S11(QUA)	KeS11	S11-Kouvatos park	20.505523410	38.163369429	0
A18=S12(TAU)	KeS12	DOUBLE	20.504655765	38.163129133	0
S13(QUA)	KeS13	S13-Kouvatos park	20.503991877	38.163347876	0
S14(QUA)	KeS14	S14-Farm field	20.502194847	38.163880017	1
S15(CMG)	KeS15	S15-Farm field	20.501630814	38.163633390	4
S16(QUA)	KeS16	S16-Farm field	20.500666851	38.163792577	5
S17(CMG)	KeS17	S17-Farm field	20.499648584	38.163865415	5
S18(QUA)	KeS18	S18-Farm field	20.499013610	38.163453124	8
S19(CMG)	KeS19	S19-Farm field	20.5037641116361	38.1588468436473	13
S20(CMG+K2)	KeS20	S20-Police Station	20.5064383227013	38.1555432598893	19
S21(CMG)	KeS21	S21-Simatos	20.5064383227013	38.1555432598893	35
S22(QUA)	KeS22	S22-Botanica garden	20.49494	38.15987	64
S23(CMG)	KeS23	S23-Stathatos	20.5453603050874	38.1000550441317	70
S24(K2)	KeS24	S24-Roundabout	20.507029403722	38.1622588678999	0
S25(K2)	KeS25	S25-Market	20.5106902141879	38.1593321469781	0
S26(K2)	KeS26	S26-Pepsi Sign	20.5131229959857	38.1562026492652	0
S27(CMG+K2)	KeS27	S27-Farm	20.5174594790168	38.1535623659434	0
S28(CMG)	KeS28	S28-Christoforatos	20.5198566396514	38.1575182690122	0
S29(QUA)	KeS29	S29-Private farm field	20.52122	38.16049	0
S30(CMG)	KeS30	S30-Koutavos park	20.5033268447373	38.1635666209924	0
SEISMO5(CMG)	KeSka	Skala	20.797808	38.073197	18
SEISMO6(CMG)	KeCha	Chavriata	20.384954	38.183407	78

Fig. 7. Plan view of the Argostoli basin together with the seismological array configuration (red points: reference rock stations).

Fig. 8. Zoom in the center of the Argostoli basin array, showing the "radial array" with an aperture of 160m.

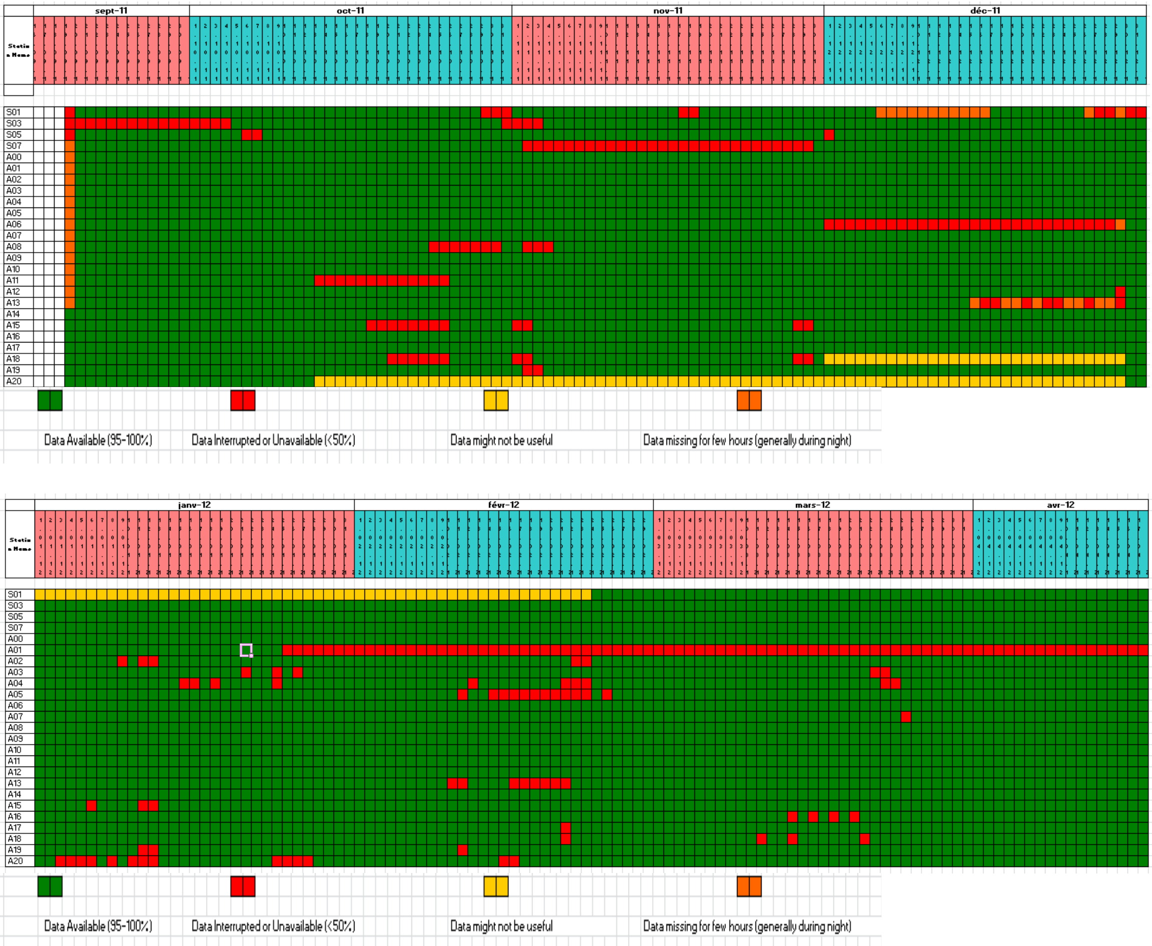


Fig. 9. Operation of the "radial array" as a function of time during the whole experiment.

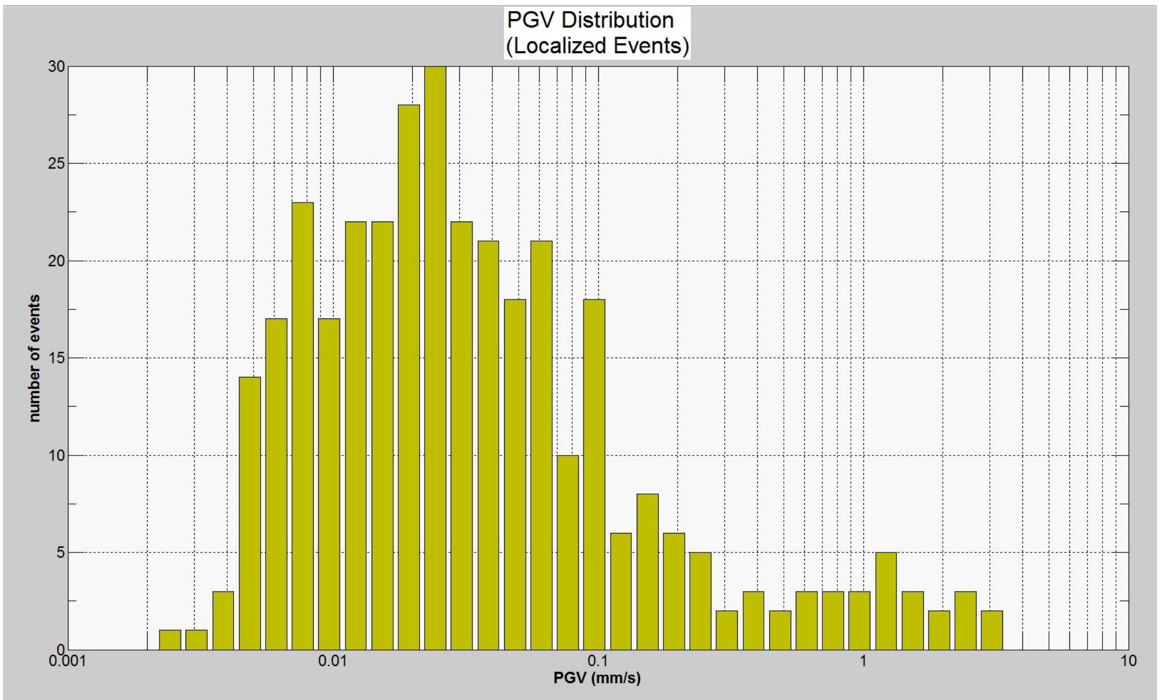


Fig. 10. Histogram of peak ground velocities of the recorded by the "radial array" events.

Fig. 11. Distribution of recorded magnitudes and peak ground velocities (PGV) as a function of epicentral distance.

In Figs. 9, 10 and 11, information about Argostoli basin array operation and distribution of data acquired is shown. For the located events the epicentral distance distribution is between 4km to 2000km while the recorded peak ground velocity ranges from about 10^{-3} mm/s up to 10^{1}mm/s.

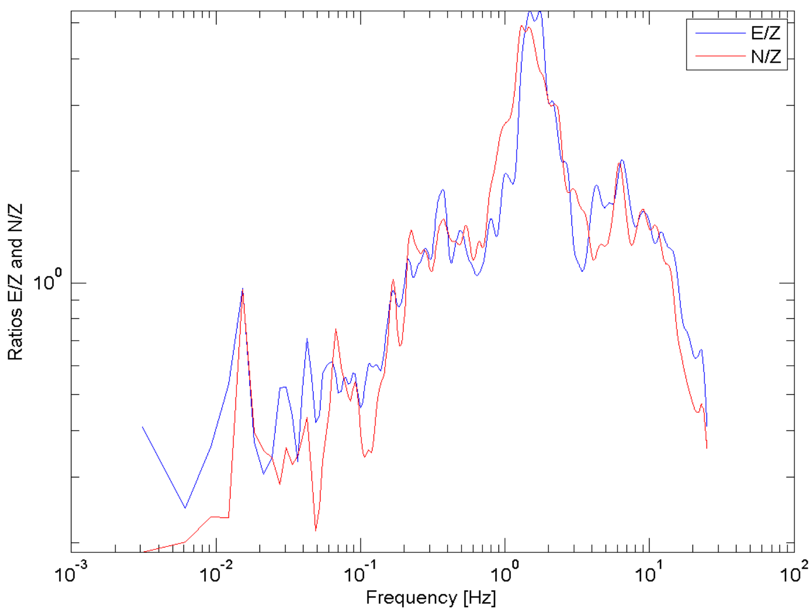


Fig. 12. Horizontal-to-Vertical spectral ratio (for both horizontal components) based on the recordings at the center of the "radial array".

In Fig. 12, the Horizontal-to-Vertical Spectral Ratio based on more than 100 recordings at the central station, A00, of the "radial array", show a fundamental frequency between 1.6Hz to 1.8Hz with a corresponding amplitude around 5. This is in very good agreement with similar results based on ambient noise data.

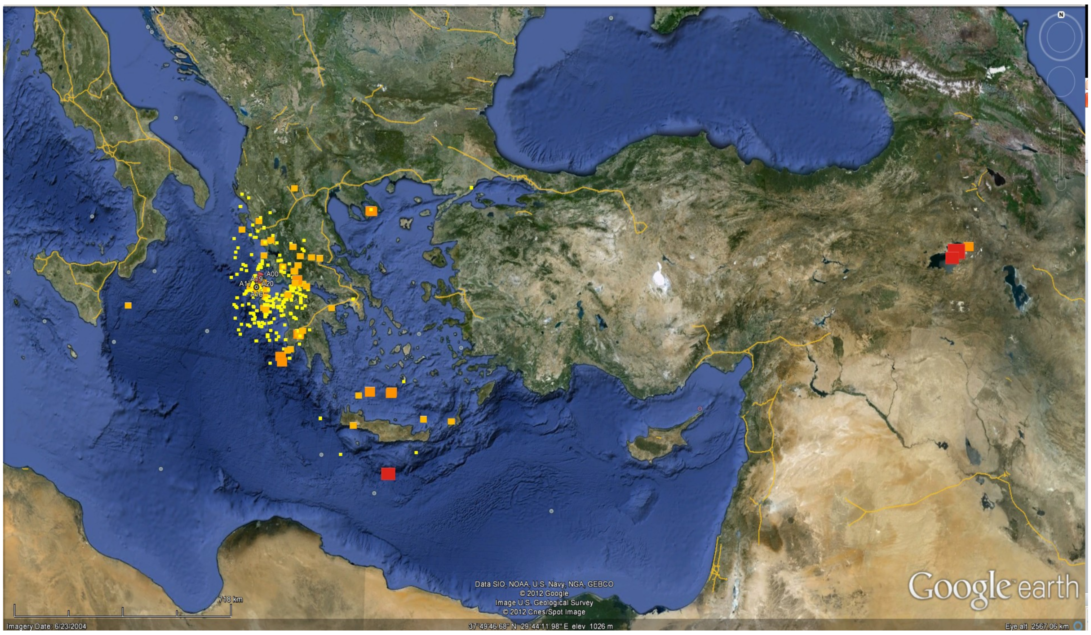
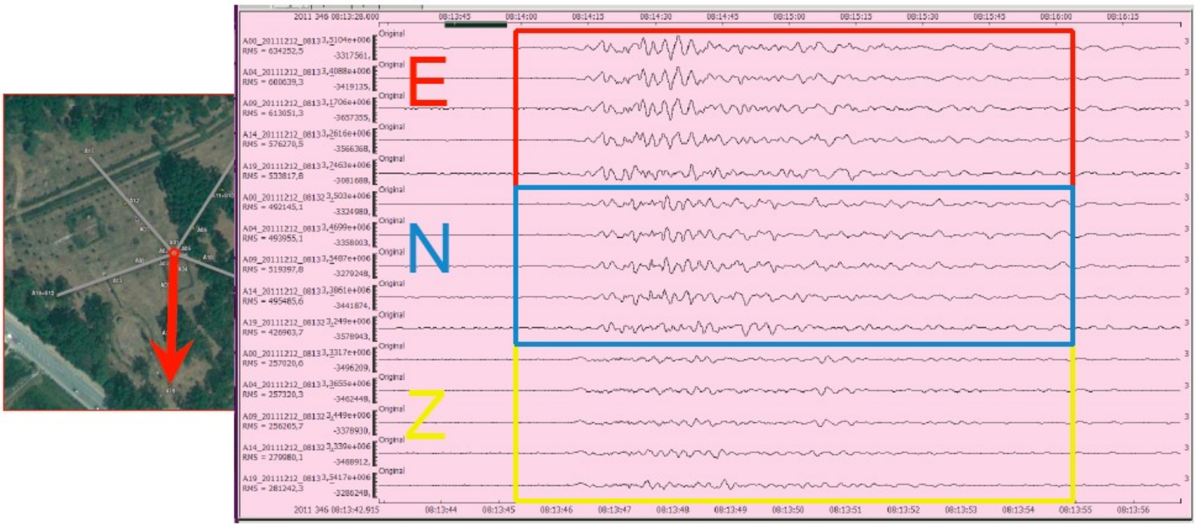


Fig. 13. Distribution of the earthquakes (localized ones) recorded by the Argostoli basin array.

