NERA

Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation

Report

Near Fault Observation Systems, Networking and Communication Protocols

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Summary

This report summarizes the activities of the Near Fault Observatories (NFO) of NERA towards preparing for inclusion as a working group in the European Plate Observing System (EPOS) and final participation in the EU infrastructure proposal to fund the Implementation Phase of EPOS. This move is a logical step towards securing sustained data access services in the future. Significantly supporting this endeavor are two EU funded geo-hazard supersite projects led by two of the NFO partners, where important infrastructures and data services are being constructed.

Most of the access to multidisciplinary data recorded at the NFOs originally planned in the work package has already been achieved by the partners, but some data services are still under construction in the two supersite projects. Some of these services replace or enhance the originally planned services in NERA

Contents

1. Introduction

The fault zones networked in the NERA WP5 include, the *South Iceland Seismic Zone* (*SISZ*) in Iceland, the *Valais* region in Switzerland, the *Alto Tiberina* and *Irpinia* faults in Italy, the *Corinth Rift* in Greece and the North Anatolian fault in the *Marmara Sea* in Turkey. These six fault zones are in different tectonic regimes: The *SISZ*, the *Marmara Sea* and the *Corinth Rift* are at plate boundaries, with strike-slip faulting characterizing the *SISZ* and the *Marmara Sea*, while normal faulting dominates in the *Corinth Rift*. The *Alto Tiberina* and *Irpinia* faults in the Apennine mountain range are dominated by low- and medium-angle normal faulting, respectively, and the *Valais* region in the Alps is characterized by both strike-slip and normal faulting. The fault structures range from well-developed long faults, such as in the *Marmara Sea*, to more complex networks of smaller, book-shelf faults such as in the *SISZ*.

The focus of the near-fault observatories (NFO's) is on research into the active processes of their respective fault zones, achieved through acquisition and analysis of multidisciplinary data. The activities include mapping the internal structure of fault systems, research into the role of fluids in fault initiation, research of site effects and derived processes such as earthquake generated landslides and tsunamis, as well as the development of automatic earthquake early warning and systems and forecasting models. The NFOs collect a varying degree of multidisciplinary data and some NFOs are more focused than others on generation of hazard products required for comprehensive monitoring and management of the seismic hazard. Together they form a community capable of monitoring and researching crustal faulting and its associated hazards.

The NERA NFO networking activity is in line with the goals of the *EPOS* (*European Plate Observing System*) project whose aim is to construct a long-term, pan-European network of Research Infrastructures in Geosciences. Therefore to sustain the NFO networking in to the future, the NFOs infrastructure was suggested to the EPOS community as a working group of interest to the project. The necessary work to reach such status was performed by the partners, and the NFOs became a working group in EPOS and finally participated in an EU Infrastructure proposal to move EPOS to the implementation phase. The NFOs thus became one of 10 thematic core services making up the data providers community of EPOS. The architecture and financial plan for the NFO thematic core services were defined as part of this work. This work was led by the partner from Alto Tiberina.

Two of the NERA partners were involved in projects developing European geoscience hazard supersites, i.e. the seismic hazard project MARsite – partner from NAFZ observatory – and the volcano hazard project FUTUREVOLC – partner from SISZ observatory. The purpose of these projects was to construct a comprehensive research, hazard-monitoring and -management system for the future, including build-up of infrastructure and sustained services to data. The two projects, which are still on-going will construct infrastructure and services directly applicable as services in EPOS. The initial plans for networking data access in NERA will be adjusted for the two partners to accommodate the services developed in the supersite projects.

Interaction with international near-fault initiatives planned in Task 5.2 was successfully pursued and resulted in an NFO session at the AGU Fall meeting in San Francisco.

The following descriptions of EPOS WG activities are extracted from the many documents the partners of NERA WP5 made during the preparations for inclusion in the EPOS infrastructure.

