This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No [308417]".

New Directions in Seismic Hazard Assessment through Focused Earth Observation in the Marmara Supersite

Grant Agreement Number: 308417
co-funded by the European Commission within the Seventh Framework Programme
THEME [ENV.2012.6.4-2]
[Long-term monitoring experiment in geologically active regions of Europe prone to natural hazards: the Supersite concept]

D1.5
Annual Public Report - 2

Project Start Date	1 November 2012
Project Duration	36 months
Project Coordinator /Organization	Nurcan Meral Özel / KOERI
Work Package Number	1
Deliverable Name/ Number	Annual Public Report – 2 / D1.5
Due Date Of Deliverable	31 October 2014
Actual Submission Date	22 December 2014
Organization/Author (s)	MARSite WP Leaders, Ocal Necmioglu, Nurcan Meral Ozel, Meral Alguadis

Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission)	
RE	Restricted to a group specified by the consortium (including the Commission)	
CO	Confidential, only for members of the consortium (including the Commission)	

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1.INTRODUCTION

The MARSITE project which started on 1 November 2012 and coordinates research groups with different scientific skills (from seismology to engineering to gas geochemistry) in a comprehensive monitoring activity developed both in the Marmara Sea and in the surrounding urban and country areas. The project coordinates initiatives to collect multidisciplinary data, to be shared, interpreted and merged in consistent theoretical and practical models suitable for the implementation of good practices to move the necessary information to the end users.

The GEO concept of Supersites has generated considerable interest since its first appearance in the GEO Work Programme 2009-2011. The concept of facilitating "Retrieval, integration and systematic access to remote sensing & in-situ data in selected regional areas exposed to geological threats (“Supersites”)" was seen as a means to improve efficiency of expensive monitoring and research efforts by geographically focussing them. MARsite will represent a significant European contribution to the Supersite initiative and thus to the Global Earth Observation System of Systems (GEOSS), and it will lead to better scientific understanding of the geophysical processes, contribute in-situ data to a unifying e-infrastructure, broaden our knowledge about geological extreme events and reduce our vulnerability to geologic hazards.
The MARsite strategic objectives are to:

i) Achieve long-term hazard monitoring and evaluation by in-situ monitoring of: earthquakes, tsunamis, landslides, displacements, chemical-radioactive emission and other physical variables and by the use of space-based techniques.

ii) Improve existing earthquake early-warning and rapid-response systems by involving common activities, participants, competences, knowledge and experts from Europe.
Improve ground shaking and displacement modelling by development/updating of source models and the use of probabilistic and deterministic techniques with real-time and time-dependent applications.

ii) Pursue scientific and technical innovation by including state-of-the-art R&D in developing novel instruments and instrumentation.

ii) Interact with end users and contribute to the improvement of existing policies and programs on preparedness, risk mitigation and emergency management.

iv) Build on past and on-going European projects by including their contributions and principal partners, avoiding duplication and using their successes and momentum to create a better understanding of geo-hazards.

MARsite is coordinated by the Bogaziçi University, Kandilli Observatory and Earthquake Research Institute, established in 1868 as the Imperial Observatory with a long tradition of earth observation and science. The MARsite Consortium brings together 18 major European research institutions with a long record of scientific history and success, and 3 SMEs, from 6 nations of the Euro-Mediterranean area. The consortium is very balanced, both in terms of specialities and in terms of distribution between EU-countries, EU-supported international organizations and Turkish national institutions. The consortium is organized in such a way that it will maximize its efficiency for meeting the objectives of the call and develop a fully integrated conceptual approach based: i) on the collaboration with existing monitoring networks and international initiatives; ii) on the development of new instrumentation such as in-situ sensors; iii) and on the aggregation of space and ground-based observations (including from subsurface), and geophysical monitoring.

2 SUMMARY OF THE ACTIVITIES IN THE SECOND YEAR OF MARSite

This section of the Annual Public Report provides a summary of work conducted and achievements accomplished during the period of November 2013 – October 2014. As can be seen in Figure 2.1, 24 deliverables are to be produced within the second year mainly concentrated on the scientific achievements of the project.

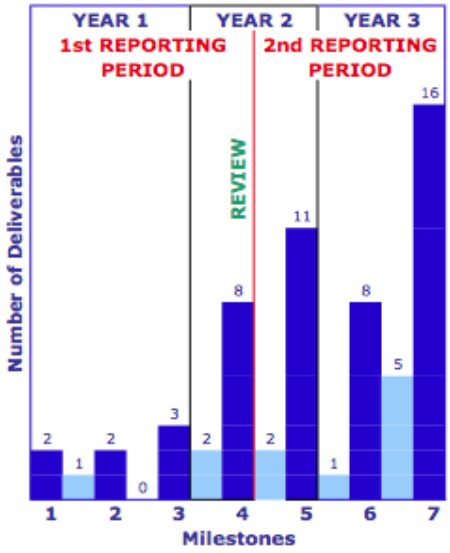


Figure 2.1: Distribution of MARSite Deliverables within Project Life-time

2.1 WORK PACKAGE 1: Management

The first General Assembly of the MARSite project was held in İstanbul, Turkey at KOERI premises on the 2nd and 3rd of December 2013 with the attendance of 56 partners from members of the Consortium and Robert Reilinger from MIT as External Experts Advisory Board Member .

Figure 2.1.1: Participants of the General Assembly 2013

MARSite Midterm Review Workshop was hosted by INGV at Hotel and Conference Venue Villa Eur Parco Dei Pini in Rome, Italy on the 7th and 8th of May 2014. 44 participants from partners attended the meeting. The work package parallel sessions were conducted in the second day of the Midterm Review Workshop. The purpose of the WP sessions was to bring each WP contributors together to discuss all possible details of the work foreseen within the WP.

Figure 2.1.2: Participants of the Midterm Review Meeting

2.2 WORK PACKAGE 2: Land Based Long-term Multi-disciplinary Continuous Monitoring

In the first year, collection of the first comprehensive data set of fluids composition around the Sea of Marmara has been accomplished and first insight in the geochemical features of the fluids expelled from tectonic structures around the Sea of Marmara has been obtained. A new data server (MARsite Main Server) located at KOERI collects data from different disciplines including geodetic, geochemical data and the online seismic stations (71 in Marmara from KOERI, TUBITAK and KOU networks) that acquire data at a rate of 50-100 samples per second. The MARsite partners also share their outputs (i.e. maps, posters, papers) via the ftp site of the Main Server. All data in the MARsite Main Server are periodically backed up on the TRUBA systems, a part of the European grid infrastructure, located in Ankara. The micro-earthquake catalogue of TUBITAK for data correlation has been updated and daily evaluation of online spring water and soil radon gas data with respect to the seismic activity took place.

In WP2 “Land-based long-term multi-disciplinary monitoring”, the collection of the first comprehensive data set of fluids’ composition around the sea of Marmara was achieved during the first reporting period. The first results on the fluids’ geochemistry of the area surrounding the Sea of Marmara allowed to gain a better insight on i) the geochemical features of the fluids expelled from tectonic structures around the Sea of Marmara, ii) the origin of the vented fluids, and iii) the occurrence of interactions processes.

