GROUP ON EARTH OBSERVATIONS

GEO Disaster Resilience SBA

GSNL - Geohazard Supersites and Natural Laboratories

Biennial report for Candidate Supersite

Marmara Region Supersite

Status	*Candidate Supersite*
Proposal documents	*http://www.earthobservations.org/documents/gsnl/proposals/MarmaraRegion_proposal_feb_2014.pdf*
Acceptance letter	*http://www.earthobservations.org/documents/gsnl/proposals/MarmaraRegion_acceptance_letter.pdf*
Previous reviews	*No previous report*
Point of Contact	*Prof. Dr. Semih Ergintav (semih.ergintav@boun.edu.tr)* *Boğaziçi University* *Kandilli Observatory and Earthquake Research Institute* *Geodesy Department* *34684 Çengelköy, İstanbul TURKEY* *T +90 216 516 33 64*

Science teams

Semih Ergintav	Boğaziçi University - Kandilli Observatory and Earthquake Research Institute, Geodesy Department, 34684 Çengelköy, İstanbul TURKEY semih.ergintav@boun.edu.tr
Rahsan Cakmak	TÜBİTAK MAM Earth and Marine Sciences Institute, 41470 Gebze, Kocaeli TURKEY rahsan.cakmak@tubitak.gov.tr
Mustafa Kemal Kosma	TÜBİTAK MAM Earth and Marine Sciences Institute, 41470 Gebze, Kocaeli TURKEY Mustafa.kosma@tubitak.gov.tr
Esra Çetin	Istanbul Technical University, Department of Geology, 34469, Istanbul, Turkey Esra Çetin <esracetinn@gmail.com>
Gokhan Aslan	Istanbul Technical University, Department of Geology, 34469, Istanbul, Turkey gokhan.aslan@itu.edu.tr
Selver Sentürk	Istanbul Technical University, Department of Geology, 34469, Istanbul, Turkey selver.senturk@gmail.com
Ziyadin Çakır	Istanbul Technical University, Department of Geology, 34469, Istanbul, Turkey

	ziyadin.cakir@itu.edu.tr
Deniz Oz	Yıldız Technical University, Department of Geology, 34469, Istanbul, Turkey denizoz@yildiz.edu.tr
Ahmet Akoğlu	Crustal Deformation and InSAR Group, 4700 King Abdullah University of Science & Technology, Thuwal 23955-6900, Kingdom of Saudi Arabia ahmetakoglu@gmail.com
Stefano Salvi	Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata, 605 - 00143 Roma, ITALY stefano.salvi@ingv.it
Falk Amelung	Department of Marine Geosciences, Rosenstiel School Of Marine And Atmospheric Sciences, University of Miami, 4600 Rickenbacker Causeway, Miami, Fl, 33149, USA famelung@rsmas.miami.edu
Kurt Feigl	Department of Geoscience, University of Wisconsin – Madison, 1215 W Dayton St, Madison, WI, 53706, USA feigl@wisc.edu
Thomas Walter	Deutsches GeoForschungsZentrum GFZ, Telegrafenberg, 14473 Potsdam, GERMANY twalter@gfz-potsdam.de
Salvatore Stramondo	Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata, 605 - 00143 Roma, ITALY salvatore.stramondo@ingv.it
De Michele Marcello	Bureau de Recherches G´eologiques et Mini`eres, Natural Risks Division, Orl´eans, FRANCE m.demichele@brgm.fr
Giuseppe Solaro	Istituto per il Rilevamento Elettromagnetico dell'Ambiente - CNR, Via Diocleziano, 328 - 80124 Napoli, ITALY solaro.g@irea.cnr.it
Francesco Zucca	University of Pavia · Department of Earth and Environmental Sciences, Pavia, ITALY francesco.zucca@unipv.it
Manuela Bonano	Istituto per il Rilevamento Elettromagnetico dell'Ambiente - CNR, Via Diocleziano, 328 - 80124 Napoli, ITALY bonano.m@irea.cnr.it
Mariarosaria Manzo	Istituto per il Rilevamento Elettromagnetico dell'Ambiente - CNR, Via Diocleziano, 328 - 80124 Napoli, ITALY manzo.mr@irea.cnr.it
Roland Burgmann	Department Of Earth And Planetary Science 389 Mccone Hall Berkeley, California 94720-4767, USA burgmann@seismo.berkeley.edu
Cecile Lasserre	ISTerre, CNRS, Université Grenoble Alpes, Maison des Géosciences, Campus Universitaire, 1381 rue de la Piscine, 38400 St Martin d Here, France cecile.lasserre@ujf-grenoble.fr
Diao Faqi	State Key Laboratory of Geodesy and Earth's Dyanmics,

