

Enceladus Supersite: The most tectonically active part of Europe - Objectives & Prospects

Dr Spyros Lalechos

Geophysicist

EPPO

Dr Thomas Salonikios

Civil Engineer

Senior Researcher

EPPO/ITSAK

The GEO GSNL Initiative

A voluntary international partnership aiming to improve, through an Open Science approach, geophysical scientific research on seismic/volcanic hazard over specific interest areas called Supersites, supporting Disaster Risk Reduction activities.

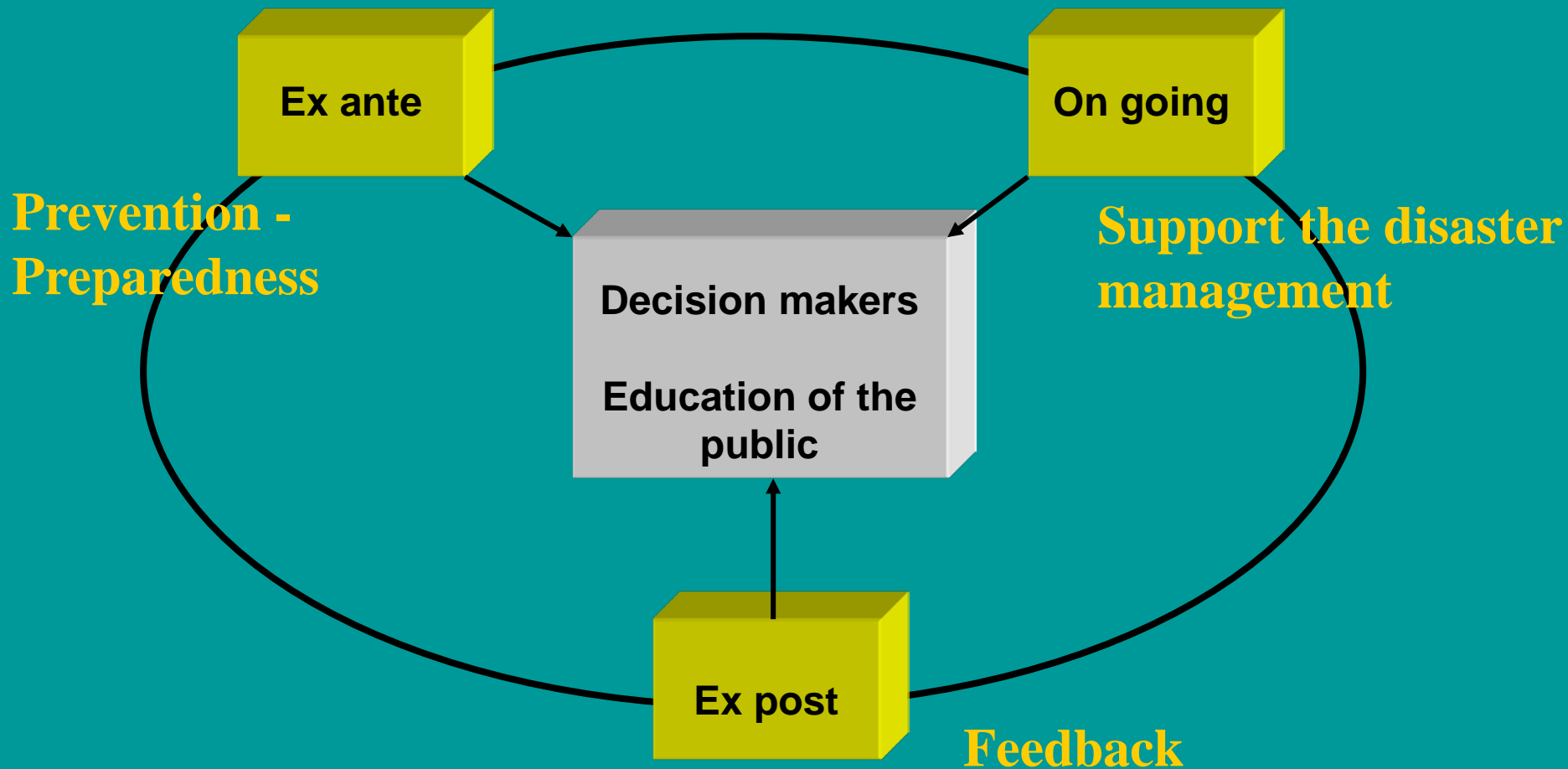


MISSION OF E.P.P.O.



Mission: Earthquake Protection

Plan and process the national policy during the pre-seismic (ex ante), seismic (on going) & post-seismic (ex post) phases



Greek Supersite Team

Thirteen Greek collaborators in the Core Team

- ❖ Earthquake Planning and Protection Organisation (Supersite Coordinator)
- ❖ Eight Earth Observation Laboratories from Universities
- ❖ Four Earth Observation Laboratories from Research Centres

Seventeen International Collaborators in the Core Team

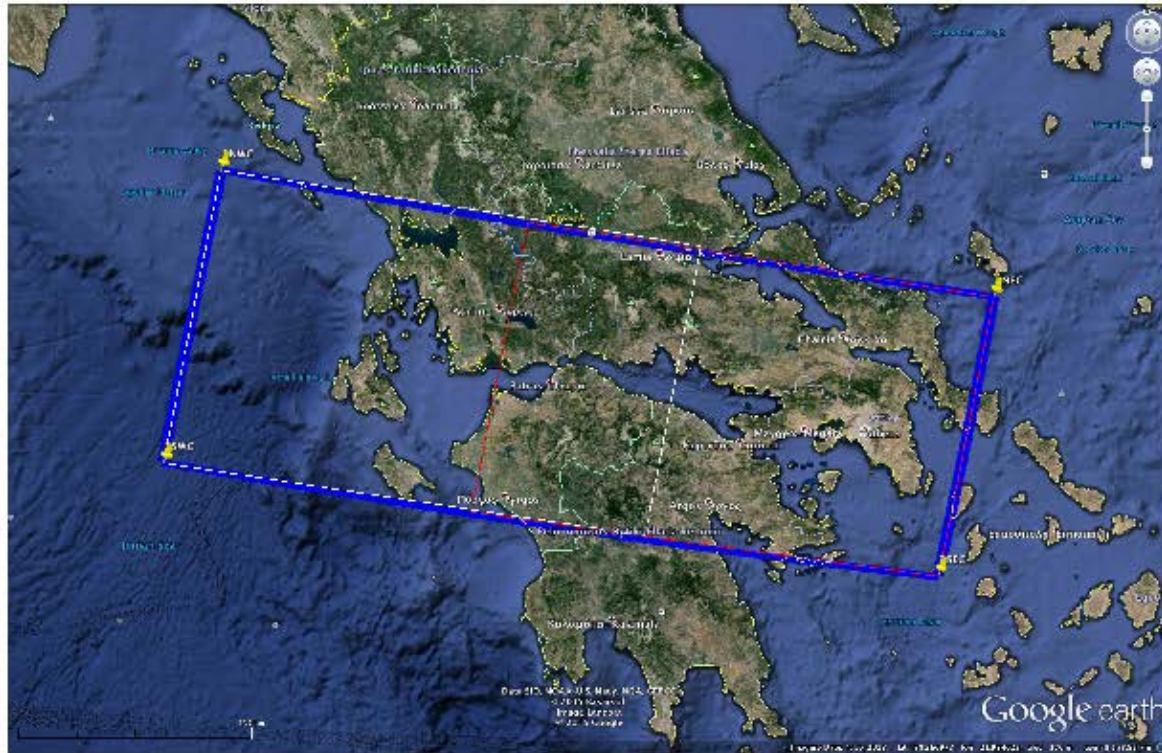
Twenty four International Organisations provided support letters

Design & Coordination 2016 - 2018: Dr Alexandros Savvaidis,
Geophysicist, Senior Researcher
EPPO / Research Division - Institute of Engineering Seismology &
Earthquake Engineering



Proposal accepted at the 30th CEOS Plenary, 2016

Region of Interest



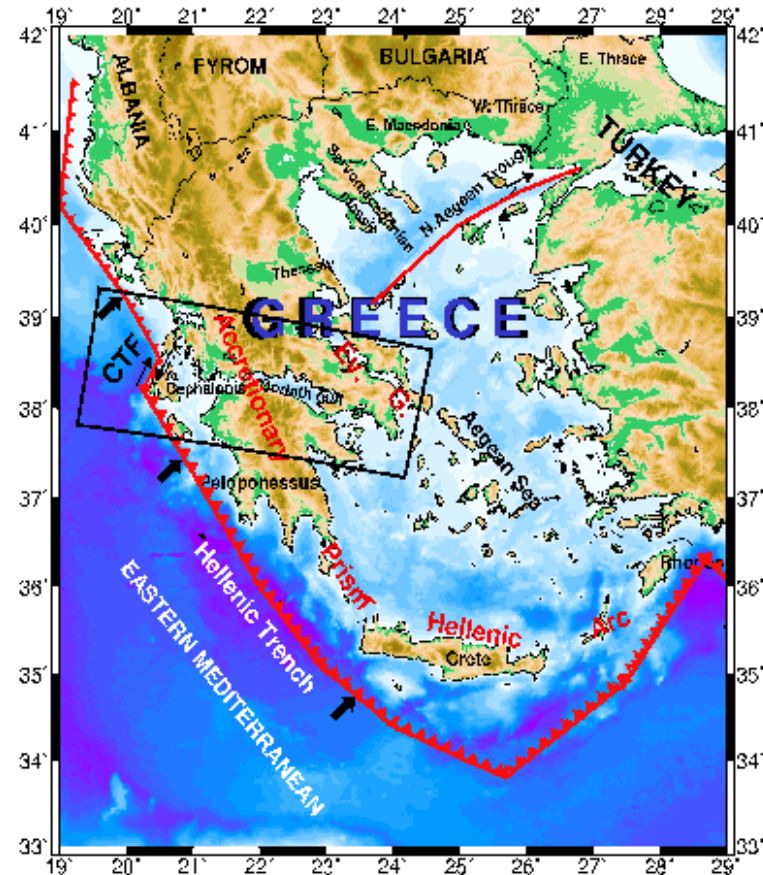
Motivation

Three sub areas of high tectonic interest

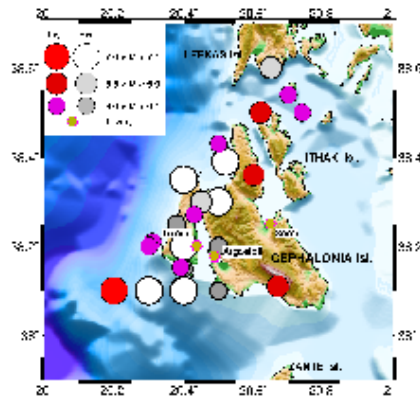
- ❖ Ionian Islands
- ❖ Corinth Rift
- ❖ Evoikos Rift

High societal impact

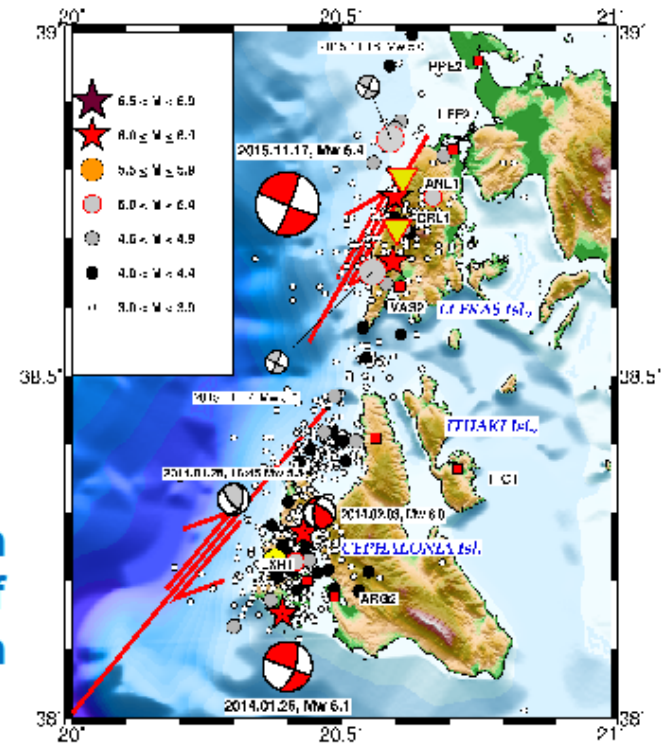
- ❖ More than 50% of the population
- ❖ Millions of visitors per year
- ❖ Cultural Heritage