In Fig. 13, distribution of the localized events that triggered the Argostoli array is shown. It is obvious that local, regional as well as teleseismic earthquakes provided good quality data. One of the events with origin time 20121212_081338 GMT, at an epicentral distance of 22km from the A00 central station is presented in Fig. 14. In Figs. 15 and 16, recordings of this event to certain stations of the "radial array" are given.

yyyymmdd	hhmmss	Mag	Depth(km)	Apprx. Dist from A00 (km)
20111212	08:13:38	2.4	3.7	22

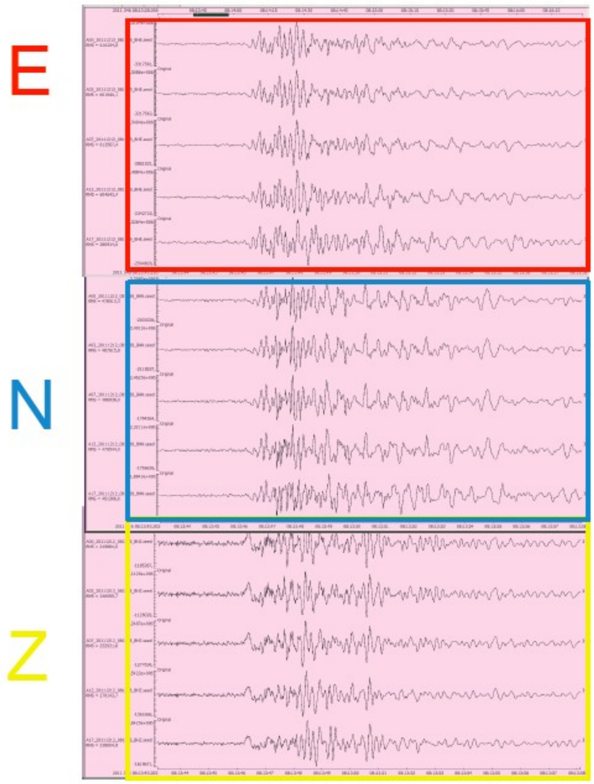
Fig. 14. Plan view of the "radial array" and one events NE of Argostoli that triggered the array.



yyyymmdd	hhmmss	Mag	Depth(km)	Apprx. Dist from A00 (km)
20111212	08:13:38		2.4 3.7	22

Fig. 15. Recordings of the 20111212_08:13:38 event, acquired by the center-to-south radius of the array.

WAVE PROPAGATION (EXAMPLE1 : LOCAL EVENT)



yyyymmdd **hhmmss** **Mag**
20111212 08:13:38
0.4

Depth(km) **Apprx. Dist from A00 (km)**
3.7 22

Fig. 16. Recordings of the 20111212_08:13:38 local local event, acquired by the center-to-northwest radius of the array.

yyyymmdd	hhmmss	Dist (A00)	Depth (km)	M
PGV(mm/s)				
20120127	01:33:57	467 km	5.20	5.3

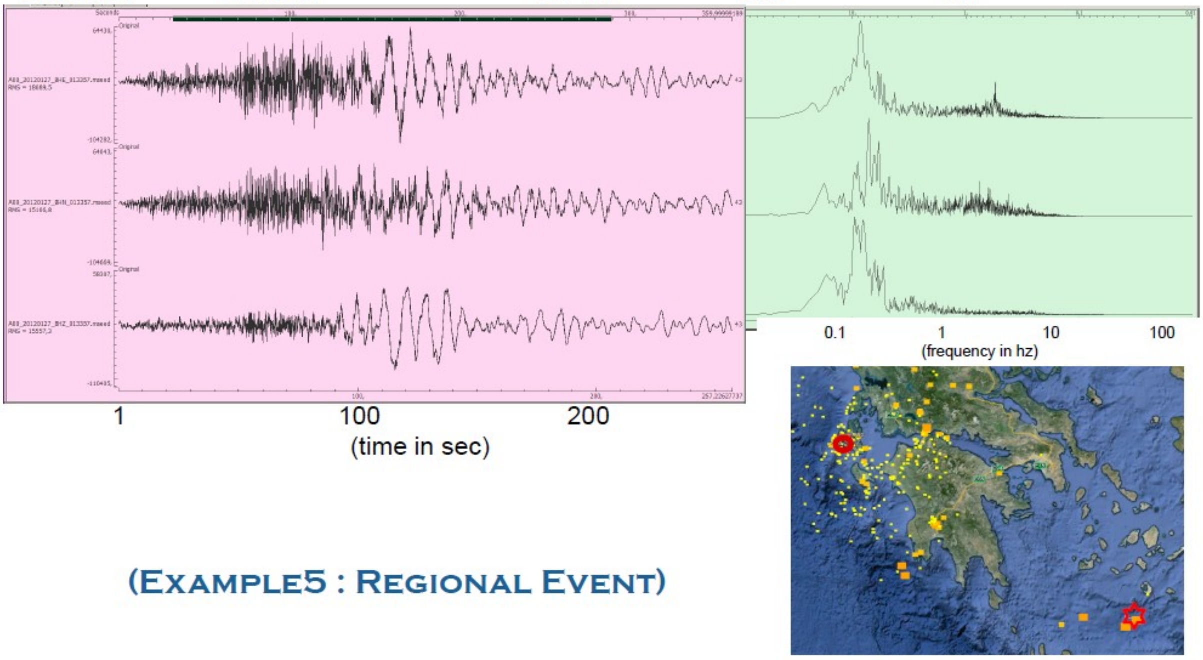


Fig. 17. Recordings at the center station (E,N, Z components) of a regional earthquake in the southern Aegean.

Recordings at the central station , A00, of the “radial array” triggered by a regional (M5.3) event in the southern Aegean, along with their Fourier spectra are presented. In this case, low frequencycontent , f<0.1Hz, is apparent.

2.3.3. Location and Relocation of Earthquakes

During the array experiment in Argostoli basin [20/9/2011 to 17/4/2012]., more than 3000 local and regional events, with *M≥2.0*, occurred in the broader Agean area (Fig. 18). However, after careful visual inspection on the A00 central station of the "radial array", 667 good quality events (with high signal to noise ratio) were recorded [see Appendix 5]. 170 earthquakes were located by the AUTH seismological station while the rest 497 are un-located ones.

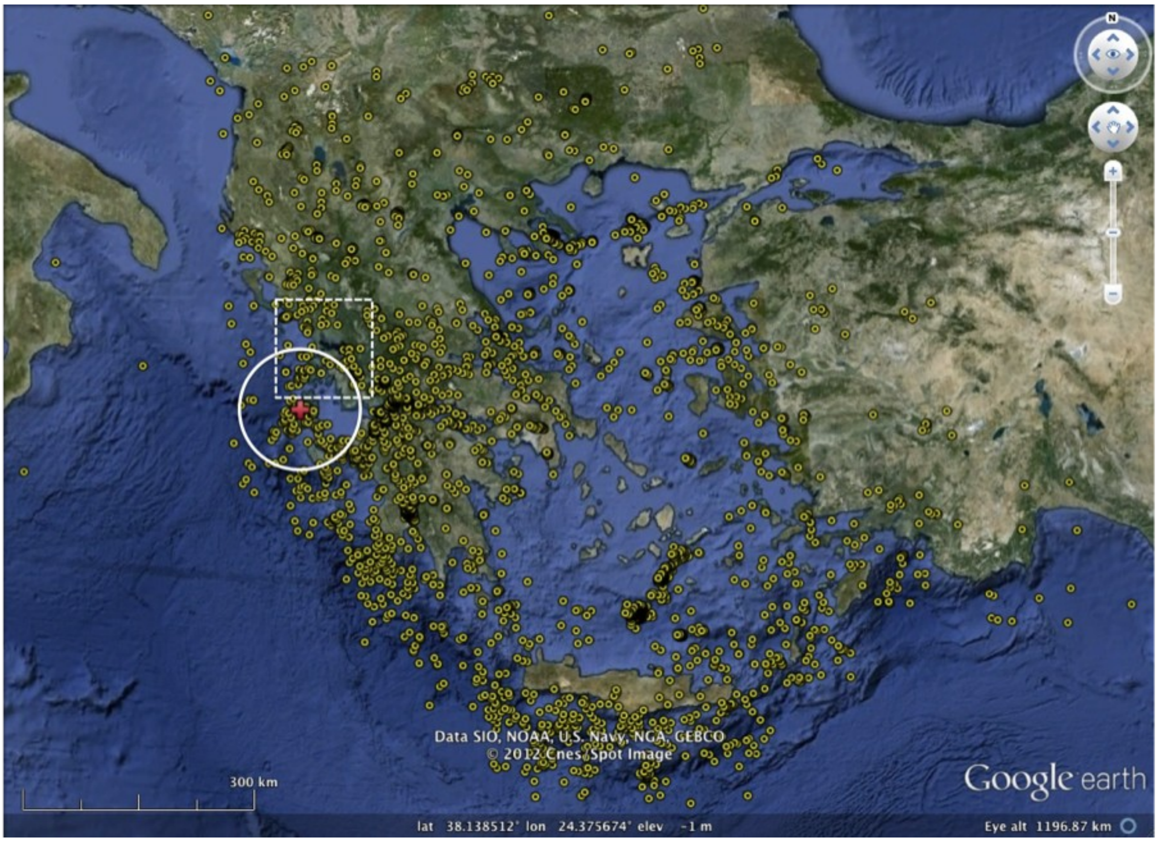


Fig. 18. Distribution of located event, with M≥2.0, occurred within the broader Aegean area during the experiment period [20/9/2011 to 17/4/2012].

The location of the events in Fig. 18, are based on a generic 1D velocity structure model for the broader Aegean area and on seismograms of the Hellenic Unified Seismological Network (HUSN). It is obvious that using as many as possible close to the event seismographs with good azimuthal coverage the location of the earthquake focus is significantly improved. For this reason, separation between local (R≤80km) and (R>80) regional events was examined. For events located at epicentral distances R>80 from the center of the Argostoli array, solutions from the HUSN catalogue are taken into account. For epicentral distances R≤80km, location and as well as relocation of local events is done using close by broad band stations as follows:

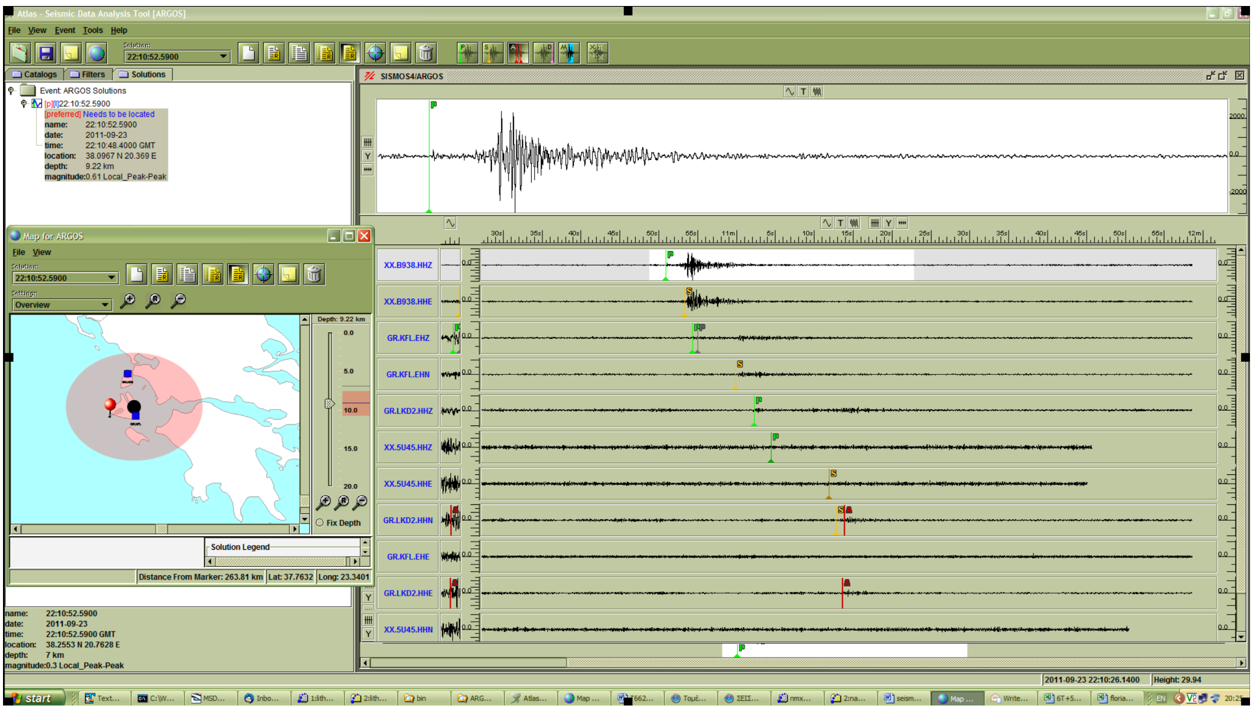
- 7 stations of HUSN in the vicinity of Ionian islands
  (5 BB [LKD2, PDO, RLS, VTN, VLS] , 2 SP [AXS, KFL])
- 2 stations of ITSAK-EPPO strong motion network [AST1, VAS2]
- 3 stations of Argostoli temporary array [SEISMOS5, SEISMOS6, R01]

These stations are located at epicentral distances less than about 80km from the station A00, and are shown in Fig. 19.

Fig. 19. Seismographs & accelerographs that are going to be used in seismic location or/ and relocation of local events.

Waveforms' compilation is done under an Oracle database (Atlas Hypo-Inverse S/W, Nanometrics). Response files will be created and their validation is done through Mw estimation based on past events. In Fig. 20, an example of relocation is shown, based on local stations P and S-wave arrivals. The results of relocation are given in Fig. 21, where the shift of epicenter as well as the depth of focus is apparent.

Fig. 20. ATLAS software to be used in location or/and relocation of local event



Test: Location of a small magnitude event

HUSN located:	20111101	12:52:47.50	38.1475	20.2697	0.9km	M2.5
Relocation:	20111101	12:52:48.38	38.1813	20.4495	14.3km	M2.6

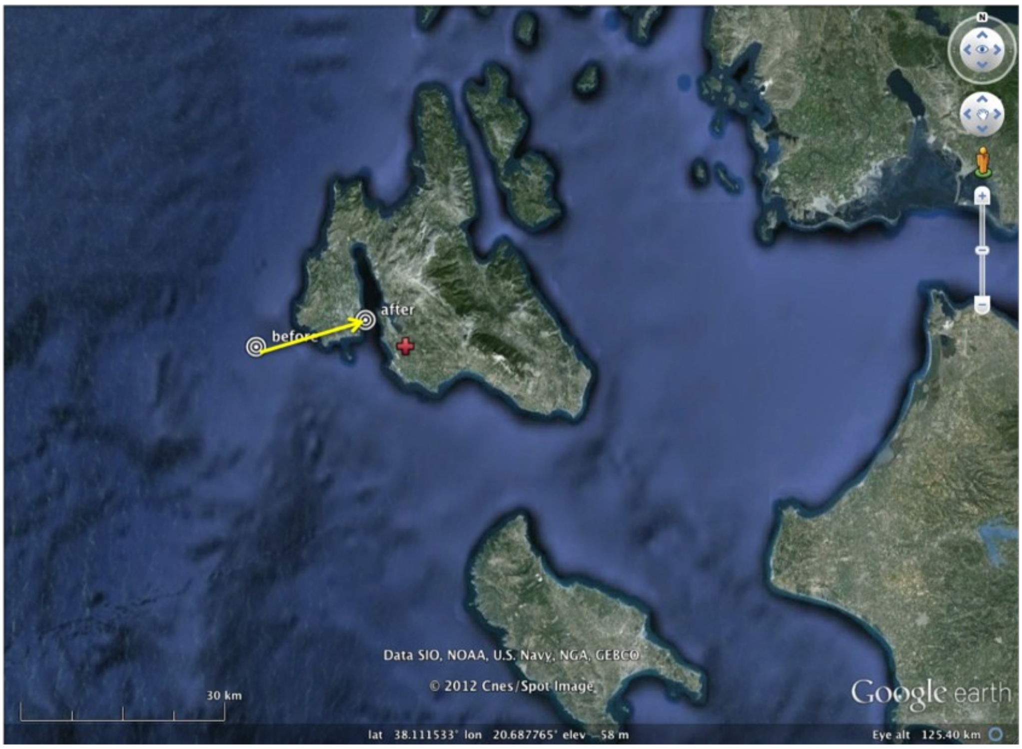


Fig. 21. Relocation of an event based on local stations P and S-wave arrivals.

In addition, it is known that a generic 1D velocity structure model may not be adequate for location of local events around the Argostoli study area. For this reason, velocity structure models are searched to better express the real model. Such a 1D velocity model has been proposed for the western Greece by Hasslinger et al. (1999) (see dashed line square in Figs. 18 and 19) and is shown in Fig. 22. The relocation of all events at epicentral distances R≤80km is in progress.