2. Establishing NFOs as a working group in EPOS

The collaborations and work carried out in the NERA NFO work package (WP5) have provided the required initial steps to establish the NFO's as a working group in the preparatory phase of the Research Infrastructure project *EPOS* (*European Plate Observing System*), whose aim is to construct a long-term, pan-European network of Research Infrastructures in Geosciences making data openly available to researchers and stakeholders, such as hazard managers and industry.

Discussions among the NERA partners started during the first workshop, held at the Irpinia NFO in March 2012 and were revisited again in the second workshop in Zürich in March 2013. The discussions were aimed towards the goal of having the NFOs recognized as EU research infrastructures (RI) within the EPOS community. The work towards preparing the required documents and justifications for acquiring this status started for real in the summer of 2013. The first NERA deliverable D5.1 "*Inventory of Operational Near-Fault Observatory Networks and Data"*, was already directly applicable as a detailed description of the infrastructures at the NFOs, of the multidisciplinary data collected and the existing services. Even though the RI descriptions in D5.1 were ready for inclusion in the initial EPOS metadata base *RIDE* (www.epos-eu.org/ride/), the group still needed to write a white paper to justify its case for being identified as a separate EPOS working group. The white paper should define the multidisciplinary nature of the community to justify its existence as a separate working group. It should identify key NFOs in Europe, describe the multidisciplinary data types, define the data policies and access rules and describe the future vision and strategies for the thematic core services of the envisioned working group.

A follow-up meeting to focus on writing of the white paper defining the NFO community to EPOS was held at the Ettore Marjorana Foundation in Erice, Sicily in August 2013, scheduled to coincide with the first part of the EPOS workshop: *A Roadmap for Earth Science in Europe: The next generation of Geophysical Research Infrastructures*. The theme in the first half of this workshop was on "*EPOS thematic and integrated services: focus on Seismology, ICT [integrated core services] innovation and associated initiatives*", which was exactly what the NERA partners needed to define for the NFOs. The infrastructures of the six NFOs and their research focus to understand the multi-scale, physio-chemical processes responsible for earthquakes were also introduced in a presentation to the EPOS workshop attendants. Following the Erice meeting the NFOs were accepted as a subgroup of EPOs WG5, Other Geosciences data.

At the onset, this work on defining the NFO working group and its thematic core services in EPOS, benefitted from the NERA partner from the SISZ observatory, Kristín Vogfjörd being a co-chair in the Volcano Observatory (VO) working group. The VO working group collects and archives much the same multidisciplinary data as the NFOs and had already mostly completed the ground work defining the data and services required for the VO thematic core service. The leadership role for this work in the NFO working group, however was taken by the NERA partner from the Alto Tiberina observatory, Lauro Chiaraluce who became the chair of the EPOS working group with the other NERA partners serving as co-chairs.

The work defining the NFO Thematic Core Services (TCS) continued through 2013 and was again a topic for discussion at the third and final NERA workshop in Reykjavík in January 2014, where the participants worked towards finalizing the definition of the four pillars describing the NFO community and its relation to the other WGs and service architecture of EPOS. This structure is shown in Figure 1. It describes existing and envisioned structure of the NFO-TCS including the multidisciplinary data, the products and services and their different levels of maturity (e.g. for data types: level 0 for raw data; level 1 for automatic

processing; level 2 for advanced scientific products and level 3 for integrated data products). The finalized definition of the NFO-TCS included definition of its architecture for data management, integration and storage, structuring of services and interaction with the EPOS ICS; also general data-access rules and the costs of the services, required in the future EPOS infrastructure to sustain access to research quality data, products and services to all relevant stakeholders.