Ionian islands



- ❖ Highest observed seismicity in Europe
- ❖ Highest recorded ground acceleration in Greece (0.77g) at epicentral distance of 7km from a M6.0 earthquake on February 3, 2014

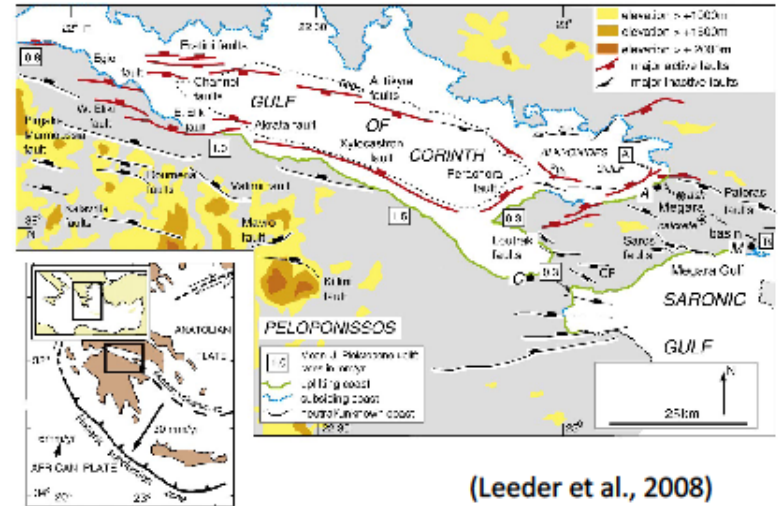


(Hatzidimitriou et al., 1994; Papazachos, 1999; Theodoulidis et al., 2016; Reilinger et al., 2010; Lagios et al., 2007, 2012; Ganas et al., 2013; Lagios et al., 2012)



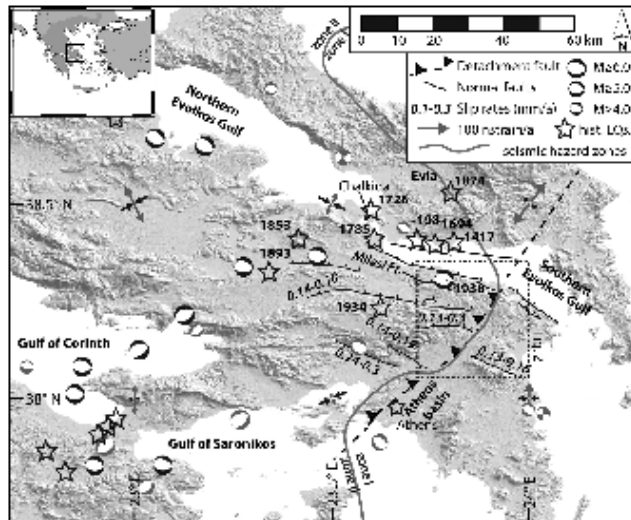
Corinth Rift

- ❖ Corinth Rift, is an ideal natural laboratory to investigate rift deformation mechanisms.
- ❖ Both 5-10-yr GPS and 100-yr triangulation GPS velocity estimates suggest N-S extension at <math><5\text{mm/yr}</math> in the east and >math>>15\text{mm/yr}</math> in the west



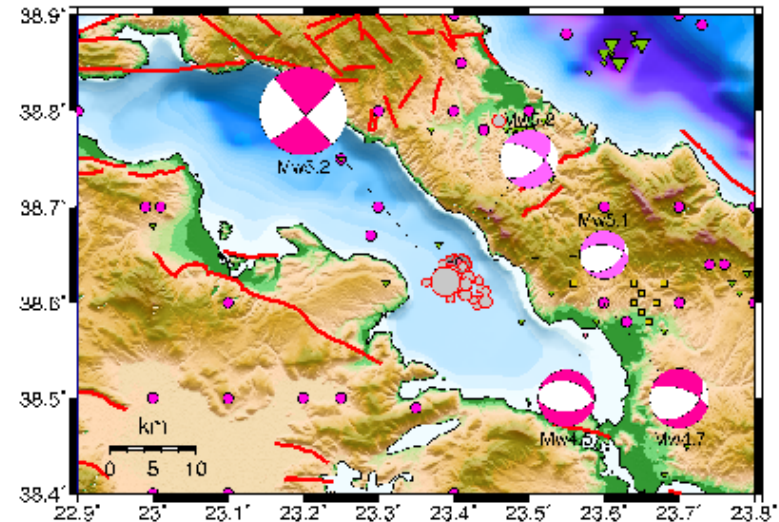
Evoikos Rift

Active faults



(Papanikolaou & Papanikolaou (2007); Papanikolaou et al. (1989); Ghisetti et al., 2016).

Recent Seismicity



- ❖ a strongly thinned continental crust below the central section of the northern part with thicknesses of only 19-20km
- ❖ a local uplift rate exceeding 1mm/year

(Makris et al., 2001; Cundy et al., 2010).



Research Objectives

- ❖ Long term monitoring of the area for mapping the crustal deformation and stress-strain regime, including time-varying patterns in an area that holds the highest seismicity in Europe.
- ❖ Perform updated seismicity relocations for the areas of interest, using the introduced calibrated crustal/upper models.
- ❖ Exploitation of the available datasets (existing and new) to obtain reliable empirical estimates of source, path and site effects for seismic motions in the Supersite area.
- ❖ Efficient fusion of the acquired earth and space observations in order to better monitor and understand the hazard sources.
- ❖ Exploitation of ground and satellite information to assess the risk in the Supersite area and achieve Disaster Risk Reduction and Quick Resilience.
- ❖ Vulnerability assessment (buildings, infrastructure, cities)