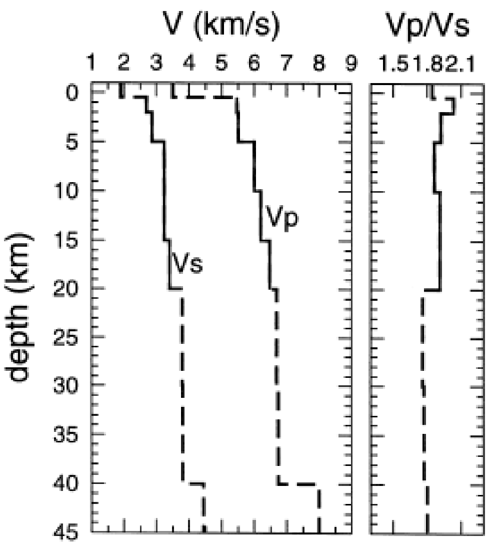


Fig. 22. 1D 'local' structure model *(Hasslinger et al.,1999).*

2.3.4 Preliminary Analyses of Selected Recordings

In Fig. 23 local earthquake (event 1) that triggered the Argostoli array is shown while in Fig. 24 a plan view of the recording stations along with the reference rock stations, are also given.

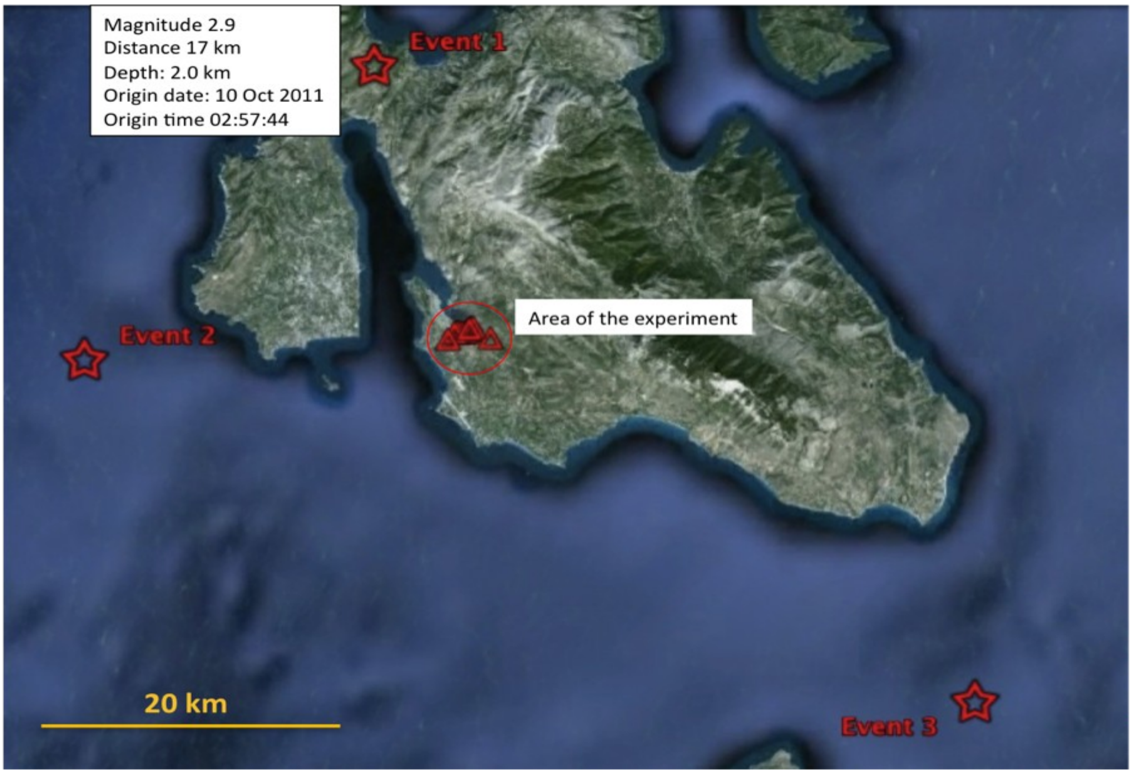


Fig. 23. Local earthquake [event 1] with M2.9 that triggered the Argostoli array.

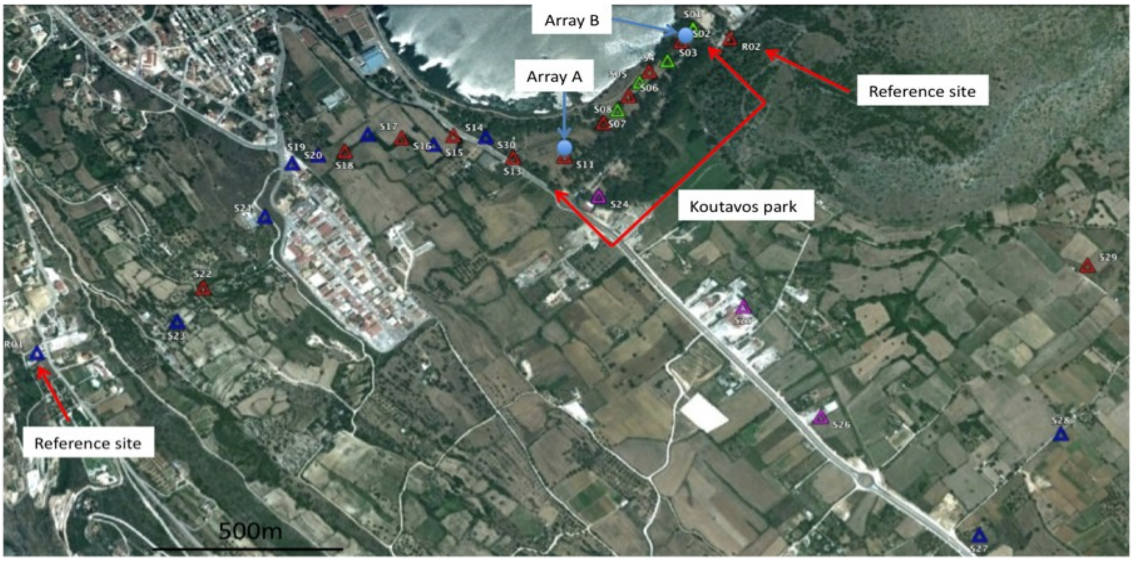


Fig. 24. Plan view of the recording stations that have been triggered by the local event 1.

In Figs. 25 and 26, time histories of the event 1 are presented. The influence in amplitude and duration on recordings in Argostoli basin with respect to the reference rock stations (R01, R02) is apparent.

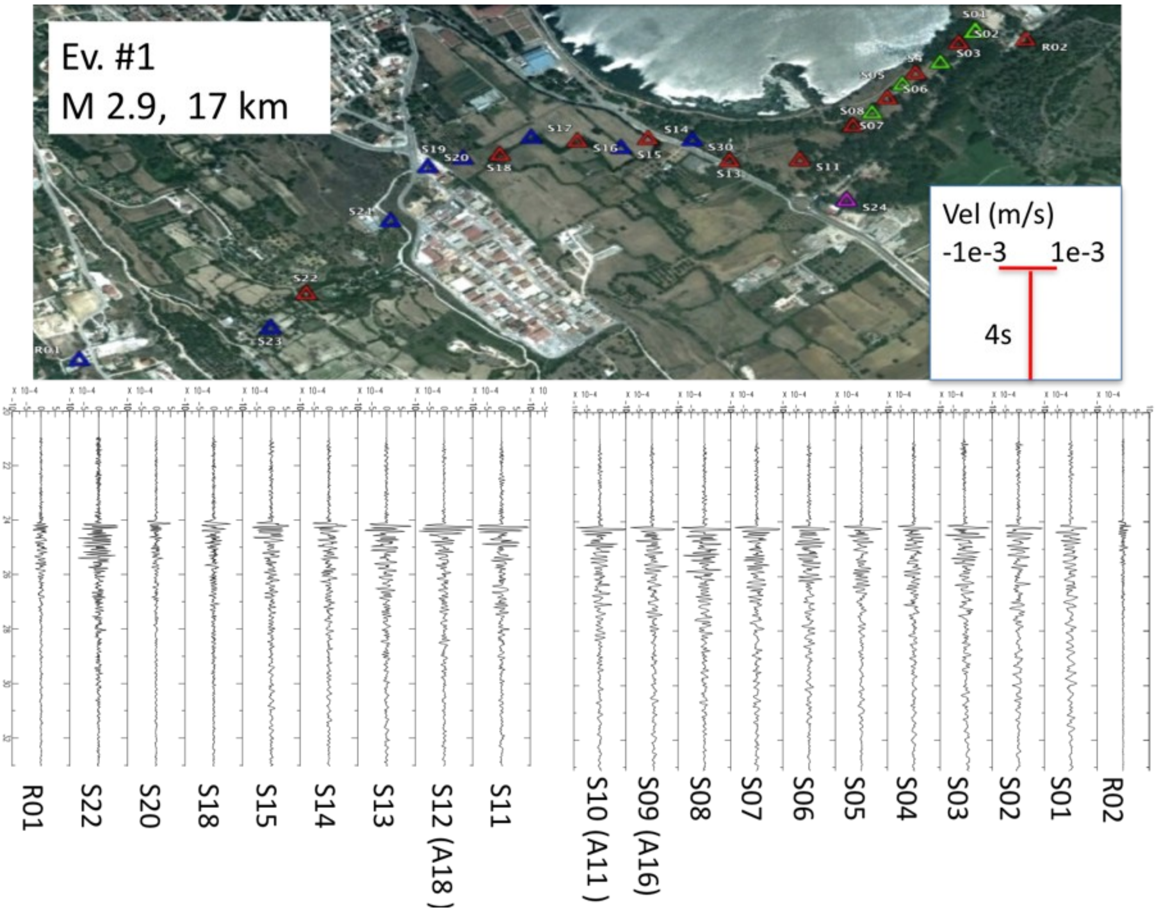


Fig. 25. Recordings at selected stations of the Argostoli array, of the earthquake event 1.

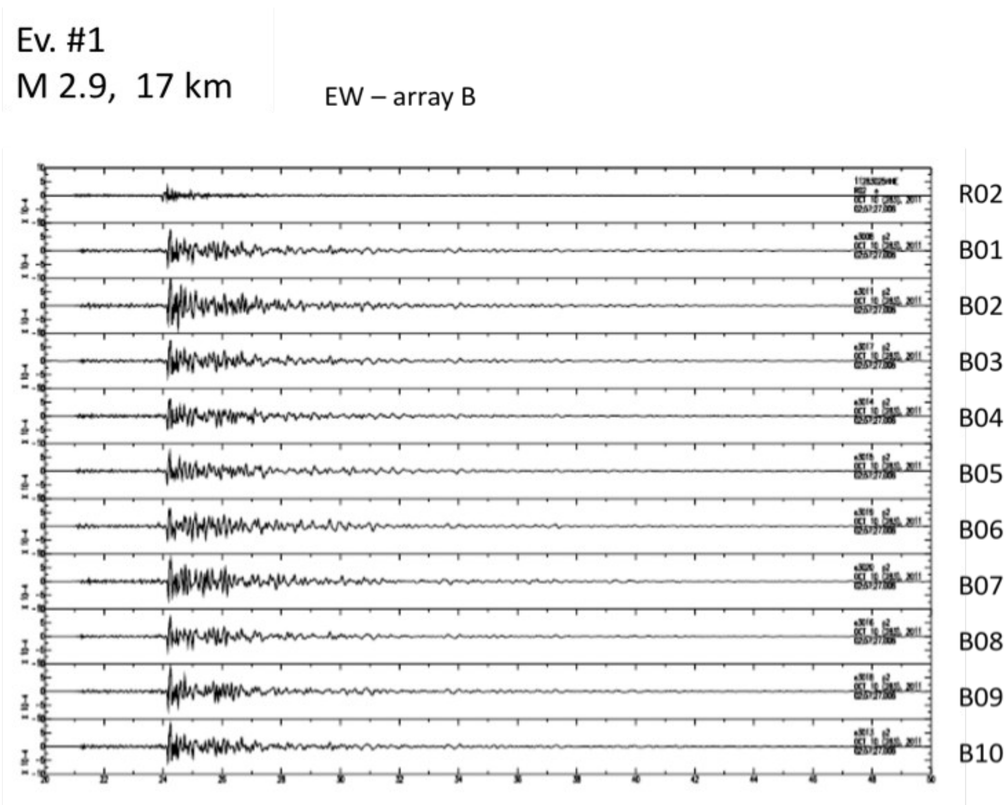


Fig. 26. Recordings at "radial array" B, of the Argostoli array, of the earthquake event 1.

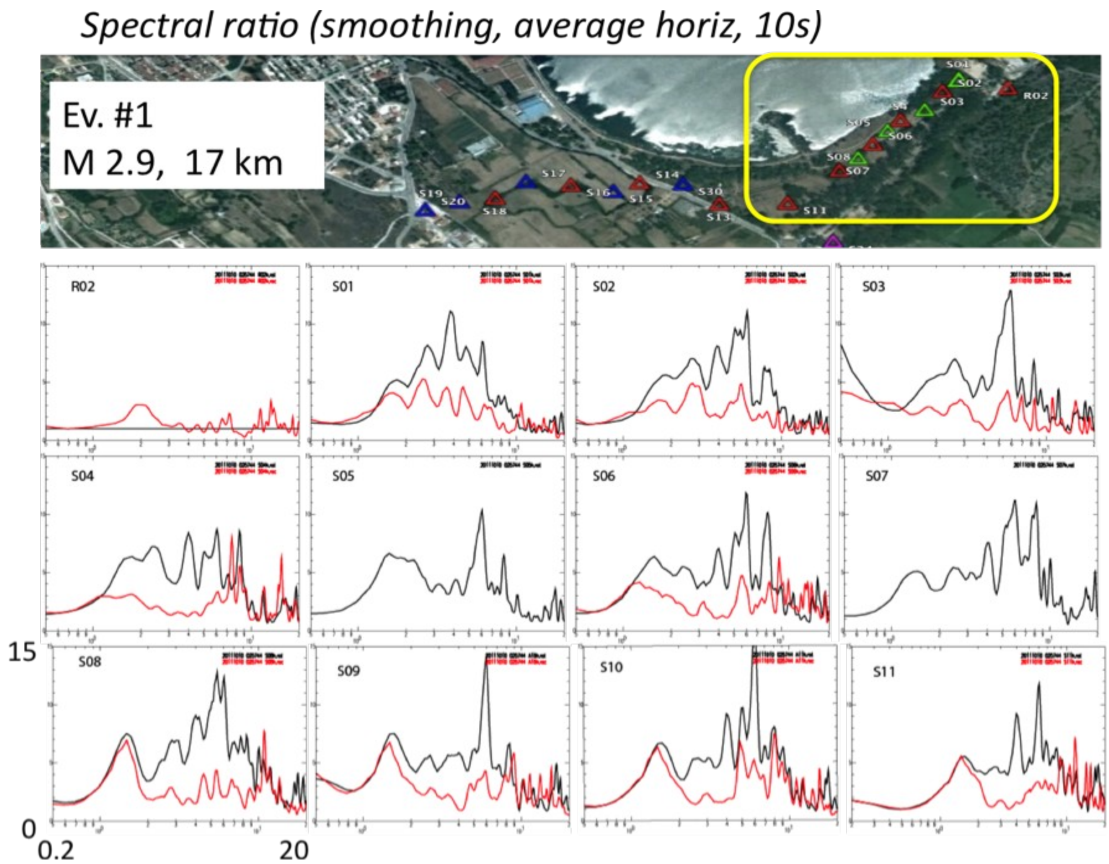


Fig. 27. Standard spectral ratios and Horizontal-to-Vertical spectral ratios for the event 1 in certain sites of the Argostoli array.

