National Observatory of Athens - Internal call for proposals by early-career researchers/ scientists

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New Teleseismic Catalogue for NOA - bridging the gap ("TELECAT")

April 2022

SUMMARY

The work proposed aims to develop a new teleseismic event catalogue for the Geodynamic Institute of the National Observatory of Athens (GI/NOA), taking into consideration strong global earthquakes with magnitude over 6. These earthquakes will be detected in the continuous 24-hour data recorded by selected broadband stations of the Hellenic Unified Seismic Network (HUSN). Stations taken into consideration will be geographically distributed across Greece in a layout designed to maximize accuracy and enrich solution parameters. For each earthquake, P-wave arrivals will be accurately determined per station and location analysis will follow to determine the epicenter by appropriately fixing depth. Solutions will include broadband amplitude measurement to estimate magnitude types MS and/or MB. The development of such a catalogue by GI/NOA will initially involve large earthquakes worldwide, considering the period from 2012 to date, during which continuous recordings are readily available, corresponding to approximately 1600 events based on global catalogues. As a result of this work, monthly bulletins will once again begin to be communicated to the ISC by NOA on a regular basis. This is a practice that was interrupted twenty years ago and will be reinstated with higher quality and manifold quantity. The final teleseismic event catalogue for the past decade will be compiled and curated in collaboration with the key NOA persons responsible for catalogues and seismic networks. It will become available to the public and the global seismological community through the official GI/NOA website and its dedicated event webservice, accompanied by all relevant information and metadata. Teleseismic information from the seismic stations of the Greek territory will offer valuable information to the international research community, bridging a decade-long gap. Such data can strongly impact and enrich several types and scales of studies, such as enhancing the understanding and interpretation of the earth's interior and its complex geotectonic structures. This work will also pave the way towards machine-learning methods which will eventually automate the procedure, thus achieving lower magnitude completeness.

CONTEXT, MOTIVATION & RESEARCH QUESTIONS

TELECAT aims to produce a teleseismic GI/NOA catalogue, contributing valuable information to the global scientific community. The teleseismic approach can contribute towards better understanding the seismicity of poorly instrumented areas. Such data are useful in many research applications, including but not limited to seismic hazard, passive tomography and anisotropy studies in subduction zones. Teleseismic events can be used for receiver function analyses for crustal and upper mantle studies, including the discontinuities within. As an example, teleseismic SKS phases from events observed at epicentral distances between 80◦ and 120◦ were analyzed to investigate the upper mantle anisotropy focusing at both edges of the Hellenic subduction system. Records of 83 events with a magnitude Mw>5.5 were used from 76 broadband seismic stations of the permanent network around the Hellenic subduction zone (Evangelidis, 2017). In an area with sparse seismic networks, Kwong et al. (2019) combined an improved teleseismic earthquake catalogue for Ecuador with analysis of coseismic interferometric synthetic aperture radar data to delineate the spatial and temporal slip history of the megathrust fault in absolute space. The authors used the phase onset times of first arrivals from 1500 individually-reviewed ISC bulletin earthquakes. With double-difference (DD) tomography, they resolved a regional 3D compressional velocity model to constrain relative location, resulting in significant hypocentral changes. Improvement of teleseismic event catalogues resulted in better definition of the geometry and extent of seismogenic zones where local data were not available. In another case, Gounon et al. (2022) made use of teleseismic data through well-constrained hypocentral locations and estimated seismic hazard in the East African Rift region. **Over the past 2 decades, there has been no systematic cataloging of teleseismic events derived from seismic stations in Greece, which constitutes a significant gap of information and subsequently of potential knowledge on a local, regional and global level**. In the distant past, starting in 1986 and up to 2002, GI/NOA published monthly bulletins that included a section of teleseismic event information using about a dozen Greek seismic stations. Sequence numbers were assigned to each event and station phase, along with phase arrival times, without attempts at location or magnitude estimation. Stations from the HL seismic network that were mostly used during that period were: PRK, RDO, APE, PLG, NPS, IDI, ATH, VAM, VLI, KZN, EVR, KYTH, ITM, VLS, KEK, NEO and were distributed across Greece. The number of teleseismic events detected per month in the period 2000-2001, as

derived from the monthly bulletins (2000 a & b, 2001 a & b), are presented in Fig. 1 (an average 14 events/month were reported).

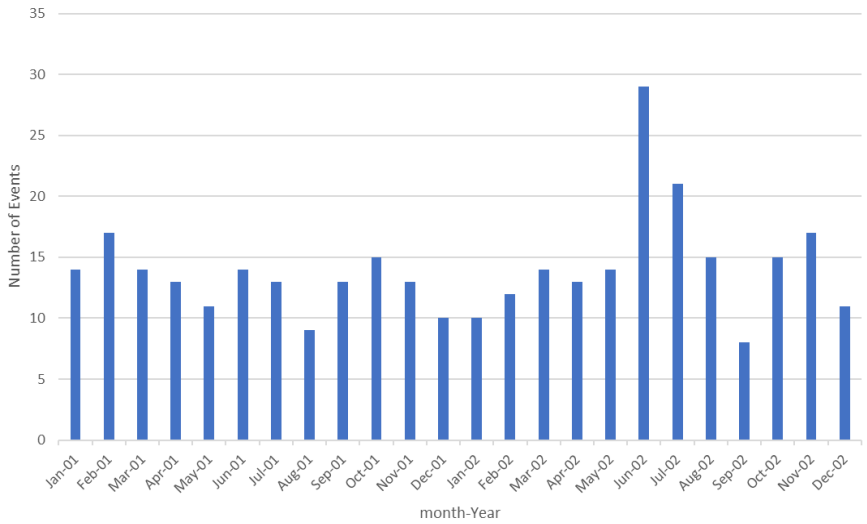


Figure 1: Teleseismic events reported per month by GI/NOA in the period 2000-2001.