The data catalogue of 13 spring water and 21 soil radon gas stations in the Marmara region has been updated and the online data added to the fluid monitoring database. Online seismological waveform data from KOERI, TUBITAK and KOU networks have been integrated to the new common server (MARsite Main Server) as well as all data from different disciplines. The data from the online spring water and soil radon probes are under evaluation in the mainframe of a degree thesis carried out at the La Sapienza University (Rome, Italy) with the tutorship of INGV, GFZ and TUBITAK.

The second field trip around the sea of Marmara (August 30-September 10) has allowed to improve the knowledge on the geochemical features of the fluids circulating over the northern and southern braches of the NZF. The analytical job has been carried out mainly at the INGV and the analytical results have been shared and are now under evaluation.

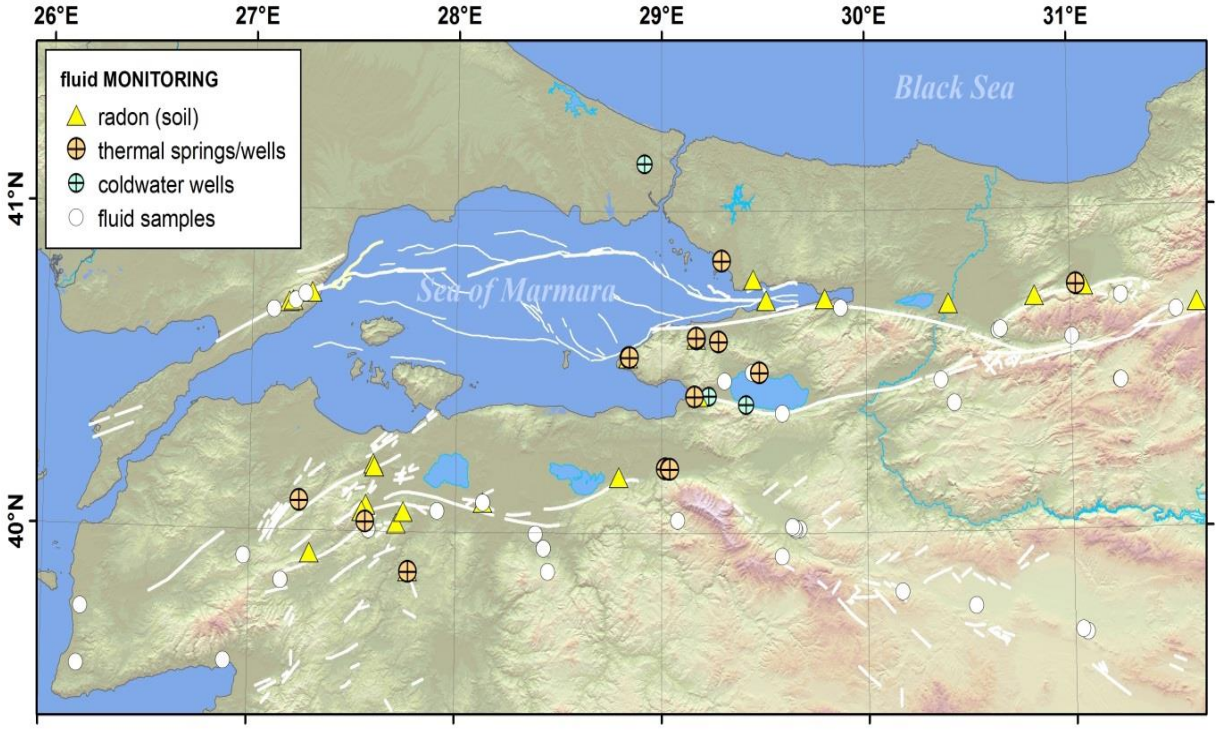


Figure 2.2.1 Location of the sampling sites where thermal waters and gases have been collected and distribution of the operating monitoring stations (radon = yellow triangles; springs and wells cross-marked circles). It is easy to observe the satisfying coverage of the area at the end of the first year of project activities.

2.3 WORK PACKAGE 3: Long-term Continuous Geodetic Monitoring of Crustal Deformation

Within this period , WP3 team continued to run the GPS data process and updated version of GPS time series and velocity files were put to the project ftp server. Now, data and results (time series, velocities) transfer to FTP server, automatically. All partners use the GPS products to control the long-term deformations in hazard&risk studies.

A new processing strategy developed to obtain high-rate GPS products, comes from WP5.1
In the first period, as we pointed, the Marmara region GEO Supersite, has been modified, , following the responses of SAC members. In early February 2014, the new version of the MARsite Proposal was submitted to CEOS for the final approval. On April 2014 CEOS accepted our proposal and decided to share the following resources with us:

CEOS agencies intend to support the Marmara Region Supersite with the following data resources:

Agenzia Spaziale Italiana (ASI)	COSMO-Skymed: 200 scenes / year 400 scenes of past acquisitions
Canadian Space Agency (CSA)	Radarsat-2: 160 scenes / year
Deutsches Zentrum für Luft- und Raumfahrt (DLR)	TerraSAR-X: 250 scenes / year 550 scenes of past acquisitions
European Space Agency (ESA)	ERS-1 / -2 / ENVISAT-ASAR, Sentinel-1, -2: Any available acquisition
Japan Aerospace Exploration Agency (JAXA)	To be determined
National Aeronautics and Space Administration (NASA)	ASTER : to be determined EO-1 : any available acquisition

In a few months, we delivered X-band data (COSMO-SkyMed and Terrasar-X) to prepare the deliverables on time, using data resources in Marmara Region GEO Supersite. To obtain time series, Wp3 team developed a set of procedures to update the SBAS processing chain for processing X-band data from TerraSAR-X, COSMO-SkyMed data.

Besides, in order to reduce atmospheric artefacts at the time of acquisition of the different SAR images the Zenith Path Delay layers will be estimated with the help of GPS data processing. The Zenith Path Delays estimated using GAMIT would be input for PSInSAR and SBAS analysis and will be combined for the initial tests to estimate and as far as possible subtract Atmospheric Phase Screen (APS) with the pre-processed ENVISAT ASAR archive data at selected tracks. Related raw SAR data sets that belong to ENVISAT ASAR sensor were archived under the defined project ftp file structure.

After that, InSAR data contributed by the partners of the projects were converted and prepared for modeling. While the WP3 team still run the processing, they feed the modelling studies. Based on the preliminary results a significant combination of postseismic (viscoelastic) deformation and afterslip was detected in the western segment of the 1999 Izmit rupture plane. These results presented in EGU, 2014.

Briefly, a zone of anomalous fault slip behavior was detected in the Main Marmara Fault zone segment located close to Istanbul. The nature of this anomalous slip, whether being fully locked or subject to conditional slip has been tested. Results suggest a release of stress that weakens in the postseismic episode. These results are significant, as they may indicate a possible delay of an anticipated earthquake.