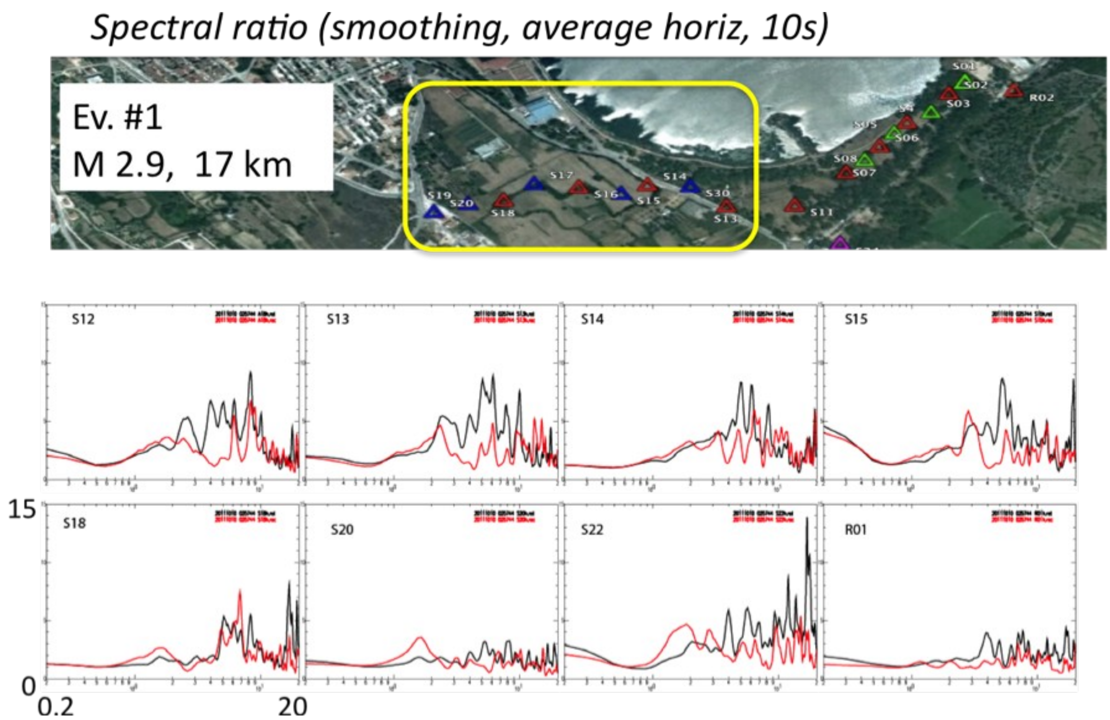


Fig. 28. Standard spectral ratios and Horizontal-to-Vertical spectral ratios for the event 1 in certain sites of the Argostoli array.

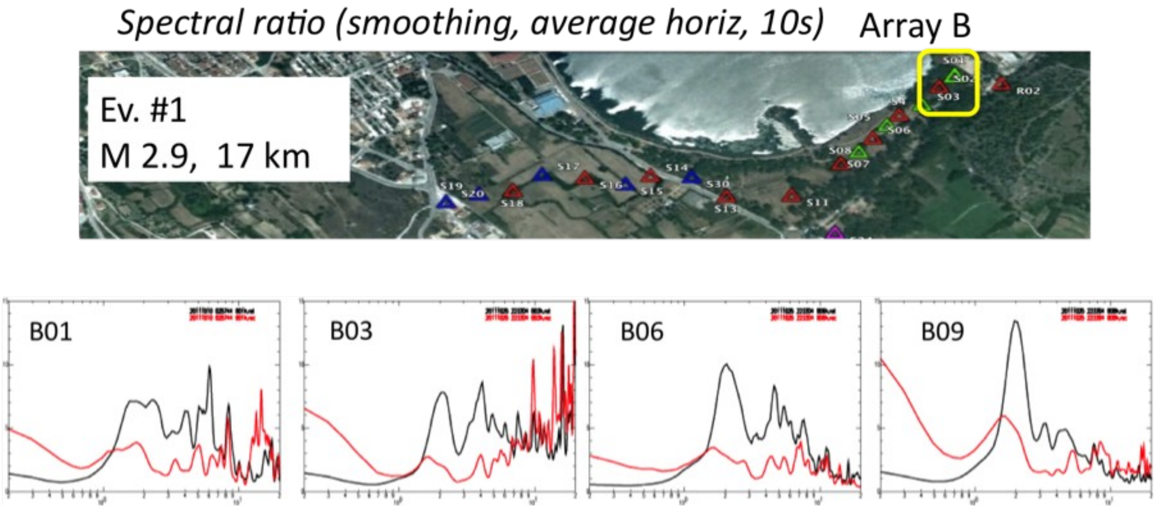


Fig. 29. Standard spectral ratios and Horizontal-to-Vertical spectral ratios for the event 1 in "radial array" B sites of the Argostoli array.

In Figs. 27, 28 and 29, standard spectral ratios and Horizontal-to-Vertical spectral ratios for the event 1, are compared. In Fig. 30, comparison between standard spectral ratios and Horizontal-to-Vertical spectral ratios for the event 1 and Horizontal-to-Vertical spectral ratios based on ambient noise measurements is also shown. The experimental work on the Argostoli array data is in progress.

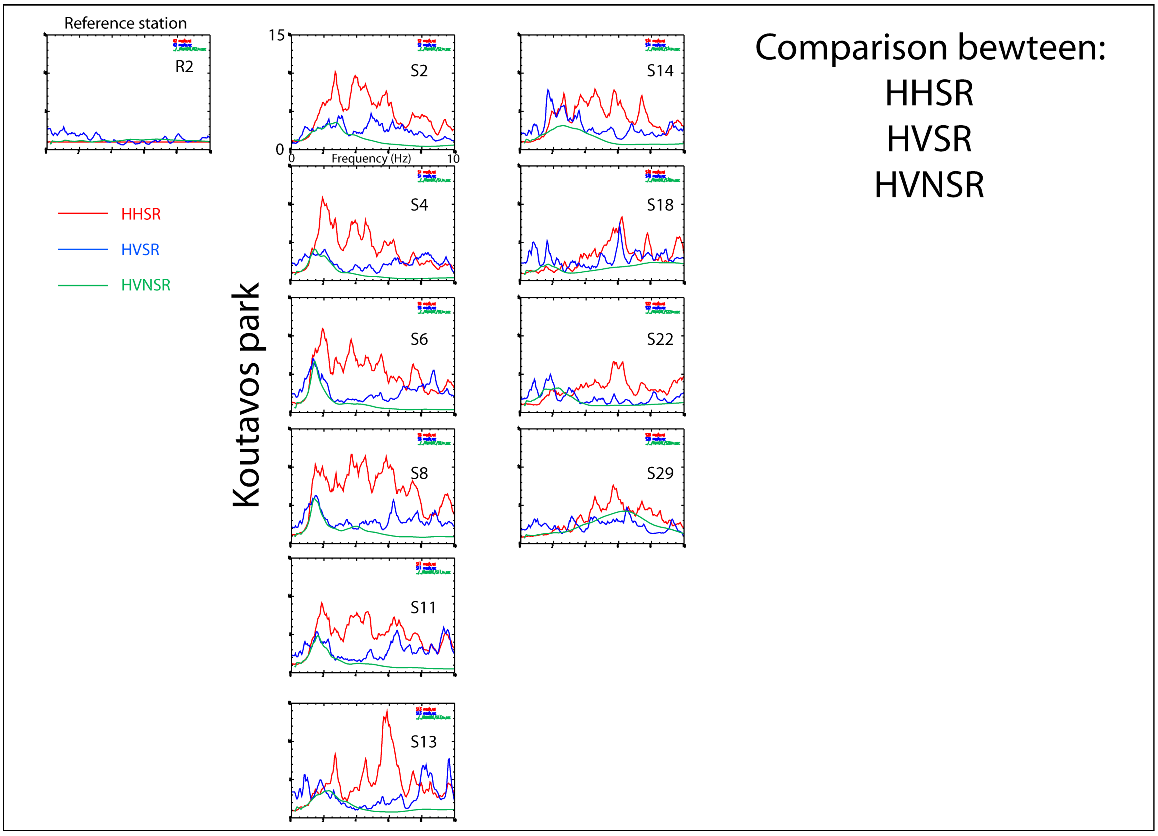


Fig. 30. Comparison between spectral ratios from earthquake recordings (HHSR, HVSR) and ambient noise data (HVNSR) for selected sites of the Argostoli array.

3. Fucino Array and Seismological Experiment

3.1 Introduction

The Fucino Basin has been selected by the NERA-JRA1 project as location for a seismological experiment devoted to study the wavefield and ground strain (in cooperation with NERA-JRA3) due to earthquakes. The characteristics of the basin, that is very deep and with important site effects at low frequency, are complementary to Argostoli site where the basin is relatively shallow.

The seismicity of the Fucino basin is severe but also low-rated. Anyhow, the availability of safe places where installing seismic stations was another important reason for choosing the Fucino basin as test site. In the next paragraphs we are going to describe the geological and seismological information of the selected area and the experiment.

The Fucino Basin: geology and seismicity

The Fucino Basin represents one of the biggest sedimentary basin into Apennines range in Central Italy (Figure 1). The origin of the basin is tectonic and a large number of active faults, mainly NW-SE trending normal faults, are present in the area (Galadini and Messina 1994 and Ghisetti and Vezzani 1997).

The extension of the basin reaches 20 kilometers in the EW direction and 10-12 kilometers in the NS direction (Figure 1), the maximum depth is of about 800 meters in the eastern sector.

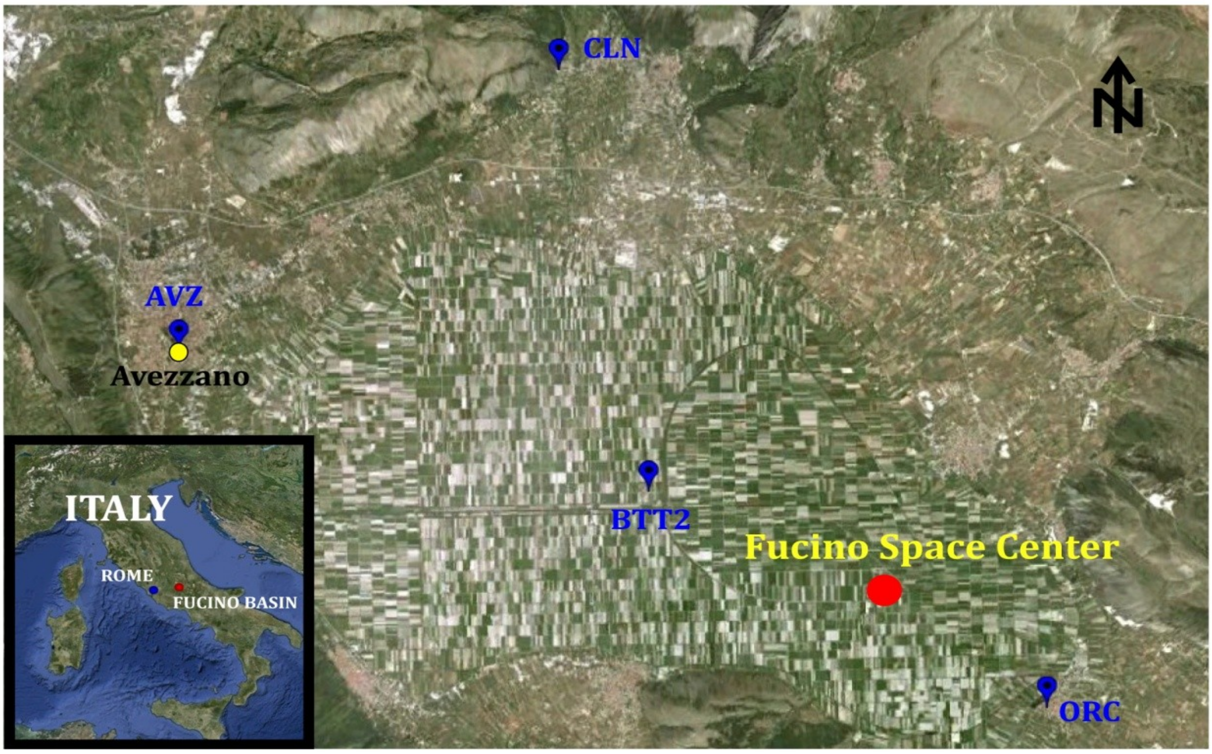


Figure 1: General view of Fucino basin. Blue markers indicate the permanent strong motion stations belonging to the Italian Strong Motion Network (RAN), the red dot represents the Fucino Space Center, the area selected for the NERA experiment.

A thick layer of recent sedimentary deposits fills the basin. They consist mainly of clay and sandy clay. In the northern edge of the basin more recent gravel deposits cover these deposits. Gravel deposits are related to the limestone reliefs often dislocated by active normal faults. Their presence in the northern sector of the basin can produce a velocity inversion in the first meters of soil that introduces some complexities in the seismic response of the basin (Cavinato et al. 2002; Cara et al, 2011). The area was interested by one of the largest earthquakes in central Italy (1915 Avezzano event, Mw 7) that caused a huge amount of casualties and almost completely destroyed the city of Avezzano and all the villages in the epicentral area. However, beside this very important event, the seismicity rate of the area is low if compared with adjacent areas in Central Italy.
Nevertheless, the basin is also affected by the seismic activity related to many sources distributed all around it and connected to extended normal fault systems. In the last three years before the NERA experiment, the major contribution to the recorded seismicity was related to L'Aquila sequence, culminated with the magnitude Mw 6.3 event of April 6^{th} 2009.

3.2 Previous studies

The basin was monitored in 2008-2009 by INGV in the framework of a project financed by the National Civil Protection Department (Dipartimento della Protezione Civile, DPC). At that time a temporary seismic network based on 18 stations, equipped with high sensitivity seismic data loggers and extended band seismometers (Lennartz LE3D-5s), was operating for few months recording many events mainly related to the L'Aquila 2012 seismic sequence (Cara et al, 2011). The deployment of the network was partially guided by the logistic of the site where the lack of security and power problems did not allow covering some important section of the basin (Figure 2).
Two stations were deployed on rock and worked as reference sites, one outside the basin in the NW area (RO01), the second in the SE part of the basin where a limestone outcrop is present in the village of Ortucchio (PI03). This last station was co-located with the ORC station of the Italian accelerometric network (RAN), owned and managed by DPC). Another RAN site, AVZ, was monitored by a weak motion instrument during the experiment. The configuration of the instruments installed in 2008-2009 is shown in Figure 2.

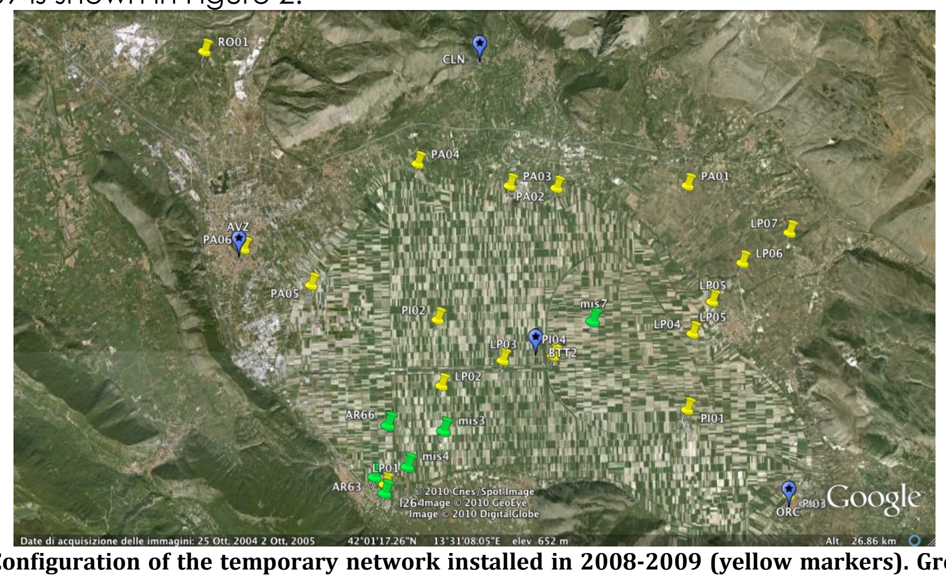


Figure 2: Configuration of the temporary network installed in 2008-2009 (yellow markers). Green markers refer to ambient noise measurements performed during the experiment.

