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

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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 <5mm/yr in the east and >15mm/yr in the west.

(Leeder et al., 2008)
Evoikos Rift

Active faults

- 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

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

Recent Seismicity

(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)
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 Deformation

Plastic Deformation
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
SUMMARY

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.

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

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

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

Retrieving Spatial & non Spatial Data

GHEAD
SHAKEMAPS

http://shakemaps.itsak.gr

Lefkas Earthquake 17-11-2015 M6.4

Distribution of the intensity

Distribution of the strong ground motion
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)
REMOTE SENSING


**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.

<table>
<thead>
<tr>
<th>Data</th>
<th>No of Scenes</th>
</tr>
</thead>
<tbody>
<tr>
<td>TerraSAR-X</td>
<td>57 stripmap SSC scenes over Patras city and Lefkada island</td>
</tr>
<tr>
<td>Pleiades</td>
<td>22 triplets</td>
</tr>
<tr>
<td>Sentinel-1</td>
<td>Unknown number (&gt;300 SLC IW products over Patras city, Lefkada, Zakynthos, Corinths city, Kaparelli-Platees fault zone).</td>
</tr>
</tbody>
</table>

**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

05/02/2019 02:26:09 (GMT) 5.2 R

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

Epicenter

Prof I. Parcharidis, Harokopio University
Overview of Megalopolis area, Peloponnese, examining the micro-mo-surface with Rheticus Displacement.

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

https://www.planetek.g
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
https://www.planetek.g
VULNERABILITY ASSESSMENT
Debosset Bridge – Argostoli, Cephalonia
Vulnerability assessment & reinforcement after the 2014 strong earthquakes

- Χρηματοδότηση από ΥΠΠΟ
- Συνεργασία με ΕΠΟΙΣΜ-ΑΠΟ (ΕΥ)

Σεισμός Μ6.1 – 03/02/2014: Καταγραφή από σταθμό ARG2 του ΙΤΣΑΚ (NS component)

EPPO / Research Division - ITSAK
Vulnerability assessment of buildings – Fragility curves
Instrumentation of buildings

Athens Earthquake 1999

OTE Ανω Λιόσια

OTE Θρακομακεδόνες

Sensor position x=3a, Event AX017

<table>
<thead>
<tr>
<th>Event</th>
<th>Mode</th>
<th>T (sec)</th>
<th>ζ (%)</th>
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<tbody>
<tr>
<td>BA007</td>
<td>1 (x-dir)</td>
<td>0.2253</td>
<td>2.928</td>
</tr>
<tr>
<td></td>
<td>2 (y-dir)</td>
<td>0.1605</td>
<td>3.780</td>
</tr>
<tr>
<td>BB010</td>
<td>1 (x-dir)</td>
<td>0.2845</td>
<td>5.069</td>
</tr>
<tr>
<td></td>
<td>2 (y-dir)</td>
<td>0.1831</td>
<td>5.105</td>
</tr>
</tbody>
</table>
Instrumentation of Lefkas City Hall
Chalkis Bridge – Permanent Monitoring

Mode 1

Mode 10

Moments $M_2$ Pier M6

Time (sec)

Fourier spectra $a_x$ middle of deck

Synch M4

asynch

Synch M5

asynch

Fourier spectra $a_x$ middle of deck

Period (sec)
Stavros Niarchos Cultural Centre - Instrumentation of the shelter

Στέγαστρο ΚΠΙΣΝ (2015)
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)
Dr. Karakostas Christos, E.P.P.O. Research Director (christos@itsak.gr) & Dr. Papanikolaou Vassilis, Assistant Prof. A.U.Th. (billy@civil.auth.gr)

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):
... for the (near) future

- **Dissemination of the scientific work**
  “The Geohazard supersites initiative with emphasis on the Greek supersite (Enceladus)”

- **Fundraising activities**
THANK YOU

The Enceladus Supersite coordinators

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EPPO

Dr Thomas Salonikios
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