	Institute of Geodesy and Geophysics, CAS Xudong Street340 #, Wuhan 430077 P. R. China faqidiao@whigg.ac.cn
Rongjang Wang	Deutsches GeoForschungsZentrum GFZ, Telegrafenberg, 14473 Potsdam, GERMANY wang@gfz-potsdam.de
Riccardo Lanari	Istituto per il Rilevamento Elettromagnetico dell' Ambiente (IREA), Consiglio Nazionale delle Ricerche (CNR), Via Diocleziano 328, 80124 Napoli, Italy lanari.r@irea.cnr.it
Alessio Cantone	Sarmap SA, cascine Di Barico 10, Purasca Switzerland alessio@sarmap.ch
Paolo Pasquali	Sarmap SA, cascine Di Barico 10, Purasca Switzerland ppasquali@sarmap.ch
Ekbal Hussain	COMET, School of Earth and Environment, University of Leeds, United Kingdom eeehu@leeds.ac.uk
Tim Wright	COMET, School of Earth and Environment, University of Leeds, United Kingdom t.j.wright@leeds.ac.uk
Richard Walters	COMET, School of Earth and Environment, University of Leeds, United Kingdom R.J.Walters@leeds.ac.uk
David Bekaert	COMET, School of Earth and Environment, University of Leeds, United Kingdom eedpsb@leeds.ac.uk

Science team issues

- The core supersite team for Marmara Region is the consortium of the European Commission funded MarSite project (2012-2016). The project addressed a call within the Environment program of the 7th Framework Programme of the European Commission ("ENV.2012.6.4-2 Long-term monitoring experiment in geologically active regions of Europe prone to natural hazards: the Supersite concept"). The full name of the proposal was "New Directions in Seismic Hazard assessment through Focused Earth Observation in Marmara Supersite". 21 partners from 6 European Countries were involved with wide expertise in the different aspects of seismic hazard and focused on the Marmara region. The project involved many experts in satellite data processing, in the monitoring of

crustal deformation and in modeling satellite outcomes and ground measurements. The link between in-situ data and EO data was established by MarSite funds.

- These experts organized the roadmap of this GSNL Supersite and signed agreements with the involved space agencies. Then all the achieved results were saved in MarSite data hub to potentially serve the other disciplines with in-situ data sets.

- Science teams, also, include individual contributions. Especially, in the Universities, Professor's students use Supersite data both in their MSc and PhD thesis works.

- The coordination was easy and productive in MarSite project. All teams were organized under one specific WP and shared the results with other WPs, in order to enhance the quality of their results. Communication was easy during many project meetings, as well as special sections in International meetings (like AGU&EGU). However, among different university teams, the coordination was not so easy. PoC tried to follow each activity, but feedback was somehow limited, because Supersite users are not required to report their results or communicate with PoC, except for some X-band data (e.g. CosmoSkyMed data distributed by PoC after the approval of ASI). A feedback mechanism from PoC would be useful to collect the information from on-going studies, as well as to demonstrate the strength of Supersite.

In situ data

<In this section please list all in situ data types available for the Supersite in the table below>

Type of data	Data provider	How to access	Type of access
National GPS (30s,raw data) network data	*General directorate of land registry&General Command of Mapping*	*http://rinex.tusaga-aktif.gov.tr*	*Registered Public*
Local GPS networks &daily solutions of national GPS network	*KOERI*	*MarSite ftp server*	*Registered Public*
Geology	*KOERI*	*MarSite ftp server*	*Registered Public*
Geochemistry	*KOERI*	*MarSite ftp server*	*Registered Public*
Meteo	*KOERI*	*MarSite ftp server*	*Registered Public*
Tide Gauge	*KOERI* *General Command of Mapping*	*Data Specific Service* *http://tudes.hgk.msb.gov.tr/tudesportal/*	*Registered Public* *Registered Public*
Strainmetre	*UNAVCO*	*UNAVCO*	*Unregistered public*
National Seismic network (*Broadband, Accelerometer, OBS, borehole***)**	*KOERI*	*Eida.koeri.boun.edu.tr*	*Unregistered public*
Multinational/Local Seismic networks	*KOERI*	*MarSite ftp server*	*Registered Public*