http://greeksupersite.eu/

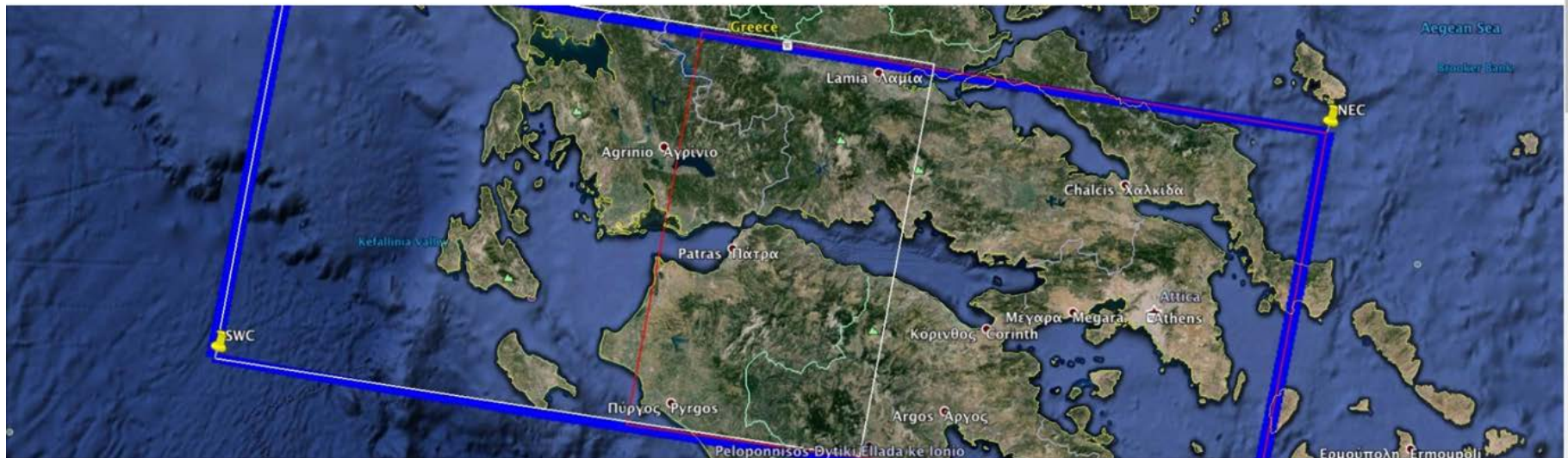
← → ↻ Not secure | greeksupersite.eu



+30 2610997592 knikolakop@upatras.gr



HOME SUPERSITE HISTORY SUPERSITE PARTNERS OPEN DATA SUCCESS STORIES CONTACT

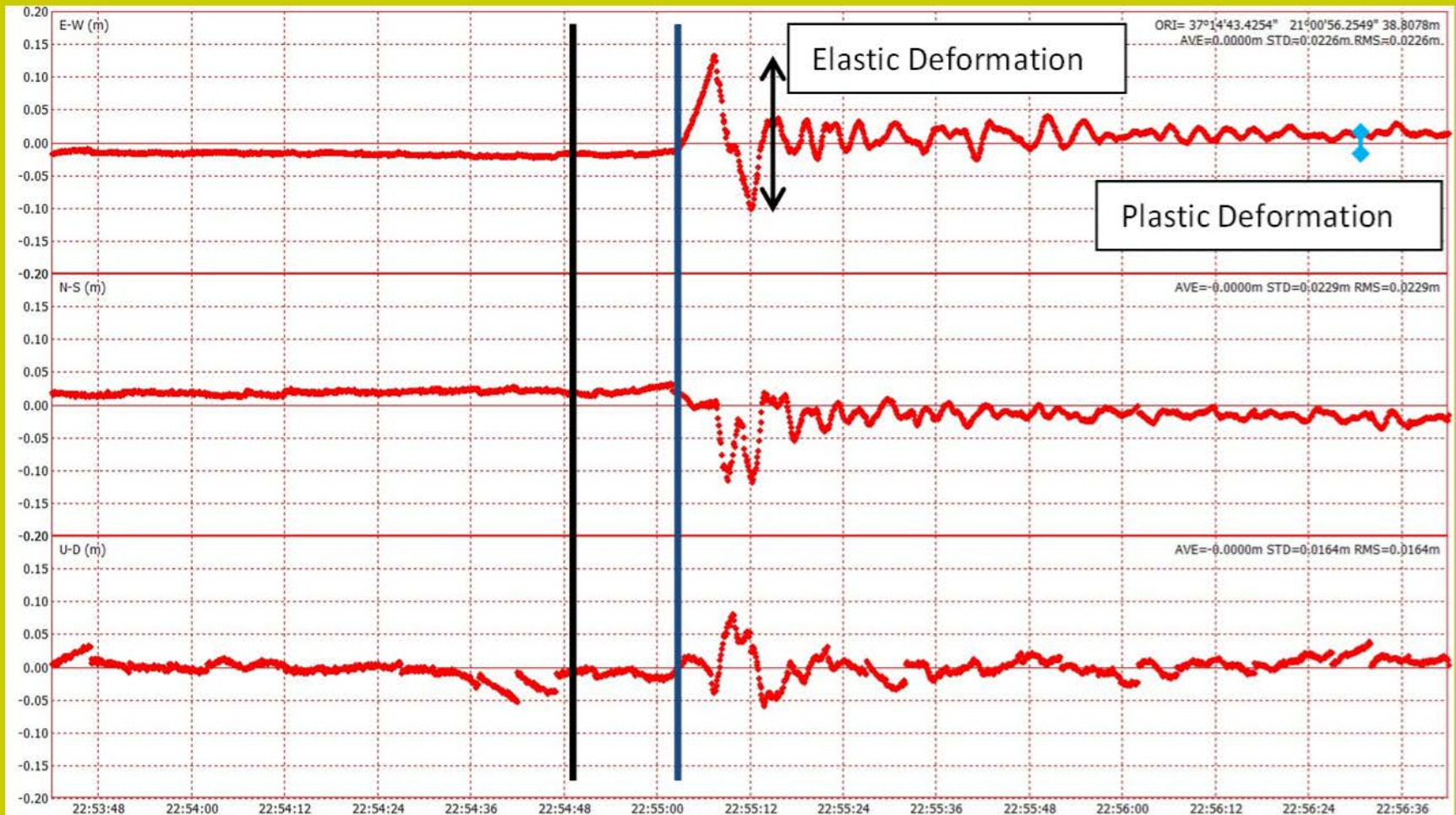


IN SITU DATA

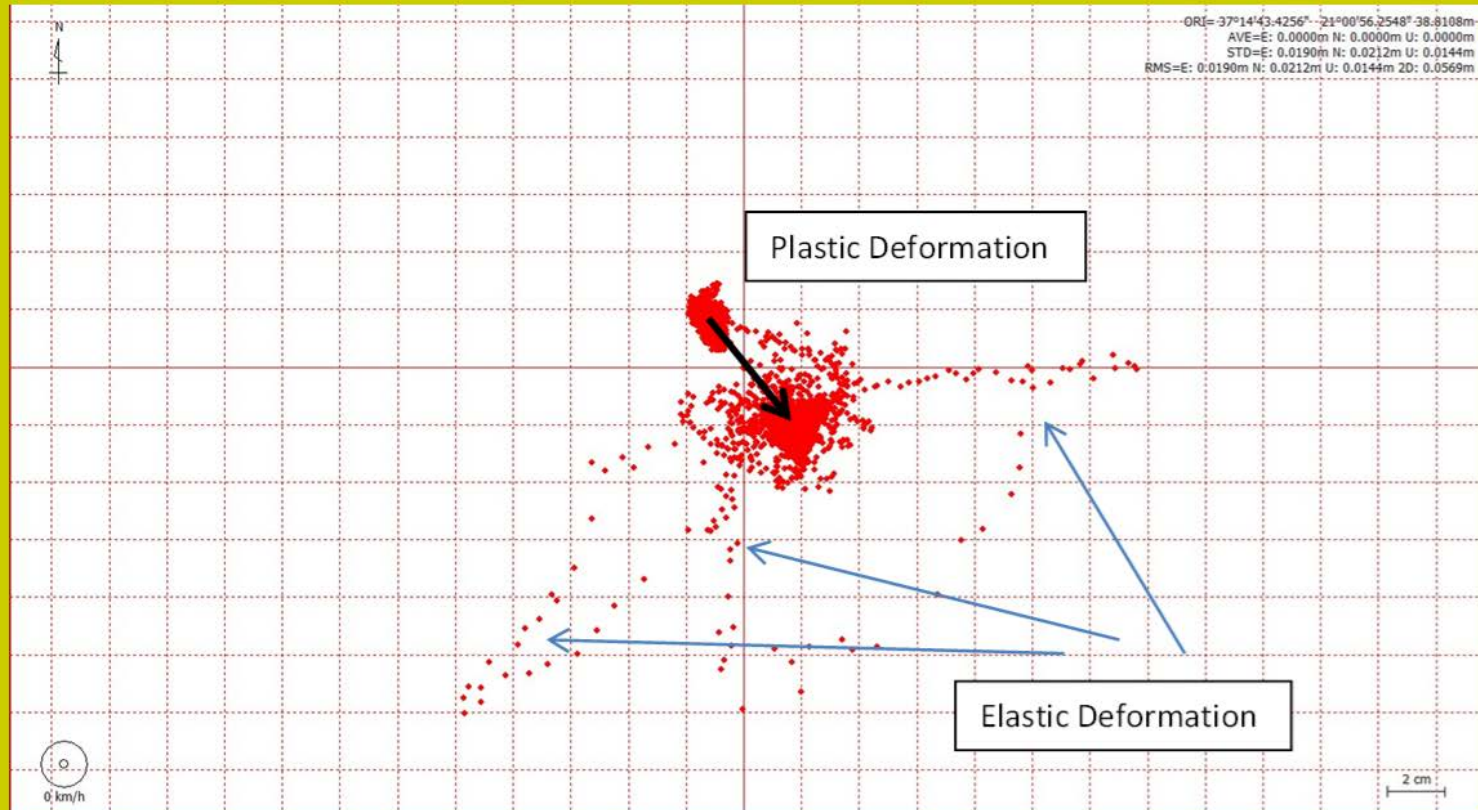
Elastic and Plastic Deformations analysis from 25 Oct 2018 Earthquake at Strofades GNSS station, 10Hz data

22:54:49 Earthquake time

22:55:02 Detection Time

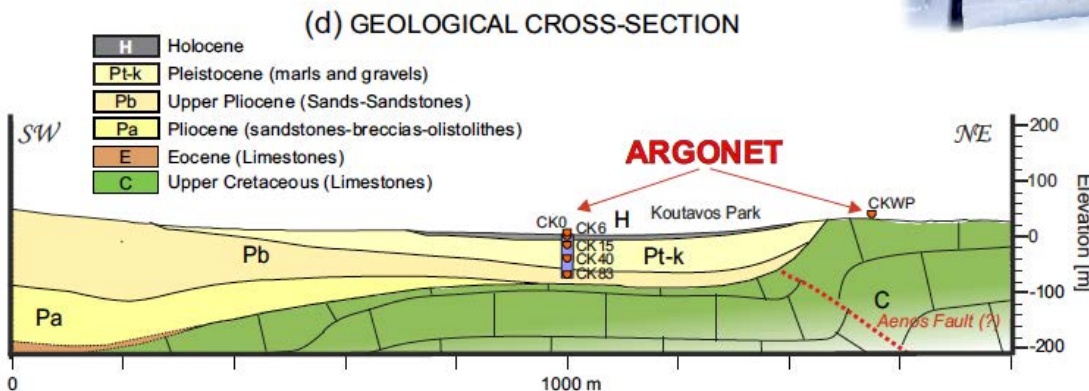
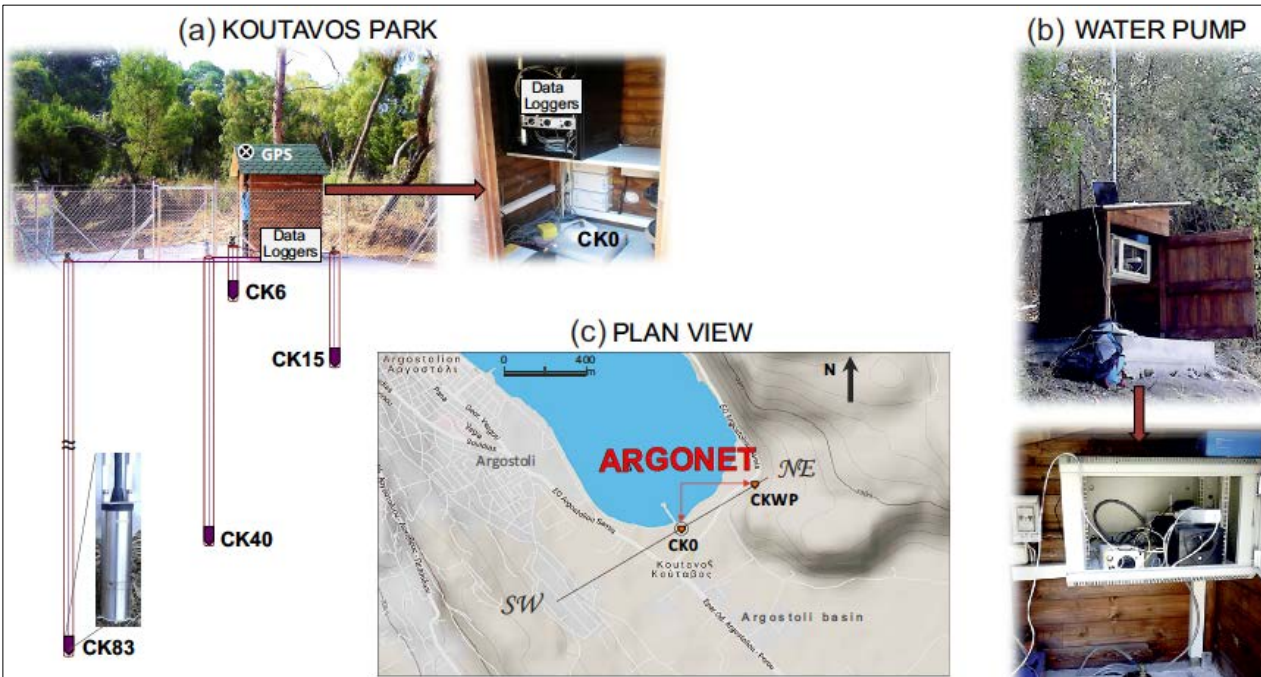


Elastic and Plastic Deformations analysis from 25 Oct 2018 Earthquake at Strofades GNSS station, 10Hz data

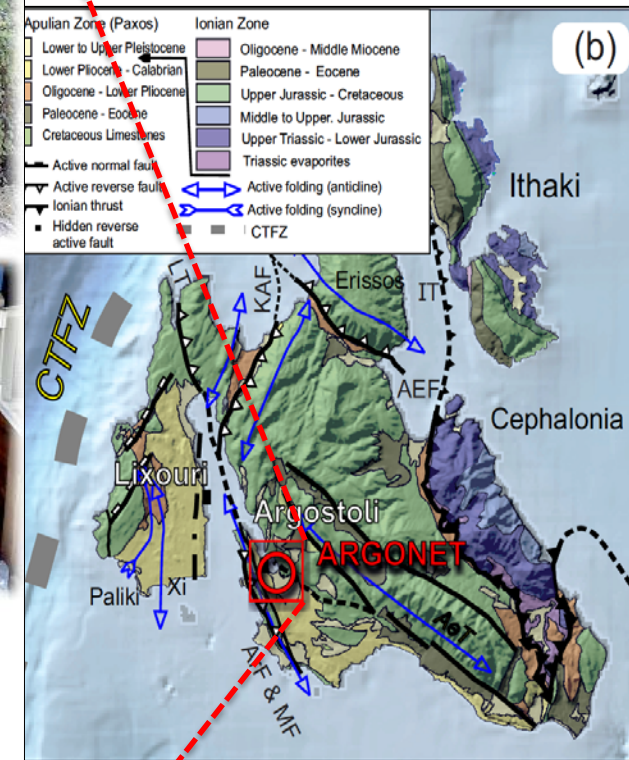


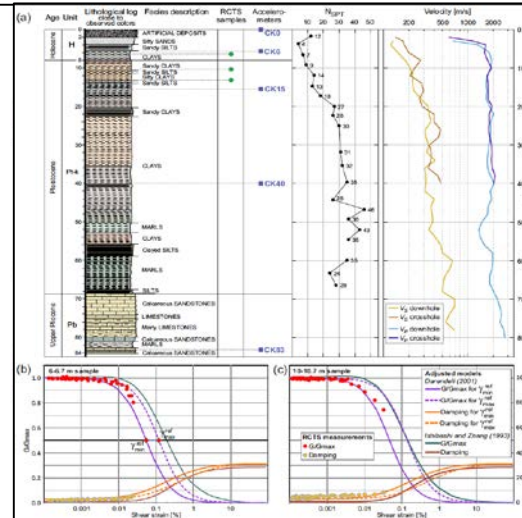
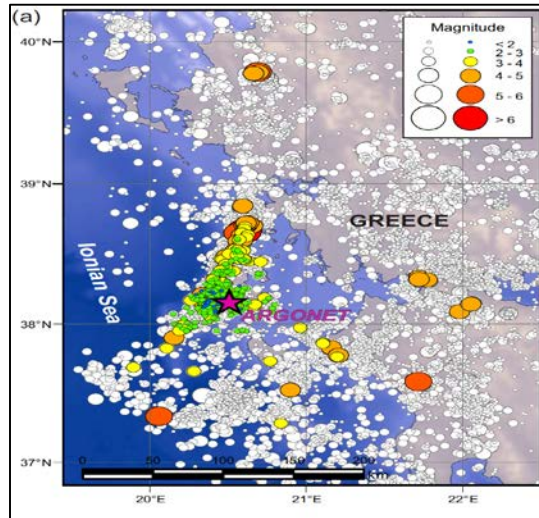
The ARGONET (Greece) Seismic Observatory: An Accelerometric Vertical Array and its Data

Theodoulidis N.*, Hollender F., Mariscal A., Moiriat D., Bard P-Y,
Konidaris A., Cushing M., Konstantinidou K., Roumelioti Z.



