Project contract no. 036851

ESONET

European Seas Observatory Network

Instrument: **Network of Excellence (NoE)**

Thematic Priority: **1.1.6.3 – Climate Change and Ecosystems**

Sub Priority: **III – Global Change and Ecosystems**

ESONET WP4 - Demonstration Missions

MARMARA-DM

FINAL REPORT

Start date of project: **1st March 2007** Duration: **48 months**

Revision [draft]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	X

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1. General information

1.1 Partnership (institutions, people, e-mails, addresses), duration (start/end dates)

DM acronym:	MARMARA-DM
DM title:	Multidisciplinary Seafloor Observatories for Seismogenic Hazards Monitoring in the Marmara Sea
ESONET Site:	MARMARA SEA, Turkey
Scientific Area(s):	- Earthquake hazards - Relations between fluids and seismicity - Processess at fluid controlled ecosystems
Technological Area(s):	Long-term, permanent monitoring of seismicity, sediment pore fluid, fluid geochemistry and gas emission activity
DM Start and End date:	from April1st, 2008 to September 30st, 2010
DM duration:	*30 months*

Partners Contact

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1.2 Work Packages activities and tasks short description (as indicated in the implementation plan)

WP	WP/Activity name	Leader Institution	Tasks short description	Related Deliverables
1	MarNaut data integration	**CNRS**	Integrate data collected during MarNaut cruise ; publish scientific results ; produce recommendations for the present demonstration mission	- D1.1 Paper on piezometer and OBS results - D1.2 Paper on flowmeters /osmo-samplers - D1.3 Paper on fluid analysis - D1.4 Paper synthezing Marnaut results
2	Marine Operations	**Ifremer**/DEU/ISMAR/ITU	Preparation and completion of the following cruises : - Marmesonet cruise with Le Suroit, with 2 legs for : i) acoustic mapping water column ; 2) high-res bathymetric survey using AUV at 3 sites ; 3) high-res seismic survey at site 1. - DEU cruises with R/V Piri Reis : high-res seismics at sites 2 & 3 - Urania cruise with R/V Uranina for SN-4 operations.	- D2.1 Cruise reports for DEU cruises - D2.2 cruise report for Ifremer cruise (Marmesonet) - D2.3 1-year time series at 3 sites
3	Land and seabottom integration	**INGV**/ITU-TUBITAK/Ifremer	Integrate the marine and land seismological data in order to : ➢ assess the true benefit of deploying seafloor stations in the MS; ➢ assess the ambient noise in the Marmara Sea ; ➢ better identify the active segments of the MS Sea fault system	- D3.1 Report (including data base) combining marine and land seismological data in the Marmara Sea - D3.2 Report on the ambient noise in the MS and recommendation for the implementation of permanent seabottom stations - D3.3 High res seismic images at 3 sites
4	Data integration and modelling	**ISMAR**/CNRS/ITU/Ifremer/INGV	- Analyze, integrate and model all available data (seismology, geophysics and geochemistry of pore fluids, sedimentology, acoustics) - Test the working hypothesis (according which some of the physical and chemical changes in the properties of the fluids within the fault zone change can be detected in surface sediments) by interpreting pore fluid pressure and chemistry variations. - Validate the concept of seafloor observatories - Select the best site for permanent seafloor monitoring	- D4.1 Report integrating all available data - D4.2 GIS including all available data - D4.3 Report validating the concept of seafloor observatories - D4.4 Report on best site selection
5	Comparative feasibility study	**Ifremer**/ITU	- Compare fiber optic cabled observatories vs permanent observatories linked to a sea-surface buoy equipped with energy supply and telecommunications systems. - Provide approximate costs on investments, maintenance and personnel, based on the local situation.	- D5.1 Recommendations report for the preferred option - D5.2 Cost estimation report - D5.3 Implementation plan
6	Public outreach, education and fund raising	**ITU**-DEU	- Disseminate results among Turkish authorities and policy makers - Propose a coordination structure and managing scheme for the implementation of the seafloor observatory. - Disseminate results among the scientific community and the public (thorugh web site, training courses and public seminars)	- D6.1 Support agreement contract with Turkish authorities - D6.2 Web Site - D6.3 Training course

1.3 Deliverables description

Deliverables have all been achieved and accessible on the data repository system of the Marmara-Dm project websit : http://www.esonet.marmara-dm.itu.edu.tr/

Deliverable N°	**Deliverable name**	**Lead contractor**
	WP1	
D1.1	Report on piezometer and OBS results[a] *Including Tary et al, Bull. Seism. Soc. Am.*, Vol. 101, No. 2, doi: 10.1785/0120100014, 2011	5
D1.2	Report on Fluid flux rates through the Marmara seafloor : Results from flowmeters and osmo-samplers *Including paper by Tryon et al, submitted to Marine Geology on March 2011*	5
D1.3	Report on the origin of fluids escaping from the Marmara seafloor Including paperss by Bourry *et al*, *Chem. Geol.*, doi: 10.1016/j.chemgeo.2009.03.007, 2009 and Tryon et al., Geochem. Geophys. Geosyst., 11, Q0AD03, DOI: 10.1029/2010gc003177, 2010	5
D1.4	Paper synthetizing Marnaut results *Géli et al, Earth Plan. Sci. Let.,* 274, 34–39, doi:10.1016/j.epsl.2008.06.047, *2008*	5
	WP2	
D2.1	Cruise report of DEU (PirMarmara) Cruise with R/V Piri Reis (June 2010)	6
D2.2a	Cruise Report on Ifremer (Marmesonet) cruise, Leg I (Oct. 4th – Oct. 25, 2009)	1
D2.2b	Cruise Report on Ifremer (Marmesonet) cruise, Leg I (Oct. 28th – Dec. 14, 2009)	1
D2.3	Cruise reports of SN4-related operations : i) Marmara 2009 Cruise with R/V Urania (october 2009); ii) Recovery and redeployment operations with R/V Yunuz (march 2010) ; Marmara 2010 Cruise with R/V Urania (october 2010). Including brief, preliminary report on SN-4 time series (6 months)	4
	WP3	
D3.1	Report combining marine and land seismological datasets	1
D3.2	Report on the ambient noise and recommendation for implementing permanent seabottom stations	4
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	WP4	
D4.1	Report on data repository system integrating all available data	3
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D4.3	Report to test working hypothesis and validate concept of seafloor observatories	5
D4.4	Report on best site selection	3
	WP5	
D5.1	Recommendation Report on the preferred option	1
D5.2	Cost estimation report	1
D5.3	Implementation plan	4
	WP6	
D6.1	Support agreement contract with Turkish authorities	2
D6.2	Web Site	2
D6.3	Training course	2