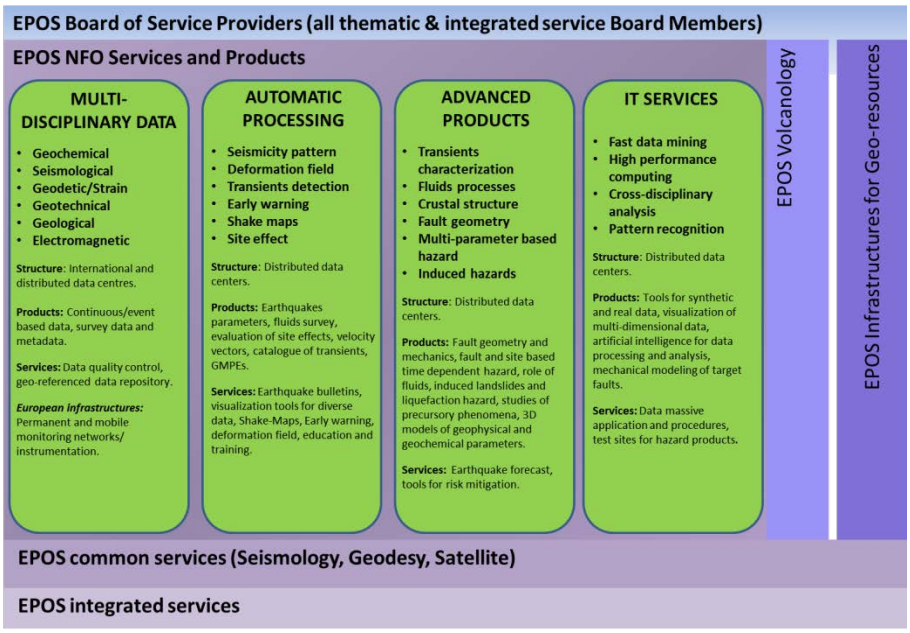


Figure 1. The four pillars defining the envisaged structure of the Thematic Core Services (TCS) of the Near-Fault Observatory working group in EPOS and their connection with other working groups and services in EPOS. The pillars define: the required multidisciplinary data, the automatic processing tools and services required to sustain future research into the physics of faulting and the resulting hazards.

In the fall of 2014, work began to prepare a proposal to an EU Infrastructure call to start the EPOS implementation phase (EPOS IP). The NFO community was an active participant in the proposal with one of the work packages (WP11) of the proposal containing the initial construction of the NFO-TCS. In the proposal the Vrancea Observatory in Romania had joined the NFO group, bringing the number of EU NFOs to seven. By the end of the EPOS IP proposal preparation, the construction of the NFO-TCS had evolved so that each NFO was considered a node providing data products and services to the NFO-TCS. The new TCS architecture consisted of three pillars:

- In situ NFOs – dealing with multidisciplinary data and metadata standards and definitions as well as coordination of the Observatories.
- Test beds – for Earthquake Early Warning and real-time processes, as well as training and education.
- Virtual Laboratory – an *e*-infrastructure to generate data products and cross-disciplinary analysis and visualization tools.

The EPOS IP proposal is under evaluation by the EU and if successful, the work towards defining data standards and quality controls for the NFO data and construction of the NFO Thematic Core Service in EPOS should start in the fall of 2015.

3. Supersites – development of infrastructures and services in MARsite and FUTUREVOLC projects

In 2011, during the first year of NERA the EC issued a research call for the construction of geohazard supersites, *ENV.2012.6.4-2 Long-term monitoring experiment in geologically active regions of Europe prone to natural hazards: the Supersite concept,* where the successful projects should contribute to building comprehensive natural hazard observatories by developing the next generation of geo-hazards monitoring systems, joining in situ and space-based observations. The projects should collaborate with other international supersites in order to contribute to building the Global Earth Observation System of Systems (GEOSS) and make a significant European contribution to the GEO 2012-2015 Work Plan.

The EPOS community encouraged focused responses to this call with proposals on seismic and volcanic hazard. Two of the NERA partners in WP5 participated in leading such proposals, the group from the NAFZ observatory leading the proposal MARsite, focusing on seismic hazard in the Marmara Sea and the group from the SISZ observatory focusing on volcanic hazard in Iceland. Both proposals were successful and started constructing their infrastructures and services in winter 2012/2013. In addition to building infrastructure, which is of direct relevance in the NAFZ observatory, one of the requirements for the Supersite projects (i.e. the reference to GEO) was that the data collected be open access to users at the earliest possible time. This meant that part of their activities involved building services to maintain this access in the long term. This also makes the constructed data services in FUTUREVOLC relevant to the NFO community, since the services to multidisciplinary data in FUTUREVOLC are all under the charge of the SISZ partner, IMO. The main aspects of the two projects are briefly summarized below.