In situ data issues

Near Fault Observatories (NFO) are advanced and multidisciplinary research infrastructures based on state of the art networks of multi-parametric sensors continuously recording high quality multidisciplinary data related to the regions, like Marmara. In the MarSite project, more than 200 geophysical and geochemical stations run on the surface and in the boreholes, to monitor the critical branches of North Anatolian fault zone in the Marmara Region. As a consequence today Marmara region in Turkey represents one of the best examples for the NFOs. Thus, as one of the youngest scientific community, it is clear the need for multidisciplinary data (and metadata) standardization and harmonization course for the all

European NFOs. This is realized under the coordination of EPOS-IP (Earth Plate Observation System-Implementation Phase.

Now, in situ data are available through the data hub, under different level hierarchy. This structure will be modified in the EPOS-IP to organize the common services as a part of NFOs.

However, some data sets (e.g. geochemistry, daily GPS solutions) require significant post-processing and they are not made available until quality control and publishing of the results. Uncorrected version of strainmeter data was made public in UNAVCO archive because it is requires specific data processing and interpretation. Hence, scientists could contact with data provider, if needed the processed version.

Some kind of specific data (e.g. National Continuous GPS Network, tide gauge) will be addressed to the sources on web page, witch have the necessary information in order to obtain from data supplier.

The open access data policy requested for European projects is modulated in the special case of Civil Security issues such as Marmara supersite by the priority of early warning and real time response. In case of crisis, data access has to be delayed for actors outside the decision making process. It will remain anyway accessible for the sake of reanalysis.

Satellite data

<In this section please list all satellite data types available for the Supersite in the table below>

Type of data	Data provider	How to access	Type of access
ERS-1/ERS-2	*ESA*	*http://eo-virtual-archive4.esa.int*	*registered public*
ENVISAT	*ESA*	*http://eo-virtual-archive4.esa.int*	*registered public*
TerraSAR-X	*DLR*	*POC requests access from DLR for individual users, data then accessible via secure MarSite ftp server*	*GSNL scientists*
Cosmo-SkyMed	*ASI*	*POC requests access from ASI for individual users, data then accessible via secure MarSite ftp server*	*GSNL scientists*
RADARSAT-2	*CSA*	*POC requests access from CSA for a specific user, data then made accessible for the specific user by POC*	*GSNL scientists*
SENTINEL-1A/B	*ESA*	*https://scihub.esa.int/*	*registered public*
ALOS-1/2	*JAXA*	*https:auig2.jax.jp/ips/home*	*Successful proposers*
ASTER	*NASA*	*https://lpdaac.usgs.gov/lpdaac/get_data/glovis*	*registered public*

Satellite data issues

- Open L/C-band data has already data distribution tool by agencies. But, X-band data of DLR has license problems. Licenses are given to the scientists and data providers require personnel authorizations and do not allow distribution of the data to the people who have not signed the license.

- Each space agency has a different data access policy. For example, CSA and ASI require users to be sponsored by the PoC and then to submit contact information and a brief research plan, which is reviewed before approval.

- In the acceptance letter, CSA agreed to provide 160 new/archive Radarsat-2 scenes per year. But, after 1-year delay, CSA modified their original idea and reduced the quota to 100 data. PoC and subset of Supersite researches have checked the archive in 2014. As the archive did not have sufficient number of images for InSAR time series processing PoC didn't ordered Radarsat data from CSA. The quota can be used in the future when an interested user wishes to use it. Or, after any unexpected event, it can be used to obtain the latest information from the field. As a last note, the APT software (it is about the selection of data set) of the CSA has some problems with its GUI that runs in Windows OS only, which makes data selection impractical.

- DLR requests any user to submit a proposal via TerraSAR-X Science Service System. This is independent from the PoC, so there is no way for the PoC to be aware of how many Supersite proposals have been submitted and approved. Accordingly, PoC systematically ordered data, based on the accepted proposal (related to Supersite) and archived the data within the MarSite server. Data are archived in DLR website for one month. Then, PoC transfers it to MarSite ftp server. When a new user wishes to use the TerraSAR-X data in PoC archive, PoC takes his/her signature and updates the proposal documents to DLR.