1.4 Milestones description

Milestone Number	Milestone description	Actual date
1	Kick-off meeting	Ifremer, October 29th and 30th, 2008
2	Ifremer Cruise (Marmesonet)	4th Nov. – 14th Dec. 2009
3	DEU Cruises (High Res Seismics with R/V Piri Reis)	4th-16th June 2010
4	Training Course	18th-19th August, 2009
5	Closure meetings with conclusions	Brest, 2nd-5th Feb., 2010 & Brest, 1st-3rd, March, 2011

2. Introduction (scope and context)

The goal of the present demonstration mission (MARMARA-DM) is to contribute to the establishment of optimized permanent seafloor observatory stations for earthquake monitoring in the Sea of Marmara (SoM), as part of ESONET NoE. The SoM offers the ideal location for seafloor seismogenic observations directed towards risk assessment, because of the following reasons:

1. The deformation rates (20 mm/y) are very high compared to any other marine sites in Europe, resulting in active submarine processes that are measurable on short time scales
2. More than 15 millions people are under the threat of seismogenic hazard in the whole Marmara Region. Hence, the continuous seafloor monitoring would have high societal impact
3. Numerous fluid vents and related features have been discovered along the SoM fault system. The SoM is thus a unique area to test hypothesis on the relations between strike-slip deformation, seismic activity, fluid flow and gas expulsion within the active fault zone.
4. Logistics are favored by the proximity to the coastlines (only 5 to 30 km), which make cost-effective and realistic the establishment of permanent seafloor observatories.

The specific objectives of the present demonstration mission are:

1. To characterize the temporal and spatial relations between fluid expulsion, fluid chemistry and seismic activity in the SoM,
2. To test the relevance of permanent seafloor observatories for an innovative monitoring of earthquake related hazards, appropriate to the Marmara Sea specific environment
3. To conduct a feasibility study to optimize the submarine infrastructure options (fiber optic cable, buoys with a wireless meshed network, autonomous mobile stations with Wireless messenger). This study will also ensure standardization and integration with other initiatives world wide (Europe through Esonet, but also with Neptune)
4. To ensure the sustainability by involving the national and local authorities, and coordinate national (Turkish) and international efforts towards a optimized, permanent seafloor monitoring for the geohazard risk assessment and mitigation in the SoM.

3. Work Description

3.1 Work Description at work package level

WP 1 : Analysis of the available time series data and in-situ samples from the Marnaut cruise.

D1.1 Report on piezometer and OBS results from the MarNaut cruise. The piezometer deployed during the MarNaut cruise presented unexplained features that could be interpreted as artifacts. Therefore, deliverable D1.1 is based on OBS data. We present **two case studies** from the Sea of Marmara :

- The **first case study** concerns the relation between the micro-seismicity and other observations we had from the seafloor (anlysis of in-situ sampled fluid sampling and detailed micro-bathymetry (based on AUV data collected in 2009 during the Marmesonet cruise). This work clearly shows that *tectonic strain below the western slope of the Tekirdag Basin contributes to maintain a high permeability in faults zones, and that the fault network provides conduits for deep-seated fluids to rise up to the seafloor [Tary et al, Bull. Seism. Soc. Am.*, Vol. 101, No. 2, doi: 10.1785/0120100014, 2011*]*.

- The **second case study**, is focused on the detailed analysis of non-seismic micro-events recorded with Ocean Bottom Seismometers and hypothetically attributed to degassing episodes from the upper sediment layers. Our analysis unambiguously confirms our hypothesis and provide insights on how gas is expelled from the uppermost sediment layers: the recorded micro-events are related to natural degassing from the seafloor and to the building and collapsing process of gas chimneys near the subsurface.

D1.2 Report on Fluid flux rates through the Marmara seafloor: results from flowmeters and osmo-samplers. The objective of the 2007 MarNaut project was to quantify the level of activity of venting sites near the fault, and the source of the fluids emitted, with the goal of understanding the processes involved and setting a baseline for long-term studies of the relationship between seismic activity and fluid migration/expulsion processes. Sites for flow meter and fluid sampler deployment and coring included basin bounding transtensional faults and strike-slip faults cutting through the topographic highs. Significant fluid flow appears to be primarily an episodic phenomenon at all sites with background rates on the order of mm/yr to cm/yr except at or very near rare focused vents. Basin bounding faults expel primarily shallow sourced fluid with a strong influence of brackish Pleistocene Lake Marmara water. Expulsion sites where the main fault crosses topographic highs are more complex with evidence for deep-sourced fluids including thermogenic gas. One site on the Western High displayed two mound structures that appear to be chemoherms atop a deep-seated fluid conduit. The fluids being expelled are brines with an exotic fluid chemistry along with thermogenic gas and oil [*Tryon et al, submitted to Marine Geology on March 2011]*.