3.1 MARsite

The MARsite project aims to compile on-shore, off-shore and space-based long-term monitoring activities in a comprehensive geophysical monitoring of seismic hazard in the Marmara region in order to move towards new concepts of risk mitigation and management. The project will integrate different types of data to study faulting and fault initiation and to develop early warning and real time systems. This includes seismological, geochemical and geodetic data to detect and model interactions between fluids, crustal deformation and faulting. MARsite will activate a multiparameter sea-floor observatory monitoring microseismicity and strain and search for possible correlations with fluid activity. The project will integrate GPS and InSAR time series to map spatio-temporal evolution of crustal deformation and implement an observatory of earthquake triggered landslides and submarine landslides. To understand the physical processes in the source region prior to the expected large Marmara earthquake, through monitoring of slow deformation, low frequency tremor and high frequency signals, MARsite will install an integrated multiparameter sensor made by Güralp in a 150 m deep borehole. The sensor consist of a broadband seismometer (CMG-3T/5T) with very wide dynamic range, a dilatometer, tilt meter, hydrostatic pressure gauge and thermometer.

The focus of the data access activity is on establishing standards for the multidisciplinary data and providing access to data and products to stakeholders and general users. This will have direct benefits for the NFO TCS construction in the EPOS IP project, where the participants from MARsite will lead the work on data standards and coordination.

3.2 FUTUREVOLC

The FUTUREVOLC project, which is focused on volcanic hazard will integrate advanced monitoring and analytical techniques in new, coordinated and innovative ways to improve understanding of magma dynamics and storage in the crust, of eruption triggers, and the dynamics of magmatic and volcanic processes during eruptions. Some of the technological developments in the project may be of relevance to the NFO community. These include seismic network operations in harsh conditions and chemical monitoring in rivers and groundwater. The chemical monitoring methodologies may be utilized for future chemical monitoring in the SISZ or other near-fault observatories, but the developments in real-time analysis of tremor characteristics and the near-real time analysis of GPS and InSAR data is most likely to be useful to the NFO community, for monitoring non-volcanic tremor in fault zones and crustal deformation due to large fault ruptures. The most relevant results of FUTUREVOLC however, are the data services being constructed to enable access to seismic, GPS and other multidisciplinary data from Iceland including also the SISZ. The data services are located and maintained at IMO, which is the Icelandic partner in the NERA near fault observatory.

In the EPOS IP project, coordination of interoperability of the infrastructures in the Volcano Observatory TCS with the ICS is led by the participant from FUTUREVOLC, IMO, which is likely to result in application of some of the FUTUREVOLC IT developments.

4. Networked data from the near fault observatories

The NFO's plans for guaranteeing access is as described below, but on-going developments in other projects, like the MARsite and FUTUREVOLC projects will change and improve some of the data services listed.

South Iceland Seismic Zone:

Seismic: Bulletin. Parameters of earthquakes located in the SISZ will be available at the FUTUREVOLC volcano supersite web portal under development at the Icelandic Meteorological Office (IMO) and which will be opened in April 2015.
Waveform. Waveforms from stations in the SISZ observatory (short-period, broad-band and accelerometer stations) will be available at the FUTUREVOLC portal. All seismic waveforms are now continuous. A SeisComP3 data base has been implemented at IMO and ArcLink is being set up to enable access to seismic data. Broadband data from 5 Icelandic stations is already streaming to ORFEUS.

GPS: The GSAC web service distributed by UNAVCO has been implemented at IMO and connected to the GPS data base. The service will be activated on the FUTUREVOLC portal in April 2015.

Strain: Will be stored in the SeisComP3 data base and will be made accessible through the FUTUREVOLC web portal.

Other: Work will continue under FUTUREVOLC towards enabling access to the other types of data recorded at the SISZ NFO.