The data collected during the 2008-2009 experiment allowed to infer many information about the resonance frequency f_o and the depth and velocity of the soft sedimentary layer. The main results have been recently published (Cara et. al, 2011).

Station PI01 was installed in the area of Fucino Space Center belonged to Telespazio SpA, a world's leading company in satellite communication services. It is located in a fenced area with a diagonal extension of about 800-900 meters (Figure 3).

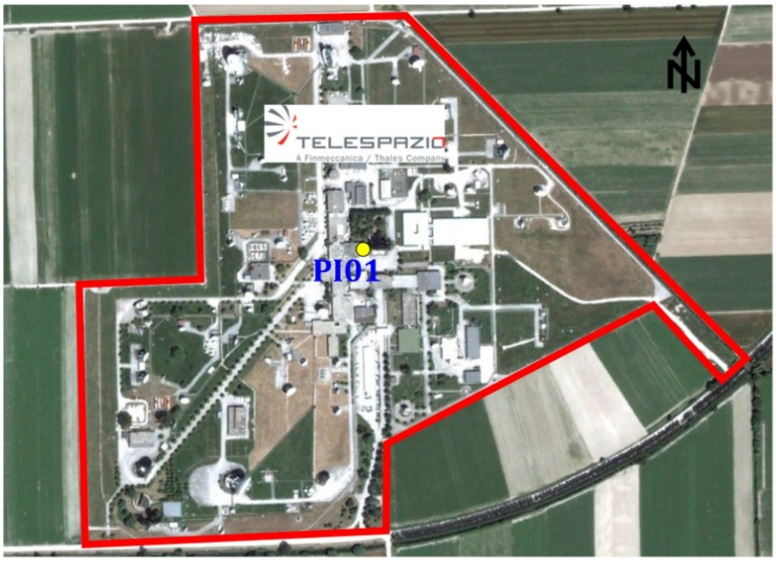


Figure 3: The area of Telespazio Space Center.

PO01 site shows strong amplification effects at low frequency as clearly evidenced by both earthquake and ambient noise data (Figure 4). The site is still monitored with an accelorometer.

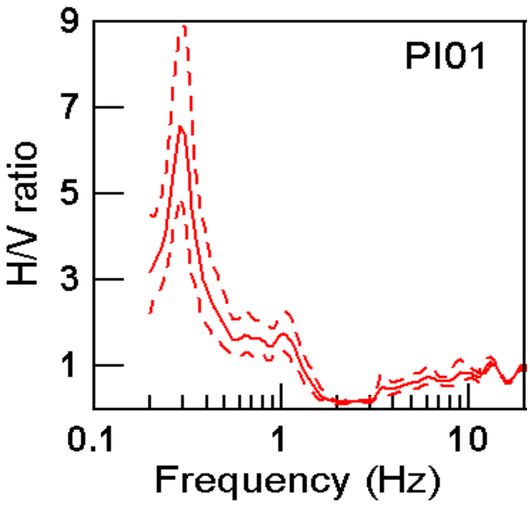


Figure 4 HVNSR in the area of Fucino Space Center.

Data in terms of shear-wave velocity are available in the area of Fucino Space Center (Figure 5). It reveals very low velocities in the first 40 mt (70-180 m/s).

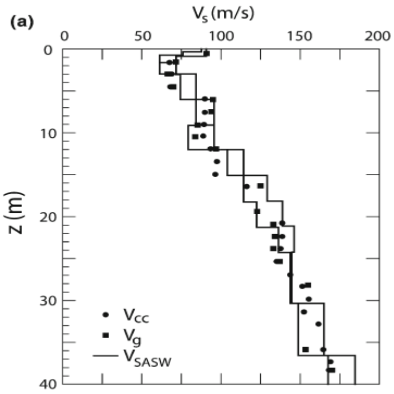


Figure 5 Vs profile from AGI (2011) in the Fucino Space Center area

Because the Fucino Space Center is a protected area, located in the deepest part of the basin, we selected it as suitable for installing a dense array for the NERA project.

3.3 The experiment

The experiment took place from 24-26th of April 2012 until 19th of September. The array consisted of 22 stations equipped with Nanometrics Taurus digitizers and Guralp CMG40T sensors (eigenperiod 30s) belonged to ISTERRE (Institut des Sciences de la Terre, Grenoble, France). The power was ensured using solar panels. The geometry of the array (Figure 6) has been driven by the logistic requirements but was also designed to reduce aliasing effects. The maximum aperture of the array was about 900m, the minimum about 80mt. Moreover, station A00 was set very close (2mt) to the accelerometric station PI01 of INGV.

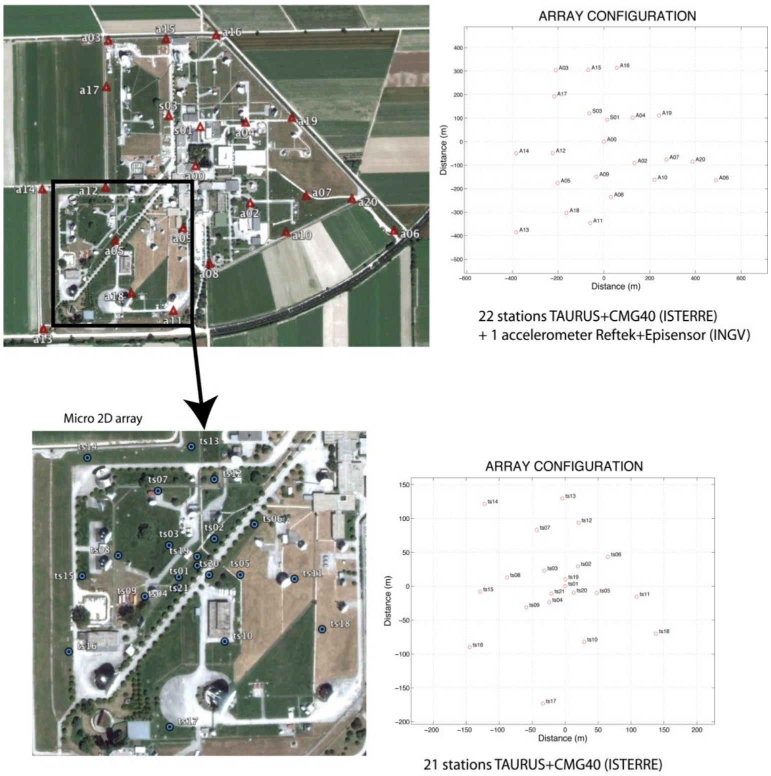


Figure 6 Top: geometry of the 2D array installed at Fucino Space Center; Bottom: geometry of the micro-2D array installed for 1 day in the area bounded by the black rectangle.

After the dismount of the 2D array, almost all stations (21) were used for another micro-2D array devoted to record microtremors in the south-west part of the area (Figure 6). The maximum aperture of the array was 320mt, the minimum 10mt, therefore it was designed to resolve the very shallow part of the basin. The array was deployed the 19th of September and ran for one day.

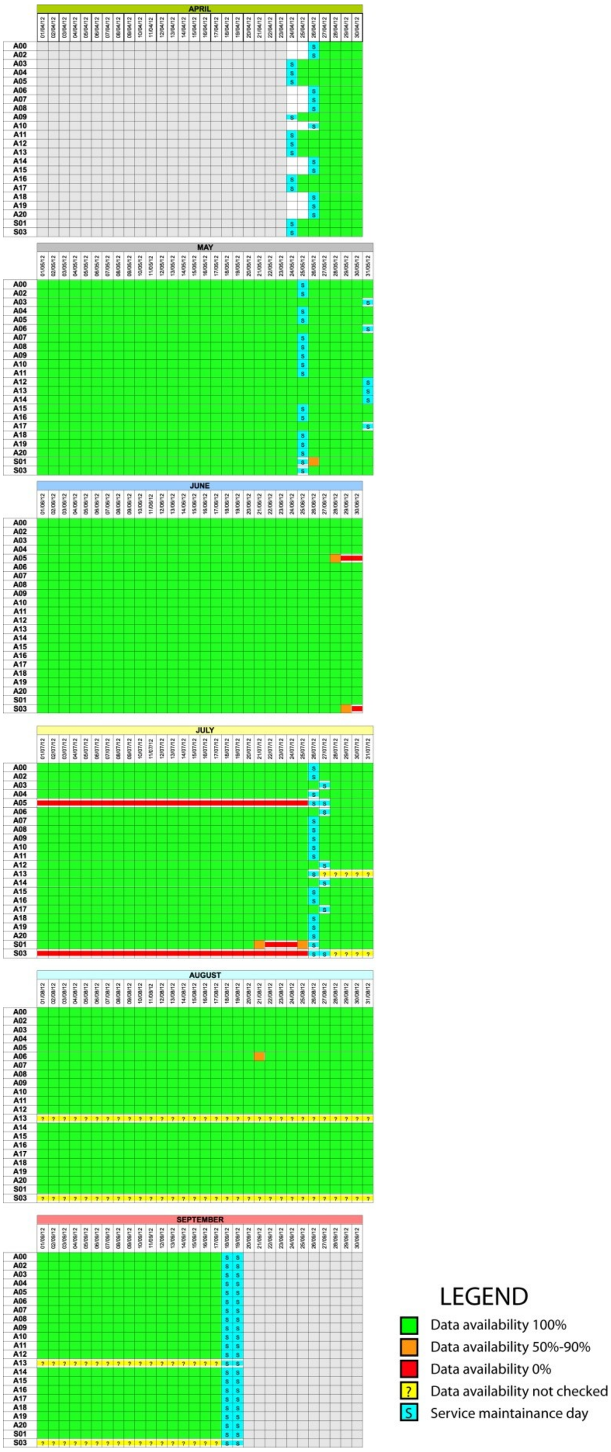


Figure 7: Data availability of the large-aperture 2D array experiment at Fucino Space Center from April 25th to September 19th, 2012

Figure 7 shows the data availability of the large-aperture 2D array from April to September 2012. Few data (in particular for station A05 and S03) were lost due to power failure.
During the recording of the main array there were a seismic sequence occurred in Pianura Padana (northern Italy) with two mainshocks of magnitude 5.9 and 5.8 (Emilia earthquakes, 20 and 29 of May 2012, respectively; Figure 8). The distance between Fucino and the epicentral area is about 380km but the first strong event occurred during night when the noise level was low. Overall, 7 earthquakes related to this sequence with magnitude Ml more than 5.0 were recorded (Figure 8).
During the recording period there were very few local earthquakes (distance less than 10km) with a magnitude Ml lower than 2.0, 13 events in the magnitude range 2.0-3.5 and distance between 10 and 40 km, only one event of magnitude 3.5 between 40 and 100km (Figure 8).

Selected events:
Distance <3000km – Magnitude > 6.0

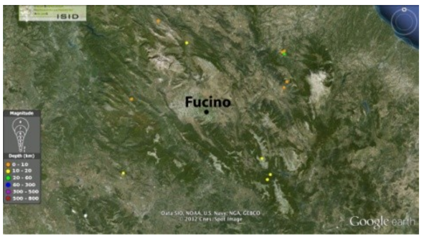
#Origin Time (UTC)		Latitude	Longitude	Depth	Magnitude
11/08/12	12:34:35	38,32	46,76	9,8	6,3
11/08/12	12:23:18	38,38	46,87	9,7	6,2
10/06/12	12:44:15	36,35	28,94	10	6

Selected events:
Distance <500km – Magnitude > 5

#Origin Time (UTC)	Latitude	Longitude	Depth	Magnitude
06/03/12 19:20:43	44.9	10.94	9.2	5.1
05/29/12 11:00:25	44.88	10.95	5.4	5.2
15/29/12 10:55:57	44.89	11.01	6.8	5.3
05/29/12 07:00:03	44.85	11.09	10.2	5.8
05/20/12 13:18:02	44.83	11.49	4.7	5.1
05/20/12 02:07:31	44.86	11.37	5	5.1
05/20/12 02:03:52	44.89	11.23	6.3	5.9

Selected events:
Distance <100km – Magnitude > 3.5

#Origin time (UTC)	Latitude	Longitude	Depth	Magnitude
09/07/12 15:13:43	41.87	12.72	10	3.5



Selected events:
Distance <40km – Magnitude > 2

#Origin Time (UTC)	Latitude	Longitude	Depth	Magnitude
24/08/12 22:18:31	41.75	13.88	16.7	2.4
24/08/12 17:42:10	41.76	13.9	10.7	2
24/08/12 05:59:09	42.22	13.51	10.4	2.1
17/08/12 12:53:22	42.02	13.25	8.8	2.5
17/08/12 05:18:18	42.02	13.25	8.9	2.8
14/08/12 23:03:27	42.18	13.97	23.8	2.1
14/08/12 19:17:58	42.19	13.97	8.6	2.5
14/08/12 11:47:55	42.19	13.96	9.9	2.3
15/07/12 11:35:52	42.08	13.97	8.6	2.4
11/07/12 13:33:43	42.29	13.38	9.6	2.1
07/07/12 10:27:41	42.07	13.97	3.9	2.6
11/06/12 14:42:19	41.76	13.21	10.5	2
19/05/12 06:46:03	41.82	13.86	11.1	2.2

Selected events:
Distance <10km Magnitude <2.0

#Origin Time (UTC)	Latitude	Longitude	Depth	Magnitude
16/09/12 14:16:29.00	42.01	13.57	7.4	1.3
16/09/12 12:24:07.00	42	13.56	10.3	1.5
15/09/12 09:46:38.00	42	13.71	12.3	1.3
08/09/12 16:24:54.00	42.01	13.57	10.5	1.2
04/09/12 15:22:11.00	41.9	13.71	10	1.7
03/08/12 03:24:28.00	41.99	13.54	12.1	1.5
30/07/12 10:03:57.00	41.9	13.71	8.9	1
30/07/12 04:15:47.00	41.9	13.7	9.8	1.8
11/07/12 16:02:44.00	41.9	13.71	9.6	1.4
12/05/12 04:05:24.00	41.94	13.71	17.1	1.6
27/04/12 02:07:46.00	42.04	13.5	11.1	1.3
27/04/12 01:58:17.00	42.02	13.48	12.1	1.3

Figure 8: Localization of the earthquakes recorded by the Italian network during the working period of the experiment (from ISIDE). The events are selected for different distance (R)-magnitude (Ml) range (from top to bottom): R<3000km–Ml>6.0, R<500km–Ml>5, R<100km–Ml>3.5, R<40km–Ml>2.

Figure 9 shows the good agreement in terms of HVNSR of all stations of the array, and confirms the resonance frequency of 0.3Hz.

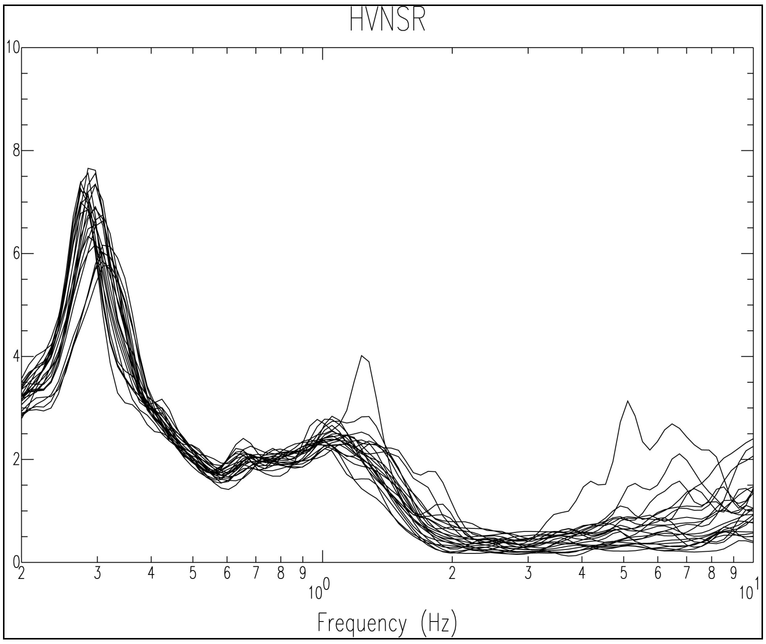


Figure 9: HVNSR of the 22 stations of the 2D array at Fucino Space Center

Figure 10 shows the 20th May 2012 M 5.9 mainshock of the Pianura Padana sequence, recorded by some stations of the 2D array at Fucino Space Center. Unfortunately, it reveals malfunction for some channels of the stations, that should be accurately checked.