***D1.3* Report on the origin of fluids escaping from the Marmara seafloor.** Gas hydrates were sampled during the MARNAUT cruise (May–June 2007) on the Western High, and three gas-bubble samples were recovered on the Western High, the Central High and in the Çinarcik Basin. Methane is the major component of hydrates (66.1%), but heavier gases such as C2, C3, and i-C4 are also present in relatively high concentration. The methane contained within gas hydrate is clearly thermogenic, with a geochemical signature similar to the one found for the natural gas from K-Marmara-af field in the Thrace Basin. Gas bubbles from Central High show also a thermogenic origin, whereas those from the Çinarcik Basin have a primarily microbial origin. UV-Raman spectroscopy reveals structure II for gas hydrates. Hydrate composition is in good agreement with equilibrium calculations, which confirm the genetic link between the gas hydrate and gas bubbles at Western High and the K-Marmara-af offshore gas field located north of the Western High. The base of the structure II hydrate stability field is at about 100 m depth below the seafloor at the Western High site, whereas in the Çinarcik Basin, P–T conditions at the seafloor correspond to the uppermost range for structure I hydrate formation from microbial gas. References : [Bourry *et al*, *Chem. Geol.*, doi: 10.1016/j.chemgeo.2009.03.007, 2009] and [Tryon et al, (2010), Pore fluid in the North Anatolian Fault in the Sea of Marmara : a diversity of sources and processes, *Geochem. Geophys. Geosystems*, **10 (11)**, doi : 10.1029/2010GC003].

D1.4 Paper synthetizing Marnaut results. The submerged section of the North Anatolian fault within the Marmara Sea was investigated during the MarNaut cruise, using acoustic techniques and submersible dives. Most gas emissions in the water column were found near the surface expression of known active faults. Gas emissions are unevenly distributed. The linear fault segment crossing the Central High and forming a seismic gap – as it has not ruptured since 1766, based on historical seismicity, exhibits relatively less gas emissions than the adjacent segments. In the eastern Sea of Marmara, active gas emissions are also found above a buried transtensional fault zone, which displayed micro-seismic activity after the 1999 events. Remarkably, this zone of gas emission extends westward all along the southern edge of Cinarcik basin, well beyond the zone where 1999 aftershocks were observed. The long term monitoring of gas seeps could hence be highly valuable for the understanding of the evolution of the fluid-fault coupling processes during the earthquake cycle within the Marmara Sea [*Géli et al, Earth Plan. Sci. Let.*, 274, 34–39, doi:10.1016/j.epsl.2008.06.047, *2008]*.

WP 2: Marine operations. A total of 6 cruises were conducted during the Marmara-Dm Demonstration Mission:

1. Marmara-2009 cruise with R/V Urania (sept 23 – oct 12, 2009), during which the INGV-SN4 station was first deployed, together with 10 OBS and 5 piezometers from Ifremer (D2.3).
2. Marmesonet cruise of R/V Le Suroit, Leg I (from november 4th to november 25th, 2009), mainly dedicated to: i) the high resolution bathymetry at potential sites of interest for future permanent instrumentation using the Autonomous Unmanned Vehicle (AUV) *Asterx* of Ifremer/Insu; ii) e.g. the systematic mapping of the gas emissions sites on the Marmara seafloor (e.g.) Fig. 3.1); iii) the deployment of the Bubble Observatory Module (BOB) in the Çinarçik basin (D2.2a).
3. Marmesonet cruise of R/V Le Suroit, Leg II (from november 28th november to december 14th, 2009), for 3D, High Resolution Seismic imagery (e. g. Fig. 3.3) of the fluid conduits below the observatory site planned at the Western High (D2.2b).
4. Yunuz-2010 cruise with R/V Yunuz for: i)recovering and redeploying SN4, after a 6 months long deployment; ii) recovering Ifremer instruments (10 OBS and 5 piezometers) and 2 Geomar instruments which were previously deployed during the Marmesonet Cruise of R/V Le Suroit (D2.3).
5. The Pirmarmara cruise was conducted from June 2 to June 12, 2010, on board R/V K. Piri Reis from Dokuz Eylül University (DEU, Izmir, Turkey), to record 2D long offset seismic profiles using a 1500 m long streamer (240 traces) in the HR-3D box, in order to provide better velocity constrains and improve the 3D seismic imaging. The recent upgrade of DEU High Resolution seismic equipment, which now include a 1500 meters length streamer (240 traces), will certainly ease to constrain velocities for deep horizons.
6. Marmara-2010 cruise with R/V Urania (sept 29-oct 18, 2010), during which SN4 was finally recovered (e.g. Fig. 3.3 and D2.3), after the second, 6-months deployment.