- 180 TerraSAR-X images have been provided through the supersite project and in order to maintain data continuity new images are being ordered over the Izmit region in regular intervals (in every 22 days). But, due to order conflict with Infoterra Ltd. over Marmara region, we are not able to order the acquisition (orbit 153, Beam Strip_008R), over Izmit region, anymore.

- In the acceptance letter, JAXA wished to share the ALOS1/2 data. In the past, we have tried to communicate with JAXA, in order to take the data, without any success. Then, JAXA opened a new call and PoC submitted a proposal with some Supersite researches during the first months of 2016. One month ago, JAXA approved the proposal for archive data and new ALOS-2 data. However, the mechanism for adding new users is not clear for us.

Research results

In the GSNL Supersite, Marmara region has been monitored by space agencies and the collected data are made available to the scientific community. The data can be used by researchers to better understand the strain accumulation and tectonic loading of Marmara region and thus will be contributed to seismic hazard assessment. But, no earthquake occurred detectable by SAR data sets, and teams studied the local deformations and interseismic field in detail. Of course, the numbers of scientific products were decreased, due to the slow process between earthquakes in the target zones. However, based on long-term systematic SAR data acquisition, teams are ready for mapping the inter-seismic and post-seismic crustal deformation and for the emergency management, via a rapid generation of critical information relevant to the co-seismic deformation event, using pre- and post-event imagery.

In following part, some interesting results are listed:

- CNR-IREA team processed a large TerraSAR-X SAR data archive made available through the Supersites Initiative, acquired over the Istanbul metropolitan area along descending orbits between 2010 and 2014. The advanced multi-temporal InSAR technique, known as the Small BAseline Subset (SBAS) approach, was exploited for the processing. The retrieved mean deformation velocity map shows a general stable

behavior during the analyzed period (2010-2014). The most important feature is a generalized stability trend over the study area, except for some localized deformation phenomena (mostly related to subsidence and slope instability events), such as those observed in correspondence to the Istanbul Atatürk Airport, characterized by a mostly linear deformation trend with a mean deformation velocity value of about 1 cm/year (although a slowdown of this trend has been measured starting from early 2014), and along the Minyatürk Park, showing a mean deformation velocity value of about 1.5 cm/year.

- INGV team processed two COSMO-SkyMed InSAR data sets covering Istanbul (west-central, and eastern part). The ground velocity field was calculated over two frames using the Persistent Scatterer technique (through the StaMPS algorithm application). The ground motions do not contain a clear tectonic signal. But, some local deformation signals are evident. The general accuracy of the results is however not always very good, mainly due to some temporal gaps in the data sets, which reduced the multi-temporal coherence.

- INGV team also studied the southern branch of North Anatolian Fault Zone, using ENVISAT data. PS velocity map was obtained by applying the IPTA-GAMMA approach to 38 Single Look Complex Image (SLC) multi-looked by factors of 4 and 20 along range and azimuth direction (~80m pixel posting). The achieved results show that no significant movements occurred along near field of this branch in the 2002-2009 time interval. On the eastern and western termination of the fault, a symmetrical behaviour occurs with a deformation rate of about +-1-2 cm/year. This may be an indicator of a possible horizontal interseismic loading.

- The BRGM team reprocessed the L-Band SAR data and developed a filtering strategy to remove the effect of RFI (Radio Frequency Interferences related with ionospheric noise) on the interferograms stack. The obtained results highlight a zone of dextral shear, consistent in magnitude and direction, with the tectonic load in the region. A comparison with GPS velocities in the region yields consistent results. A space-variable depth dependence of shallow fault creep along the Ganos fault is observed.

- At GFZ in Potsdam, InSAR (ENVISAT data) and GPS observations were modeled to explore the fault-locking status at the Princes' Islands Fault (PIF) segment, 10 km south of Istanbul, as well as to localize primary and secondary fault branches. With this aim, the modeling and analysis strategy accounts for overlapped deformation signals. First, the post-seismic viscoelastic relaxation effect in the wide Istanbul region was investigated based on GPS data observed between 2002 and 2009. Then, the effect of adjacent faults was estimated based on models inferred from previous studies. The two effects were removed from the observations as described in the following sections before inverting the locking status and slip rate of the PIF. After removing the effects caused by viscoelastic relaxation and locking/creep of adjacent faults, clear strain accumulation at the eastern main Marmara fault in the vicinity of the Princes' Islands was found. Despite the big advances in decomposing and understanding processes involving the Istanbul area, the uncertainties of the results are largely due to the limited data coverage. Therefore, improved data coverage is highly necessary for further assessing the earthquake potential of this fault segment.