2.4 WORK PACKAGE 4: Establishment of Borehole Observation System and High Resolution Seismic Studies in the Marmara Sea

The 146 meter deep borehole was successfully drilled and cased. The internal diameter of the borehole is 155 mm. All the sections of the casing are welded to each other so as to provide dry cased borehole. Each welded section is further sealed with bitumen based sealant. The maximum inclination of the borehole is less than 2 degrees form the vertical. The borehole inclination was measured at the bottom of the borehole. The complete length of the casing was surveyed with a borehole camera. Attached photo shows the welded casing seams and the small amount of water at the bottom of the borehole. The water level is measured at 145.60 meters depth. In conclusion the drilled bore is consistent with the initially set out specification at the beginning of the project

The tilt meter is installed with three jaw hole-lock at 145 meters depth and above the tilt meter a cable strain relief mechanism is installed with internal transient protection and dc power supply.

All the sensor outputs are differential capable of driving the 200 meter cable to the surface. Within the tilt meter housing there is also a temperature sensor used to apply temperature correction to the tilt-metre outputs. The high sensitive sensor can be “zeroed” over a range of ± 5 Degrees using precision motorised micrometres.

The initial results from the measurement is very encouraging with the following conclusions:

- The sensor system was very easy to install and centring of the tilt meters could be accomplished down to milli-volts level.
- The stability of the tilt-meter is adequate to record “Earth tides”. The provided plot is 10 days of data for both the X and Y axis of the tilt meter from installation. The data shows that the “Earth tides” can be easily recoded.
- Within the next three months the performance of the system will be characterised.

Analyzing Response Of Near-Surface Geology To Earthquake Ground Motion And Its Effects Masking The Source Related Information Through Borehole Data

Realistic ground-motion predictions of future earthquakes can be obtained only by a combination of realistic source, wave propagation and site-response models. To this regards, vertical arrays are a useful and important tool for improving the understanding of in situ behavior, including insights into the wave propagation in soil. Furthermore, buildings of different construction types respond differently to seismic source excitation. Not only the material and structure of a building but also the soil on which the building is built can have an influence on the building motion. Hence, information about the dynamical properties of buildings (obtained from a vertical array installed on different floors in a building), the

characteristics of the soil (obtained from borehole data) and the soil-structure (soil-building) interaction are needed to better estimate the seismic risk. The interferometric approach is one tool to investigate the wave propagation, both inside buildings and through the soil.

The interferometric approach was applied to either borehole or building data. For one event the data was available for both. By combination of two vertical arrays (borehole and building), we obtain a unique vertical array from -140m to 44m. The propagation of the waves from the deepest downhole sensor to the ground surface, the basement of the building up to the roof and back can be studied and the investigations of structural, site response, and soil-structure interaction is carried out in a comprehensive way. Since the new borehole system (WP4, Task 1) was installed at the end of October 2014, till now, in order to calibrate the methodologies to be adopted in the project, data from the vertical array in Ataköy, Istanbul (Parolai et al. 2009) were used for studying the wave propagation through vertical arrays of seismological stations.

Monitoring The Fault Zone and Source Process in The Near Field Recent regional seismicity

We use seismic waveform data that were acquired between 2007-2012. The data were compiled from 132 seismic stations belonging to local permanent and temporal networks (see Figure 1). The starting date of 2007 was chosen because of the station density increase around the Cinarcik basin.

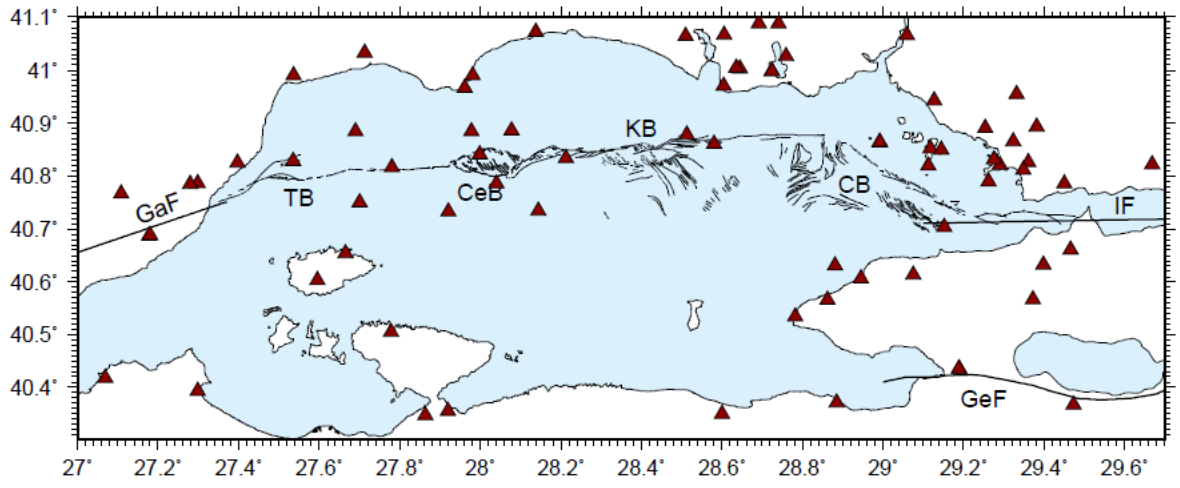


Figure 2.4.1: Map of the seismic stations

The obtained earthquake catalog consists of 4759 events including 1683 events along the MMF (within a maximum horizontal distance of 10 km away from the fault trace). We compared our catalog to the KOERI catalog computed from the only permanent networks and observed that our catalog contains _ 30% more distinct events and is much more precise in terms of location (see figure below). Indeed, relative location using HypoDD was performed and improved the catalog locations moderately compare to the absolute location error.

As a result of the good network coverage we were able to reduce magnitude completeness (Mc _ 1) and the location errors of the events. Typical errors in longitude, latitude and depth are: 1km, 1km and 3km. Based on the geographical and depth distribution of micro-seismicity between 2007 and 2012, four domains can be defined along the MMF (within a thickness of 10 km) (see Figs. 2 and S1): a) theWest Marmara (WM) zone which includes the Tekirdag and Central Basins where seismicity is abundant and well distributed in depth (from surface to 17 km) with a few vertical clusters, b) the Kumburgaz basin (KB) in the center zone of the Marmara Sea where seismicity is very sparse, and c) the Cinarcik basin (CB) to the east where seismicity is uniformly distributed along the Princes Islands (PI) segment within a narrow depth range except at both ends of this basin where it extends vertically.

High Resolution Seismology in Marmara Sea With Arrays

The online data transfer from PIRES network was fully implemented in 2013 and described in detail in the progress Report 1. Drawbacks regarding the data transfer were largely eliminated by changing the modems during a second stage of upgrading in April 2014. New modems used 3G transmission which improved the data transfer bandwidth and quality.. The second major problem was the damage to the stations by fire, by storms, and also by theft. All these problem were somehow magnified with the inadequate maintenance by the company which was contracted for servicing.

In the sequel, a graphical representation for the time evolution of the performance for each station are given. The y-axis shows the data gap in second in an interval of 1 hour, ie varies between 0-2600 second. A general view shows clearly the improvement in performance after March-April 2014 where the modem upgrading took place. We expect to test the network in the coming months for the more precarious conditions of the winter.