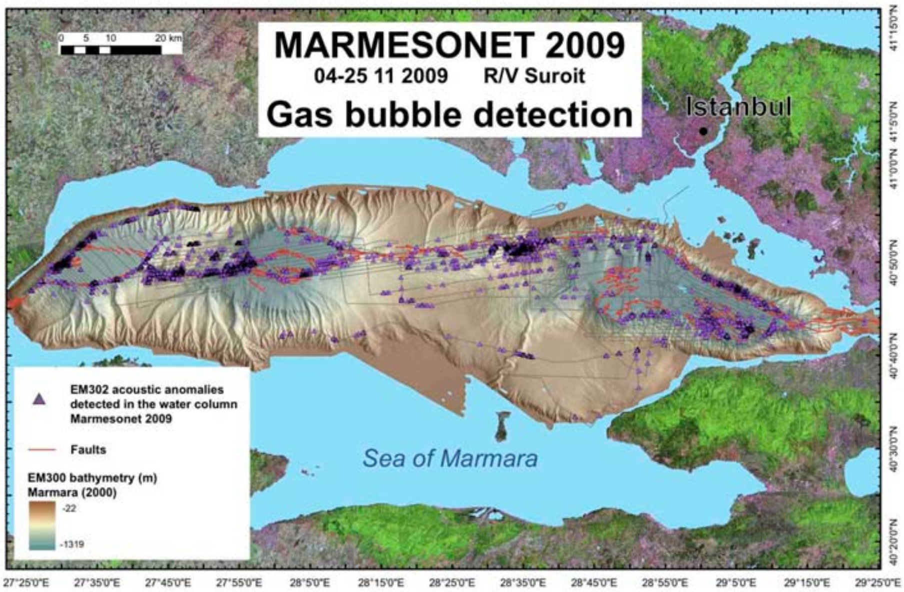


Fig. 3.1 Geographical distribution of acoustically detected gas emissions sites in the Sea of Marmara. Acoustic detection was performed using multibeam echo-sounder of R/V ME Suroit during Marmesonet cruise, Leg I.

WP 3 : Integration of land and seafloor seismological data.

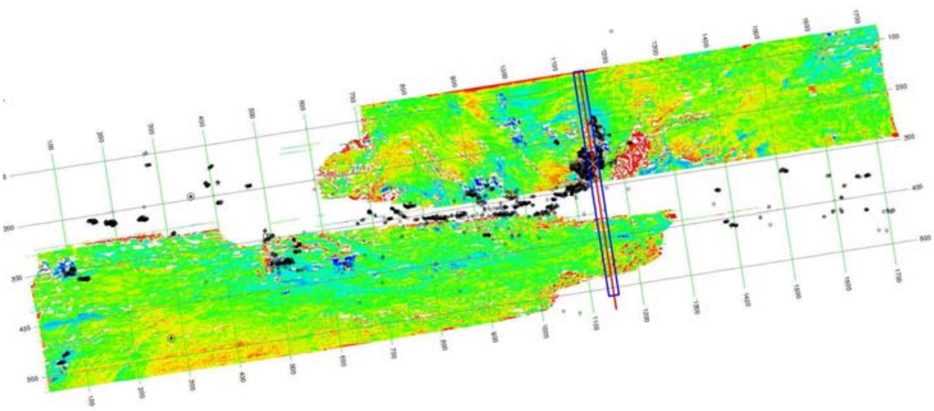
D3.1 Report combining marine and land seismological datasets. The present delivrable was addressed during Jean-Baptiste Tary's *PhD* work (defended on march 15th, 2011). Part of this work is subject to a publication in press: Tary *et al* (2011), Sea-bottom observations from the western escarpment of the Sea of Marmara, *Bull. Seism. Soc. Am.*, in press (april 2011). *Available at:* http://wwz.ifremer.fr/drogm/Presentation-GM/Pages-perso/Louis-Geli/Publications. Because the basins of the Sea of Marmara are filled with more than 5 km of Plio-Quaternary soft ("slow") sediments, the velocity structure of the offshore domain is drastically different from the one onshore. **Therefore, merging land and sea-bottom datasets has proven to be very challenging, if not hopeless**. To improve the real-time, absolute locations of hypocenters near the submerged fault zone and enhance the search for seismic tremors [*Bouchon et al.*, 2011], specific networks of permanent, cabled sea-bottom seismometers are required. Each network should be consistent *per se*, and allow the high-resolution characterization of earthquakes below the Sea of Marmara. In addition, it is of critical importance to create an high-resolution, 3D velocity model. This could be achieved by performing velocity analysis using the numerous multi-channel that cover the Sea of Marmara.

D3.2 Report on the ambient noise and recommendation for implementing permanent seabottom stations. This delivrable was addressed during by Jean-Baptiste Tary's *PhD* work (see reference in above paragraph) and by the INGV group who worked on the data recorded with SN-4. The analysis on the ambient noise was focused on the detailed study of non-seismic events recorded with the Ocean Bottom Seismometers. High resolution, seismic data collected with the sediment penetrator (3.5 kHz) during the Marmesonet cruises of R/V Le Suroit (from October 4th to December 14th, 2009 clearly indicate that gas occurrence is ubiquitous in the sub- surface sediments covering the Marmara seafloor. Therefore, we propose that the recorded micro-events are related to natural degassing from the seafloor and to the building and collapsing process of gas chimneys near the subsurface. The Broad-Band OBS data recorded in the Gulf of Izmit with SN-4 indicate that these non-seismic degassing events are correlated to a long duration (~3 hours) phase observed on the vertical component, preceded by long period (~ 30 s) signals recorded on the horizontal component. We propose that this phase is likely related to the progressive build-up of mounds due to gas migration and outbursts from the seafloor. Our study clearly shows that OBSs represent powerful tools to study natural degassing processes from the seafloor.

For permanent, multi-disciplinary seafloor observatories for earthquake monitoring in the Sea of Marmara, we thus recommend specific networks of Broad-Band OBSs (see D2.2) and multi-parameters approaches in order to understand the background noise. For each measured parameter, the background variability must be assessed. Data processing and research on the physics of the phenomena should be intimately related.