EPPO / Research Division -
ITSAK

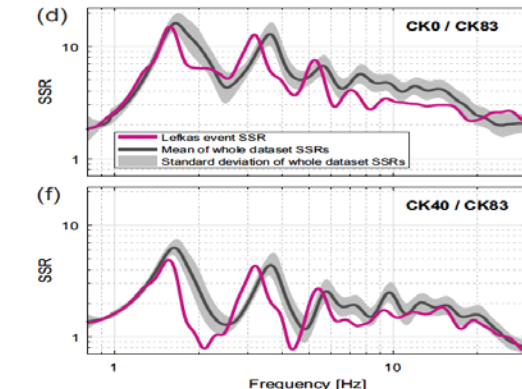
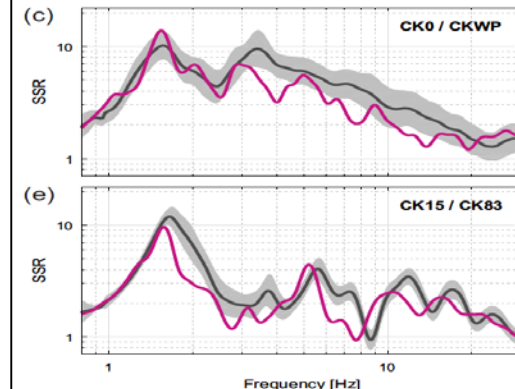
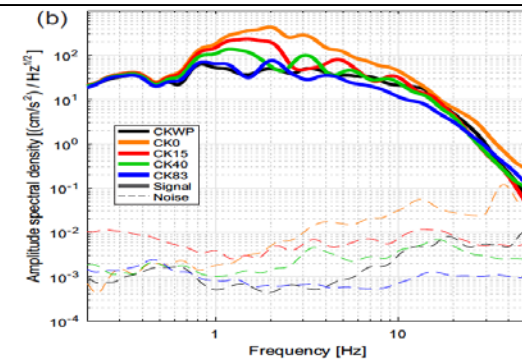
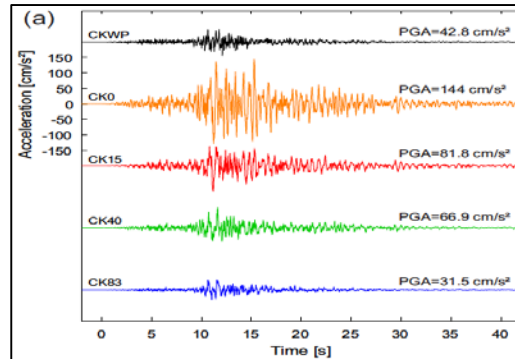




High seismicity makes it very likely for the ARGONET to capture strong ground motion in the near future. Open data & metadata offer opportunities for site response study.

Promising indication for increased likelihood of clearly observing non-linear site response especially in the topmost layers, soon.

Lefkas eq. 17 Nov. 2015 (M6.4)



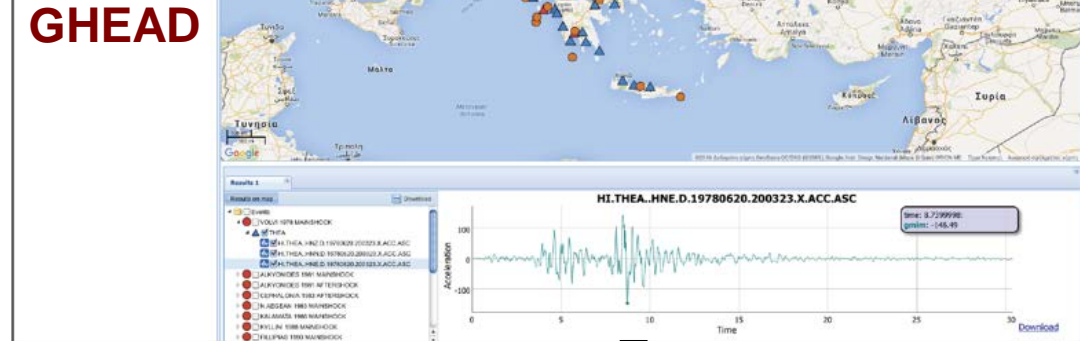
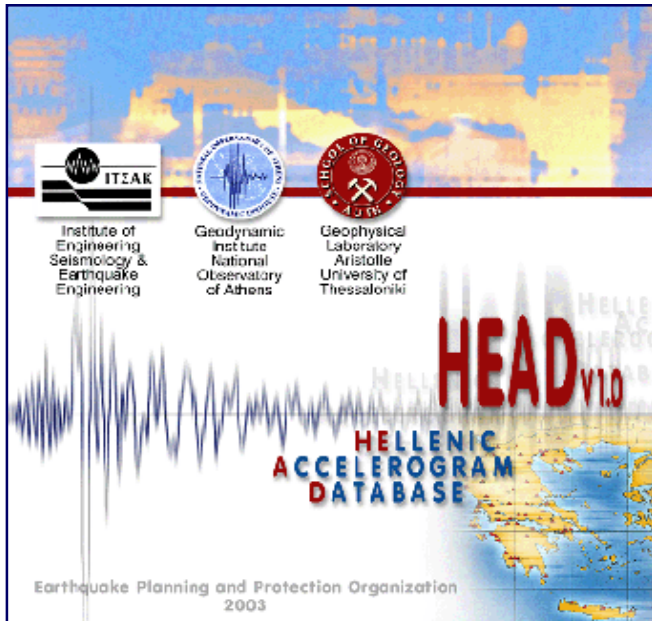
The detailed knowledge of the dynamic and geometrical properties of the site would then allow to test and upgrade 1D/2D/3D wave propagation methods and codes.

The ARGONET high dynamic range and sensitivity array operates in real time continuous streaming mode, aiming to serve as a near-fault observatory providing information on the study site 'before-during-after' the occurrence of a strong earthquake.

GEOPORTAL INSPIRE COMPLIANT

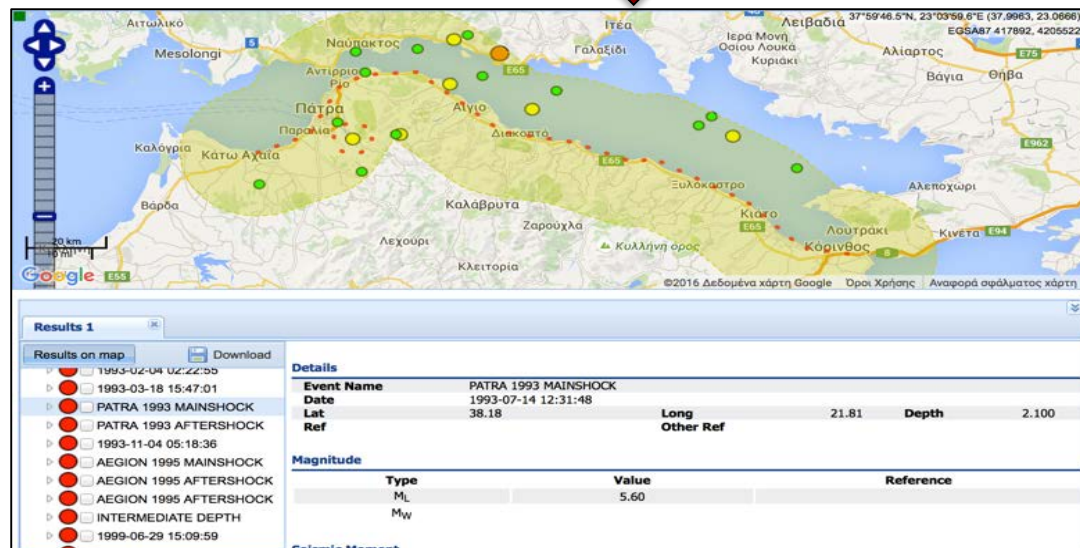
[<http://ghead.itsak.gr/map>]

[www.itsak.gr/en/db/data]



GHEAD

Retrieving Spatial & non Spatial Data

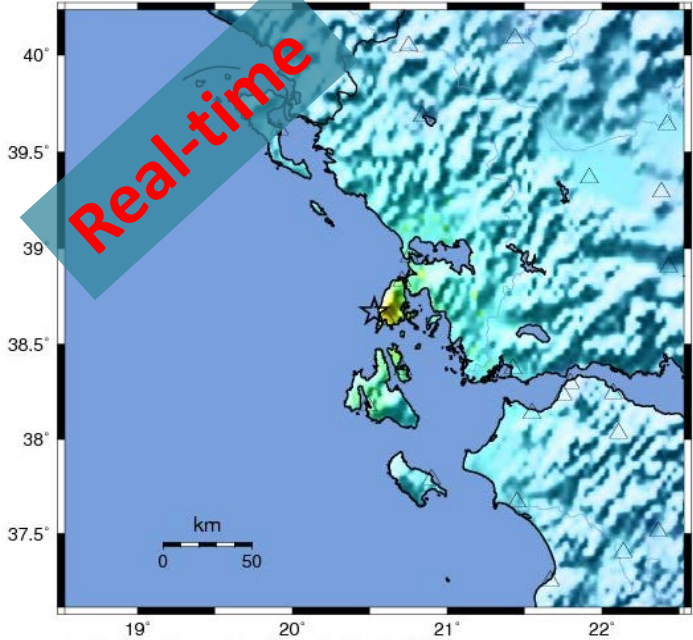


SHAKEMAPS

<http://shakemaps.itsak.gr>

ITSAK ShakeMap : Greece

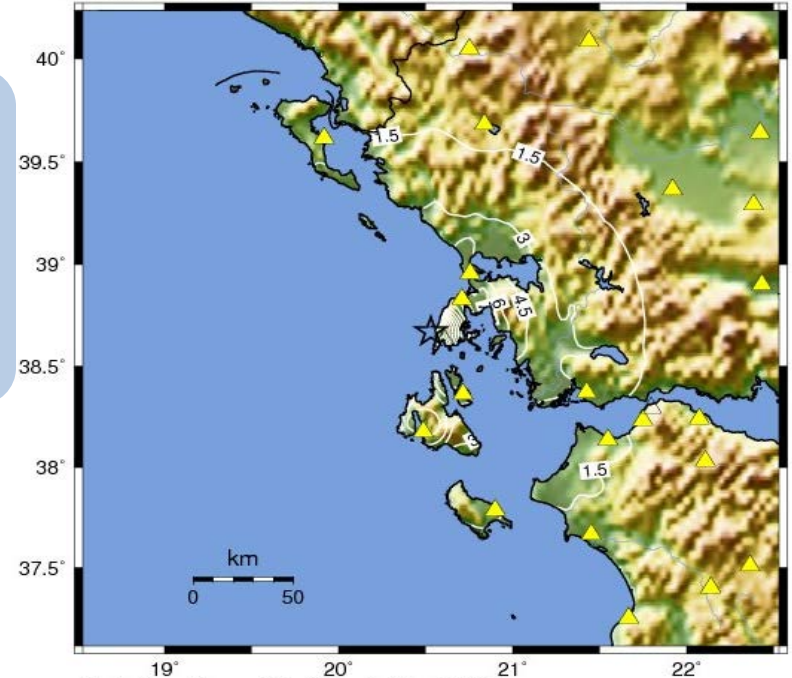
NOV 17 2015 07:10:07 AM GMT M 6.4 N38.67 E20.53 Depth: 0.0km ID:auth2015wrmvj