North Anatolian Fault Zone:

Seismic: Bulletin. The monthly and yearly bulletins are available through the KOERI, NEMC (National Earthquake Monitoring Centre) web portal
http://www.koeri.boun.edu.tr/sismo/indexeng.htm

Waveform. The waveforms from stations are available on request. Registration is necessary in order to access continuous waveforms or event data. The continuous data is in GCF format and event data is in SAC format.

GPS: Access to GPS data and products from the NAFZ will be made available in the MARsite project.

Other: To be determined as MARsite data services come into effect.

Alto Tiberina Fault (TABOO; http://taboo.rm.ingv.it/):

Seismic: Bulletin. With the stations being part of the Italian National Network, the earthquakes parameters of the events located by the Real Time Monitoring System are already available at the ISIDE portal (Italian Seismological Instrumental and Parametric Data). The higher resolution bulletins produced by researchers will be available with the publications of scientific papers at the near fault observatory web site (TABOO; http://taboo.rm.ingv.it/.

Waveform. All the data recorded at SP, BB and SM stations are already available as continuous waveforms. Data can be freely downloaded from the EIDA portal.

GPS: Data from GPS stations are distributed within INGV by a centralized archive.

Other: Installation of corner reflectors, stations monitoring free gas emissions, and strong motions, possibly at the majority of the sites is in progress. Data access to be determined.

Corinth Rift Laboratory:

Seismic: Bulletin. Accessible through the http://crlab.eu web site.

Waveforms. Will be accessible through the RESIF portal, presently not accessible on the web; contact Hélène Lyon-Caen: helene.lyon-caen@ens.fr, or Anne Deschamps: deschamps@geoazur.unice.fr

GPS: GPS data in RINEX format available on line on the GPSCOPE web portal.

Strain: Will be accessible through RESIF, presently not accessible on the web. Contact Pascal Bernard: bernard@ipgp.fr.

Geology: Contact Mary Ford.

Other: To be determined.

Irpinia Fault (ISNet):

Seismic: Bulletin. The bulletin is available at the ISNet portal http://isnet.fisica.unina.it/. Information about earthquake location, local and magnitude, source parameters and shake maps are available in html format at http://isnet.na.infn.it/cgi-bin/isnet-events/isnet.cgi. They can also be downloaded in ASCII files. The early warning system PRESTo also generates a specific bulletin available at http://isnet.fisica.unina.it/PRESTo/index.php.

Waveforms: Waveforms from local earthquakes are freely available in SAC format directly at the website http://isnet.na.infn.it/cgi-bin/isnet-events/isnet.cgi, into the triggered station section. A waveform database is also included in the global ISNet database at http://seismnet.na.infn.it/, which also contains information about stations and instruments.

Valais Area:

Seismic: Bulletin Parameters of earthquakes located in Switzerland and surrounding areas are available on the website of the Swiss Seismological Service (SED).

Waveforms. As part of the SED transition to SeisComP3, the SED now runs ArcLink, which allows open access via both scripting and interactive web requests, to the entire continuous archives, making high-quality waveforms available. The continuous seismic data are available within ten minutes through the SED Arclink@SED (arclink.ethz.ch). All strong motion and weak motion data is available over this platform.

GPS: Continuous and campaign GPS data are available from the Federal Office of Topography (swisstopo).

Geochemical data: A system to access geochemical data is under development. Data is generally available from a web interface (credentials on request) as well as from ArcLink. However, the instrument is currently in revision and will be deployed at a new hot-spring site within the next months.
Pressure data from boreholes, strain data: This instrumentation is still in the phase for getting the permissions for installation; the data archival and distribution strategy is pending.
Magnetic data: Magnetic data is converted to miniseed and will be available using Arclink. Due to the high noise-level, hardware (sensors or filters) needs to be modified.

5. Dissemination and international interaction

The planned interaction with corresponding international Near Fault initiatives (Task 5.2) materialized in the final months of the project in a joint session at the AGU Fall Meeting in San Francisco. This session, which was convened by the NERA partners from Alto Tiberina and Corinth Observatories was coordinated with scientists from the USGS and GFZ in Potsdam. Most NERA partners contributed one or more presentations on research and observations at their observatories to the session, 13 presentations in all.