2.5 WORK PACKAGE 5: Real and quasi-real-time Earthquake &Tsunami Hazard Monitoring Seismic Studies in the Marmara Sea

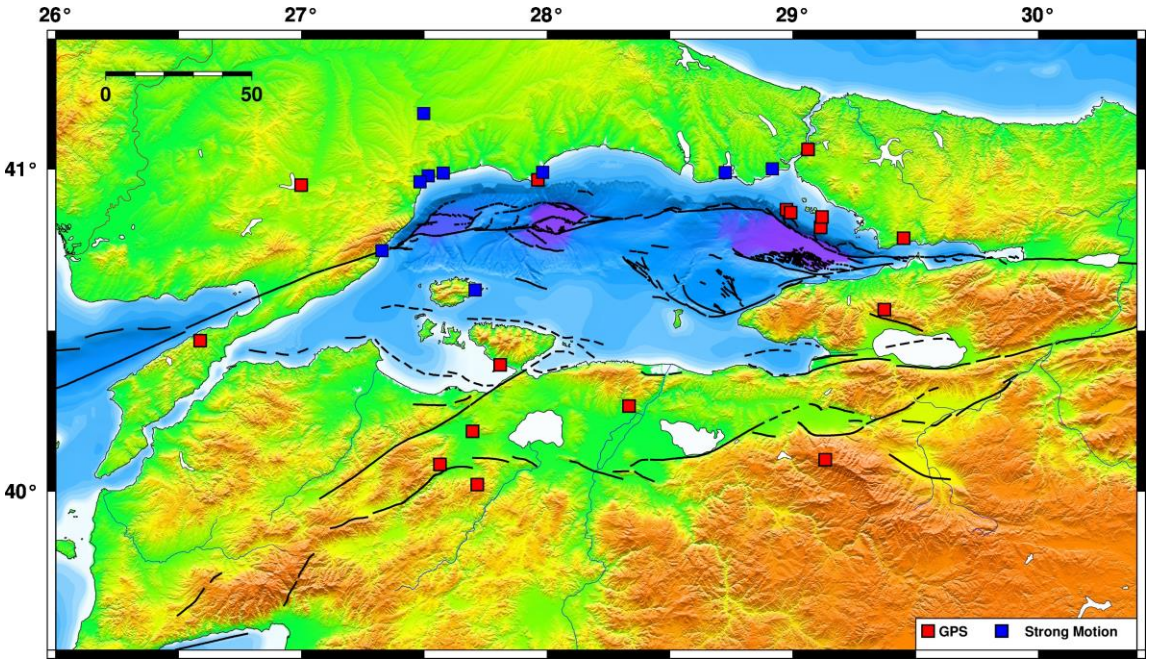


Figure 2.5.1 Continuous GPS stations (MAGNET) in the Marmara Region and Strong Motion surface arrays.

Within the WP5 the technical structures including electricity, communication and data transfer, renovation of the other critical components of the Continuous GPS stations of MAGNET (**Error! Reference source not found.**) has been updated since the beginning of the project. Additionally as committed in the task surface array of strong motion network installation has been started. 6 strong motion observation station has been installed (Figure 2.5.1) in consistence with the GPS site. More will be added in the future. In October, 2014, 16 Continuous GPS stations with purple squares (**Error! Reference source not found.**) were updated to real time data transmission according to the power and data transmission tests previously done. For this purpose the power systems for cGPS stations operating with electricity and stations without electricity were improved and 3G GPRS modems were got into use for high-rate data transmission. Processing of High Rate GPS data (1Hz) has been studied and an algorithm using TRACK/TRACKRT software as a part of routine daily GPS processing with GAMIT/GLOBK is developed and tested with 1s GPS data sets of Van eq (Mw7.2), 2011. From now on the algorithms will be tested with real time GPS data within the project and setup for data process will be completed.

In Task 2 3D wave propagation simulations in a 3D geological model (Bayrakci et al., 2013) coupling a 1D structure (Karabulut, pers. Comm.)has been carried out. The earthquake scenarios (of about M7.0 – 7.3) along the North Anatolian Fault in the Sea of Marmara, dynamically simulated in complex fault system (Aochi, EGU, 2014) were taken into account. Coupling with a logic tree approach on the model parameters, it is possible to assess probabilistically the ground motion levels at give sites (Aochi and Ulrich, ECEES, 2014; Aochi and Ulrich, in revision, BSSA, 2014). These synthetic ground motions were provided at the

locations of real observation network (strong ground motion, broadband, GPS including OBS) for the purpose of blind tests of finite source inversions. The first test was correctly inverted by another partner (Diao and Wang, pers. Comm.) and this reassured the following tests (correctness and rapidity). Work has been carried on the comparison of the estimated ground motions by different methods; deterministic simulations for low frequencies and stochastic approaches for broadband frequencies, for the purpose of proposing a hybrid approach for simulating the referential ground motions at given sites. The earthquake scenarios and synthetic ground motions are going to be provided for the tsunami modeling and geomechanical modeling of landslides in the region.

To this goal INGV team obtained a complete kinematic description of the rupture process of the 2011 M_w 7.1 Van earthquake, by using a non-linear inversion approach. INGV researchers investigated these issues by imaging the rupture history through the inversion of strong motion, GPS and DInSAR data (inverted either separately or jointly). The methodology, developed at INGV, is a two-stage nonlinear technique (Piatanesi et al., 2007), which involves the joint inversion of strong motion records and geodetic data. For the application to the Van earthquake, 10 three-component digital accelerometers belonging to the AFAD (Earthquake Department of the Disaster and Emergency Management Presidency) and BHRC (Iranian Strong Motion) networks; and 10 GPS displacements have been selected. A Differential SAR Interferometry image from the descending orbit Cosmo-SkyMed (*Moro et al., 2013*) has been considered. The comparison between the results obtained from the separate inversions, shows how the different dataset are able to 'illuminate' in different way the rupture process on the fault plane; especially due to the different azimuthal coverage. The joint inversion of GPS, DInSAR and ground velocity time histories allows us to better constrain the slip model and to extract the relevant features characterizing the rupture history of the 2011 Van earthquake. Slip is concentrated in two main asperities: a shallow patch of slip located south-westward from the hypocentre and a second deeper asperity located northeastward from the nucleation. The retrieved seismic moment is 1.01 $\times 10^{27}$ dynxcm, corresponding to a M_w 7.1, in agreement with the result obtained by Fielding et al.,2013.

GFZ team implemented and tested an open-assess software for the purpose of automatic finite-fault source imaging based on the IDS (iterative deconvolution and stacking) method (Zhang et al. 2014).

Sensitivity tests has been done using synthetic strong-motion data and sensitivity tests for the finite-fault source imaging has been done using synthetic data at the existing strong-motion and GPS networks in the Marmara area.

The performance of the IDS method for automatic imaging of the rupture processes has been proved using off-line data from several recent major earthquakes (2008 M_w7.9 Wechuan, 2011 M_w9.0 Tohoku, 2014 M_w8.2 Pisagua, 2014 M_w7.7 Iquique) as well as various synthetic data for scenario earthquakes in the Marmara region. The synthetic test has shown

that the presently available seismic/GPS networks around the Marmara Sea, if they are all upgraded for real-time data transmission, are able to provide sufficient information for a rapid source characterisation (i.e. within a few minutes) of large earthquakes (M_w = 7.0+) on the major NAF segment in the Marmara Sea. Uncertainties in the Earth structure are found to have a large effect on the recovery of slip pattern and moment magnitude. However, the coseismic static displacement data from high-rate GPS ('0' frequency data) can overcome the problem caused by the structure uncertainty and highly improve the spatial resolution of slip and the accuracy of magnitude estimation.