Since 2003, which was the time of transition to the digital era for earthquake analysis and the unification of the seismic network in Greece, GI/NOA monthly bulletins refer only to earthquakes that occurred in Greece and the surrounding areas. An approximate tenfold increase of available broadband seismic stations in combination with high local seismicity rates increased considerably the workload of the seismicity monitoring service. Thus significant global events outside these geographical limits are not analyzed anymore and such events, whether regional or teleseismic, are characterized as out of limits of the area of national interest. Nowadays, the significant improvement achieved in GI/NOA automatic seismic monitoring workflows allows to re-initiate GI/NOA teleseismic monitoring routine. As an initial step, we attempt to close this noticeable 20-year gap of teleseismic information, starting with the readily accessible data of the past decade (2012-2022).

DATA AND METHODOLOGY

The aim of this proposal is to build a teleseismic catalogue for GI/NOA, covering mainly the period between 2012 up to now, where 24-hour digital records per station are easily accessible through the EIDA@NOA node, see Evangelidis et al. (2021). The data will be collected based on catalogue criteria, and a cut-off date will be fixed, e.g. 31/12/2022, to freeze the dataset at least until this decade-long gap is completed. Based on the global USGS and ISC catalogues, global events of magnitude over **M**6 will be extracted, accompanied by their origin and focal information (~1600 events). These events will be detected directly from the raw data of the 24-hour recordings of selected stations from the Hellenic Unified Seismic Network (HUSN). If needed, a low-frequency bandpass filter will be applied to distinguish long-distance higher period phases. A limited number of teleseismic events from different regions around the globe **have been analyzed already as a proof of concept**, some examples of which are presented below.

HUSN is an extensive seismic network comprising almost 150 stations nationwide in continuous operation with real-time data transmission. 2/3 of these are triaxial broadband seismometers with different sensor characteristics and sensitivity and 1/3 of them are triaxial short-period seismometers. **Sensor types** and operational availability from the epoch metadata of the selected stations, through the time-period of 2012 to date, will be taken into account. More specifically, Streckeisen STS2 seismometers, well-known as high-performance broadband instruments will be preferred, as well as other broadband sensors with respect to **noise quality control** per station (e.g. Nanometrics Trillium 120s, Guralp 3ESPC 100s). Ambient seismic noise across Greece as recorded at HUSN was investigated by estimating power spectral densities (PSDs) and their corresponding probability density functions (PDFs) for 110 broadband seismic stations over a period 2007-2010 by Evangelidis & Melis (2012). The overall station quality and the level of noise at each site was estimated at certain frequency bands for different noise sources. Based on this work, daily plots of noise quality control are available for HUSN, by estimating the noise levels for the entire frequency spectrum that the corresponding seismic sensors resolve (Fig. 2).

Sites with high noise levels due to site conditions, sensor installation or cultural noise (that exhibits high diurnal variation at frequency bands of 7-16 Hz) will be excluded, since they affect the earthquake monitoring capability of the station.

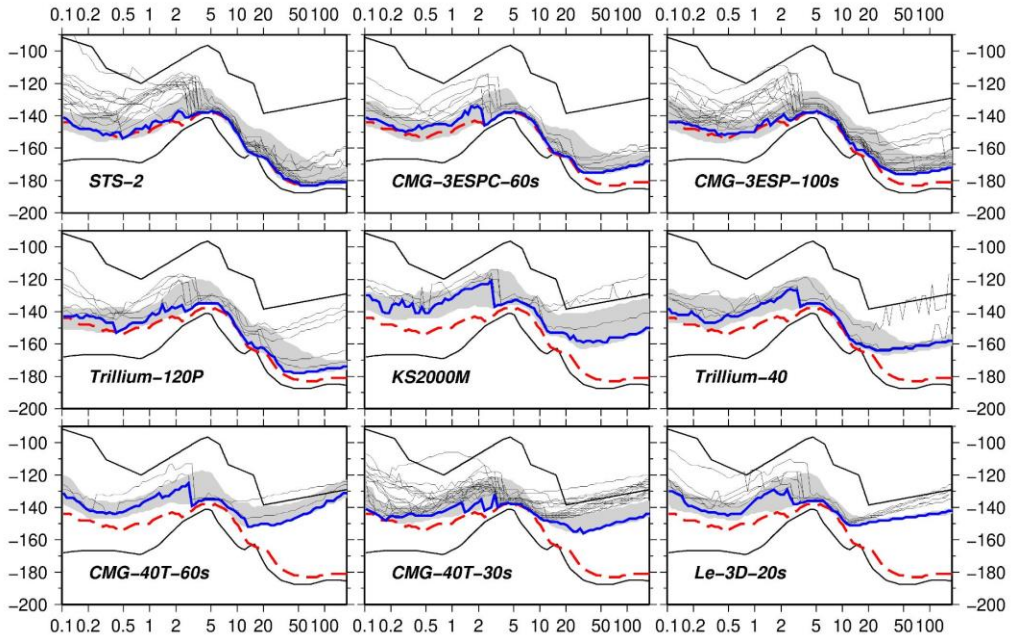


Figure 2: Minimum PDF mode noise levels for each seismic sensor group that operates in HUSN (bold line). They are calculated as the minimum of all station individual modes (thin lines) that have the same sensor. The overall PDF mode noise model (HMLNM) is also plotted (bold red dashed line). Adapted from Evangelidis & Melis (2012).