D3.3 Three-D, High Res Seismic Images at Western High Site. The second leg of the Marmesonet cruise (november 28th to december 14th, 2009), was dedicated to 3D, High Resolution Seismic imagery of the fluid conduits below the observatory site planned at the Western High, where oil and gas seeps from the Thrace Basin were found at the seafloor, together with gas hydrates. This site is considered to be a priority, as we may there expect gas emissions resulting from pressure increases in the gas reservoirs. To image the connections between the fluid migration conduits and the main fault system, the acquisition system consisted in 2 seismic streamers, 25 meters apart, equipped with 48 traces each, spaced by 6,25 m; the sources consisted of 2 lines of 3 mini-GI (24/24 cu-inch) airguns each, firing alternatively in flip-flop mode every 3 s (6 s spacing for the same line). An area of 3,6 x 10 km2 was covered during 11 days of acquisition. A total of 119 lines were successfully shot, providing data of exceptional quality. Along with HR-3D seismics, chirp and multibeam bathymetry (Simrad EM-302) data were collected

The fluid conduits associated to gas seeps visible at the seafloor were successfully imaged, down to about 500 to 800 ms-twt below seafloor. The present deliverable includes images obtained using pseudo-3D migration (in 2 passes, along and across line, with constant velocity of 1500 m/s) and two reports on advanced processing.



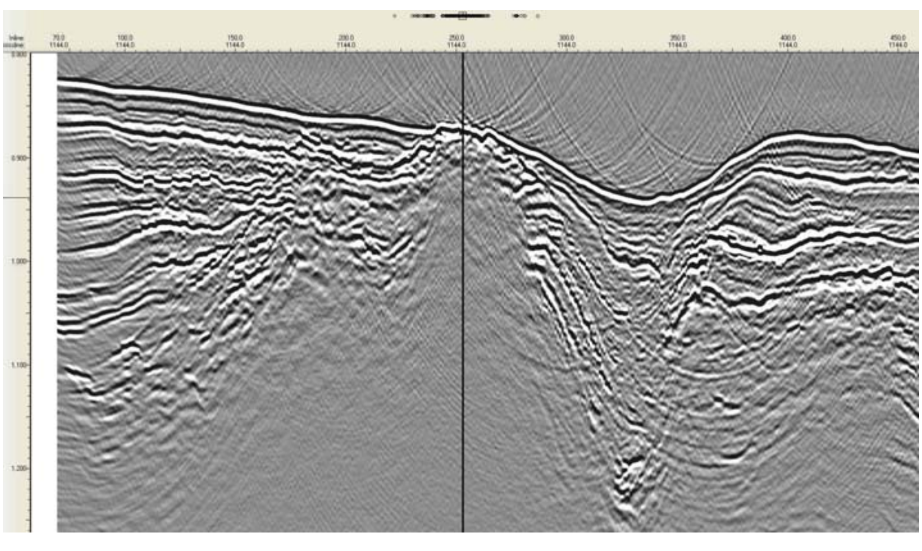


Fig. 3.3: After D3.3 (Thomas et al). Top figure : Map of seismic amplitudes of the H1 reflector (red : maximum ; blue : minimum) in the box covered with High-Res 3D seismics. The covered area is about 3,6 x 10 km2. Bin size within box is 6,25 m. Distance between grid lines is 625 m. Bottom figure : Cross line, across the mud volcano where gas and oil seeps were found, together with outcropping gas hydrates.

WP 4 : Data integration and modeling.

D4.1 Report on integration of all available data in a data repository system. All data collected during the Marmara-DM project were deposited on ITU-EMCOL Network Attached Storage (NAS). NAS is a solution for safe and platform independent file storage over Internet. According to Wikipedia, "NAS is a file-level computer data storage connected to a computer network providing data access to heterogeneous network clients". The characteristics of ITU-EMCOL NAS and the connexion procedures (in terms of both SSH and FTP protocols) are given in Deliverable 4.1. Each MARMARA-DM member has been notified about his or her username or password. Further instructions about data repository can also be found in the Marmara_DM web page (http://www.esonet.marmara-dm.itu.edu.tr/) EMCOL-NAS section.

D4.2 GIS including all available data collected during the Marmara-DM project. The GIS data is presently stored both in IFREMER and ITU's servers. ITU Eastern Mediterranean Centre for Oceanography and Limnology (EMCOL) has dedicated a Network Attached System (NAS) to share all available and classified data between partners of the project (D4.1). The copy of GIS files will be stored in this restricted system and be available among only allowed users via ftp (ftp://160.75.30.57) and ssh (ssh server 160.75.30.57). Usernames and their passwords have been already sent to the project partners. Other users should apply to the project coordinator Dr. Louis Geli (Louis.Geli@ifremer.fr) or Umut B. Ülgen (ulgenum@itu.edu.tr) to get their login details.

D4.3 Report to test working hypothesis and validate concept of seafloor observatories. Marmara-DM was driven by the 3 following hypothesis: H1): *Physical and chemical properties of the fluids and deformation within the fault zone change systematically with time throughout an earthquake cycle, and some of these changes, or their consequences, can be recorded at the seafloor; H2) Strain rate variations induce pore pressure variations in subsurface sediments; H3) Fluids from the seismogenic depth reach (locally and episodically) the sediment surface.* The objective of D4.3 was to assess the results of the Marmara-DM with respect to this hypothesis testing approach, and conclude on future observatory planning.

Hypothesis H1 does little more than stating that seafloor observatories can record signals linked to seismogenic zone processes. Marmara-DM demonstrated the possibility to monitor variations of fluid fluxes and composition, and defined sites where coupling with strain in the NAF seismogenic zone is hypothesized. As formulated, (H1) refers primarily to variations over the time scale of the earthquake cycle. However, this time scale may be considered long even for an observatory project, and it is also unclear whether progressive changes –resulting for example from interseismic loading and fault healing at depth– can be recorded at the seafloor and resolved among the shorter term variations that could result from a variety of processes occurring near the seafloor, or from transient events affecting the crust. Setting aside the fluid component, results obtained from a re-analysis of foreshock data from the Izmit 1999 earthquake [*Bouchon et al., 2011*] lead to consider that seismometers set close to an active fault could be used to detect the nucleation of large earthquakes. Hence, the objectives of setting an offshore observatory in the SoM should be extended to include the improvement of the predictability of earthquakes in the Istanbul area.