Partners agreed on co-operations in working in progress on the analysis of the performance of the available inversion codes in the Marmara configuration; to this goal we are performing a blind test for kinematic source inversion. This approach allows us to compare the resolution and efficiency of different inversion techniques and to understand their limits and advantages. The idea is that one research group (BRGM) generates a synthetic dataset obtained by dynamic modelling of a single earthquake scenario; and provides these synthetics to the other teams (GFZ, INGV, KOERI), to invert for the most relevant earthquake source parameters, by using the different codes we have. A description of the proposed blind test can be found on http://aochi.hideo.perso.neuf.fr/marmara/.

In Task 4, The work on the compilation of the historical seismicity and moment tensor catalogues (database) has been finalized. The deliverables D7.2 GIS Database of the fault parameters "and "D7.4 Revisited historical earthquake have been provided internally and will contribute to this task. Topography and bathymetry data sets to be used in the tsunami modeling are ready. Grid locations and the conceptual framework to be used in the creation of the tsunami scenario database are identified

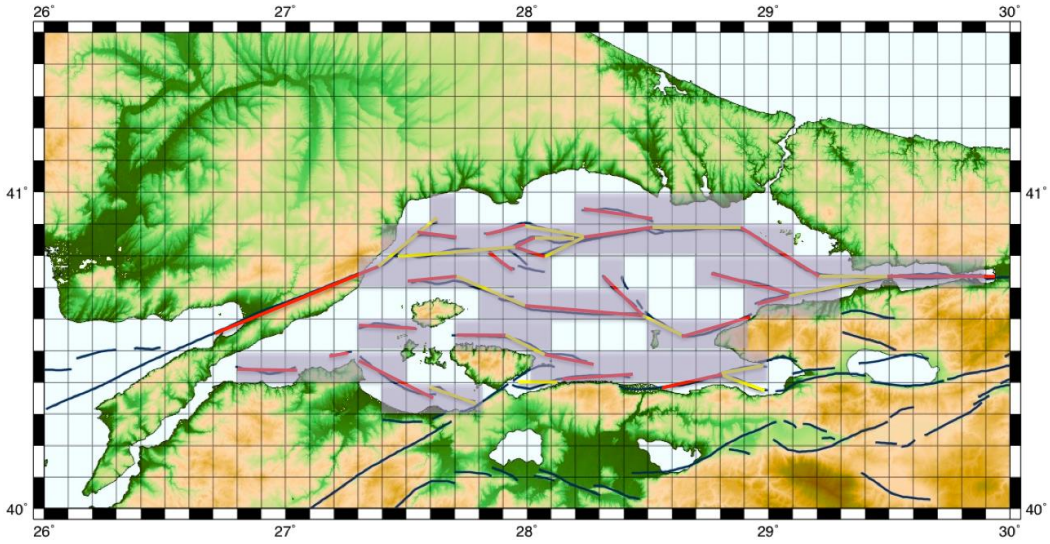


Figure 2.5.2: Conceptual framework showing the grid locations and associated fault segments.

One other aim of WP5 is the reinvestigation of the probabilistic seismic hazard in the Marmara region in the light of new data and methods. Literature survey on required databases such as fault models, historical earthquake catalogues, geodetic slip rates and

existing seismic hazard studies has been conducted in the first year of the project. In the light of the compiled information, fault source and background seismicity modelling approach has been adopted for the modelling of the seismogenic sources in the Marmara region. During the second year of the project, fault source models have been developed and the applicability of Poisson and time-dependent models for the earthquake recurrence of the fault sources has been investigated. The occurrence probabilities of characteristic earthquakes for various time periods ahead have been investigated for the individual seismogenic sources of the model, considering the uncertainties in the slip rate, characteristic magnitude, corresponding recurrence time and aperiodicity of the statistical distribution associated to each examined fault source, by a Monte Carlo technique. The analysis indicated that when considering the 50th percentile for the next 50 years, according to Poisson and BPT models, the largest value of the occurrence probability for the Poisson probability is observed on the faults Manyas, Cinarcik, West Marmara and Duzce, while the largest value of the occurrence probability from BPT renewal model may be observed for Cinarcik, Western Marmara and Bursa faults. The impact of fault parameter uncertainties (maximum magnitude, and slip rates) on the ground motion hazard for Poisson and BPT forecasting models have also been considered.

Another important parameter in the quantification of the epistemic uncertainties involves the identification of applicable ground motion prediction models. Both regional and global ground motion prediction models applicable to the region have been compiled and their agreement with available regional strong motion data has been evaluated. The comparisons so far have yielded favourable results for the tested Ground-Motion Prediction Equations (GMPEs). However, the final decisions on the selection of the GMPEs as well as the weights to be assigned will be determined in the next period, based on comparisons of other ground motion parameters, such spectral accelerations (SAs) at various periods, as well, as well as on the range of estimated hazard values.

The deliverables D7.2 “GIS Database of the fault parameters” and D7.4 “Revisited historical earthquake catalogue” which have been provided internally will contribute to the development of the model revisions and corresponding time-independent and time-dependent hazard computations that will be conducted during the last year of the project.

2.6 WORK PACKAGE 6: Earthquake-Induced Landslide Hazard in Marmara

A geophysical field campaign aiming at better characterizing the landslide under study was performed by the **IFSTTAR-“La Sapienza”** team in collaboration with **IU** team in May 2014. This campaign was conducted considering different passive and active seismic methods: MASW, local seismic noise measurements at single points, seismic noise arrays, etc. Data collected were analyzed by IFSTTAR-Sapienza and IU teams to derive local seismic amplification effects along the landslide in terms of characteristic frequencies and

amplitudes. These results were coupled with stratigraphic data collected during previous geological campaigns (IFSTTAR-Sapienza team during the first year of the project) and already available data from literature to better constrain the geological-geotechnical model of the landslide.

For two-dimensional numerical analyses, one longitudinal and four transversal cross sections were defined to consider the variability of the local seismic response. For each of them, an analysis of the propagation of P-, SV- seismic waves vertically incoming (in the form of delta-like functions) from the bottom of the models was performed. The aim was to highlight focusing of the seismic energy along the slope surface due to the generation of surface waves and refractions of volume P-, SV-waves as well as to infer on the local stratigraphic amplification.

In July 2014, this active landslide, chosen as pilot site, was instrumented by **INERIS** with a multi-parameter observational system. It is composed of:
- two 3C seismic probes (2 Hz geophones), one in borehole at 50 m depth (MarF) to limit urban noise and the other in surface at 1.5 m depth (MarS);
- two piezometers in the same borehole of the MarF seismic probe, at 15 and 30 m depth with two temperature sensors;
- one reference GPS station and two measurement GPS stations;
- one meteorological station for rainfall and temperature measurement
- one soil moisture sensor.

The installation was completely achieved in October 2014.