- ITU team examined the local deformations in some landslide zones of Istanbul, using SENTINEL 1A data and GMTSAR software.

- Then, ITU team focused on the 1999 Izmit Earthquake rupture zone to monitor creep related phenomena, started after 1999 earthquake. The TerraSAR-X data set (38 images) covers the central area section of the 1999 İzmit earthquake rupture between Gölcük and Sapanca, acquired between 2011 and 2015, obtaining 101 interferograms with short baseline (< 350). Analysis of interferograms shows that afterslip on the Izmit fault is still taking place at a rate of ~8 mm/year, in a 17 years time interval. This shows that the whole rupture zone of Izmit earthquake still creeps and this result was validated by GPS surveys. This phenomenon is very important to understand the fault dynamics. This is the part of a PhD thesis in ITU. In this study, TanDEM-X dataset (12m DEM generation) was used to improve the results. PoC didn't share this DEM data with science community, directly, because it was received from DLR within a specific proposal frame and individual scientist should take a permission to use it from DLR.

- ITU team also studied Ismetpasa creeping section with ENVISAT and TerraSAR-X data. Until now, the properties of creeping section in time and space have been demonstrated. This is the part of a PhD thesis in ITU. In order to monitor creep motion over Ismetpasa segment, 90 TerraSAR-X images from 2012 to 2015 has been provided in a regular basis through the Supersite project. The team also studied the interseismic deformation along the eastern section of the North Anatolian Fault using Supersite Envisat archive and published the results (Çakir et al., 2014).

- Leeds teams studied the 1999 Izmit rupture zone, like ITU teams. Izmit area was imaged by the radar on ENVISAT sensor with a total of about 480 times during its interferometric lifetime (2003-2010) on 5 image-modes and 14 wide-swath tracks. Then, all of these data

was processed to form deformation time series for each track, and combined with the GPS data to give 3D, time-varying velocity field for the region. This new data set was particularly important in constraining the vertical deformation rates, which are a key discriminator between different postseismic models. The team also measured the deformation elsewhere along the North Anatolian Fault to determine whether the spatial pattern in strain accumulation varies as a function of time since the last earthquake. This was the part of a PhD thesis in Leeds University.

- In MarSite, SARMAP developed a lot of software tools, especially for atmospheric corrections, for SENTINEL 1A/B. These codes are available in their commercial software package, namely Sarscape.

Publications

Peer reviewed journal articles
Diao F., T. R. Walter, R. Wang, M. Bonano, G. Solaro, M. Manzo, S. Ergintav, Y. Zheng, X. Xiong, and R. Lanari (2016), Fault locking near Istanbul: Indication of earthquake potential from InSAR and GPS observations, Geophys. J. Int.,205,477-485, doi:10.1093/gji/ggw048
Hussain E; Wright TJ; Walters RJ; Bekaert D; Hooper A; Houseman GA (2016) Geodetic observations of postseismic creep in the decade after the 1999 Izmit earthquake, Turkey: Implications for a shallow slip deficit, Journal of Geophysical Research B: Solid Earth, 121, pp.2980-3001. doi: 10.1002/2015JB012737
Çetin, E., Çakir, Z., Meghraoui, M., Ergintav, S., Akoğlu, A., (2014), Extent and distribution of aseismic slip on the Ismetpaşa segment of the North Anatolian Fault (Turkey) from Persistent Scatterer InSAR, Geochem. Geophys. Geosyst., 15, doi:10.1002/2014GC005307. *Çakir, Z., S. Ergintav, A. M. Akoğlu, R. Çakmak, O. Tatar, M. Meghraoui (2014), InSAR velocity field across the North Anatolian Fault (E. Turkey): Implications for the loading and release of interseismic strain accumulation, J. Geophy. Res., doi: 10.1002/2014JB011360.*
Conference presentations/proceedings
F Diao, *Uncertainty of rapid earthquake source inversion using the regional seismogeodetic networks around megacity Istanbul*, 27 April– 02 May 2014, *EGU, Vienna*, Austria

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F Diao, Continued fault locking near Istanbul: Evidence of high earthquake potential from InSAR observation, April 27– 02 May 2014, *EGU, Vienna,* Austria