D4.4 Report on best site selection. The detection of transient crustal events now appears as a scientific objective *per se.* The identification of seismic tremors and low frequency earthquakes –and of their relation with episodic "silent" slip– has been progressing very rapidly, first at subduction zones [e.g. *Shelly et al., 2006*], and now at strike-slip faults [*Nadeau and Dolenc, 2009; Bouchon et al., 2011*]. These progresses lead to consider the identification of slipping zones on the edges of seismic gaps or at the upper/lower limits of the seismogenic zone, as the next objectives to be achieved in the SoM. Work performed on Marmara-DM data met difficulties in the precise determination of the depth of offshore earthquakes and in the identification of tremors from noise analysis in the marine environment. Emphasis could now be given to focused, small-scale networks and to the identification of repeating earthquakes. Best targets for this approach are microseismically active zones that also appear as hypothetical nucleation sites for a rupture on the Istanbul-Silivri segment:

1. The Istanbul-Silivri segment: although there is little microseismic activity, the eastern end of the seismic gap (toward Cinarcik Basin) should, however, be monitored. Furthermore, South of Istanbul,

intense bubbling is observed on a structural high, 1 km south of the main fault trace, while no evidence of fluid expulsion is found on the fault itself. Here, it would be of critical importance to monitor micro-seismic activity and strain with a view to determine if the fault segment is locked or creeping.

2. Western High and Central Basin. The westward termination of the Ganos 1912 earthquake rupture is still debated [*Ambraseis, 2002; Armijo et al., 2005*] and the whole segment extending from the Tekirdag basin to the Central Basin appears microseismically active, but repeating earthquakes were recognized in the Central Basin area. Ideally, a monitoring network should span the Central Basin and the gas hydrates area on the western high. The gas hydrate site is remarkable as the only site next to the main fault where a relatively deep source is recognized for both interstitial water and hydrocarbons.
3. Entrance of Izmit Gulf. This site is near the western end of the rupture associated with the 1999 Izmit earthquake. The fault trace is well defined at the seafloor, and the fault slipped at depths in 1999 but little evidence for seafloor rupture was found at this site, leading to hypothesize it may slip again and rupture the seafloor during future earthquake occurrences [*Gasperini et al., 2011*]. It is thus one area where the next earthquake affecting the fault strand towards Istanbul may nucleate. It is also a relatively accessible area, at shallow depth (200 m) and less than 5 km from the coastline. An extension toward the Cinarcik basin where active microseismicity was triggered after Izmit 1999 earthquake [e.g. *Karabulut et al., 2002*] and fluid emission are observed may also be considered.

WP 5: Comparative study and project feasibility.

D5.1 Recommendation Report on the preferred option. Based on the conclusions of the Marmara-DM project, two different designs are recommended for the future, cabled multi-disciplinary seafloor observatories. At sites 1 and 2 (Istanbul-Silivri fault segment and Western High), the shore station will be cabled to one node, itself connected to four junctions boxes : one on each side of the fault (JBN and JBS), one to the east (JBE) and one to the west (JBW). Junction boxes should allow the connexion of up to 12 instrument packages each (Table 1). Clusters of seismometers connected at each junction box will allow the ultra-precise characterization of earthquakes near the fault zone, using array-based methods for hypocenter determination. At the entrance of the Gulf of Izmit (site 3), deploying a node is not necessary, due to the short distance to the shore station (< 2 km). We propose to deploy one single junction box, with, at least, one OBS, 3 distance meters, one BOB, one methane sensor, one piezometer and one CTD.

D5.2 Cost estimation report. Elements for cost estimations are given as examples in the tables here below. Note that this table only includes 5 junction boxes : two (JBN and JBS) at sites 1 and 2 respectively and one at site 3. The cost of adding 2 junction boxes and instrument packages (JBE and JBS) at sites 1 and 2 can be easily determined.

Description	Engineering	Estimated price per equipment	Qty of equipments	Estimated total
Data management center & web (equipment + software)	350K€	150K€	3	800K€
Construction of shore station	30K€	40K€	3	150K€
Shore station equipment	50K€	50K€	3	200K€
Cable	100K€	20€/m	2*25Km + 5	1200K€
Cable deployment	100	(2x)1000 k€ +(1x) 500 k€	3	3500
Node	200K€	350K€	3	1250K€
Node deployment	250K€			250K€
Junction box	200K€	300K€	5	1700K€
Junction box deployment	300K€			300K€
Instrumentation	800K€	500K€	5	3300K€
Instrumentation deployment	3 days per site	60K€ / day	15 days	900K€
				13050K€

Table 3.2 Cost of investments for multi-parameter observatories including 2 junction boxes only at deep sites (Western high and Istabul-Siliviri) and one junction box at shallow site (entrance of Izmit Gulf). Each JB is connected to the instrument package listed in Table 3.1.

Description	Per year	Estimated total
Training	20K€	20K€
On site operation maintenance	4 days per site / year (4 sites)	960K€
Equipment maintenance	15% of equipment cost (instruments + cable + shore) station	750K€
Personnel cost (3 engineers, 3 technicians)	(3 techs+ 3 engineers)*12 months*1,5K€	108K€
		1838K€

Table 3.3 Indicative annual maintenance and training costs for the equipment and investment listed in Tables 3.1 and 3.2.