The system is powered by batteries; data are collected in loggers and transmitted via a Turkish GPRS card in internet. The data arrive in real time to INERIS laboratory in France (Nancy) and they are shared via a web-monitoring page “e-cenaris” provided by INERIS. The data access is controlled thanks to secure accounts.
The main aims of this local network are to:

- get observations related the hydromechanics of landslide hazards;
- build up a microseismicity and earthquake catalogue to study seismic site effects (stratigraphic and topographic amplification, directivity, etc.);
- study correlations between rainfall and mass movements;
- test the technology as Early Warning System at a local scale.

The first earthquake (Ml 4) was recorded on the 22nd October 2014. The signals are of good quality for the 2 seismic probes, with a good signal/noise ratio.
In the last 6 months **UNIPV** continued the search for available satellite data (both optical HR and hyper spectral) and produced a database of metadata for data sets related to the Avcilar peninsula, as well as other sites of interest to the project. UNIPV also revised the

UNIPV WebGIS to improve its performances and integration capabilities. Finally, UNIPV worked on the re-analysis of PLEIADES data acquired from INGV, to extract a new digital model with finer spatial resolution (0.5m) over Avcilar, hence being able to directly extract urban features such as buildings and roads. In parallel, UNIPV also kept working on the extraction of urban extents and urban density from 30 m spatula resolution satellite hyper spectral data, developing a new technique based on non-linear spectral unmixing.

A new interferometric dataset from COSMO Sky-Med has been integrated into the GIS project by **INGV**. These new temporal series are still interpreting in relation with the ERS-ENVISAT dataset and comparing the observed deformation with the geomorphological feature derived from photogeological interpretation. The analisys are still in progress.

2.7 WORK PACKAGE 7: Re-evaluation of the seismo-tectonics of the Marmara

In WP7 “Re-evaluation of the seismo-tectonics of the Marmara Region”, geological synthesis of the Marmara Region from Eocene to present is completed and accepted for publication. Nature and distribution of activity along the North Anatolian Shear Zone (NASZ) in the Marmara Region has been finalized and Neogene Sediments have been mapped and correlated within the Sea of Marmara. Fault systems, which were formed during the evolution of the NASZ and the Thrace Basin have been compiled. Mapping of active faults for all the Marmara Region have taken place in addition to collection of new Marine Geology data and processing and revision of previously collected data. Paleoseismological studies along the middle strand of the North Anatolian Fault has been conducted and subaqueous paleoseismology of the Sea of Marmara by the study of seismo-turbidites from the collected sediment cores has been determined. Study of sediment cores to unravel the historical and proto-historical record of large magnitude earthquakes. Development of a segmentation model for the Marmara area by integrating different data has also taken place during this reporting period.

In WP7 “Re-evaluation of the seismo-tectonics of the Marmara Region”, the deliverable of GIS database of fault parameters has been completed. Accordingly, the fault database includes information about all the segments from Bolu to Gulf of Saros along the northern NAF, from Mudurnu to Gemlik along the southern NAF, and the whole Sea of Marmara (from Sengor et al., 2014). In the summer of 2014, ITU team has performed paleoseismological studies along the southern branch of the NAF. The trenches are examined and logged; ^{14}C are sent for age analysis. The results will be evaluated when the radiocarbon analysis received. INGV team lead by Dr. Danieala Pantosti also conducted tectonic geomorphology field study along the southern segment during August 2014. Detailed sedimentological studies are done on two cores (KM13-01 and 13-08) from 2013 Marmara cruise at the

EMCOL laboratories of ITU. Study of the cores aim to identify seismo-turbites that are triggered by large earthquakes in the Sea of Marmara. During October 2014, a detailed planning done for the Marsite cruise 2014 with Pourqoui Pas vessel.

The ITU team visited the Institute of Marine Sciences and Technology of Dokuz Eylül University in Izmir to work on the high-resolution multi-channel seismic dataset to locate the planned 30-m-long sedimentary cores for the Marsite cruise. The study focuses on Imrali basin and Kumburgaz basins. Cores in Kumburgaz basin will address some problems regarding seismoturbidites and possible creeping of the Central high segment whereas Imrali basin cores will focus on determining age constraints of the stratigraphic units. During the second leg of the Marsite cruise cores are successfully recovered and brought to EMCOL for analysis.

2.8 WORK PACKAGE 8: Monitoring seismicity and fluid activity near the fault using existing cabled and autonomous multiparameter seafloor instrumentation

Within Task 1 ("Collect multi-parameter time-series through repeated sea- based cruises, using existing autonomous seafloor observatories"), different actions at sea were conducted over the last year. In October 2013, the multi-parameter seafloor observatory of INGV (SN4) was deployed at the entrance of the Gulf of Izmit with R/V Urania. The vessel also installed 4 OBSs from INGV and 2 piezometers from Ifremer on top of the Western High. On September 19th, 2014, a total of 10 OBSs of Ifremer were deployed in the western part of the Sea of Marmara to monitor shallow seismicity below the Western High, with the objective to decipher the relations between gas and seismicity. All the above listed equipments will be returned back to Ifremer and INGV in November 2014, after the Marsite Cruise of R/V "Pourquoipas?" of Ifremer. Since October 1st, 2013, this cruise was actively prepared by the different groups involved in the programme (Ifremer, CNRS, INGV, ITU, KOERI, DEU). A MOU was signed between KOERI and Ifremer to set the specific conditions of collaboration under the cruise of R/V "Pourquoipas?" .

Within Task 2 ("Seabed, continuous seismological monitoring and integration of multi-parameter datasets from cabled and autonomous systems"), KOERI and Ifremer conducted studies to determine the velocity structure below the Marmara Region and to improve the high-resolution determination of near-fault epicentres.

KOERI worked on the three-D velocity structure of the Marmara Region using both land and sea seismic data (see mid-term report, from November 2012 to April 2014). This study was a part of a MSc Thesis, which now in the process of being improved in order to be published. The results are encouraging for the upper crustal structure, but lower crust is not well resolved due to the lack of rays crossing the lower crust and the Moho. Thickness and S-velocity structure of the Marmara Region was obtained by receiver function analysis using

land and seabottom broad-band seismological stations. The feasibility of using OBS stations for receiver function analysis was also examined. Teleseismic events were analyzed, but there were not any clear receiver function. Regional (local) events need to be analyzed in detail to allow definite conclusions. Future studies by KOERI will involve S-wave local earthquake tomography by adding new data to the existing data from newly installed OBS stations. Will be also improved the S-wave velocity by inversion of receiver functions and the anisotropy beneath the Moho discontinuity by looking at the radial and transversal receiver functions from different azimuths. Repeated earthquakes will also be analyzed by correlation methods. For this, cabled observatory data and short period OBS data will be used, especially those stations close to the Central High and Western High.

Ifremer has developed an opposite, but complementary approach, for the high resolution determination of hypocenters of near-fault earthquakes from the Western Sea of Marmara. This approach is strictly based on seabottom stations, to be used only for those earthquakes that are located within the network. A high resolution velocity model with a 750 m x 750 m x 400 m grid spacing was built, using multibeam bathymetry and wide-angle seismic data, in order to account for the velocity contrast at the water/sediment interface and the slow seismic velocities within the sediment infill in the main Marmara Trough.