Geographical criteria will be also considered so as to achieve better location. Selected stations must have an appropriate distribution across the center and borders of the geographic HUSN layout. Then, phases will be picked per event, mainly first P-phase arrivals, and on a secondary level some S-wave onsets (only where appropriate). The location analysis will be processed fixing the depth to the original reported hypocentral solution. Solutions will **include broadband amplitude measurements for estimating magnitudes MS and/or MB**. Broadband magnitude MS, used in distance ranges of 2◦ to 160◦ and period ranged of 3 to 60 s, is expected to have a much wider use and applicability, and is particularly valuable for large regional events. Broadband MB magnitudes are rather rarely reported to the ISC (Havskov & Lieser, 2021). A proof-of-concept analysis of this procedure was performed to a selected subset among this decade of events. A few location examples are presented in Figs 3a,b for the Cuba earthquake of 28/01/2020 19:10:23 (depth 5.9 km, Ms7.6) accompanied with station records from HUSN and in Fig 3c for the Indonesia earthquake of 13/03/2022 21:05:49 (depth 10 km, M6).

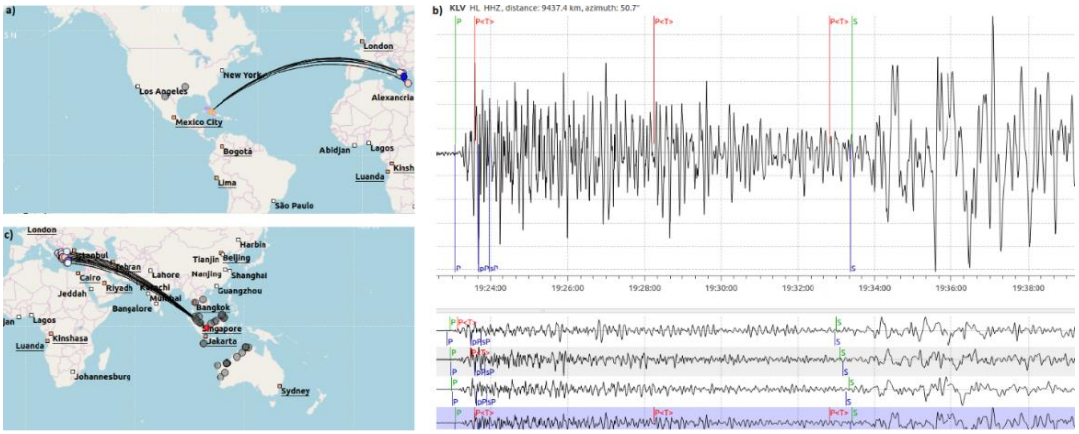


Figure 3: Teleseismic events a) Cuba earthquake 28/01/2020 19:10:23 Depth: 5.9 km of magnitude Ms7.6, b) as it was recorded at several stations of HUSN. c) Indonesia 13/03/2022 21:05:49 Depth:10 km of magnitude 6.

Furthermore, there will be an attempt to **distinguish more phases such as lithospheric, core & mantle phases**. Fig. 4 shows the Vanuatu earthquake of 02/10/2021 at 06:29:18, as it was recorded at station KEK (HL). Core phases can be observed PKP (green) and SKS (light blue) with blue lines representing theoretical onsets of PKP and SKS, respectively. The processed events will be tagged with a name characterization different from earthquake/outside our network interest & known, to be easily distinguished in the current GI/NOA earthquake database.

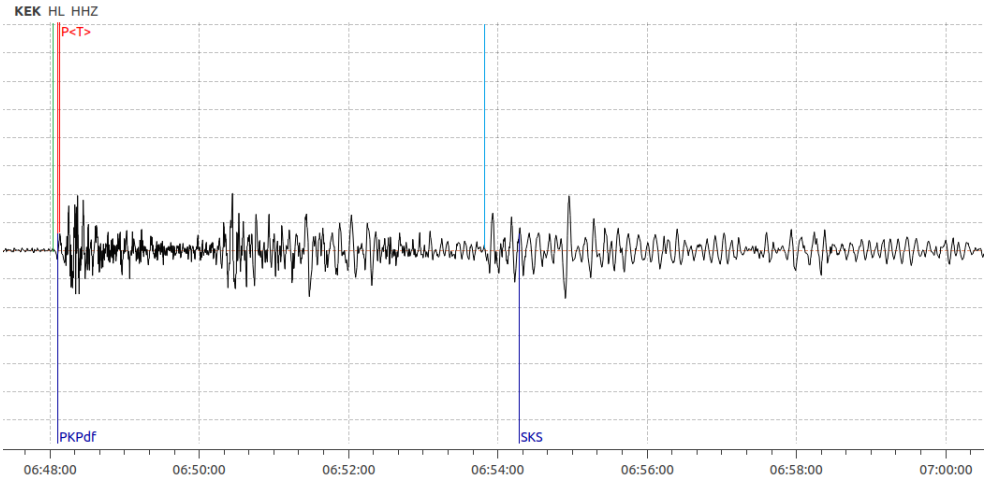


Figure 4: Example of Vanuatu earthquake 02/10/2021 06:29:18 Depth: 529 km of magnitude 7.2 as recorded at KEK station HL network. Blue lines are theoretical onsets and the observed PKP and SKS (green & light blue respectively).