Lefkas
Earthquake
17-11-2015
M6.4

ITSAK Peak Accel. Map (in %g) : Greece

NOV 17 2015 07:10:07 AM GMT M 6.4 N38.67 E20.53 Depth: 0.0km ID:auth2015wrmvj



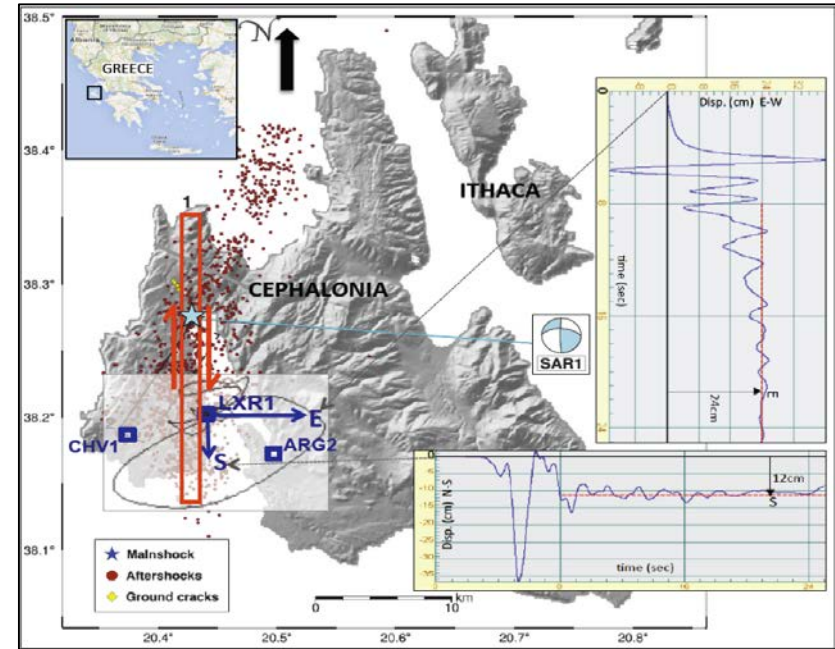
Distribution of the strong ground
motion

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	<0.02	0.1	1.4	4.7	9.6	20	41	86	>178
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

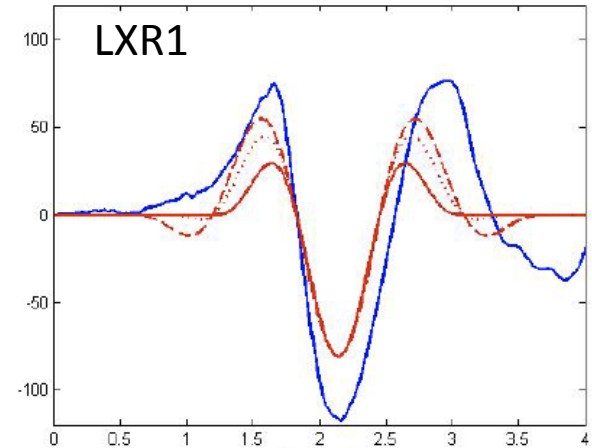
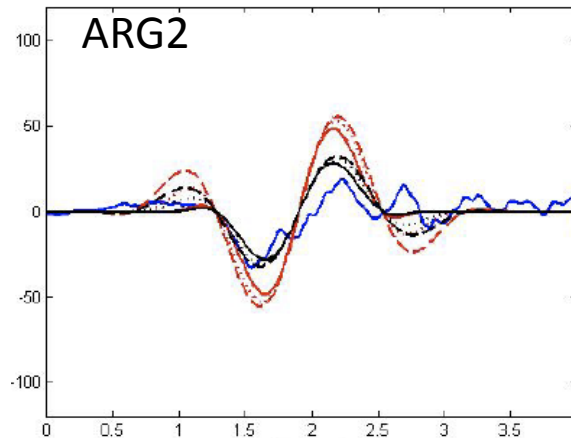
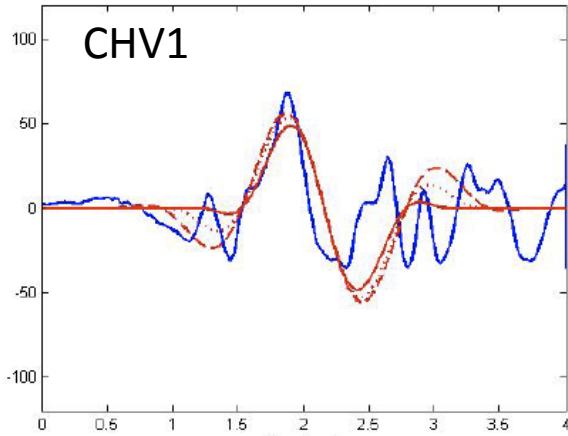
Scale based upon Worden et al. (2011)

Distribution of the intensity

SIMULATION OF THE STRONG GROUND MOTION IN THE NEAR FIELD OF THE ACTIVE FAULT



Σεισμός Κεφαλονιάς, 3/2/2014 (M6.0)
(Grendas and Theodoulidis 2016)



— Καταγραφή
— Προσομοίωση

REMOTE SENSING

Sentinel-1 **ESA** <https://scihub.esa.int/> **Registered public**

Satellite data issues

The collaboration of the Enceladus team with the space agencies providing data has been proved excellent. Through the contact persons all the necessary requests for data have been successfully performed. The satellite data supply and use has been executed in agreement with the guidelines provided by each of the space agencies supporting the supersite initiative. The total number of data requests through Enceladus is presented in the next table. In the next figures the allocation of the TerraSAR-X and Pleiades data supplied to the Enceladus core teams are presented.

Data	No of Scenes
TerraSAR-X	57 stripmap SSC scenes over Patras city and Lefkada island
Pleiades	22 triplets
Sentinel-1	Unknown number (>300 SLC IW products over Patras city, Lefkada, Zakynthos, Corinthos city, Kaparelli-Platees fault zone).

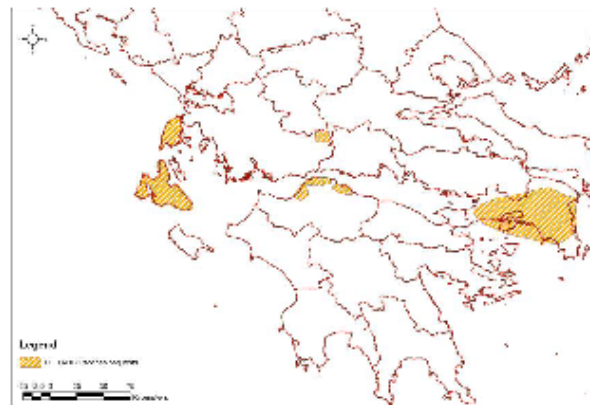


Figure 4. Pleiades scenes requests



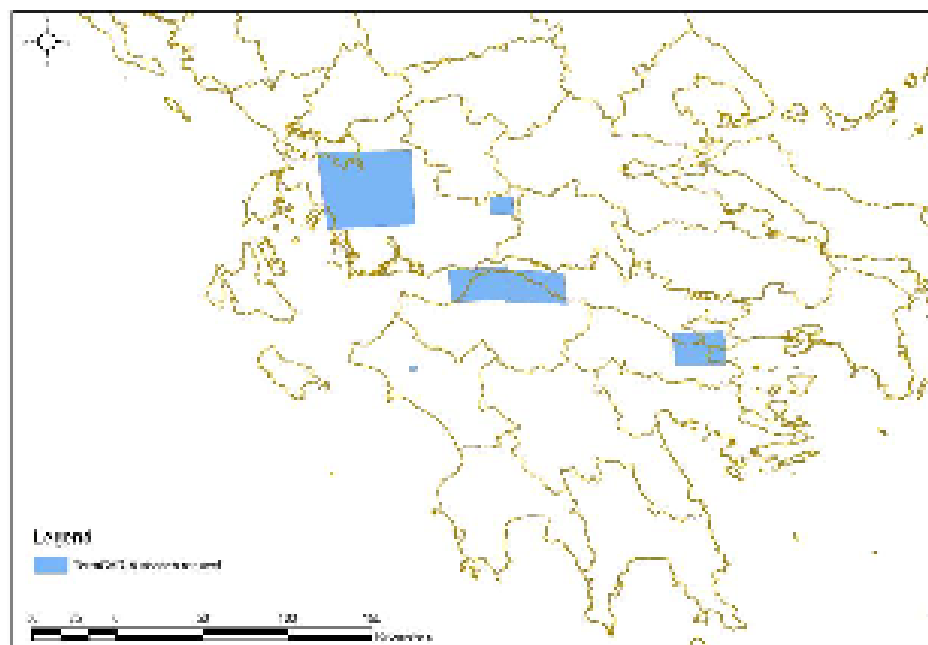
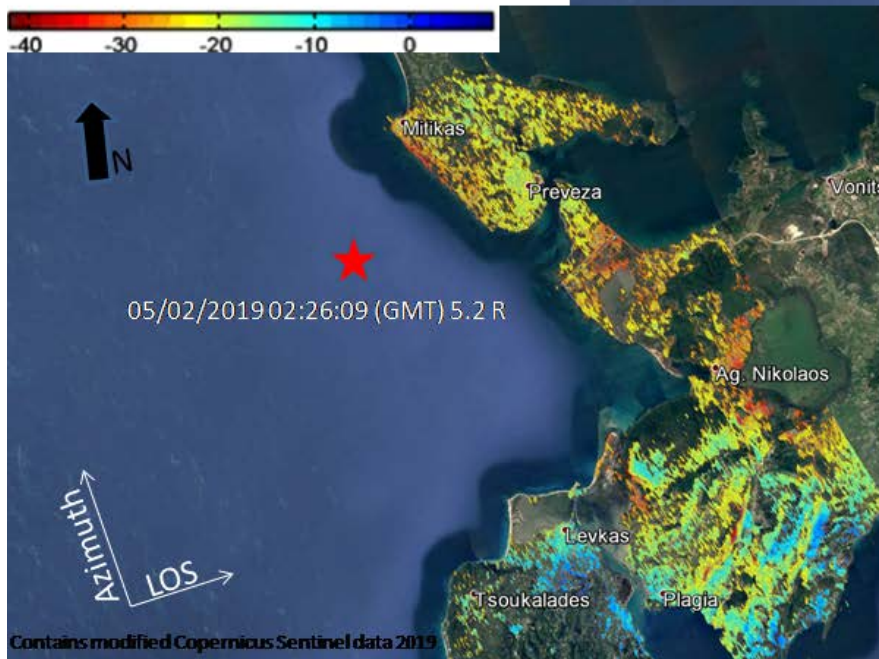
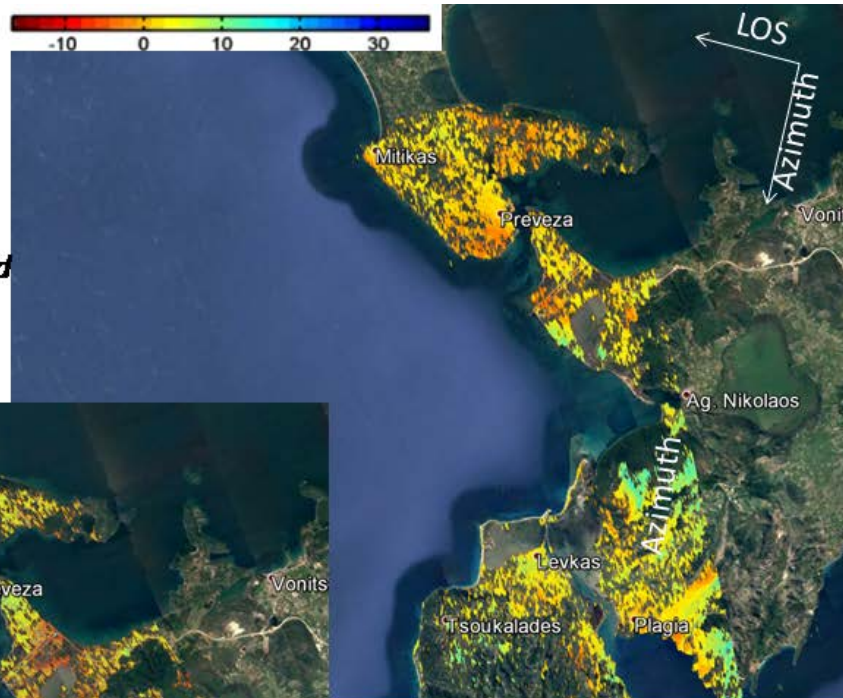