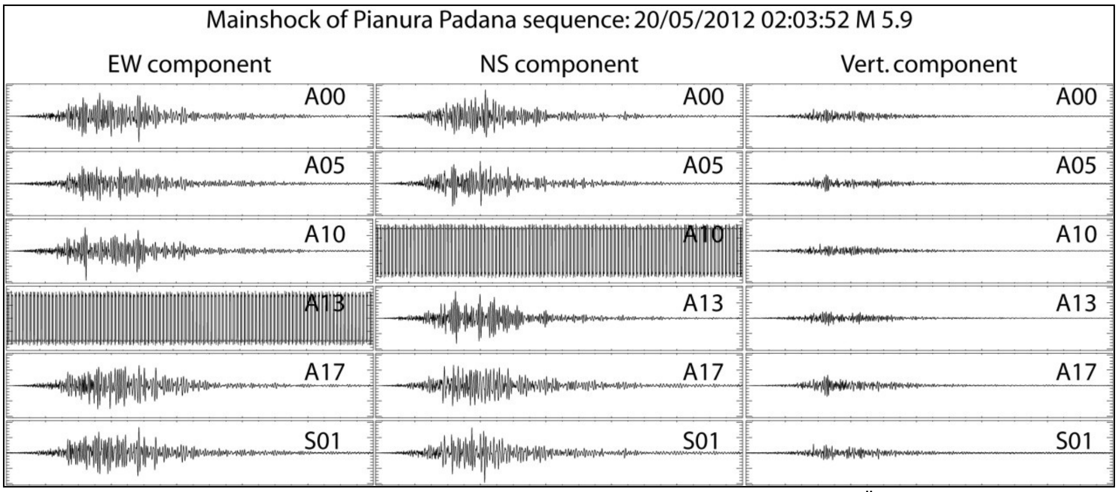


Figure 10: Recordings of the Emilia mainshock occurred in northern Italy the 20th of May 2012. Station codes refer to sites in Figure 6. Note the square-shaped time series for channels EW and NS of stations A13 and A10, respectively, indicating malfunctioning of the stations.

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Appendix 1

Roma meeting 2-4 March 2011
Minutes of sub-meeting on Data Sharing Scheme and New Experiment
Roma, INGV, 3/3/2011

Participants for Data Sharing Scheme & New Experiment

AUTH: K. Pitilakis (first part then moved to modellers')
INGV: G. Cultrera, G. Milana, G. DiGiulio, F. Cara, D. Famiani, P. Bordoni
SED:D. Faeh, Jan Burjanek
ITSAK: N. Theodoulidis
GFZ: S. Paolai, Ang. Strollo
ISTERRE: C. Cornou

To discuss and conclude about:
1. Sites with good quality of data (presentations)
2. Old data gathering and dissemination (web database, format…)
3. New experiment (site selection 1 or 2)
   - where
   - when
   - instruments available
   - manpower needed & participate

Sites presented

Mygdonian basin_EUROSEISTEST area- basin effect
- Geodata available
- Waveforms available

CORSSA area-Basin and topo effects
- Geodata available(?)
- Waveforms available(?)
- Proposed for new experiment for basin(?) and surface topography

Sion area- basin effect
- Geodata available
- Waveforms available

Visp area-basin effect
- Geodata available (? End of 2012)
- Waveforms available (? End of 2012)

Wakkerschamatt area-Rockfall
- Randa site-Rockfall
- Graechen site-deep seated landslide

L'Aquila are – basin and topo effects
- Geodata available
- Waveforms available

Gubbio basin – basin effects
- Geodata available
- Waveforms available

Fucino area -basin effects
- Geodata available
- Waveforms available
- Proposed for new experiment for basin and surface topography effects*

Nocera Umbra area – topo effects
- Geodata available
- Waveforms available

Narni hill – basin and topo effects

- Geodata available
- Waveforms available
- Proposed for new experiment for surface topography effects (more geophysical work needed)

Selected broadband Italian stations for surface topography effects

- Geodata available
- Waveforms available

Cavola site – landslide

- Geodata available
- Waveforms available

Grenoble area – basin effects

- Geodata available
- Waveforms available

Grevena – basin effects

- Geodata available
- Waveforms available

Argostoli – basin effect

- Geodata available
- Waveforms available
- Proposed for new experiment for basin and surface topography effects*

List of parameters required for basins & surface topography studies

Amplification (SSR)

Fundamental fo
Vs profile (of reference station)
Vs profile (of valley stations, Vs-aver-bed, Vs30)
Station-Site classification based on geology (few classes based on age)
Q, kappa value(?)

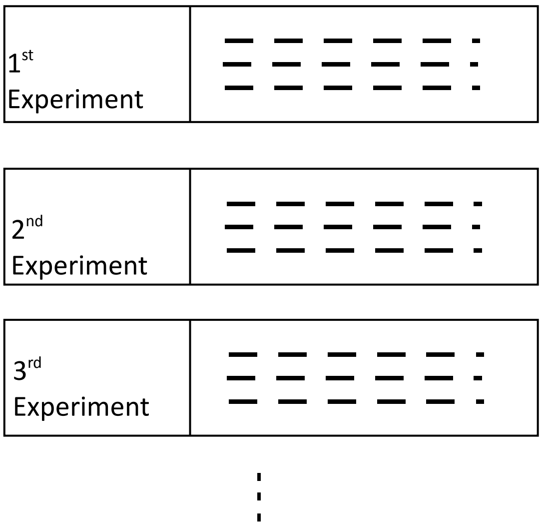
Morphology of the basin (2D/3D)
(depth below station, depth, length, width of valley, edge slope, closest distance to edge)

Morphology of topography (2D/3D)

Data gathering and dissemination

Simple web page

Short description



(i) Name of Experiment

(ii) Date of Experiment

(iii) Short description

(iv) Link to the Table

(v) FTP link to the data

2. GEOMIND db

The Partners complete an *.xls with specific description

The *.xls → converted to XML file [tool provided by GEOMIND]

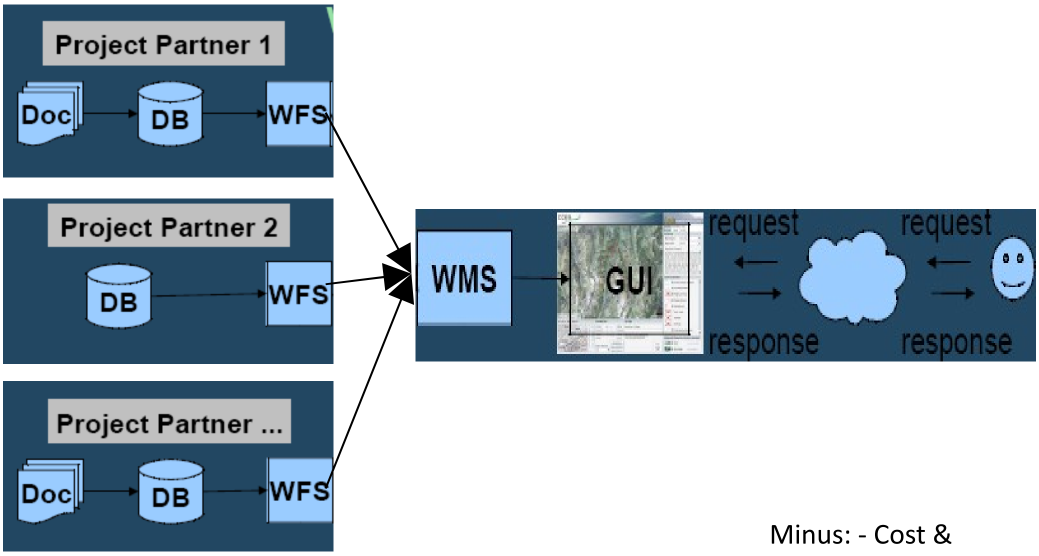
XML file uploaded to GEOMIND db by each Partner

Plus: - Central Portal
- Distributed data

Minus: - Cost & Time to create FTP
- Sustainability???

3. Use of WFS [like COGEAR prj.]

Each Partner has/create its own database (or create one and distribute among Partners)



Plus: - Central Portal
- Distributed data
- sustainable

Minus: - Cost &
-Time to create FTP

Data Sharing Scheme Discussion

(i) Format of the data remains as it is for each Institute (SAC, miniseed, GSE, CGY, ascii)
(ii) For new experimental data → EIDA data archiving db

To do within next 2 months:

1. To ask NERA portal help for GUI and WMS
2. To prepare description of metadata fields-XML
3. To prepare web page and distribute to all partners (within 2-3 months??)

Selection Criteria for the New Experiment Sites

1. Previous data availability
2. Surface topography & basin effects
3. Safety of instruments
4. Housing & Electricity
5. NERA-JRA3 near fault strain requirements
6. High seismicity rate
7. Local people to monitor & check (safety, operation etc.)

Guliano Milana & Nikos Theodoulidis to check for the details of the 2 sites selected (Fucino & Argostoli) and inform participants by April 15, 2011.

New experiment

Duration 4-6 months starting from 1st Sept. 2011.

Availability of Participants – Instruments - Manpower
ITSAK: 13 CMG 6TD 30s, 3 persons, 5 solar panels, (15th August + 6 months)
ISTERRE: 20-25 Taurus with CMG40, 30s, 3persons (including a PhD student)
All station with solar panel, (1st Sept. + 6 months)
INGV: 12 Quantera or Reftek (6 channels Le5s, episensors), 3-4 persons
All station with solar panel, (15th Sept + 6 months)
GFZ: 10 EarthData EDL with Mark 1Hz, and 5 K2 with episensors,2 persons)
All station with solar panel, (15th July + 6 months)
SED: Will know by July 2011
AUTH: Will be asked

Concluding for the new experiments:
- Available 55 to 60 instruments
- 4 Institutes
- 12 persons

Appendix 2

Meeting: Topographic effects in past earthquakes
Tuesday 21. June, Time 8:30-17:00
Place: ETH Zürich, NO building, room F47

ISSUE

Polarization and amplification of the ambient vibration wave-fields and earthquake ground motion can have particular properties at sites where topographic effects have been observed in past earthquakes. Polarization is seen in Italian sites, Swiss sites, and sites in Southern France. It seems that not only geometrical factors contribute to these observations, but mostly the internal structure of the rock, the presence of weathering or sedimentary deposits contribute significantly to the amplification/polarization.

GOALS

INGV-Roma, ITSAK-Thessaloniki and SED-ETH Zurich together with interested persons from INGV-Milano and CETE Nice will meet in Zurich to compare the findings, and to
1) Decide on the possibility to apply of a common processing to all datasets.
2) Prepare the base for deciding a number of models for numerical simulations
3) Discuss a potential test site

Tentative Programm:

Donat Fäh: Goals of the workshop

Vera Pessina: GIS-based identification and morphometric analysis of topographic sites with seismic amplification effects

Jan Burjanek: Seismic response of unstable rockslopes: Topographic site effect?

Nikos Theodoulidis: Suspected Topographic Effect: Case Study for the town of Grevena-Greece

Marta Pischiutta: Directional amplification of rock stations of the Italian Broadband Network: the role of topography and intensely fractured rocks.

Antonio Rovelli: Topographic effects in Italy: a review.

Etienne Bertrand: The case study of Rognes
……………………..
……………………..

Discussion (Jan Burjanek)
Overview of available data
Common Strategy for processing

A possible test site for topographic effects (Antonio Rovelli)

Models for numerical simulations (Pierre-Yves Bard)

Appendix 3

Minutes of the Skype conversation on January 20, 2012

Participants:

Giovanna Cultrera, Fabrizio Cara, Giuseppe DiGiulio from INGV-Rome
Nikos Theodoulidis from ITSAK-Thesaloniki
Cècile Cornou from ISTERRE-Grenoble
Tobias Boxberger from GFZ-Potsdam

Purposes of the meeting:

a) Update on the ongoing NERA-JRA1 experiment at Argostoli,
b) Data storage in EIDA db,
c) Instruments' take off - end of the Argostoli experiment,
d) Other geophysical investigation at Argostoli and research studies.

Update

Since the end of October, there are several irregular lack of data due to the bad weather, which prevents the solar panels to charge the batteries. To solve the problem, Tommy changes the batteries about every 2 weeks, and Cècile has sent 10 new solar panels at Argostoli that can be used to support stations in trouble.
TO DO— 1) all the partners must update the status table sent by Cècile and indicate which are the stations having a critical status; 2) on the basis of this check, INGV will decide if it is necessary to go to Argostoli to fix problems (Alekos is going next week, Nikos at the end of February or beginning of March)

Data storage in EIDA db

Giovanna sent the table with information needed for the ISC registration of the stations
TO DO— 1) all the partners must check and add the missing information by end of January; 2) all the stations in the Koutavos park need to be located with the differential GPS which is more accurate than the stations' gps (except stations from S1 to S7, already measured), whereas for the other stations we can use the location from their GPS (if possible station S16 in the farm field in front of Koutavos park needs to be located with the differential GPS because its gps is not working as expected until now). Cècile is in charge of this task and probably she (or Afifa) will be in Argostoli by the end of February and in any case before the NERA meeting in Rome or before the 17th of April.

Instruments' take off

We agree to take off the stations during the week 17-21 of April (2 days for take off, 2-3 days for noise array measurements). Nikos is in charge to inform all the people involved in Argostoli about the extension of the experiment.
French team is going to install the stations in Italy just after that.

TO DO

1) Verify the period and the people availability for each group; 2) Verify the possibility to install French (and if not redundant Italian) stations in the Fucino plain in the week 24-28 of April (warning: it is the EGU week!); 3) French team has problems with the car: the Italian group should verify if it is possible to rent a van in Italy that can travel in a ferry outside Italy; or maybe find a large INGV car that can be used to transport the French people and the French stations from Italy to Greece and viceversa.

Other geophysical investigation at Argostoli and research studies

Afifa verified from H/V (on noise or earthquake?) that the deeper soft soil is below S3. We discuss on where to perform some noise-array experiments: there are at least four-to-six interesting sites at Argostoli to investigate but we wait for Alekos to have a more clear idea on that (most probably 3 arrays across the section r01 to r02 and another 3 into the southeast parts of the valley). End of February could be a good chance to visit these sites for the people that will be there (Nikos for sure, maybe some Italians, maybe Cècile) and if possible to design the arrays having in mind the actual logistic: in any case the design of the arrays should be done before April, since during the meeting in Rome we should reach a final agreement on that.
Cècile propose also to perform, if possible, few down-hole measurements using a system of geophones belonged to ISTERRE.
All partners must prepare a plan of their future research work based on the Argostoli experiment data and present it in Rome next meeting 26-28 March (as was also asked by Pierre-Yves).
TO DO— Nikos is going to send the list of the localized events in the broader area of Cephalonia (with M>3). Nikos or Alekos shall check for available cased boreholes within the valley of Argostoli in order to perform down-hole measurements .

Further communication among partners

We agree to have another Skype meeting at the beginning of March to discuss on the studies we want to do and on the missing measurements to perform before the end of the experiment.

Appendix 4

Minutes of the NERA-JRA1 Skype meeting of March 12th 2012

Participants
ISTerre: C. Cornou, A. Imtiaz
INGV: G. Cultrera, F. Cara, G. Di Giulio, G. Milana
GFZ: T. Boxberger
ITSAK: N. Theodulidis

Purposes of the meeting
1. Update on the ongoing NERA-JRA1 experiment at Argostoli,
2. Instruments' take off - end of the Argostoli experiment and geophysical investigation
3. Preparation of the NERA meeting in Roma
4. Wishes of each partner regarding the data analysis
5. Fucino experiment

1. Update on the ongoing NERA-JRA1 experiment at Argostoli
The experiment suffered from large data gaps during the period from mid-Nnovember 2011 to February 2012 due to bad weather conditions. Since the mid of fFebruaray - begin of march, most of the stations are fine. However, we agree that Tommy should dedicate more time than usual until mid of Aapril checking the stations.