F Diao, *Postseismic deformation near Istanbul: evidence from long-term InSAR observation and modelling*, 27 April – 02 May 2014, *EGU, Vienna,* Austria

Solaro G., M., *InSAR analysis of the crustal deformation affecting the megacity of Istanbul: the results of the FP7 Marsite Project as a GEO Supersite Initiative*, *17-22 April, 2016*, *EGU,Wien,* Austria

Salvi S.,., , InSAR analysis of ground deformation over the Istanbul Area in the framework of the FP7 MARsite Project. 12-17 April, 2015, EGU,Wien, Austria

Solaro G., The FP7 MarSite Project as a Supersite Initiative: Exploitation of X-Band InSAR Results for Surface Deformation Analysis over the Istanbul Area, 23-27 March, 2015, Fringe, Frascati, Italy

Ergintav, S, Seismic Potential of the North Anatolian Fault in the Sea of Marmara, Turkey (invited), 9-13 December, AGU, San Fransisco, USA

Ergintav, S., Geodetic Observations of Strain Accumulation on Faults in the Marmara Seismic Gap Near Istanbul, Turkey, 27 April – 02 May 2014, EGU, Wien, Austria.

Ergintav, S., New Directions in Seismic Hazard Assessment through Focused Earth Observation in the MARmara SuperSITE, 8-10 June, GEO Meeting, Atina, Greece

Aslan, G., Surface Creep along the 1999 Izmit Earthquake's Rupture (Turkey) from InSAR, GPS and Terrestrial LIDAR, 7-9 Oct. 2015, Workshop ForM@Ter MDIS (Deformation Measurement by Space Imagery): Grenoble, France

Cakir, Z., Surface Creep along the 1999 Izmit Earthquake's Rupture (Turkey) from InSAR, GPS and Terrestrial LIDAR, 14-18 Dec. 2015, AGU fall meeting, San Francisco, United States

Cakir, Z., Asesismic slip behaviour of North Anatolian Fault, Turkey, 17-22 April 2016, EGU General Assembly, Vienna, Austria

NOTE: The list of the papers and presentations are prepared, using the Internet searching. The PoC is not aware about them, especially the papers, which use ESA data sets. ESA data sets are downloaded from UNAVCO or ESA links and no one put a link to active Supersite in study region (e.g. Leeds group didn't give any reference to this Supersite)

Research products

Type of product	Product provider	How to access	Type of access
Ground deformation maps, using CosmoSkyMed data in shape format	*A. Nobile, J.P. Merryman Boncori, S. Salvi*	*POC requests access from INGV for individual users, data then accessible via secure MARsite server*	*Registered Public*

Research product issues

Generally, there are no formally complete, publically available research products. However, some PS maps (CosmoSkyMed) has been converted to Shape format and saved in secure MarSite ftp site (see the Table)

Normally, in academic community, where publishing is emphasized, there is little reward for making research products accessible. Obviously, this needs extra manpower for the re-formatting of the products and sharing with scientific community from a web server. Now, there are no common formats available in InSAR software. In EPOS-IP, one of the main targets is to define standard formats to share the results. This can solve large parts of the problem. Others are related with funding.

Until the definition of the formats and solving the manpower problems, interesting users can communicate with owner of the products, in order to take them in proper formats.

Dissemination and outreach

Dissemination and outreach were not requirements of Marmara Region Supersite. However, as a nature of the hazard related studies, we informed decision-makers at every appropriate opportunity. Within the MarSite, end users were defined very well and the outputs of the SAR

related studies were shared with them in many public lectures, briefings and interactive project meetings.

Funding

The Marmara Region Supersite has no specific funding mechanism. But, until the end of EU-funded MarSite, it used the limited sources of MarSite for the creation of in-situ data hub. The core team, post-doc and PhD students working on the MarSite data are mostly funded by MarSite project.

MarSite project has finished by the end of April 2016. However, the core supersite team is willing to continue its close collaboration in the future, within the framework of innovative research activities and new creative projects. All attempts will be made to sustain the established infrastructure until relevant calls would be made under the framework of Horizon-2020 (Societal Challenge 5), expected to be released in 2017. KOERI and other institutions will support the maintenance of the infrastructure using different local and international sources (e.g. EMSO, INSU-CNRS), during this period.