In collaboration with WP11 a flyer to introduce the NFOs and their infrastructures was made at month 42 (see Appendix) for distribution at conferences and a poster summarizing the characteristics of the NERA NFOs, their observational systems and planned activities was presented at the 2014 EGU in Vienna (see Appendix).

6. Future prospects/developments after NERA

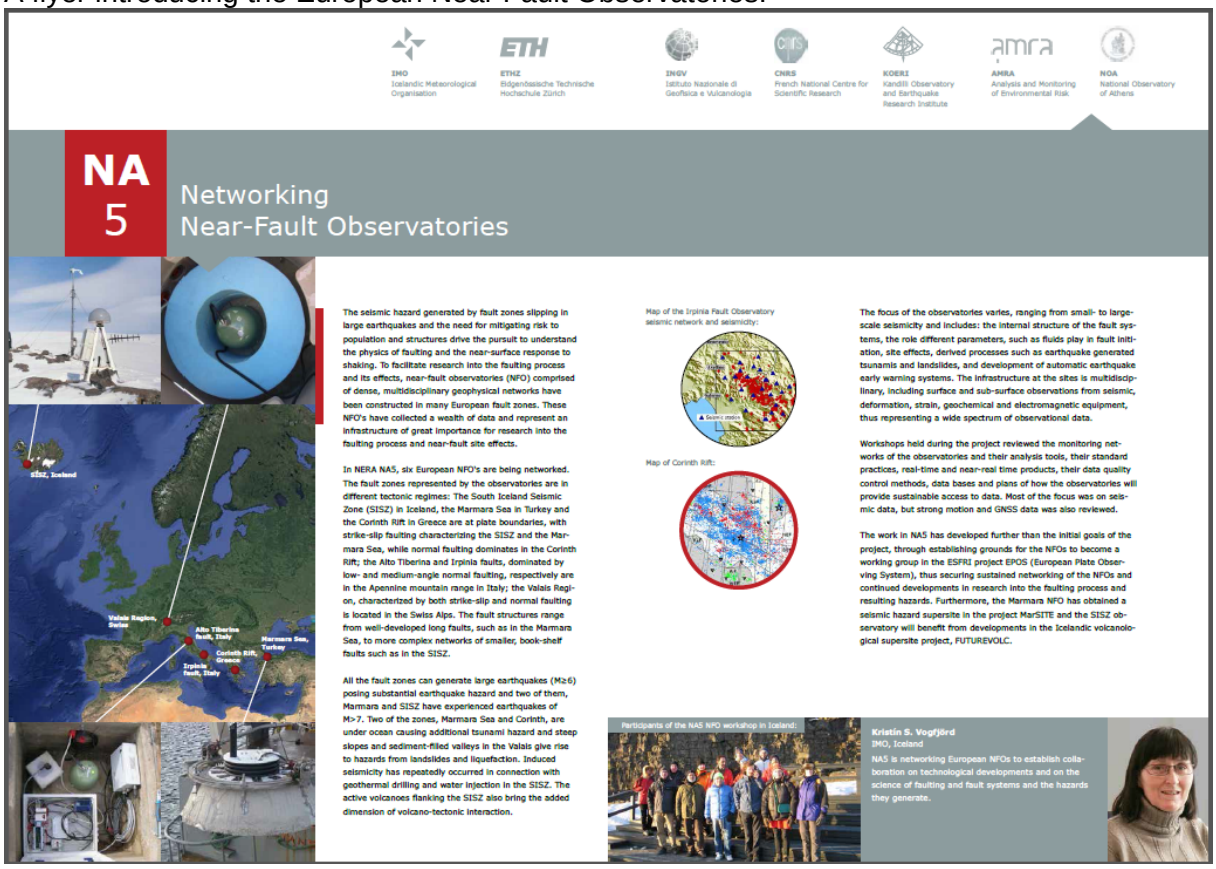
The NFOs have already succeeded in becoming a working group in EPOS and are participating in the EPOS Implementation phase (EPOS IP) proposal with a Near fault Observatory Thematic Core Service (NFO-TCS). The tasks to be performed include the definition of standards for the multidisciplinary data and metadata that are collected at the NFOs and do not already have standards defined (i.e. data other than seismic and GPS). To finalize these standards the NFO-TCS will need to collaborate with the Volcano Observatory TCS, which also deals with many of the same multidisciplinary data as the NFOs. The partner from the SISZ observatory is a co-chair in the VO working group, which should facilitate coordination and synergy of the future work needed to standardise the observations.