The conclusion of this work is that merging land and sea-bottom datasets is certainly appropriate for improving the quality of earthquake catalogues but it is very challenging for the high-resolution characterization of earthquakes below the Sea of Marmara. To improve the location of hypocenters near the submerged fault zone and enhance the search for seismic tremors, specific networks of permanent, cabled sea-bottom seismometers are required. A velocity model has been proposed for the Western part of the Sea of Marmara. Next steps should be to create high-resolution, 3D velocity models, specifically adapted for the Central and Eastern Sea of Marmara.

Within Task 3 (“Multi-parameter data analysis”), bottom pressure records were analyzed by ITU and CEREGE, in search of resonant frequencies influencing the characteristics of tsunamis in the Sea of Marmara. Work has started on the limited data set currently available. Several characteristic pressure oscillation frequencies were identified in the period range 24-150 minutes in data from a bottom pressure recorder deployed in Tekirdag Basin in 2007. The power spectrum differs from previously reported spectra from near shore pressure gauges. A prominent peak is found in the power spectrum at 78 minutes. Acquisition of data from other locations is needed before the results of the frequency analysis can be interpreted in term of water column (seiche) oscillations.

Ifremer analyzed the OBS data along with the acoustic data deployed in 2009 and 2011 by a gas bubble detector (BOB) to study the temporal variations of gas emissions from the Marmara Seafloor. The study provides evidence that the numerous micro-events (characterized by short-durations of less than 0.6 s, frequencies ranging between 5 and 30

Hz and variable amplitudes) that were recorded on the OBSs are likely produced by gas-related processes within the near seabed sediments. The further analysis of SDEs also revealed that, for all OBSs, the number of SDE per hour is greater during day time, between 06h00 and 20h00, suggesting that part of the OBSs are related to human activity. To interpret our results, we propose that human activity could produce bioturbation. A method was then proposed to eliminate these SDEs, hereafter considered as man-made noise. This method allows a better identification of those SDE swarms that occur in response to earthquakes.

Within Task 4 ("Prepare the next generation of seafloor observatories for geo-hazard monitoring"), Daimar realized the electronics of a prototype observation module for both slow and quick variations of long-term data in a near-real-time mode, including a low power, High-speed, 8 channel, 24 bits, digitizer for simultaneous sampling and a underwater module directly connected to the internet via modem (note : the system does not require Linux system to work). The first tests in marine environment were made for the underwater module and 3 analog Sensors : temperature, pressure, and Wide Band Hydrophone.

2.9 WORK PACKAGE 9: Early Warning and Development of the Real-time shake and loss information cabled and autonomous multiparameter seafloor instrumentation

Within the Task1, some interpolation methods with recent event records in Marmara Sea have been studied. Using the different interpolation methods, it is proposed to generate real-time shake maps for Istanbul City with the use of denser station network information from KOERI and IGDAS strong motion networks.

Within the Task2, a pilot landslide EW system is being carried out in Cekmece district with 3 boreholes incorporation of partners TUBITAK and INERIS.

In the Task3, the automatic shakemapping for Istanbul City has been achieved by KOERI. With the developed system, a testing shakemap is generated every day to check the system work. Currently, improvement on the system is studied in order to integrate the EW information in the Rapid Response tool by KOERI and AMRA.

In the Task4, some methodologies have been already developed by EUCENTRE, but some others are still under development. The developed methodologies will be applied to high resolution data in Istanbul.

2.10 WORK PACKAGE 10: Integration of data management practices and coordination with ongoing research infrastructures

Within this work package, the report on international standards on architecture principles, metadata, data models and services was submitted in April 2014 as planned. As part of this deliverable a pilot implementation of a pilot implementation of an interoperable portal

allowing access to data relevant for the scientific goals of the project was developed (this can be accessed at http://marsite.brgm-rec.fr/marsite/). This portal may be updated during the final year of the project if more data becomes available. In addition, the second report (updating the first report that was submitted in October 2013) on the integration and links to other initiatives is being drafted. Naturally, concrete collaborations and the exchange of information will be pursued by the MARsite project partners in the final year of the project.

In terms of development of standards for metadata, data models and services following international norms, D10.3 "Report on international standards on architecture principles, metadata, data models and services and improving links with other projects" was produced, where each chapter of this deliverable addressed a different aspect of such a distributed system, namely: metadata, data models, the web services themselves and, finally, the portrayal of the data. Existing standards and systems were summarised, their relevance for MARsite detailed, and ideas for future developments suggested. In order to demonstrate how such a distributed system would work and to clearly show the benefits of adopting such an approach for MARsite, and Supersite projects in general, a portal (http://marsite.brgm-rec.fr/marsite/) was created by BRGM to serve various data collated or generated within the project or already available online from previous projects. As far as ESA EO data are concerned, Virtual Archives for selected data have been created, which are queriable through a webinterface and expose an OpenSearch interface that can be queried directly by the MARSite webportal. As far as exploitation platforms are concerned, dedicated Virtual Machines have been configured for the MARSite project and different algorithms have been integrated. This will offer the users with ready-to-be-used services. At the present the algorithms are being tested and will be released in the next period of activity. Finally, the update (entitled "Second report on the integration and links to other initiatives") of the deliverable D10.1 is being drafted to summarise efforts to collaborate with projects of relevance to MARsite.

2.11 WORK PACKAGE 11: Dissemination

Marsite uses the social media accounts of the partners to disseminate key messages. The Marsite Website is the repository to which users are drained in order to raise the trafic on the website and give the opportunity to the users to discover every aspects of the Marsite Project.

Marsite materials were spread within:

- Facebook (14,176fans)
- Twitter (5,100followers)
- Google+ (570 contacts)
- Linkedin (Company page)
- Pinterest (within « EU projects » board)

Marsite on partner's websites

In addition to the Marsite's website, some partners display informations about the project or link their own website to its website in order to send trafic to it and increase its page rank in search engines (Google, Bing, etc.).

- EMSC

http://www.emsc-csem.org/Project/#marsite
http://www.emsc-csem.org/News/

- INGV

http://moist.rm.ingv.it/projects/marsite/8
http://www.emso-eu.org/management/index.php?option=com_k2&view=item&layout=item&id=12&Itemid=137

- CNR

http://www.irea.cnr.it/index.php?option=com_k2&view=item&id=443:marsite&Itemid=167

- GFZ

http://www.gfz-potsdam.de/en/research/organizational-units/departments-of-the-gfz/department-2/physics-of-earthquakes-and-volcanoes/projects/marsite/

A survey has been run to gather all existing channels that partners have, such as Facebook Pages, Twitter feeds and News sections on their own websites.