Individual users, of course, used research funding from different sources but since there are no reporting requirements, the PoC is not aware of those projects.

Societal benefits

Last destructive earthquake (M7.2) occurred in 1999 and many new monitoring strategies have been started in the following period. Unfortunately, before the 1999, there were a few seismological sites and the monitoring of the earthquake cycle was impossible from the ground sites.

SAR data opened a new horizon for the Marmara Region. After 1992, the monitoring was started through ERS1/2 data and, until now, different phases of crustal deformations were tracked by the SAR time series, related with 1999 events. The results show that the region has not a unique earth cycle. Along the 1999 rupture zone, immediately after the earthquake, creeping was observed by SAR data and, now, fault-healing stage is monitoring.

These observations have the fundamental importance for a wide range of the studies, perhaps most especially for probabilistic seismic hazard analysis. All hazard models should be modified based on the SAR results.

SAR data constitute a critical resource for this monitoring and research. In a short time (<1 week), a large area (>150km) can be mapped (<mm/year). The results can be regularly presented to the decision-makers in order to compare them with other data sets and interrupt the current state/changes in any local deformations (substances, landslides) and earthquakes. Then, decision-makers could be ready for the emergency management, via a rapid generation of critical information relevant to the co-seismic deformation event, using pre- and post-event imagery.

Conclusive remarks and suggestions for improvement

- Under the GSNL initiative, joint interpretation of satellite and in-situ data could be made and new understandings of fault kinematics/dynamics and local deformations in the cities could be carried out. The results could be published and distributed to a general scientific community. This is a major scientific challenge.

- A number of the researchers, postdocs and graduate students obtained the huge amount of SAR data by CEOS and this increased the number of the productive researchers.

- SAR data and in-situ data have been jointly used to provide the continuous information to decision-makers, in order to be ready for unexpected issues of natural hazard.

- Usage of in-situ data is not under the control of PoC. PoC gives a link to available sites and projects for in-situ data. This worked very well in this Marmara Region Supersite with the contribution of MarSite. But, it finished and in-situ networks need funding to survive the long-term data flow. Now, PoC will work with the PI of MarSite in order to solve sustainability problem of ground networks.

- Until now, we couldn't check the fast response of space agencies. During a catastrophic event, space data might be a unique data set. To estimate the delays, PoC can run some scenarios with space agencies.

- The procedure for accessing, to Supersite SAR data in space agencies, should be standardized. This makes a lot of difficulties to know who is working with Supersite data, thereby complicating the efforts to coordinate work and to report results.

- The methodology of Space Agencies is different to share the SAR data with individual researchers. Generally, PoC controls the data transfer between space agency and researchers. But, in some case, PoC may be unaware about the usage of data, results and

teams. Especially, this is important to demonstrate the power of Supersite team to scientific community and to the public.

- Each space agency has a commercial partner and, when the orders are overlapped, the orders of commercial partners are accepted by space agencies. There should be a high priority for the hazard related studies. Of course, among the events, commercial partner can have high priority. This is important for emergency case studies.

- Some data sets generated noisy results (e.g. CosmoSkyMed). To increase the quality, a feedback mechanism is needed with Space Agencies and individual researchers (of course, PoC will be the contact point in this communication).

- There is a noteworthy lack of non-SAR data sets. Much of them are freely available but there is no archive in Supersite. There has been no effort to obtain the commercial optic/thermal data (e.g. Pleiades, Quickbird).

- There is a lack of supporting data, like digital elevation information. Tandem-X data (from DLR) can provide high-resolution topography. This data is essential to improve the resolution for SAR systems. DLR opens some part of this data to the accepted proposal by their system. But, the usage of the data is restricted to the owners of the proposals. This is not an open data set.

- As PoC, I did not receive any response to my emails, which are about the on-going activities of the users. Unfortunately, Supersite users are not required to report the results or communicate with the PoC, after the receiving the data. Obviously, we need a formal

method for the accountability of users and accessing the data. With a Web-based recording and feedback mechanism, users can be tracked and their outputs can be listed to show the benefits of Supersite in different reports and web pages.

- Without a dynamic web for data and products, there is no means of sharing with science community and public. Of course, PoC can use the available Web pages in the Internet. But, Supersites need specific address to demonstrate the importance of a GSNL Supersite, to fund agencies in order to obtain the long-term sustainability. SAC can organize the Supersite-specific dynamic pages to show the results in a very short time.