The EPOS IP proposal plans for the construction of the NFO-TCS to enable, where necessary, the generation of services to provide users with access to the NFO data. The TCS will also construct an Earthquake Early Warning testing facility to test and develop EEW codes for distribution within the NFO community and build a virtual laboratory to generate products and analysis tools for users.

7. Appendix

Dissemination material on the WP5 activities

A flyer introducing the European Near Fault Observatories:



IMO Icelandic Meteorological Organisation
ETH ETHZ Eidgenössische Technische Hochschule Zürich
INGV Istituto Nazionale di Geofisica e Vulcanologia
CNRS French National Centre for Scientific Research
KOERI Kandilli Observatory and Earthquake Research Institute
AMRA Analysis and Monitoring of Environmental Risk
NOA National Observatory of Athens

NA 5

Networking
Near-Fault Observatories

The seismic hazard generated by fault zones slipping in large earthquakes and the need for mitigating risk to population and structures drive the pursuit to understand the physics of faulting and the near-surface response to shaking. To facilitate research into the faulting process and its effects, near-fault observatories (NFO) comprised of dense, multidisciplinary geophysical networks have been constructed in many European fault zones. These NFO's have collected a wealth of data and represent an infrastructure of great importance for research into the faulting process and near-fault site effects.

In NERA NA5, six European NFO's are being networked. The fault zones represented by the observatories are in different tectonic regimes: The South Iceland Seismic Zone (SISZ) in Iceland, the Marmara Sea in Turkey and the Corinth Rift in Greece are at plate boundaries, with strike-slip faulting characterizing the SISZ and the Marmara Sea, while normal faulting dominates in the Corinth Rift; the Alto Tiberina and Irpinia faults, dominated by low- and medium-angle normal faulting, respectively are in the Apennine mountain range in Italy; the Valais Region, characterized by both strike-slip and normal faulting is located in the Swiss Alps. The fault structures range from well-developed long faults, such as in the Marmara Sea, to more complex networks of smaller, book-shelf faults such as in the SISZ.

All the fault zones can generate large earthquakes (M≥6) posing substantial earthquake hazard and two of them, Marmara and SISZ have experienced earthquakes of M>7. Two of the zones, Marmara Sea and Corinth, are under ocean causing additional tsunami hazard and steep slopes and sediment-filled valleys in the Valais give rise to hazards from landslides and liquefaction. Induced seismicity has repeatedly occurred in connection with geothermal drilling and water injection in the SISZ. The active volcanoes flanking the SISZ also bring the added dimension of volcano-tectonic interaction.

Map of the Irpinia Fault Observatory seismic network and seismicity:

Map of Corinth Rift:

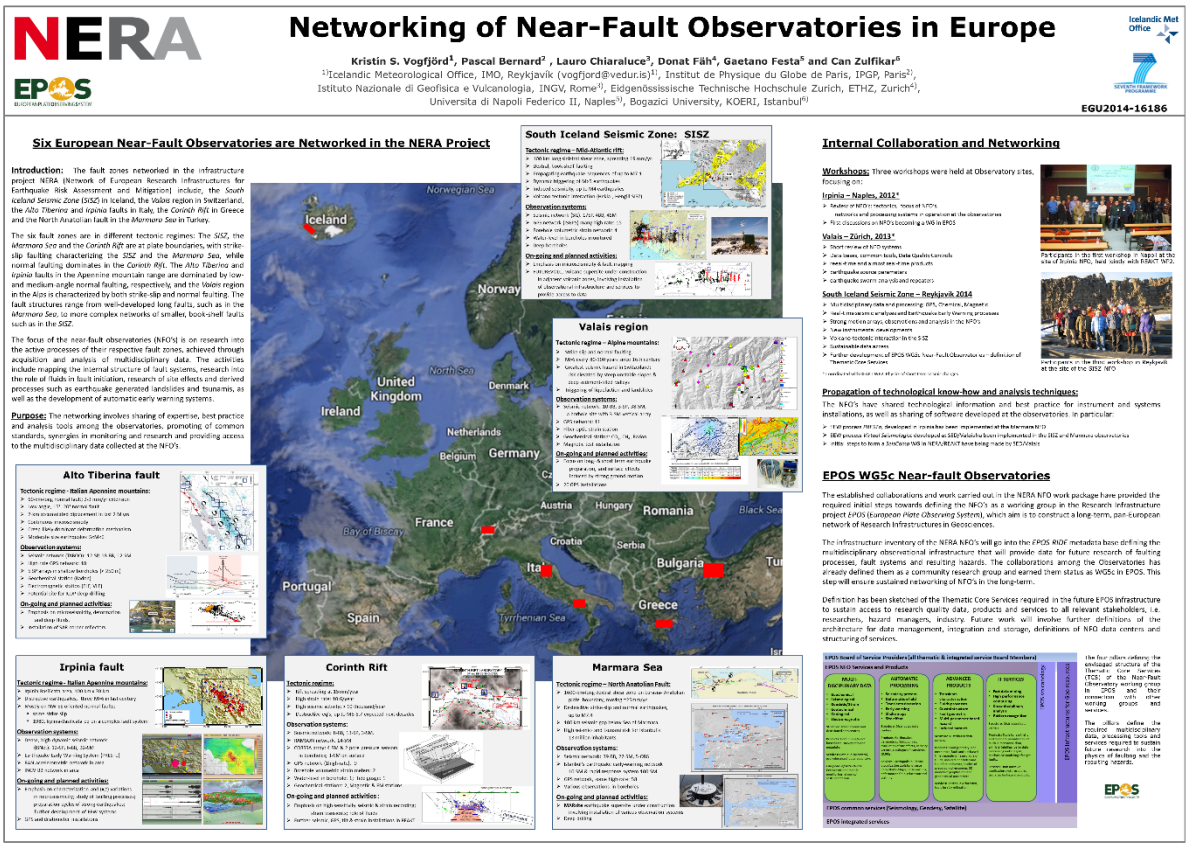
The focus of the observatories varies, ranging from small- to large-scale seismicity and includes: the internal structure of the fault systems, the role different parameters, such as fluids play in fault initiation, site effects, derived processes such as earthquake generated tsunamis and landslides, and development of automatic earthquake early warning systems. The infrastructure at the sites is multidisciplinary, including surface and sub-surface observations from seismic, deformation, strain, geochemical and electromagnetic equipment, thus representing a wide spectrum of observational data.

Workshops held during the project reviewed the monitoring networks of the observatories and their analysis tools, their standard practices, real-time and near-real time products, their data quality control methods, data bases and plans of how the observatories will provide sustainable access to data. Most of the focus was on seismic data, but strong motion and GNSS data was also reviewed.

The work in NA5 has developed further than the initial goals of the project, through establishing grounds for the NFOs to become a working group in the ESFRI project EPOS (European Plate Observing System), thus securing sustained networking of the NFOs and continued developments in research into the faulting process and resulting hazards. Furthermore, the Marmara NFO has obtained a seismic hazard supersite in the project MarSITE and the SISZ observatory will benefit from developments in the Icelandic volcanological supersite project, FUTUREVOLC.

Participants of the NA5 NFO workshop in Iceland:

Kristín S. Vogfjörd
IMO, Iceland
NA5 is networking European NFOs to establish collaboration on technological developments and on the science of faulting and fault systems and the hazards they generate.



A poster introducing the NERA NFOs was presented at the 2014 EGU in Vienna.