D5.3 Implementation plan. The conclusions of the Marmara-DM project were used to build a full implementation plan, submitted to two funding agencies as 2 different proposals, respectively MARQUAKE and MARDEP:

- the MARQUAKE Proposal was submitted on november, 16th, 2010, to the FP7 Cooperation Work Programme 2011for Environment, Sub-Activity 6.1.3 « Natural Hazards », Area 6.1.3.1 « Hazard assessment, triggering factors and forecasting », Topic ENV.2011.1.3.1-1 « Towards real-time earthquake risk reduction ». Partners re : Ifremer (coodinator), ITU, AFAD, Ismar-CNR, CNRS and DEU. This proposal (see appendix in deliverable D5.3) received a mark of 10 out of

15, the negociation phase is still pending.

- The MARDEP Proposal will be submitted in june 2011 to the Disaster and Emergency Management Presidency (AFAD) of the Republic of Turkey (see Deliverable 6.1).

WP 6: Public and education outreach, coordination at national (Turkish) level and fund raising.

D6.1 Support agreement contract with Turkish authorities. The major effort to fulfill this deliverable was the preparation of a project proposal "*MARDEP project: Marmara Seafloor Observatory Infrastructure for Earthquake and Environmental Research and Modeling*" by June 2010 to obtain funding for the establishment of the permanent seafloor observatories in the Sea of Marmara. The proposal was prepared by consensus among the main Turkish Marine institutions after two important meetings in İstanbul. However, the submittal of the proposal was delayed the next call in 2011, which appeared to be the most opportune period because of the political reasons. We will submit the *MARDEP Project* proposal for funding to the Prime Ministry of Turkey State Planning Department's (DPT) next call that will be either April or June 2011. The proposal will then be evaluated, and the final decision will be made by the DPT sometime during June to September 2011, depending on the time of the call. This deliverable will be fully realized if and when the Mardep proposal is funded. The chances of funding have increased by the support letters provided by Turkish and European institutions and public organizations.

During the 30 months of the Marmara-DM project several activities were carried out for fund rising within WP6. First we increased the visibility of the ESONET and EMSO projects' activities in the Sea of Marmara by special presentations in scientific meetings and by organizing an ESONET training course and a symposium in August 2009. Second, we held meetings of Turkish institutions of marine and geohazard studies to reach a consensus for the preparation of *MARDEP*. *MARDEP* is designed as a national project with participation of all concerned marine institutions, as well as the Turkish Geological Survey (MTA), Undersecretariat for Maritime Affairs, Department of Hydrography Navigation Oceanography (SHOD), Istanbul Metropolitan Municipality (IBB), and Coast Guards General Command in the meetings. The Istanbul Metropolitan Municipality will be a user of the MARDEP project (see Annex 2). MTA (Mineral Research and Exploration General Directorate: Turkish Geological Survey) also strongly supports the project (Annex 3). If funded, we plan the completion of the infrastructure by 2014, and thereafter start its operation as regional department of the EMSO science infrastructure. In Turkey there are 11 stakeholders in the MARDEP proposal including the MTA (Turkish Geological Survey), Istanbul Municipality, and all Marine Sciences Institutes. The European partners include: IFREMER, CNRS, INGV and ISMAR, (French EMSO and Italian EMSO) all providing support letters (Annexes 4 and 5). Furthermore the ESONET and EMSO partners of the Marmara node applied to a recent EC FP 7 call: ENV.2011.1.3.1-1: Towards real-time earthquake risk reduction with a proposal: "MARQUAKE: Earthquake Predictability in the Sea of Marmara areas" in November, 2010.

D6.2 Web Site. **www.esonet.marmara-dm.itu.edu.tr** **Note** : A window in turkish may open, asking for a certificate (İTÜ Güvenlik Sertifikası). In which case, just click on the cross in the upper-right corner to close the window.

D6.3 Training course. The Marmara-DSM Training Course was given in Istanbul, on august 18-19, 1999, on "Seafloor Observation Techniques for Marine Geohazard Monitoring".

3.2 Work done by each partner

The project was a full success mainly because all partners contributed far beyond their initial commitment. Each partner conducted the task he was initially assigned and provided valuable input to improve the observatory design and implementation strategy for multi-parameter, cabled observatories in the Sea of Marmara. The main contribution of each partner is listed hereafter.

3.2.1 Partner 1 : IFREMER.

Project coordination. This task consisted in reporting (on a 6-months basis), organizing project meetings, interfacing with the ESONET administration, scientific animation, etc.

Marmesonet cruises (D2.2a and D2.2b). Ifremer organized and conducted the two Marmesonet Cruises with R/V Le Suroit :

- Leg I (november 4th to november 25th, 2009) was mainly dedicated to: i) the high resolution bathymetry at potential sites of interest for future permanent instrumentation using the Autonomous Unmanned Vehicle (AUV) *Asterx* of Ifremer/Insu; ii) the systematic mapping of the gas emissions sites on the Marmara seafloor; iii) the deployment of the Bubble Observatory Module (BOB) in the Çinarçik basin.
- Leg II (november 28th to december 14th, 2009), for 3D, High Resolution Seismic imagery of the fluid conduits below the observatory site planned at the Western High.

Observatory design, comparative study and project feasibility (WP5). Considerable work was conducted under this work package, namely: i) to design the future multi-parameter observatories; ii) to estimate costs; ii) and to prepare implementation plans. This work was used to build a full implementation plan (D5.3 and D6.1), submitted to two funding agencies as 2 different proposals, respectively MARQUAKE and MARDEP (see D5.3 and D6.1).