The produced teleseismic catalogue will be communicated through bulletins to the ISC, so that per station, the phases of the earthquakes can be retrieved with their corresponding travel time residuals. The new catalogue will be published and made available through the official website of GI/NOA and their dedicated FDSN event webservice (eida.gein.noa.gr/fdsnws/event). Since **a catalogue is a dynamic entity**, experienced analysts will be trained to ensure its sustainability. As a future goal, this work will set the basis to **close the last decade-long gap from 2002-2012 and the enrichment gradually with lower magnitude events in combination with the current daily teleseismic analysis**. The experience, derived data and metadata that will be accumulated in *TELECAT* will set the foundations for the prospective research into automation and machine-learning techniques in event detection and parameter estimation. A subset of picked data will serve as a training testbed for the development of AI techniques, which will then be tested blindly on the remaining set. Investigating further phase-picking techniques and modern event detection tools (Pikoulis & Psarakis 2015, 2010) with data-driven beamforming/stacking for signal enhancement (Pikoulis & Psarakis 2018) will also help detect and estimate the onset of teleseismic arrivals which are typically **recorded with a low signal-to-noise ratio**. This type of approach is necessary for dealing not only with higher-noise data, but **also to eventually lower the threshold magnitude for inclusion** in the database.

RESEARCH GROUP

On the NOA side, the research team will comprise the PI and two key participants, but it will remain open to the participation of all NOA scientific and research staff who wish to contribute to its goals, particularly those involved with seismic analysis and networks. This proposal includes researchers with whom the PI has worked successfully in the recent past analyzing NOA seismic data, thus ensuring a smooth implementation of the envisioned work. Each member's particular expertise was chosen as being key to a specific aspect of the project. Professor Emeritus Jens Havskov (Bergen University), who has visited NOA before and exhibited high interest in teleseismic event records, will be the external participant providing guidance and facilitating knowledge transfer to NOA, based on his extensive expertise in teleseismic event analysis. JH, a prominent scientist in the domain of seismology, networks, data processing and use of distant data,

will significantly strengthen the capacity of the research group. Each member's uitably and complementarity in the envisioned research are presented below:

Dr Fevronia Gkika (FG): GI/NOA (*principal investigator - PI*). FG was recently elected as permanent research personnel at GI/NOA, specialized in slope stability monitoring with the use of acoustic emission techniques developing an early warning system for Corinth Canal Greece. Focused on modeling fault rupture propagation (Gkika & Tselentis 2005, Gkika et al. 2005, Tselentis et al. 2005 & 2010) and seismic hazard studies (Gkika et al. 2005, Tselentis et al. 2004 & 2005). PI has extensive experience in seismic data analysis from seismic arrays (Pylos) and passive tomography projects of high demands, in different continental environments around the world (Greece, Albania, India, Papua), plus experience in the 24h earthquake monitoring & analysis of the Greek territory of the GI/NOA. In the past two years, PI has collaborated with the other members of the proposed team in analyzing GI/NOA data to derive amplification functions at seismic stations and assess their suitability as reference stations (Ktenidou et al., 2021ab). Dr Gkika is also coordinating the ongoing initiative of checking the GI/NOA catalogue as to depth distribution of deep events across Greece. Dr Gkika will be assisted by a postgraduate student (to be selected) in the initial stage of compiling global data from catalogues.

Dr Olga-Joan Ktenidou (OJK): GI/NOA (*associate researcher, head of seismic analysis & NOA catalogue*). OJK specializes in engineering seismology, focusing on ground motion, amplification and variability. Since 2020 she leads the seismic analysis/monitoring group at NOA and is responsible for the NOA seismic catalogue. She recently oversaw the bridging of a past 3-year gap in the monthly seismicity GI/NOA bulletins to the ISC. She has worked with data from networks around the world (e.g. the Greek CORSSA and Euroseistest downhole arrays, the New Zealand strong-motion network, the Swiss strong-motion and broadband network, the Japanese Kik-net and k-net, and the severely bandlimited US transportable array, as well as proprietary data by critical facility operators, often with severe noise issues; e.g. Ktenidou et al. 2017, 2018, 2021c among others). She co-developed the signal processing procedure for the NGA-East database of University of California at Berkeley (Kishida et al., 2016). OJK is an elected member of EFEHR (European Facilities for Earthquake Hazard and Risk) and an invited member of the UAG committee for strong motion data of ORFEUS (Observatories and Research Facilities for European Seismology) and EPOS (European Plate Observing System).

Dr Christos Evangelidis (CE): GI/NOA (*senior researcher, head of NOA seismic network*). CE is the Manager of NOA broadband seismic network (HL network) and Head of the European Integrated Data Archive (EIDA) National Node at NOA. He serves as the elected Chair of the EIDA Management Board (EMB) of ORFEUS and Member of the Executive Committee (ExeCom) of ORFEUS. In 2018-2021 was the appointed delegate for Greece on EPOS-European Research Infrastructure Consortium (ERIC). He has served and coordinates as PI many European and National research projects, infrastructural national development funds on seismology, EU Civil Protection projects and exercises and major Seismic Monitoring Assessment commercial projects in the energy sector in Greece. He has extensive field experience in seismic station deployments and has participated in seismic exploration research cruises. His publications include the current state-of-the-art reference articles on earthquake backprojection.

Dr Erion-Vasilis Pikoulis (EVP): University of Patras (*postdoctoral researcher*). EVP is an electrical and computing engineer specialized in stochastic signal processing and Machine Learning applied to seismic waves. He has developed techniques for automatic event detection and P-picking, data-driven beamforming in seismic arrays, stochastic signal modeling and parameter estimation, among others. EVP will bring crucial insight to the project, primarily contributing to signal enhancement through stacking/ beamforming for teleseismic event detection and phase arrival-time estimation (Pikoulis & Psarakis 2010, 2015, 2018), as well as improved detecting algorithms for automating picks and lowering magnitude threshold. EVP and OJK co-developed a method for improving the usability of noisy data in the frequency domain (Pikoulis et al., 2020). EVP, OJK, FG and CE have collaborated in Ktenidou et al. 2021ab on understanding Greek station response.