Figure 5. TerraSAR-X scenes requests

Co-seismic displacement maps (in mm) of 5/2/2019 earthquake event using Sentinel 1 IW SLC pairs of both orbital mode

Descending pair 30/01/2019 and 05/02/2019



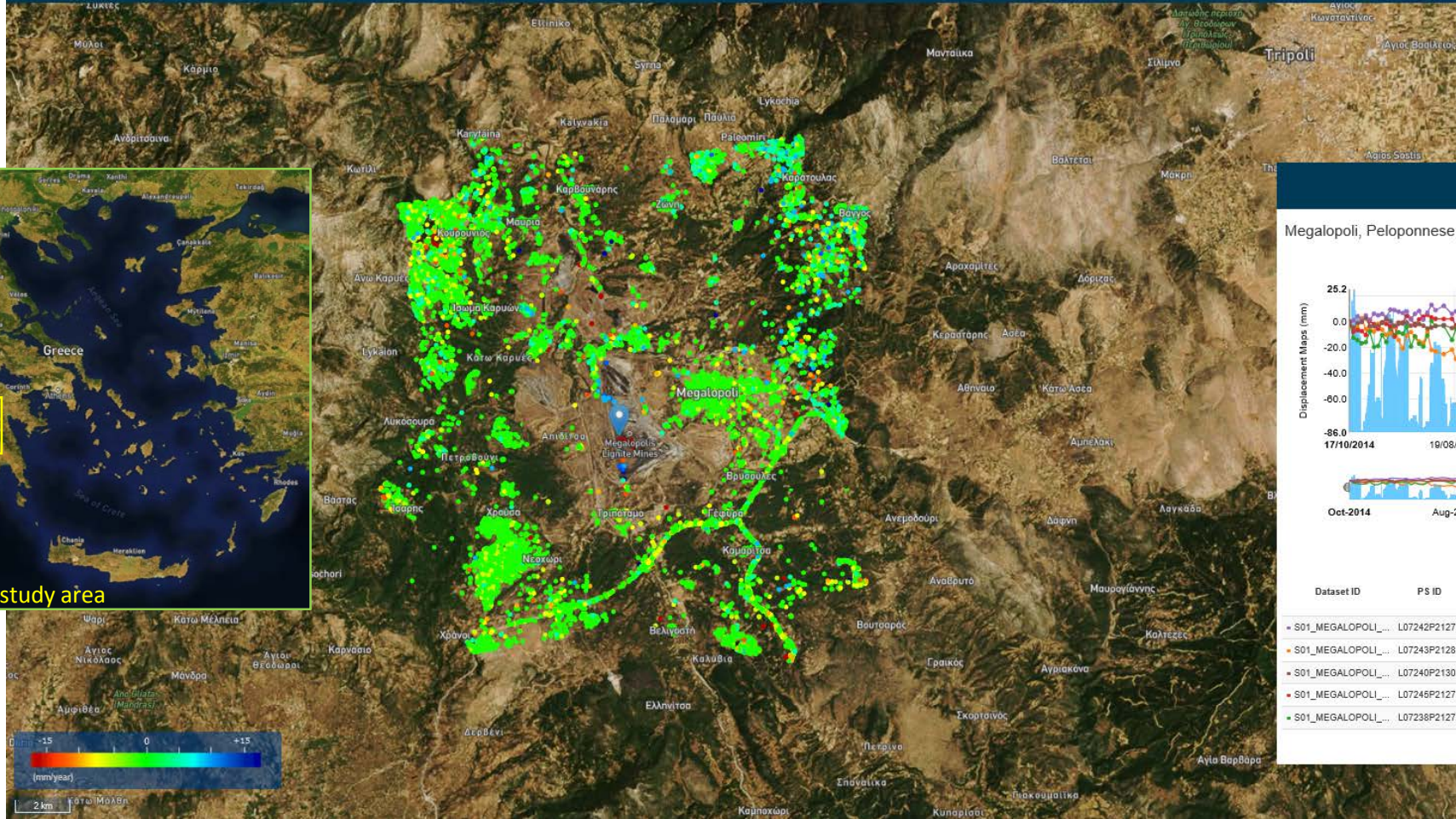
**Harokopio University
Department of Geography**

Ascending pair 30/01/2019 and 05/02/2019

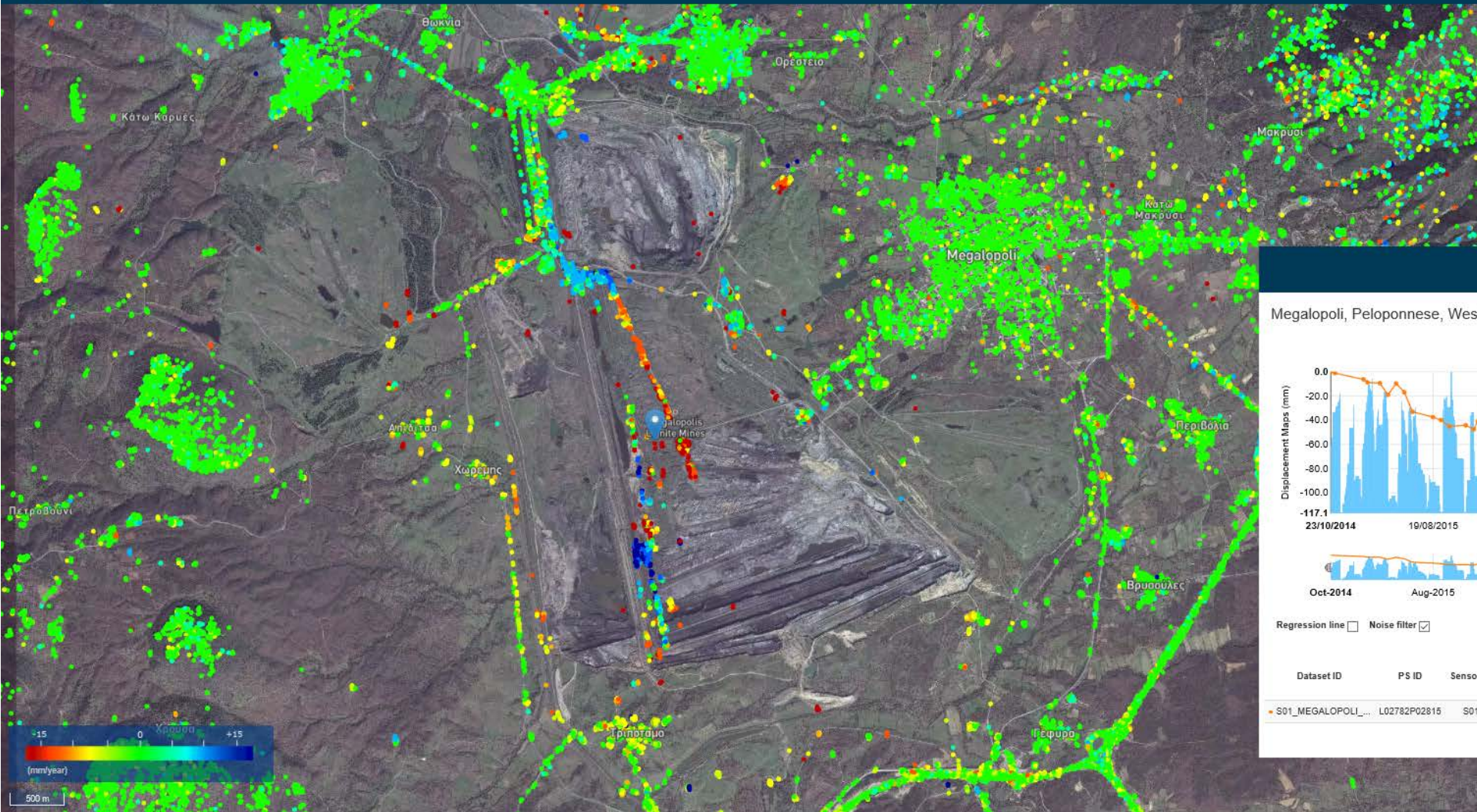


Epicenter

Prof I. Parcharidis, Harokopio University



Overview of Megalopoli area, Peloponnese, examining the micro-mo surface with Rheticus Displacement.



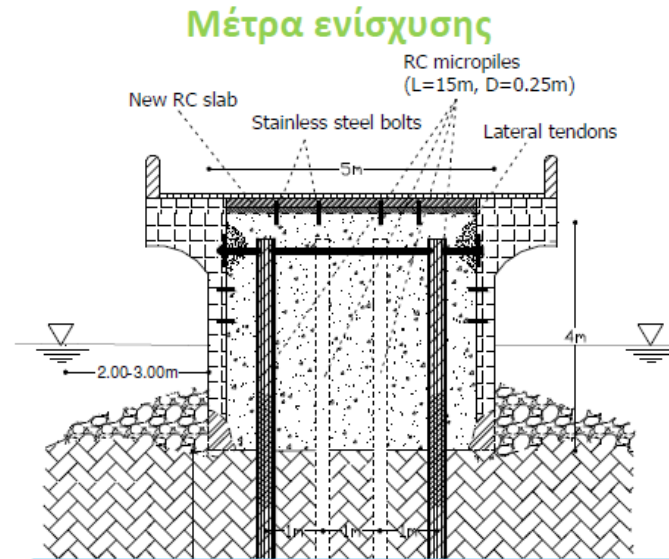
**Subsidence in mining area:
Megalopolis Lignite Mines – Greece**

The activity was performed in the framework of the EUGENIUS project, from H2020, for the partner TERRASPATIUM

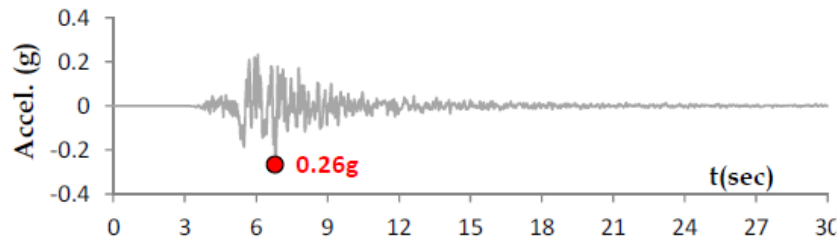
VULNERABILITY ASSESMENT

Debosset Bridge – Argostoli, Cephalonia

Vulnerability assessment & reinforcement after the 2014 strong earthquakes

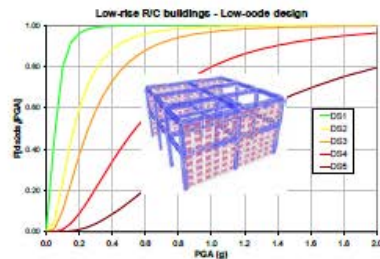


Σεισμός M6.1 – 03/02/2014: Καταγραφή από
σταθμό ARG2 του ΙΤΣΑΚ (NS component)