2. Instruments take off

Dates	Planned tasks
16/04/2012	Arrival in Argostoli
17/04/2012	Precise GPS measurements of all stations Removal of stations Positioning the best places for array noise measurements
18/04/2012	Precise GPS measurements of all stations Removal of stations Positioning the best places for array noise measurements
19/04/2012	Ambient array noise measurements (two groups)
20/04/2012	Ambient array noise measurements (two groups)
21/04/2012	Ambient array noise measurements (two groups)
22/04/2012	Departure to Roma (INGV+ISTerre)
23/04/2012	Arrival in Roma (INGV+ISTerre)
24/04/2012	Installation in Fucino
25/04/2012	Installation in Fucino
26/04/2012	Installation in Fucino
27/04/2012	Return to Grenoble (ISTerre)

IsTerre has to communicate as soon as possible if it is necessary to use INGV cars to bring the French stations to Italy or if it is possible to rent a van directly from France.

Regarding geophysical and geological investigation of the Argostoli basin:
- N. Ttheodulidis and A. Savvaidis collected information from 15 boreholes in the area
- Cedric Guyonnet-Benaize will come during the removal of stations for performing additional geological surveys
- Array noise measurements will be performed in the valley of Argostoli and close to R1 station. The exact number and location of arrays should be decided during the Rome meeting.
- Nikos and Alekos is suggesting to perform also electric profiles close to the valley edges
- C. Cornou also suggest to perform active surface wave measurements and ask if some equipment from the university of Thessaloniki might be available during the time period

3. Preparation of the NERA meeting in Roma

- Afifa Imtiaz looked at the data for A00 station until the end of December. About 200 of earthquakes has been visually recognized gathering events localized by regional networks and unlocalized events. She is currently working on computing various parameters (e.g PGV, signal-to-noise ration, etc.) useful for checking the quality of the signal and will present the results during the Roma meeting.
- We selected three events recorded in October 2011. Data (sac format) from these three events will be exchanged between partners for vizsualaiszation and analysis (time series, PGV, H/V). Results will be discussed during the Roma meeting.

4. Wishes of each partner regarding the data analysis

INGV:

- Cross-correlation on the array data for tomography purposes (INGV group has not experience on this topic but it would like to learn it)
- Quantification of the difference between SSR H/V on noise and earthquake and SSR on earthquakes by using the canonical correlation approach
- Correlation between strong ground motion parameters and basin characteristics

ISTerre:

- Correlation between strong ground motion parameters and basin characteristics
- Differental motion, coherency analysis, characteristics of ground motion wavefield by using array techniques
- 2D/3D modeling

GFZ

- 3D site effects and polarization analysis by using array techniques
- Use of vertical array data if data are available

ITSAK

- 2D tomography across the R1-R2 section
- Geophysical/geological model
- Relocation of the seismic events
- 2D/1D aggravation factors
- Generalized inversion following Drouet approach

These different wishes may be distributed in the following packages:

1. 1. Sources (EQ relocation, source characteristics, …)
2. 2. Tomography and 3D model of Argostoli basin (cross-correlation, ambient array noise, geology, electric profiles, …)
3. 3. Ground motion properties through array analysis
4. 4. Strong ground motion parameters (canonical correlation, correlation with basin characteristics, differential motion)
5. 5. 2D/3D modeling
6. 6. 2D or 3D/1D aggravation factors

5. Fucino experiment

Cécile and INGV team will go to the Fucino area for a preliminary survey the day after the NERA meeting in Roma. Meanwhile Giuliano Milana will send a map of the area so that IsTerre can start to have an idea of a possible array layout.

Appendix 5

Catalogue of Localized & Un-localized events Recorded by the Argostoli Array

ddmmyyyy	**hh:mm:sec**(cut)	**Solution by Seismological Centers**
21092011	15:59:25	? Local EQ
22092011	10:43:39	? Local EQ
23092011	22:10:53	? Local EQ
24092011	21:14:19	? Local EQ
30092011	0:30:56	
30092011	6:54:30	
11102011	12:50:40	
11102011	13:04:50	
11102011	13:20:00	
12102011	4:54:48	
11102011	20:50:00	
19102011	23:25:00	
20102011	7:35:40	
20102011	17:46:00	
20102011	20:40:00	
20102011	22:01:46	
20102011	22:24:00	
21102011	20:25:00	
22102011	21:02:00	
23102011	2:12:00	
23102011	21:40:00	
24102011	7:48:00	
24102011	18:04:00	
25102011	0:10:20	
28102011	13:01:40	
30102011	11:36:00	
30102011	15:02:00	
31102011	7:22:00	
31102011	20:40:39	
1112011	7:04:44	
1112011	13:25:00	
1112011	15:47:00	
1112011	15:55:00	
1112011	17:01:00	
1112011	17:13:50	
2112011	21:27:00	
5112011	21:55:20	
5112011	22:38:00	
9112011	1:50:42	
10112011	23:10:35	
13112011	0:36:16	
13112011	23:44:00	
14112011	16:47:00	
14112011	19:36:25	
16112011	2:16:19	
16112011	7:10:00	
17112011	1:33:09	
17112011	2:06:38	
17112011	4:14:00	
18112011	23:14:00	
20112011	1:48:40	
20112011	22:14:00	
22112011	19:41:30	
25112011	13:19:00	
27112011	0:28:10	
27112011	16:27:00	
27112011	23:33:30	

27112011	23:35:00
27112011	23:42:00
28112011	3:18:00
28112011	3:21:00
29112011	15:12:00
29112011	16:56:40
29112011	20:36:30
30112011	10:27:13
30112011	17:21:00
30112011	21:27:00
1122011	3:51:38
1122011	4:58:20
2122011	1:45:25
2122011	13:06:44
2122011	14:38:01
3122011	0:01:21
3122011	7:02:42
3122011	11:27:21
3122011	12:54:00
3122011	21:49:12
4122011	2:08:30
5122011	8:20:40
5122011	8:22:57
5122011	8:23:02
5122011	8:33:45
5122011	8:46:59
5122011	13:00:32
5122011	14:27:51
5122011	16:17:56
5122011	16:20:50
5122011	23:29:50
6122011	2:20:47
6122011	8:54:42
6122011	10:42:08
7122011	0:50:08
9122011	0:28:55
9122011	19:19:26
9122011	20:18:22
10122011	0:28:40
10122011	2:00:45
10122011	14:34:18
10122011	16:18:20
10122011	18:41:11
11122011	15:42:00
11122011	15:47:00
11122011	20:25:30
11122011	21:19:00
11122011	21:26:00
11122011	22:10:00
11122011	22:10:45
11122011	22:17:30
12122011	2:23:20
12122011	5:35:30
12122011	8:04:40
12122011	8:13:30
12122011	8:31:00
12122011	9:52:20
12122011	10:36:10
12122011	11:16:00
12122011	11:33:10
12122011	13:36:10
12122011	17:00:00
12122011	17:06:00

12122011	17:12:00
12122011	17:42:10
12122011	18:06:00
12122011	22:21:40
12122011	22:52:00
13122011	4:01:00
13122011	4:40:10
13122011	4:59:50
13122011	7:29:00
13122011	16:54:40
13122011	17:45:40
13122011	19:55:30
13122011	19:57:30
13122011	20:51:20
13122011	22:55:40
13122011	23:40:00
14122011	0:51:30
14122011	11:17:00
14122011	11:24:20
14122011	20:03:00
15122011	0:08:00
15122011	2:22:40
15122011	5:34:45
15122011	6:44:10
15122011	15:36:30
15122011	16:08:10
15122011	16:18:20
15122011	17:06:10
15122011	23:24:00
15122011	23:25:30
16122011	7:06:10
16122011	8:11:30
17122011	4:01:20
18122011	0:58:30
18122011	11:42:00
18122011	11:10:10
18122011	12:18:40
18122011	15:03:40
18122011	15:14:30
18122011	19:54:30
19122011	1:59:20
19122011	20:06:00
19122011	20:40:10
19122011	20:42:00
20122011	2:47:00
20122011	4:47:00
20122011	4:49:20
20122011	7:13:50
20122011	9:18:00
20122011	13:30:45
20122011	20:15:00
20122011	22:05:20
21122011	2:40:20
21122011	4:02:25
21122011	4:04:00
21122011	6:01:00
21122011	8:23:00
21122011	9:01:00
21122011	9:44:50
21122011	12:43:20
21122011	17:11:50
21122011	23:20:35
22122011	4:49:30

22122011	15:46:40					
22122011	22:46:40					
22122011	23:27:10					
23122011	14:14:45					
23122011	16:47:30					
23122011	17:20:30					
24122011	13:40:00					
24122011	14:51:05					
25122011	0:23:10					
25122011	0:27:00					
25122011	2:22:20					
25122011	3:57:50					
25122011	5:13:00					
25122011	7:27:00					
25122011	7:30:20					
25122011	8:40:30					
25122011	11:44:40					
26122011	11:41:30					
27122011	10:26:20					
27122011	21:17:10					
28122011	0:34:20					
28122011	0:49:40					
28122011	1:27:20					
28122011	2:52:40					
28122011	18:54:41					
28122011	19:18:16					
28122011	23:48:04					
29122011	14:05:04					
29122011	14:06:25					
29122011	14:35:20	14:36:06.10	35.331	22.903	17.90	2.3
29122011	15:19:57	15:19:35.80	38.341	22.020	09.00	4.0
29122011	19:21:57					
30122011	0:45:41					
30122011	1:02:55	01:02:40.60	38.002	21.534	15.20	2.6
30122011	2:10:02	02:09:46.40	38.840	21.232	01.80	2.4
30122011	17:44:03					
30122011	20:50:35	20:50:41.60	40.783	27.315	06.40	2.4
30122011	22:04:33					
31122011	8:55:30					
31122011	16:25:36					
31122011	16:48:32					
31122011	17:09:55					
31122011	23:24:16					
1012012	11:46:11	11:45:55.50	37.369	20.805	02.30	2.6
1012012	12:26:53					
1012012	14:35:17					
1012012	19:19:39	19:19:15.90	39.370	20.872	00.30	2.7
2012012	1:53:28	01:53:00.00	38.810	21.134	02.80	2.4
2012012	2:52:48	02:52:20.80	38.819	21.148	06.30	2.2
2012012	8:59:53	08:59:38.80	37.835	21.419	18.50	2.5
2012012	18:34:36					
2012012	18:43:36	18:43:15.60	38.318	22.002	07.10	2.4
2012012	19:29:39					
2012012	23:32:30					
3012012	1:20:06	01:19:48.80	37.398	21.096	04.00	2.4
3012012	18:19:15					
3012012	19:43:11					
3012012	23:11:57					
4012012	3:08:35	03:08:19.60	37.950	21.692	13.70	3.0
5012012	20:26:20	20:25:49.50	38.972	22.230	16.30	3.9
5012012	22:59:33	22:59:16.60	37.334	20.540	00.90	2.6
6012012	8:24:30					
7012012	11:04:46					

7012012	23:00:27	23:00:10.60	38.567	21.700	00.00	3.4
8012012	1:29:53	01:30:59.00	36.328	25.427	18.40	2.2
8012012	3:07:53					
9012012	0:59:30	00:59:02.90	37.482	21.172	03.10	2.2
9012012	16:44:40	16:44:24.70	37.497	20.889	07.40	2.2
9012012	21:57:51	21:57:21.90	39.142	21.899	07.70	3.1
10012012	0:42:55					
10012012	6:46:25					
10012012	13:31:47					
11012012	17:34:07					
11012012	17:40:15					
11012012	22:24:20					
12012012	5:16:57					
12012012	14:47:16	14:47:14.00	38.146	20.597	12.40	2.4
12012012	18:39:10	18:38:47.10	39.288	20.253	00.00	2.7
12012012	19:43:07	19:42:47.60	39.219	21.030	00.00	2.7
12012012	22:11:24	22:11:00.10	39.294	20.274	00.00	2.5
13012012	10:34:06	10:33:41.80	39.288	20.307	01.30	2.7
13012012	12:31:40	12:31:23.50	39.295	20.269	00.00	2.7
14012012	10:00:39					
14012012	19:40:41	19:40:19.90	37.578	21.410	21.10	2.6
14012012	23:00:01					
15012012	13:10:16					
15012012	16:03:46					
16012012	4:01:10					
16012012	5:34:18					
16012012	5:59:07					
16012012	10:06:12	10:05:56.80	37.557	20.923	11.90	2.7
16012012	10:18:29	10:18:24.40	38.161	21.648	15.30	2.9
16012012	12:22:48					
16012012	15:39:02					
17012012	1:51:53	01:52:28.90	40.182	19.891	10.70	2.1
17012012	4:58:51					
17012012	8:15:00	08:14:44.10	40.241	19.657	04.60	3.0
17012012	14:49:05	14:48:49.00	37.408	20.477	00.00	2.6
18012012	4:49:04					
18012012	19:49:55	19:49:23.80	38.964	22.498	01.30	3.6
19012012	10:39:50					
19012012	12:50:56	12:50:51.50	38.107	20.743	14.10	2.4
19012012	13:19:18					
19012012	23:46:17	23:46:09.30	38.561	20.490	11.10	2.0
20012012	0:44:42					
20012012	5:57:42					
20012012	6:01:50					
20012012	6:42:20					
20012012	13:57:23					
20012012	14:09:53	14:09:18.90	38.115	21.953	20.90	2.5
20012012	19:38:22					
21012012	1:55:21	01:55:02.10	38.371	21.853	00.10	3.1
21012012	17:04:08					
21012012	19:25:18	19:24:53.30	38.346	22.079	05.80	3.2
21012012	23:24:29					
22012012	2:22:51					
22012012	3:30:18					
22012012	4:29:02	04:28:35.10	39.102	21.952	00.00	3.4
22012012	12:58:08	12:58:51.00	35.492	26.941	18.00	3.5
22012012	21:40:56	21:40:41.80	37.749	21.272	12.90	2.3
23012012	0:32:32					
24012012	11:17:11					
24012012	20:33:30					
24012012	21:40:59	21:40:29.70	36.825	21.793	08.70	3.9
25012012	0:44:35	00:44:18.20	37.344	20.869	14.50	2.1
25012012	7:49:58	07:49:41.90	38.163	21.723	14.60	3.1