Prof. Jens Havskov (JH): University of Bergen (*Professor Emeritus*). JH was professor at the Department of Geoscience from 1995-2008 and has been emeritus since. With over 5000 citations, some of his key contributions to the state of the art include authoritative textbooks and methods/codes for local and global event location, analysis and data processing, as well as instrumentation (Lienart & Havskov 1995; Havskov & Ottemoller 1999; Havskov & Alguacil 2016; Havskov & Ottemoller, 2010). His current research activities are international cooperations in developing and setting up seismological networks and standardization of seismological observatory routines to facilitate research in the increasingly large volume of digital data, particularly in the fields of determining seismic source parameters and seismic attenuation.

DELIVERABLES AND BUDGET

The activities and tasks detailed above will be achieved through the following milestones and deliverables (M and D items listed below). The timeframe has been based on the assumption that the starting date will be November 2022, but can be adjusted to reasonable time shifts. According to the scholarship rules, budgeted items include training visits to and from NOA and dissemination of the research produced. The assumption is made that conferences will take place on site in the post-covid era.

M1. Visit of FG to Bergen University (Norway) in 2023, to interact on key aspects of teleseismic data analysis through well-constrained hypocentral solutions.

M2. Visit of JH to NOA in mid/late 2024 to provide feedback on the teleseismic catalogue and products.

D1. One presentation (oral/poster) of the preliminary results at the European Geosciences Union (EGU) General Assembly 2023 in Vienna.

D2. One presentation (oral/poster) of the near-final results at the European Seismological Commission (ESC) General Assembly 2024 (location not announced yet).

D3. Article in an international journal (Q1 quartile after Scimago).

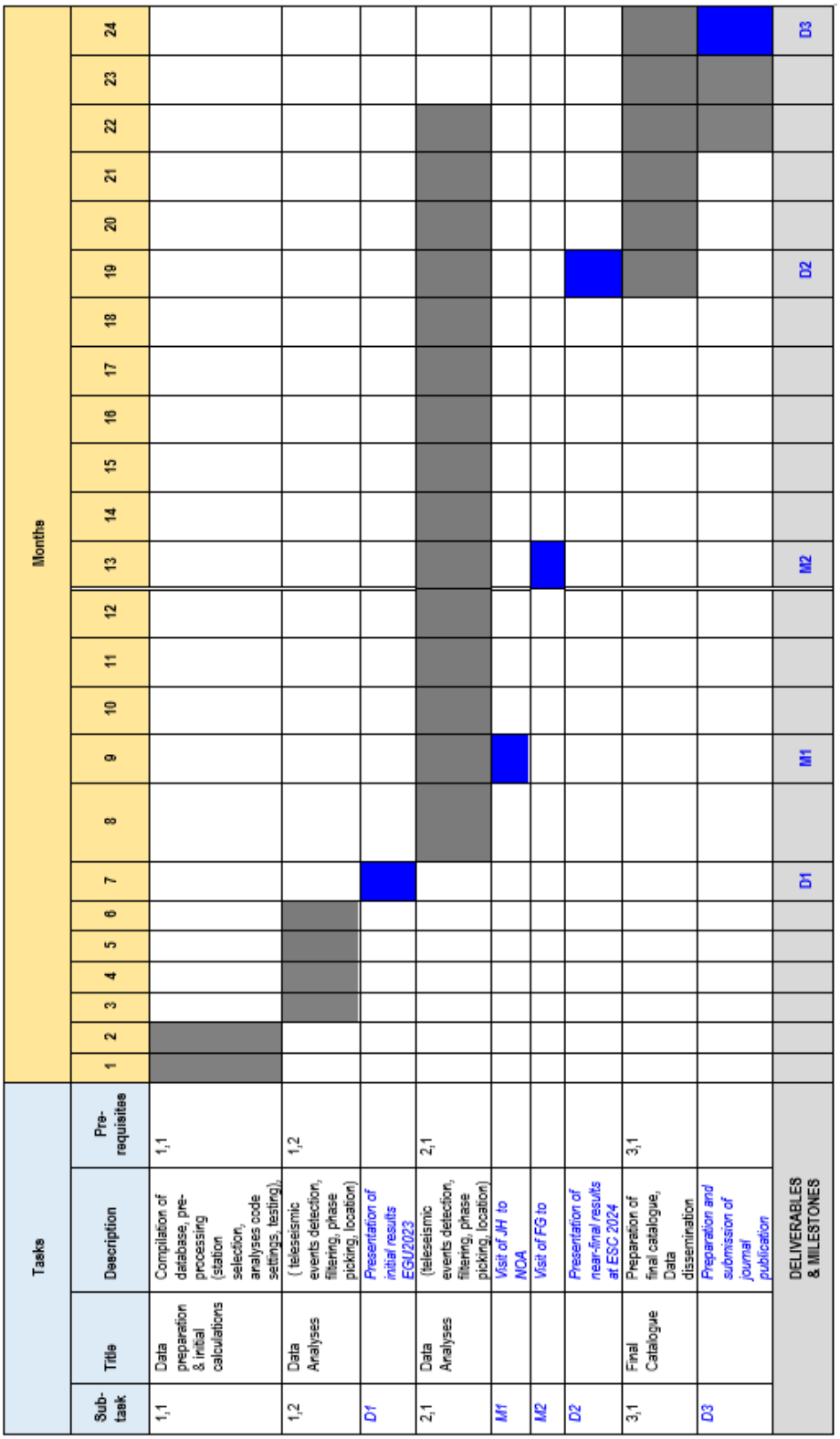
The budget to support the main collaborations, activities and deliverables is detailed in the table below:

Item/activity budgeted	Cost (EUR)
YEAR 1	
D1. Presentation at EGU 2023, 1 participant (fees 450, airfare 250, hotel 500, subsidence 300)	1500
M1. Visit of FG to Bergen University,, 1 week (300 airfare, hotel 800, subsidence 900)	2000
Postgraduate student	500
Total Year 1	**4000**
YEAR2	
D2. Presentation at ESC 2024, 1 participant (fees 450, airfare 250, hotel 500, subsidence 300)	1500
M2. Hosting JH in Athens, 1 week (400 airfare, hotel 800, subsidence 1100)	2000
D3. Publication in international journal	500
Total Year 2	**4000**
PROJECT TOTAL	**8000**

ACTIVITY PLANNING

The tasks planned to achieve the project objectives are shown in Table 1, with the aid of a Gantt chart. Certain subtasks need the previous ones to be completed before they can begin.

Table 1. Gantt chart describing the planning and sequence of tasks, including deliverables and milestones.



Tasks				Months																								
Sub-task	Title	Description	Pre-requisites	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1,1	Data preparation & initial calculations	Compilation of database, pre-processing (station selection, analyses code settings, testing).	1,1																									
1,2	Data Analyses	(teleseismic events detection, filtering, phase picking, location)	1,2																									
D1		*Presentation of initial results EGU2023*																										
2,1	Data Analyses	(teleseismic events detection, filtering, phase picking, location)	2,1																									
M1		*Visit of JH to NOA*																										
M2		*Visit of FG to*																										
D2		*Presentation of near-final results at ESC 2024*																										
3,1	Final Catalogue	Preparation of final catalogue, Data dissemination	3,1																									
D3		*Preparation and submission of journal publication*																										
DELIVERABLES & MILESTONES										D1		M1				M2						D2						D3

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SUPPORTING DOCUMENT

Curriculum Vitae of the PI

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Permanent research scientist (elected 29-12-2021)

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EDUCATION:

2000 - 2006: PhD: Department of Geology, University of Patras. 'Developing a slope stability early warning system – case study Corinth Canal'. Advisor: G.-A. Tselentis.

1992 - 1997: BSc: Department of Geology, University of Patras. Bachelor thesis 'Microtremors: Processing and analyzing data of background noise in the city of Patras'

GRANTS AND AWARDS:

2000 - 2004: Scholarship awarded by the Greek State Scholarships Foundation for doctoral studies (only 1 scholarship per year with a **5% success rate**)

LANGUAGES:

2005: Greek (mother tongue)

English (fluent - Advanced Certificate in English))

PROFESSIONAL EXPERIENCE:

01/2021 – 10/2021:

Employer: National Observatory of Athens.

Project: Active Faults Geophysical Research in the area of Heraklion.

Main tasks: Local network micro-earthquake analyses, monitoring active faults in the wider area of Heraklion Municipality (Kasteli Fault). Bibliographic investigation about the seismicity and the geological - tectonic framework of the study area & data compilation.

03/2021 – 10/2021:

Employer: National Observatory of Athens.

Project: Bradwell -2

Main tasks: Strong-motion data processing, quality assurance, empirical site response estimation (Matlab codes).

04/2020 – 02/2021 & 06/2021 – today:

Employer: National Observatory of Athens.

Main tasks: Participation as research staff in the 24-hour operation of the Geodynamic Institute seismological service. Real-time monitoring and analysis of seismicity in Greece, earthquake announcements and early tsunami warning.

04/2019 – today:

Employer: National Observatory of Athens.

Project: Seismological and Seismic Hazard Research - W. Patras Gulf.

Main tasks: Local network microseismicity analyses, earthquake focal parameters detection (Scolv).

04/2018 – 11/2020:

Employer: National Observatory of Athens.

Project: HELPOS.

Main tasks: Pylos seismic array data analyses, beamforming, f-k analyses, earthquake focal parameters detection (matlab & python codes, Hyposat).

02/2016 – 12/2016:

Employer: National Observatory of Athens.

Project: Aristotelis.

Main tasks: Seismic array (Cephalonia & Pylos) data analyses, beamforming, f-k analyses, earthquake focal parameters detection (seisan & python codes). Investigation of station sites installation for Cephalonia array. Cooperation with the sub-program RADONS.

12/2014 – 12/2015:

Employer: Institute of Geological and Mineral Research.

Main tasks: Electrical tomography (Res2dInv) and magnetic field intensity measurements analyses and interpretation. Development of GIS database with corresponding topographic, geological and geophysical data of the areas investigated (Kimmeria, Mavra Litharia, Volos, and Igoumenitsa).

01/2010 – 01/ 2011:

Employer: Greek Ministry of Agriculture.

Main tasks: data analysis, manipulation and interpretation of multi-spectral satellite images.

6/2008 – 03/2009 και 06/2016 - 12/2016:

Employer: Landtech Geophysics, UK.

Main tasks: Micro - earthquake analyses for Passive tomography projects (Albania – India, Papua).

01/2001-06/2005:

Employer: Seismological Laboratory – University of Patras.

Project: Ability Enlargement for Geophysicists and Information Technology Specialists (AEGIS).

Main tasks: handling, manipulating, digitizing, analysing and interpreting all the geographical data relevant to the project of the seismic risk analysis in the city of Patras.

10/2001-05/2006:

Employer: Department of Geology University of Patras, Greece.

Assistant Lecturer in Teaching Seismology and Applied Seismology.

02/2004 – 04/2004:

Employer: Seismological Laboratory – University of Patras.

Project: Safeguarding Hydrocarbons inside Earthquake Local Defence Systems.