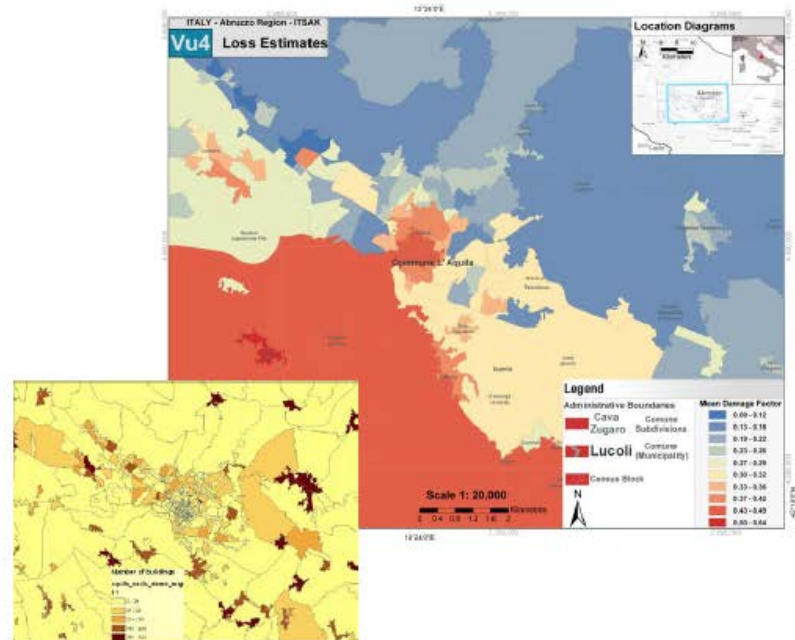


Vulnerability assessment of buildings – Fragility curves

Άνω Λιόσια – Σεισμός Αθηνών 9/7/1999



L' Aquila – Σεισμός 6/4/2009



Statistical usability damage data (SGE)

	A	B	C	D	E	F
Number of buildings	4031	1661	217	33	1043	585
Percentage	38.5%	15.9%	2.1%	0.3%	17.6%	5.6%

Predicted tagging of buildings using the Italian (Rota et al.) fragility curves

	DS0	DS1	DS2	DS3	DS4	DS5
Number of buildings	3547	4213	1085	1057	641	1565
Percentage	30.6%	36.3%	9.4%	9.1%	5.5%	13.5%

Predicted tagging of buildings using the Greek (AUTH EPPO-ITSAK) fragility curves

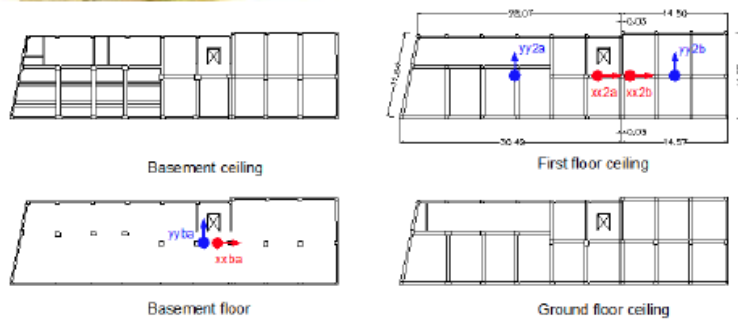
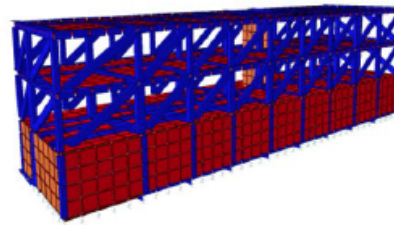
	DS0	DS1	DS2	DS3	DS4	DS5
Number of buildings	333	2686	2241	2802	635	1483
Percentage	2.9%	23.1%	19.3%	24.1%	5.4%	12.8%

Συνεργασία με Τμ. Πολιτικών Μηχ. Α.Π.Θ. & Ινστ. Εφαρμογών Διαστήματος & Τηλεπισκόπησης Αστεροσκοπείου Αθηνών

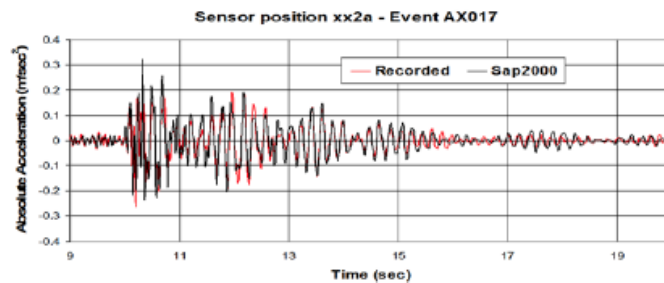
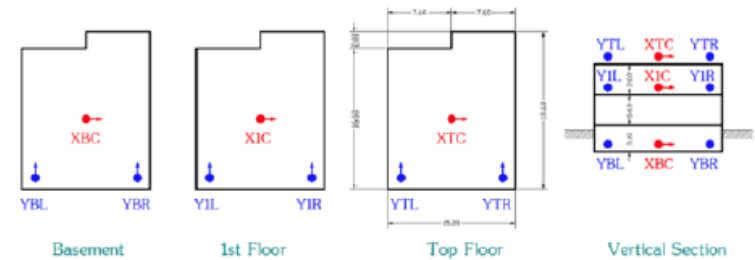
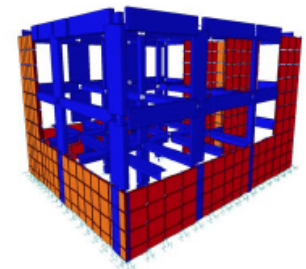
Instrumentation of buildings

Athens Earthquake 1999

ΟΤΕ Άνω Λιόσια

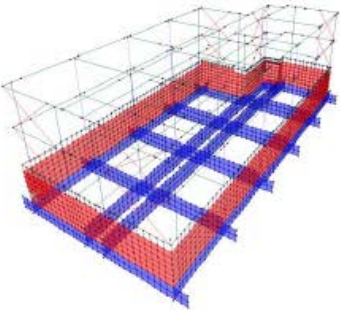
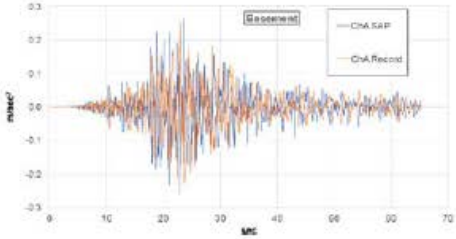
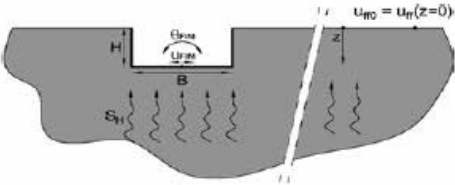
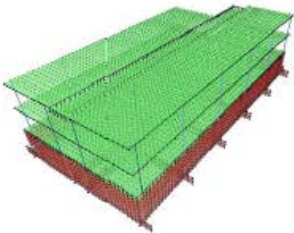
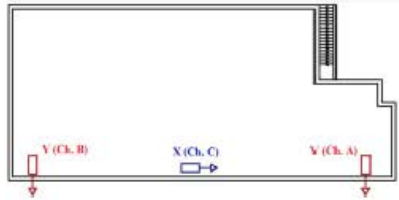
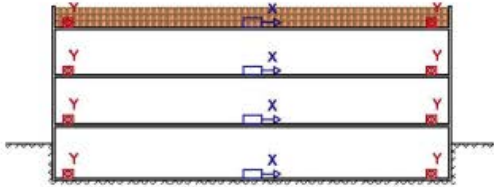


ΟΤΕ Θρακομακεδόνες

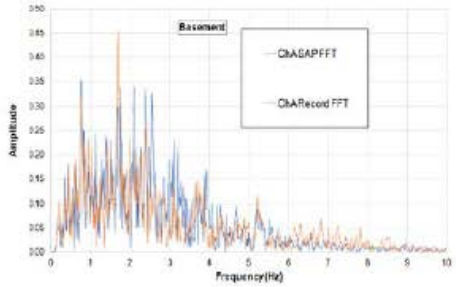


	Event BA007 (2.02÷3.41 mg)		Event BB010 (35.10÷40.13 mg)	
Mode	T (sec)	ζ (%)	T (sec)	ζ (%)
1 (x-dir)	0.2253	2.928	0.2845	5.069
2 (y-dir)	0.1605	3.780	0.1831	5.105

Instrumentation of Lefkas City Hall



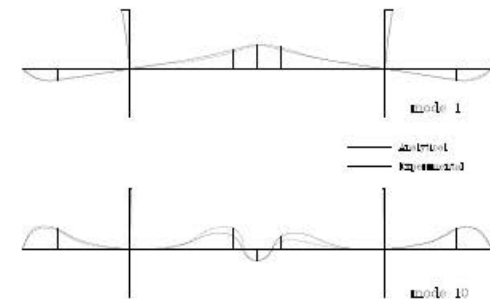
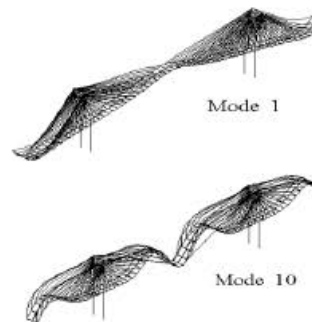
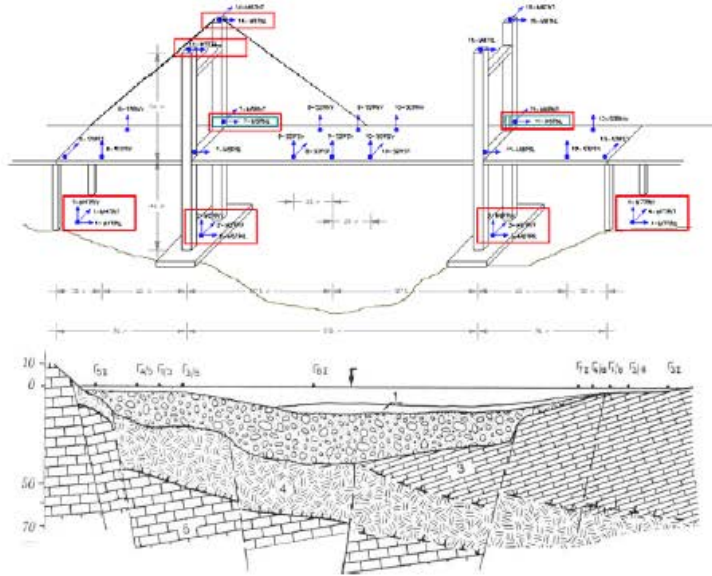
Ground Motion Parameter	Recorded response	Predicted response	Recorded response	Recorded response	Predicted response	Recorded response
	X-dir (Ch.C) (Basement)	X-dir (Ch.C) (Basement)	X-dir (Ch.C) (Free field)	Y-dir (Ch.A) (Basement)	Y-dir (Ch.A) (Basement)	Y-dir (Ch.A) (Free field)
Max Acceleration (m/sec²)	0.22356	0.22833	0.28052	0.23633	0.26286	0.33375
Arias Intensity (m/sec)	0.01670	0.02211	0.03050	0.02056	0.02411	0.03190
Acceleration Spectrum Intensity (m/sec)	0.20817	0.26401	0.33276	0.24299	0.29431	0.36368



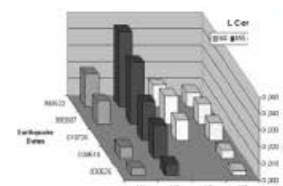
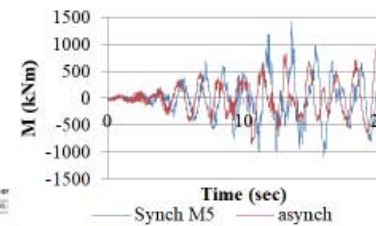
Chalkis Bridge – Permanent Monitoring