Paper/electronic materials

Figure 2.11.1: MARSite Newsletter

The newsletter aims at spreading MARsite latest news. It is issued every 6 months and distributed through various distribution channels (e.g. mailing lists, partners' social networks, and websites). It provides the latest status of the project, links to the latest deliverables on the MARsite website, and information on upcoming meetings. It is available on the website. The first newsletter's issue were published on 7th October 2013: http://marsite.eu/?p=1770

The Marsite Project in the Turkish news:

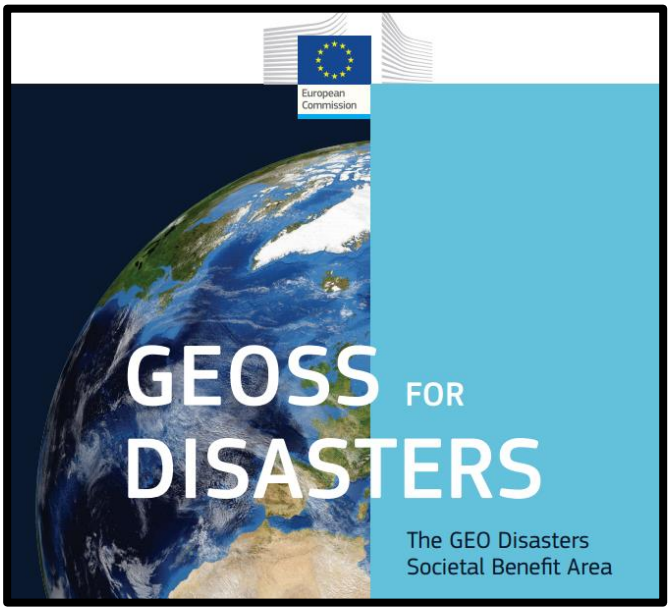
http://www.sabah.com.tr/gundem/2014/11/17/marmara-fayina-yakin-takip#

http://www.sabah.com.tr/yasam/2014/05/23/fayin-kalbine-iniliyor

The Marsite project was discussed in the EPOS newsletter.

http://www.epos-eu.org/assets/documents/newsletter/newsletter_epos_2013_06_June-2.pdf

The Marsite Project was presented in the GEOSS for Disasters.




GEOSS FOR DISASTERS - THE GEO DISASTERS SOCIETAL BENEFIT AREA 15

MARsite

New Directions in Seismic Hazard Assessment through Focused Earth Observation in the Marmara Supersite

In the last 12 years, Europe experienced destructive earthquakes such as 1999 Izmit (Turkey), 1999 Athens (Greece) and 2009 L'Aquila (Italy). More destructive earthquakes happened earlier: Istanbul in 1509 and 1766, Izmir in 1688, Eastern Sicily in 1693 and Lisbon in 1755.

Such catastrophic event is now expected in the Marmara region, with a probability in excess of 65% in 30 years, due to the existing seismic gap and the post-1999 earthquake stress transfer at the western portion of the 1000km-long North Anatolian Fault Zone (NAFZ), passing through the Marmara Sea about 15 km from Istanbul.

MARsite (New Directions in Seismic Hazard Assessment through Focused Earth Observation in the Marmara Supersite) project will identify the Marmara region as a 'Supersite' in order to **compile on-shore, off-shore and space-based observations, comprehensive geophysical monitoring, improved hazard and risk assessments** encompassed in an integrated set of activities. The project coordinates research groups with different scientific skills (from seismology to engineering to gas geochemistry) in a comprehensive monitoring activity developed both in the Marmara Sea and in the surrounding areas.

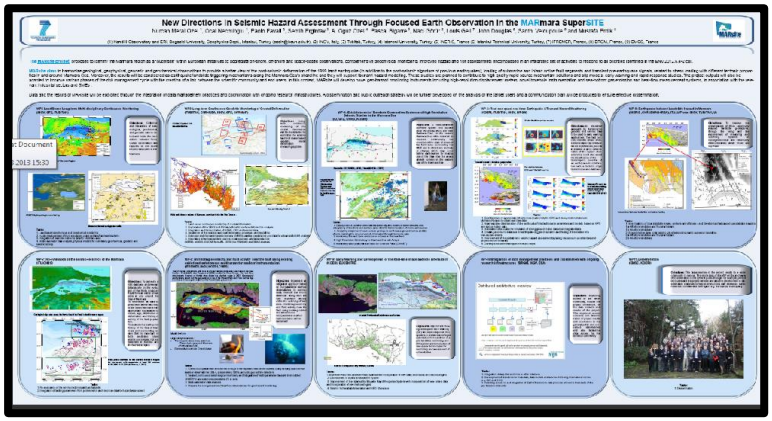
The MARsite objectives are to:

- Achieve long-term hazard monitoring and evaluation by in-situ monitoring of: earthquakes, tsunamis, landslides, dis-

veloping novel instruments and instrumentation.

http://www.ab.gov.tr/files/ardb/evt/GEOSS-for-disasters.pdf

The Marsite Project was presented at the AGU –American Geophysical Union 2013, 46th Fall Meeting

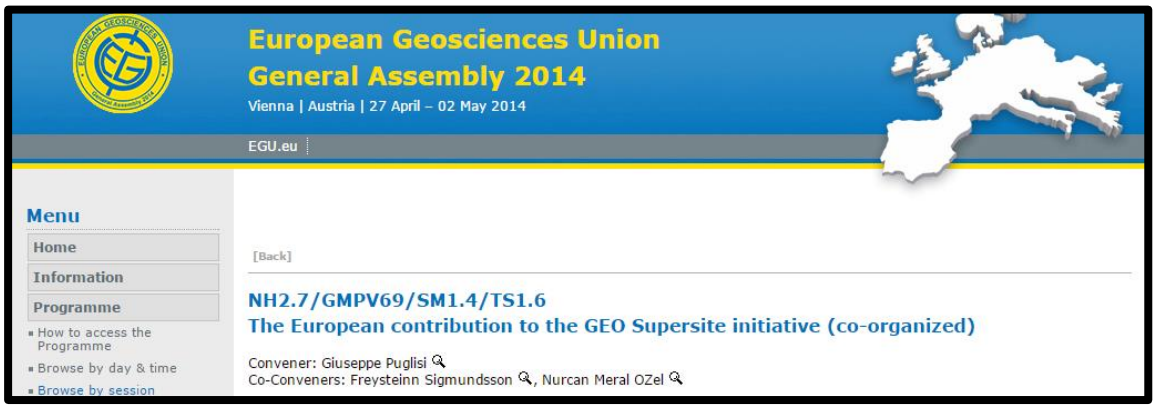


2014 GEO Geneva Ministerial Summit

Between 13 and 17 January 2014, MARsite project took part to the GEO-X Plenary Session and 2014 GEO Geneva Ministerial Summit that were held in Geneva (Switzerland). The Marsite poster was included in the EPOS stand together with the other two supersite projects MED-SUV and FUTUREVOLC.

EGU 2014

Marsite was one of the co-organizers of the The European contribution to the GEO Supersite initiative. Given the main objectives of the Supersite initiative and, in particular, of the MARSITE, FUTURVOLC and MED-SUV projects, this EGU 2014 Supersite session welcomes contributions based on the activities of each of the three projects and other supersite related efforts, as well as proposals for promoting the cooperation between the teams of different supersite projects.



http://meetingorganizer.copernicus.org/EGU2014/session/15748

The Marsite Project was presented in the 8th GEO European Projects Workshop

http://www.gepw8.noa.gr/files/presentations/splinter5/3%20-%20Semih%20Ergintav.pdf