Main tasks: Seismological data analysis, digitization and data management in GIS environment.

12/2003 – 03/2004:

Employer: Seismological Laboratory – University of Patras.

Project: Soils Seismic behavior - microzonal investigation at Bartholomio –Hleias Greece.

Main tasks: Seismological data analysis for earthquakes focal parameters detection. Data management in GIS environment

11/2003- 05/2004:

Employer: Seismological Laboratory – University of Patras.

Project: Seismological Research Rion - Antirion Area.

Main tasks: Simulating potential fault activations located in the surrounding area of Rion-Antirion: calculating stresses, deformations and displacements in 3D grids and cross sections along the axis of the probable construction of the submarine project (Poly 3D). Data management in GIS environment.

06/1999 – 09/1999

Employer: Seismological Laboratory – University of Patras.

Project: Monitoring of suitable seismic stations installation sites in the area of Lefkada.

Main tasks: Geological investigation, earthquake analyses - detection of focal parameters.

05/1999-05/1999:

Employer: Seismological Laboratory – University of Patras.

Project: LIFE95/GR/A11/1048/KRI.

Main tasks: Seismic refraction data analyses.

04/1999-05/2000:

Employer: Seismological Laboratory – University of Patras.

Project: Geophysical and seismological research sidelong Airport air path at Heraklion Crete, Greece.

Main tasks: Simulation of the blind fault crossing underneath the air path. Deformations and differential settlements were calculated due to its potential slip (Z-Soil).

PUBLICATIONS:

INTERNATIONAL JOURNAL ARTICLES

1. Tselentis, G.-A., G. Stavrakakis, E. Sokos, **F. Gkika**, and A. Serpetsidaki, 2010, Tsunami hazard assessment in the Ionian Sea due to potential tsunamogenic sources – results from numerical simulations, Natural Hazards and Earth Science Systems, Vol. 10, pp. 1-10.
2. Tselentis, G.-A., **F Gkika** & E. Sokos, 2005, Tsunami hazards associated with the Perachora fault at Eastern Corinth Gulf – Greece, Bulletin of the Seismological Society of America, Vol. 96, No. 5, pp. 1649–1661.
3. **Gkika F.**, Tselentis G-A. & Danciu L., 2005, Seismic risk assessment of Corinth Canal Greece, Coastal Engineering, Vol. 78, p. 323-332.
4. Tselentis, G.-A., & **F. Gkika**, 2005, Boundary element slope instability modeling of Corinth Canal Greece due to nearby fault activation, Coastal Engineering, Vol. 78, pp. 313-322.
5. **Gkika F**., Tselentis G-A. & Danciu L., 2005, Finite element fault rupture propagation modelling in the Corinth Canal, Greece, Coastal Engineering, Vol. 78, pp. 305-312.
6. Tselentis G-A., Danciu L. & **Gkika F.**, 2005, Empirical Arias Intensity attenuation relationships for seismic hazard analysis of Greece, ERES, Earthquake Resistanse Engineering Structures, Vol. 81, pp. 33-42.

1. Tselentis, G.-A., A. Serpetsidaki, **F. Gkika**, E. Sokos, L. Danciu & P. Paraskevopoulos, 2004, Seismic hazard simulation and risk reduction training algorithm for the city of Patras, Greece, Risk Analysis IV, Vol 77, pp. 13-22.

CONFERENCE ABSTRACTS

1. Ktenidou, O.-J. , **F. Gkika**, E.-V. Pikoulis (2022). 'Amplification across a seismic network - regional application to the Gulf of Corinth'. EGU General Assembly, Vienna, 23-27 May
2. Ktenidou, O.-J., **F. Gkika**, E.V. Pikoulis, C. Evangelidis (2021). Hard as a rock? Looking for typical and atypical reference sites in the Greek network, EGU General Assembly (online).
3. Ktenidou, O.-J., **F. Gkika**, C. Evangelidis (2021). 'The Quest for Rock Site Characterization for the Greek National Seismic Network'. EUROENGEO: 3rd European Regional Conference of IAEG), 6-9 Oct, Athens/online.
4. Bocchini G. M., Karastathis V. K., Voulgaris N., Mouzakiotis A., Papadopoulos G. A., **Gika F**., Liakopoulos, S., Tselentis, A., Lantzourakis, P. (2018) Enhancing routine seismicity monitoring by using a small aperture seismic array, results from the Pylos array (Western Peloponnese, Greece). ESC General Assembly 2018, Valletta.
5. Karastathis, V.K, K. Tsinganos, M. Kafatos, A. Tselentis, G. Eleftheriou, D. Ouzounov, E. Mouzakiotis, G.A Papadopoulos, N. Voulgaris, G.M. Bocchini, S. Liakopoulos, T. Aspiotis, **F. Gika**, B. E Psiloglou (2018). Two years of continuous radon observations for a pre-earthquake process monitoring in Peloponnese, Greece. EGU General Assembly, Vienna.

6. Karastathis, V.K., K. Tsinganos, M. Kafatos, G. Eleftheriou, D. Ouzounov, E. Mouzakiotis, G.A. Papadopoulos, N. Voulgaris, G.M. Bocchini, S. Liakopoulos, T. Aspiotis, **F. Gika**, A. Tselentis, A. Moshou, B.E. Psiloglou (2017). An integrated monitoring system of pre-earthquake processes in Peloponnese, Greece. AGU Fall Meeting, New Orleans.
7. Tsinganos, K., V.K. Karastathis, M. Kafatos, D. Ouzounov, G. Tselentis, G.A. Papadopoulos, N. Voulgaris, G. Eleftheriou, E. Mouzakiotis, S. Liakopoulos, T. Aspiotis, **F. Gika**, B.E. Psiloglou (2017) An integrated observational site for monitoring pre-earthquake processes in Peloponnese, Greece. Preliminary results, GU General Assembly, Vienna.
8. Velez, A.P., K. Tsinganos, V. Karastathis, M. Kafatos, D. Ouzounov, G. Papadopoulos, A. Tselentis, G. Eleftheriou, E. Mouzakiotis, **F. Gika**, T. Aspiotis, S. Liakopoulos, N. Voulgaris (2016). A pilot study of the earthquake precursors in the Southwest Peloponnes, Greece, AGU Fall Meeting, San Francisco.