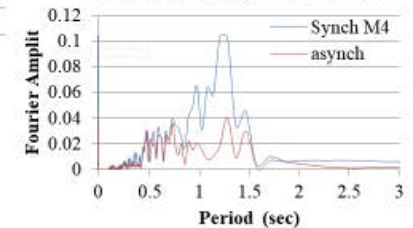
ΙΔΙΟΜΟΡΦΗ	2-output / Quasi Newton gradient-based		2-output / Υβριδικός γενετικός αλγόριθμος		4-output / Υβριδικός γενετικός αλγόριθμος	
	Ιδιοπερίοδος (sec)	ζ (%)	Ιδιοπερίοδος (sec)	ζ (%)	Ιδιοπερίοδος (sec)	ζ (%)
1	-	-	1.1344	0.9556	1.1644	1.5015
2	-	-	-	-	0.3618	1.6149
3	0.2923	0.7151	0.2924	0.8194	0.2921	0.8960
4	0.2109	2.6941	0.2114	1.9659	-	-
5	0.1894	0.6642	0.1910	0.7439	0.1811	1.1464
6	0.1757	0.9914	0.1755	0.8410	0.1762	0.3351



Moments M_2 Pier M6

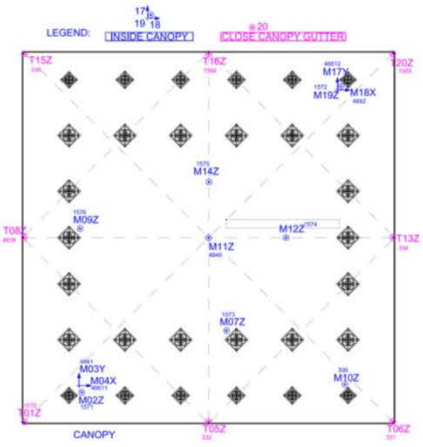


Fourier spectra a_z middle of deck

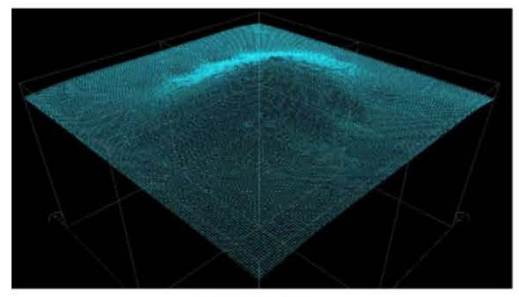


Stavros Niarchos Cultural Centre - Instrumentation of the shelter

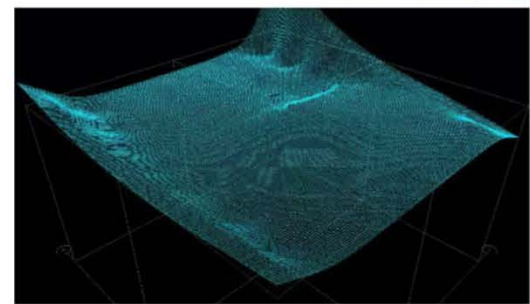
Στέγαστρο ΚΠΙΣΝ (2015)



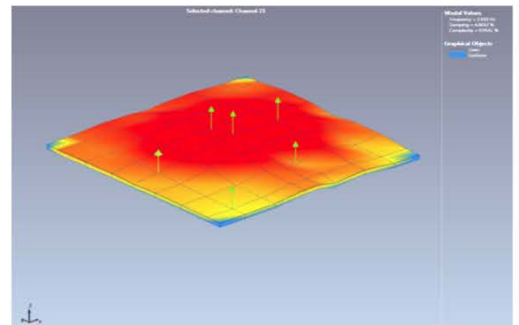
24 αισθητήρες



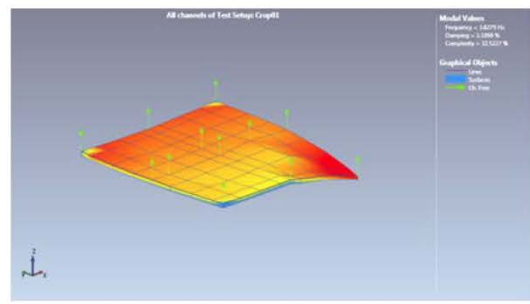
Mode 4 (Z - 2.646 Hz)



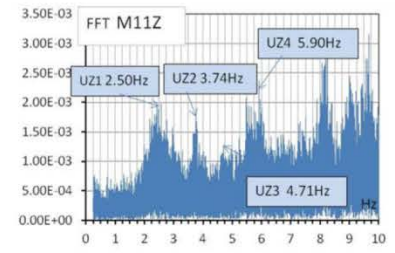
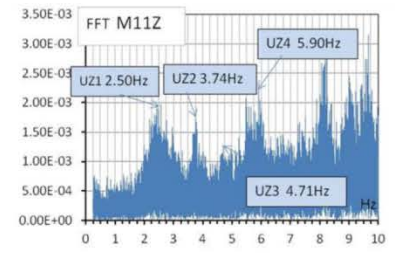
Mode 7 (Z - 3.630 Hz)



Mode 4 (Z - 2.646 / SSI-UPC 2.858 Hz)



Freq 3.6279 Hz (Mode 7 - 3.630 Hz)



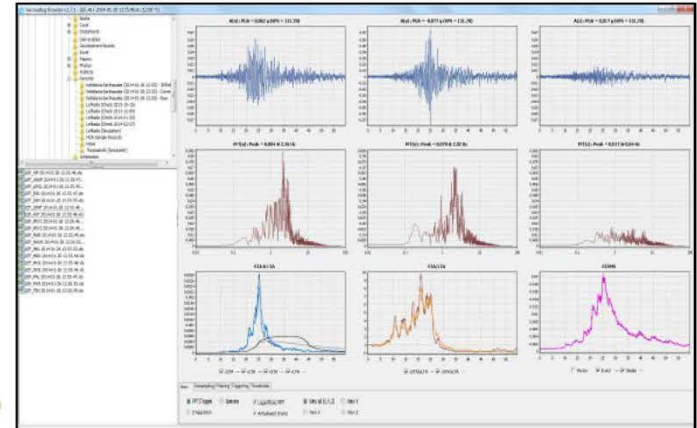
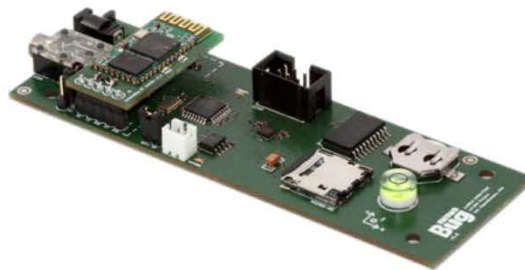
NEW TECHNOLOGIES

Seismobug[®] : Innovative MEMS-based, low-cost triaxial digital accelerograph

(www.seismobug.com)

Dr. Karakostas Christos, E.P.P.O. Research Director (christos@itsak.gr) & Dr. Papanikolaou Vassilis, Assistant Prof. A.U.Th. (billy@civil.auth.gr)

Design / hardware assembly / firmware & software development / laboratory validation tests / pilot on-site network of 21 units at the island of Lefkada
(action "Supporting Postdoctoral Researchers" co-financed by European Social Fund and Greek State 2012-2014)

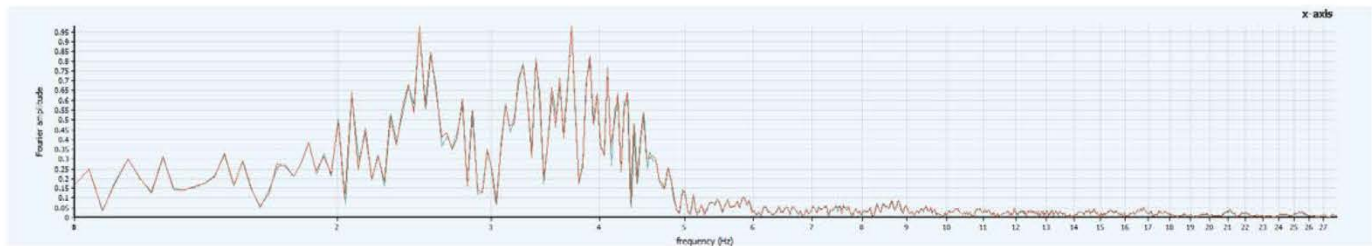
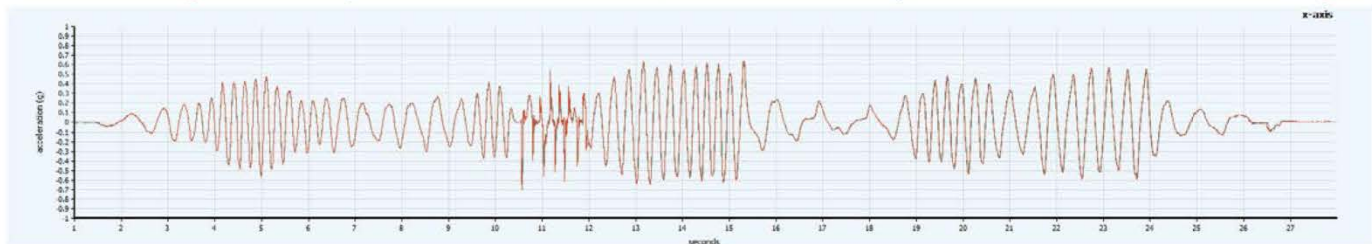


3 custom-made software programs

Seismobug[®] vs Guralp[®] validation results (ITSAK laboratory) – Almost identical recordings

SeismoBug
(cost of components < 100 €)

Guralp
(3800 €)



Seismobug[©] : Innovative MEMS-based, low-cost triaxial digital accelerograph

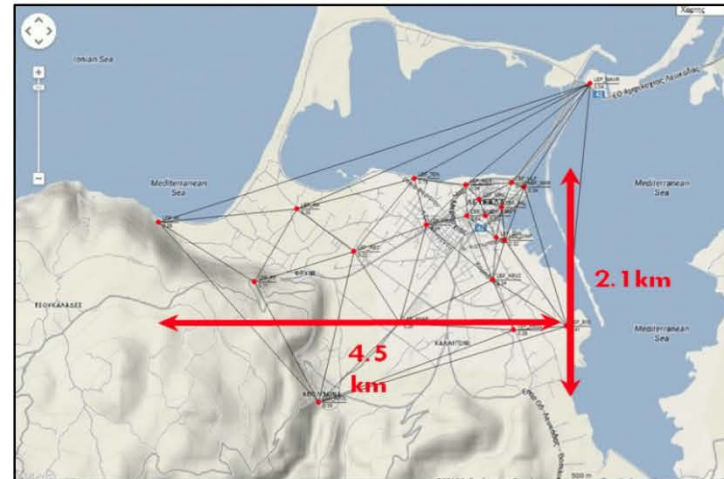
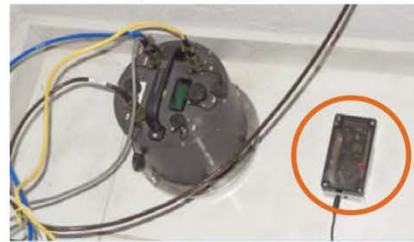
(www.seismobug.com)

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The Lefkada pilot network

20 units in a 4.5 x 2.1 km area

The majority in Free-Field Conditions / Some at buildings' basements



26/1/2014 Cephalonia earthquake
PGA contours / E-W direction

PGA variation : Min 19mg / Max 77mg !!!



Future prospects

Design of 2nd generation units with Ethernet communication capabilities and upgraded MEMS sensors

Most recent literature (available upon request) :

Christos Z. Karakostas, Vassilis K. Papanikolaou, Nikolaos P. Theodoulidis "An Ultra-Dense Strong-Motion Urban Network Based On in-House Designed MEMS Accelerographs: The Case of Lefkas City, Greece", Proceedings of the 16th European Conference on earthquake Engineering (16ECEE), Thessaloniki, Greece, June 18-21, 2018, paper no 11191

... for the (near) future

- **Dissemination of the scientific work**
15th International Congress of the Geological Society of Greece
(<https://www.gsg2019.gr/special-sessions/>)
“The Geohazard supersites initiative with emphasis on the Greek supersite (Enceladus)”
- **Fundraising activities**

THANK YOU

The Enceladus Supersite coordinators

Dr Spyros Lalechos

Geophysicist

EPPO

Dr Thomas Salonikios

Civil Engineer

Senior Researcher

EPPO/ITSAK