25012012	13:34:58	13:34:33.90		36.797	21.704	00.10	3.6
25012012	16:34:41						
26012012	4:26:03	04:24:59.30		36.066	25.070	14.80	5.2
26012012	15:19:52	15:19:46.10		37.888	21.039	16.50	3.1
27012012	1:34:27	01:33:24.00		36.044	25.064	05.20	5.3
27012012	1:41:06	01:40:59.20		38.971	21.853	06.80	4.0
27012012	9:32:06						
27012012	13:24:16						
27012012	22:40:20	22:40:07.00		37.555	20.917	00.00	3.0
28012012	8:16:49						
28012012	11:47:34	11:47:22.20		37.415	20.534	00.00	3.1
29012012	13:46:09	13:45:59.70		37.877	20.957	15.40	2.2
29012012	21:26:12	21:25:45.40		36.817	21.577	00.00	3.0
30012012	0:18:23						
30012012	3:47:01	03:46:29.00		36.455	21.172	03.70	3.3
30012012	5:23:01						
30012012	7:31:56						
30012012	22:25:11						
31012012	7:44:51						
31012012	16:33:09						
1022012	9:38:13	09:37:43.7		40.167	24.062	08.80	2.0
1022012	20:12:58						
2022012	1:53:09	01:52:56.7		37.828	21.108	08.60	2.3
2022012	21:29:49						
3022012	13:23:00	13:22:39.2		39.190	20.606	00.00	3.7
4022012	1:25:10						
4022012	6:11:22						
5022012	05:58:11.19	not_localized					
5022012	16:08:14.1		38.181	21.728	17.5	3.0	AUTH
5022012	16:11:26.00	38.174	21.712	16.50	2.9	AUTH	
6022012	03:28:36.0		37.27	20.12	10.00	2.6	IONIAN SEA chek 46
11022012	04:47:07.40	37.691	21.406	07.20	3.1	AUTH	
11022012	14:03:47.40	37.329	20.701	09.10	2.5	AUTH	
11022012	15:41:01.10	38.275	20.317	02.70	2.4	AUTH	
11022012	23:14:59.44	unlocalized					
13022012	18:39:23.00	37.218	21.985	01.10	3.3	AUTH	
13022012	23:46:24.00	38.084	20.419	07.50	2.4	AUTH	
14022012	01:34:39.00	40.129	24.089	03.80	5.0	AUTH	
14022012	09:28:23.89	unlocalized					
14022012	12:08:12.80	40.136	24.061	08.90	3.6	AUTH	
14022012	13:21:43.80	37.703	20.805	00.20	4.2	AUTH	
15022012	8:17:42		38.132	20.903	02.60	2.1	
17022012	03:11:32.50	37.747	20.292	00.00	3.0	AUTH	
17022012	03:39:35.60	40.124	24.025	16.50	2.0	AUTH	
17022012	03:59:02.90	38.764	21.519	53.30	2.8	AUTH	
17022012	06:55:56.20	40.173	24.015	10.90	2.2	AUTH	
17022012	08:05:04.60	37.862	23.019	08.40	4.0	AUTH	
18022012	01:57:40.90	37.535	21.901	00.10	3.4	AUTH	
18022012	14:02:41.30	38.125	20.826	00.00	3.6	AUTH	
18022012	15:46:14.00	37.755	21.118	00.00	2.5	AUTH	
18022012	22:10:25.40	unlocalized					
19022012	5:29:03						
19022012	06:17:08.17	unlocalized - strong local event					
19022012	11:21:41.56	unlocalized - strong local event					
19022012	15:06:20.12	unlocalized - strong event ...					
20022012	8:46:57		37.245	20.400	0.10	3.0	
20022012	18:08:34.20	37.653	20.906	12.80	2.5		
20022012	23:15:27.49	unlocalized - local event					
21022012	17:17:37.20	unlocalized local event					
22022012	00:01:45.00	unlocalized local strong event					
22022012	00:25:35.20	38.104	20.780	13.50	2.0	AUTH	
22022012	00:25:35.20	38.104	20.780	13.50	2.0	AUTH	
24022012	20:13:29.44	unlocalized local strong event					

25022012	20:46:07.07	unlocalized local strong event				
25022012	21:19:27.20	unlocalized local strong event				
25022012	21:48:58.70	unlocalized event (local ?)				
26022012	06:17:19.00	51.72	95.99	10	6.6	SW SIBERIA, RUSSIA - CSEM
26022012	16:17:21.00	37.28	16.18	10	3.7	IONIAN SEA - CSEM
26022012	16:53:54.34	unlocalized local event				
26022012	21:19:02.63	unlocalized strong local event				
26022012	00:58:25.06	unlocalized strong local event				
26022012	17:48:16.86	unlocalized srong local event				
26022012	18:44:49.34	unlocalized local event				
28022012	04:39:21.80	37.929	20.858	12.40	2.8	AUTH
1032012	18:24:52.03	unlocalized local event				
2032012	00:53:30.90	unlocalized event				
2032012	00:53:53.34	unlocalized event				
2032012	02:56:20.36	unlocalized strong local event				
2032012	15:53:21.20	36.985	21.086	03.90	2.6	AUTH
2032012	19:44:16.85	unlocalized local event				
3032012	07:49:43.60	38.577	21.268	00.00	2.7	AUTH
3032012	23:04:38.04	unlocalized event				
4032012	01:15:44.40	38.266	21.642	17.40	3.0	AUTH
4032012	03:31:08.40	40.134	24.058	02.50	5.0	AUTH
4032012	05:35:33.80	38.272	21.648	21.90	2.3	AUTH
4032012	15:45:24.70	34.732	25.911	00.00	2.5	AUTH
4032012	19:37:16.70	37.543	20.394	00.00	2.6	AUTH
5032012	16:37:37.10	38.264	21.635	24.40	2.2	AUTH
5032012	17:46:56.30	38.248	20.705	00.10	2.0	AUTH
5032012	21:44:11.10	unlocalized event				
5032012	22:01:48.10	39.439	20.334	00.00	2.8	AUTH
5032012	23:30:22.02	unlocalized strong local event				
6032012	18:52:52.40	38.042	20.384	06.40	2.3	AUTH
6032012	20:40:07.40	38.266	21.621	15.30	2.6	AUTH
7032012	06:42:45.70	38.268	21.646	15.40	2.3	AUTH
7032012	21:51:37.50	38.271	21.630	20.60	2.4	AUTH
7032012	22:50:20.20	37.620	20.921	00.30	2.4	AUTH
7032012	22:55:52.90	37.589	20.879	09.90	2.2	AUTH
7032012	23:18:16.26	unlocalized event				
7032012	23:30:47.20	37.557	20.878	00.00	2.7	AUTH
8032012	03:51:43.06	unlocalized local event (same waveform as at 03.55)				
8032012	03:55:51.60	38.110	23.692	04.00	2.5	AUTH
8032012	18:54:24.40	38.690	21.317	16.00	3.4	AUTH
8032012	19:30:48.30	38.678	21.302	03.80	3.1	AUTH
8032012	19:39:27.90	38.677	21.278	02.10	3.3	AUTH
9032012	07:09:53.00	19.10	169.71	29	6.7	VANUATU - CSEM
9032012	17:09:25.55	unlocalized strong local event				
9032012	20:29:51.70	38.664	21.305	14.50	3.1	AUTH
9032012	22:12:25.30	38.261	21.639	23.90	2.5	AUTH
9032012	22:21:38.32	unlocalized strong local event				
10032012	03:57:57.00	38.346	20.546	01.80	2.2	AUTH
11032012	07:02:23.00	38.694	20.808	17.00	2.5	AUTH
11032012	07:02:23.00	38.694	20.808	17.00	2.5	AUTH
11032012	16:30:44.30	38.262	21.633	22.00	2.5	AUTH
13032012	10:59:37.20	38.604	21.714	00.00	3.7	AUTH
13032012	22:54:41.38	unlocalized local event				
14032012	01:13:40.89	unlocalized local event				
14032012	09:08:35.00	40.95	144.91	10	6.9	OFF EAST COAST OF JAPAN - CSEM
14032012	09:13:08.00	38.61	21.69	16	3.6	GREECE - CSEM
14032012	16:35:31.10	38.261	21.631	20.60	2.6	AUTH
14032012	17:34:52.14	unlocalized local event				
14032012	21:44:43.00	37.705	20.089	00.00	2.7	AUTH
14032012	22:17:41.19	unlocalized local event				
15032012	01:07:14.47	unlocalized strong local event				
15032012	05:40:58.60	38.695	21.305	00.00	4.3	AUTH

15032012	06:26:16.45	unlocalized local event					
17032012	02:37:00.40	37.981	20.948	21.20	2.2		
17032012	22:37:48.00	unlocalized strong local event					
18032012	04:44:38.50	38.248	21.681	20.40	2.0	AUTH	
18032012	13:52:20.90	37.999	20.168	00.00	3.0	AUTH	
18032012	14:23:34.85	unlocalized local event					
18032012	17:35:22.74	unlocalized local event					
18032012	18:11:26.14	unlocalized strong local event					
20032012	01:48:25.00	01:46:44.2		35.242	23.937	41.90	3.6
20032012	02:02:24.00						
20032012	16:41:35.00	16:41:51.6		38.221	20.645	08.50	3.0
20032012	16:45:21						
20032012	16:46:17						
20032012	16:46:41						
20032012	16:49:48						
20032012	16:53:27	Teleseisme ??					
20032012	18:20:45	Guerrero M7.4					
20032012	18:50:54	18:50:52.9		38.237	20.586	07.50	2.8
20032012	19:07:42						
20032012	19:23:45						
20032012	19:53:13						
20032012	20:06:06						
20032012	21:22:44						
20032012	22:07:50						
20032012	22:09:15						
20032012	22:09:39						
20032012	23:44:43						
20032012	23:52:05	23:51:10.7		36.039	24.398	71.30	4.5
20032012	23:55:29						
21032012	0:13:33						
21032012	0:52:23						
21032012	0:53:29						
21032012	2:11:21						
21032012	2:28:04						
21032012	5:51:06	05:50:48.3		38.627	21.705	04.00	3.8
21032012	15:27:10						
21032012	20:43:48						
21032012	20:56:32						
21032012	21:00:07						
21032012	21:03:35						
21032012	21:29:20						
21032012	21:35:06						
21032012	21:36:21						
21032012	22:05:20						
21032012	22:09:20						
21032012	22:14:46						
21032012	22:15:30						
21032012	22:17:29						
21032012	22:19:36						
21032012	22:32:57	22:32:54.4		38.317	20.424	00.00	3.0
21032012	22:56:24						
21032012	23:07:04						
22032012	0:39:40	00:38:13.1		35.501	26.089	09.80	4.2
22032012	2:28:36						
22032012	2:47:50						
22032012	3:08:33						
22032012	3:35:26						
23032012	13:25:16						
23032012	20:20:47	teleseismic					
23032012	21:06:28						
23032012	21:07:22						
23032012	21:12:37						
23032012	21:49:18						

23032012	21:56:30					
23032012	22:18:30					
23032012	22:22:05					
23032012	22:24:50					
23032012	22:34:22					
23032012	22:38:30					
23032012	22:50:10					
23032012	22:52:10					
23032012	22:57:50					
24032012	5:56:07	05:55:11.1	35.937	24.052	31.10	3.9
24032012	11:44:15					
24032012	16:36:01					
24032012	21:45:00					
25032012	3:46:48					
25032012	4:18:06					
25032012	4:39:40					
25032012	6:58:10					
25032012	8:41:20					
25032012	9:00:21					
25032012	22:20:00	teleseismic				
26032012	1:13:04	01:14:57.8	34.546	23.590	00.00	2.6
26032012	3:01:13					
26032012	5:44:00					
26032012	9:01:32					
26032012	10:04:29					
26032012	10:07:20					
26032012	12:01:34					
26032012	16:10:27					
26032012	19:36:26					
26032012	21:47:11					
27032012	14:33:03					
28032012	1:42:51					
28032012	2:33:01	02:32:33.6	38.376	21.767	10.50	2.0
28032012	4:47:33	tele				
28032012	5:11:37					
28032012	5:35:59					
28032012	6:05:33	06:06:59.9	34.549	25.472	00.00	2.4
28032012	7:15:08					
28032012	8:15:10	teleseismic				
28032012	9:26:00	teleseismic				
28032012	9:32:55					
28032012	13:33:03					
28032012	17:22:20	17:21:50.1	36.569	21.430	05.20	3.0
28032012	18:21:18					
28032012	19:47:41	19:47:22.8	38.412	21.825	00.00	3.6
28032012	22:51:47					
28032012	23:18:14					
28032012	23:42:35					
29032012	13:14:35	13:14:02.8	39.952	19.654	00.00	3.1
29032012	16:25:06					
29032012	20:44:56	20:44:31.1	38.264	22.165	04.00	2.5
30032012	9:52:57					
30032012	11:32:47					
30032012	11:58:14	11:58:09.4	38.257	20.709	15.30	2.5
30032012	12:20:37	12:20:32.5	38.266	20.686	14.70	2.4
30032012	17:38:18					
31032012	6:12:08	06:11:57.9	37.793	20.927	12.40	2.2
31032012	9:18:49					
31032012	11:04:31					
31032012	23:17:31					
1042012	15:58:21					
1042012	21:53:14					
1042012	22:13:38	22:13:18.0	39.217	20.799	00.10	3.2

1042012	23:48:53					
2042012	0:05:44					
2042012	0:48:41					
2042012	8:52:52					
2042012	11:48:36					
2042012	15:59:52					
2042012	17:38:22					
2042012	20:22:46					
2042012	0:22:59					
2042012	23:31:26					
2042012	23:35:22					
2042012	23:37:07					
2042012	23:42:10	23:41:58.5	38.043	21.378	10.40	2.2
3042012	1:02:22					
3042012	7:19:58					
3042012	19:54:46	19:54:30.9	38.186	21.718	18.40	2.9
4042012	0:49:35					
4042012	1:45:45	01:45:30.9	38.057	21.563	17.50	3.5
4042012	2:35:22	02:34:51.3	38.242	21.678	19.80	2.2
5042012	3:52:35					
6042012	9:35:10					
6042012	14:18:29					
6042012	15:07:49					
6042012	17:56:18					
6042012	18:42:55					
6042012	18:50:30	18:49:14.0	36.627	21.790	15.50	2.3
6042012	20:48:20					
6042012	21:07:15					
6042012	22:12:30					
6042012	23:12:14					
7042012	0:02:15					
7042012	0:20:31					
7042012	0:35:38					
7042012	1:59:50					
7042012	2:31:27					
7042012	7:26:25					
7042012	7:26:48					
7042012	7:33:14					
7042012	7:43:06					
7042012	11:24:32					
7042012	13:09:41					
7042012	13:24:12					
7042012	13:54:32					
7042012	18:52:07					
7042012	19:55:45					
7042012	21:07:05					
8042012	6:32:03					
9042012	7:57:58					
9042012	18:52:50					
9042012	23:10:27	23:10:10.0	38.069	21.561	08.40	2.8
10042012	0:26:12					
10042012	0:40:03					
10042012	2:39:11					
10042012	2:43:48					
10042012	9:41:07					
10042012	13:33:42					
10042012	13:45:49	13:45:44.4	38.042	20.188	00.90	2.4
10042012	14:24:40					
10042012	14:48:47					
10042012	14:53:22					
10042012	14:53:58					
10042012	15:21:54					
10042012	15:33:18					

10042012	17:43:27	17:43:21.0	37.957	20.124	00.10	2.6
10042012	18:30:00					
10042012	19:07:51					
10042012	21:55:42					
10042012	23:50:33					
10042012	23:54:27					
11042012	0:09:06					
11042012	6:19:21	06:18:52.8	39.674	20.347	00.00	3.6
11042012	6:22:04	06:21:34.8	39.675	20.343	00.00	3.2
11042012	7:52:23					
11042012	8:50:20					
11042012	10:55:00					
11042012	15:30:58					
11042012	17:03:07					
11042012	22:08:10					
12042012	7:53:03					
12042012	20:07:33	20:07:01.6	36.978	22.077	13.10	3.4
12042012	20:10:33					
12042012	22:55:26	22:55:10.0	37.776	21.312	29.60	2.9
12042012	23:02:00	23:01:42.7	37.761	21.281	29.10	2.4
12042012	23:04:46	23:04:32.3	37.775	21.299	28.50	3.0
12042012	23:19:30	23:19:13.8	37.768	21.325	28.00	2.3
13042012	0:27:11					
13042012	2:51:15					
13042012	3:46:41					
13042012	4:03:45					
13042012	6:58:08					
13042012	16:28:46					
13042012	21:31:27	21:31:07.9	36.932	20.664	00.00	2.7
14042012	1:29:42					
15042012	13:25:50					
15042012	22:19:12					
16042012	0:33:20					
16042012	3:20:13	03:19:48.8	38.288	22.136	01.50	3.1
16042012	8:40:46	08:40:23.3	38.299	22.148	00.00	3.8
16042012	11:24:11	11:23:42.7	36.646	21.497	13.00	5.2
16042012	12:02:47	12:02:15.6	36.517	21.568	05.50	4.1
16042012	12:48:18	12:47:58.5	38.293	22.120	02.50	3.3
16042012	15:07:23	15:06:53.5	36.525	21.556	01.50	4.6
16042012	15:46:43					
16042012	20:53:54					
17042012	0:41:28	00:41:12.2	37.749	21.298	19.00	2.1
17042012	4:38:11					
17042012	6:50:21	06:50:17.0	38.410	20.417	04.60	2.0