FULL TECHNICAL REPORTS

Gkika F. (2015). Geophysical Research at Mavra Litharia - Serres, Institute of Geological and Mineral Exploration (IGME).

Gkika F. (2015). Geophysical Research at Kimmeria - Xanthis, Institute of Geological and Mineral Exploration (IGME).

INVITED TALKS / TEACHING SEMINARS:

15-17/03/2005: F. Gkika (2005). *GIS Seismic Risk GIS Database - City Of Patras.* In: GIS 4 Planned Training Course: GIS-based tools for volcanic and seismic risk assessment and management Parador de las Cañadas del Teide (Tenerife, Spain).

19-21/06/2005: Sokos E. & Gkika F. (2005) *Demonstration of Seismic Hazard computation – GIS platform*. In: GIS 4 Planned Training Course: GIS-based tools for volcanic and seismic risk assessment and management Parador de las Cañadas Del Teide (Tenerife, Spain).

INTERNATIONAL COMMITTEES, UPON INVITATION:

01/2021 – today : Member of the Tsunami-Ready Working Group of the Transnational Tsunami Warning & Mitigation System for North-East Atlantic, Mediterranean & Connected Seas (ICG/ NEAMTWS), representing Greece and GI/NOA.

TRAINING COURSES AND SEMINARS:

05/2010: 70-hour Seminar in project implementation in **Relational Databases,** National Centre for Public Administration and Local Government

04/2010: 35-hour Seminar in administration of environmental, urban and land-planning data with GIS, National Centre for Public Administration and Local Government

11/2004: 20-hour seminar in **Pattern recognition and clustering in geophysical applications**, **Paris, IPGP**. European Program “Ability Enlargement for Geophysicists and Information Technologies Specialists”

11/2003: 20-hour seminar in **GIS, Barcelona**, Institute of Earth Sciences "Jaume Almera". European Program "Ability Enlargement for Geophysicists and Information Technologies Specialists"

06/2002: 30-hour seminar in Remote Sensing - GIS, organized by Environmental Sciences Interdepartmental post graduate Program.

12/1997-06/1998: **340-hour** seminar training provided by the Hellenic Mathematical Society (11th annual seminar, Patras) for enhancing professional skills in informatics. Training in **Access 7, Visual Basic 4, Personal Oracle 7, Unix, C & C++**, Corel Draw, Photoshop & PageMaker.

SOFTWARE USE

Programming languages:

- Python: co-developed codes for seismic array data processing & data picking
- Matlab: co-developed codes for microtremor analyses

Seismological:

- Scolv, Atlas, Hyposat (Earthquake focal parameters)
- Isola (Focal mechanisms)
- Seisan, fk-analysis (Processing of seismic array data)
- Tunami-N2, TAT (Tsunami Analysis Tool)
- SeismoSignal, Seismwin (Signal Processing)
- SeisriskIII (Seismic Hazard)
- AEwin (Acoustic Emission Data Analyses)

Numerical analysis:

- Z-Soil (2D Finite Elements)
- Poly 3D (2D Boundary Elements)

Site Response:

- EERA (1D Equivalent-linear Earthquake Site Response Analyses)
- NERA (1D Non Equivalent-linear Earthquake Site Response Analyses)

Geographic Information Systems –Illustration and design:

- ArcGis, GMT, ER Mapper
- Surfer, Grafer

Electrical tomography - Magnetic:

- Reflex-W, Res2dInv, DC2dPro, Geosoft Oasis

SUBJECT: DEVELOPING A SLOPE STABILITY EARLY WARNING SYSTEM – CASE STUDY CORINTH CANAL GREECE

Dr Fevronia Gkika

Corinth Canal is one of the most important civil engineering marine projects in Greece. There have been many cases during the past were significant slope instability problems resulted in the abrupt closure of the canal causing serious problems. The finite elements method (FEM) was used to analyze the pattern of ground deformations caused by the potential slip of two active faults crossing the Corinth Canal. The analysis was based on detailed geological-geotechnical data of the area and showed regions possessing high risk of future slope movement.

The effect of local seismicity upon Corinth Canal was studied by assessing the corresponding site specific seismic risk. Special parameters such as the expected peak ground acceleration (PGA) and the arias intensity which are closely related with local slope instabilities have been determined. In addition, three characteristic active faults located in the adjacent area of the Corinth Canal were simulated in order to describe their effect on the canal. Causative deformations and displacements were calculated using boundary element code in 3D grids representing the two sides in the Canal. These simulations were conducted in order to define the most dangerous fault which could cause secondary instability effects along the slopes of the canal and to assess the damage distribution along the axis of the canal pinpointing regions of high instability risk.

Based on the above, an early warning slope stability monitoring system was proposed in order to continuously monitor the stability of particular high risk sites of the canal. This system is based on a new acoustic emission monitoring rod that was constructed for this reason and extensively studied in the laboratory.

Keywords: Corinth Canal, Greece, Fault Rupture Propagation, Finite elements, Boundary Elements, Seismic Hazard, Acoustic Emission, Monitoring Rod, Early warning.