Project GIS (D4.2). Ifremer coordinated the work to finalize the Project Geographical System which now includes all meta-data and part of the data collected during the Marmara-DM Project. The full dataset is available on the project data repository system, hosted by the ITU's server (D4.1).

Contribution on OBS data. Ifremer contributed to D1.1 (Report on piezometer and OBS results from MarNaut cruise, D3.1 (Report combining marine and land seismological datasets) and D3.2 (Report on the ambient noise and recommendation for implementing permanent seabottom stations), mainly through the *PhD* Thesis of Jean-Baptiste Tary.

Participation to observatory concept validation (D4.3). Ifremer contributed to almost all workpackages, particularly for validating the concept of permanent, cabled, multi-parameter observatories for earthquake predictability in the Sea of Marmara.

3.2.2 Partner 2 : ITU.

Coordinating Marine Operations (WP2; D2.1 and D2.2). ITU organized, coordinated and actively participated in the all the cruises, and contributed to the cruise reports Namik Çagatay of ITU acted as the Turkish coordinator, which implied considerable work on practical details, particularly for logistics, administration, customs and autorizations, etc. ITU therefore contributed to deliverables D2.1-D2.2.: Cruises and cruise reports.

Integration of all available data and development of data repository system (D4.1). ITU (Umut Ülgen and Cengiz Zabci) contributed to integration of all Marmara-DM project data, and developed the project data repository system. It consists of a server system called 'EMCOL-NAS' (Network Attached System) presently hosted by ITU. It can be reached by an ftp connection for uploading and and receiving data by the partners.

Contribution to the GIS Project (D4.2). Cengiz Zabci participated in the finalization of the GIS system, which includes all data collected during the Marmara-DM project. Earlier, Devrim Tezcan developed a GIS system and incorporated some cruise data into the system.

Report on best site selection (D4.4). This task has been completed as a result of site surveys carried out during several Marmara-DM cruises in the Sea of Marmara. Three main sites have been selected for observatories. The specifics of these sites have been reported in the MARDEP proposal prepared by ITU with help from IFREMER, CEREGE, ISMAR, DEU-IMST, INGV.

Comparative feasibility studies (WP5; D5.1, D5.2, 5.3). ITU contributed deliverables related to the comparative feasibility studies of establishing permanent multidisciplinary seafloor observatories in the Sea of Marmara. These involve recommendation for a cabled observatory option with node and junction box technology (D5.1), cost estimation (D.5.2) and an implementation plan (D.5.3). All these deliverables were incorporated into the MARDEP project proposal prepared under the leadership of ITU (see below).

Support agreement contract with Turkish authorities (D6.1). ITU built up a Turkish consortium and prepared a project proposal entitled "MARDEP": Marmara Seafloor Observatory Infrastructure for Earthquake and Environmental Research and Modeling, to obtain funding from Turkish Governement for the establishment of permanent seafloor observatories in the Sea of Marmara. The 'MARDEP' project proposal will be presented to the Prime Ministry of Turkey State Planning Department (DPT) in June 2011, for funding.

Public outreach - Project website (D6.2): Umut Ülgen and Cengiz Zabci of ITU created the Marmara-DM Project website (http://www.esonet.marmara-dm.itu.edu.tr/).

Public outreach - Training course (D6.3) : ITU organized and hosted a short course on *"Seafloor Observation Techniques for Marine Geohazard Monitoring"* during 17-19 August 2009. About 40 engineers and scientists participated in the short course from Turkey and Europe. ITU also organized a one-day symposium on *"An overview of the research in the Sea of Marmara region over the last 10 years"* on the 10th Anniversary of 17 August 1999 İzmit Earthquake. The workshop and symposium were important public outreach events, as well having scientific importance.

3.2.3 Partner 3 : ISMAR

Organizing and conducting URANIA Cruises, 2009 and 2010 (WP2). ISMAR spent considerable efforts in two cruises of R/V Urania and one cruise of R/V Yunuz which were critical for the Marmara demo mission :

- during the Marmara-2009 cruise (September 22 to October 12th, 2009), SN4 was deployed at the entrance of the Gulf of Izmit, together with 10 OBSs and 5 piezometers of Ifremer covering the whole Sea of Marmara. In addition, new geophysical and geological data were collected from the eastern part of the Sea of Marmara.
- During the R/V Yunuz cruise in march 2010, all instruments were recovered, and SN-4 was redeployed
- during the Marmara-2010 cruise (September 25th to October 15th, 2010), SN-4 was eventually recovered and new geophysical and sedimentological data were collected.

For each cruise, the work conducted by ISMAR included : 1) Compilation and submission to the Italian CNR commission (Gruppo coordinamento infrastrutture) of the proposal for the MARMARA 2009 and 2010 expeditions; 2) Practical preparation (e.g. problems with logistics, customs clearance, etc); 3) processing and re-analysis of the existing geophysical data (multibeam, chirp sonar, etc..) in the area of SN-4 deployment (Izmit bay and Cinarcik basin).

Integration of the geological data at site 3 (entrance of Izmit Gulf).

3.2.4 Partner 4 : INGV

Preparation, deployment and recovery of SN-4. INGV completed the upgrade of SN4 observatory adding new sensors to the basic SN-4 configuration. This upgrade was made in order to perform a multiparametric monitoring requested by the project objectives (gas seepage and seismicity). SN-4 was then deployed, as scheduled, in the Marmara Sea site selected for the long-term monitoring.

The first deployment operations were successfully performed on October 4th, 2009, in collaboration with ISMAR, who coordinated the operations of R/V Urania. Although selected prior of the cruise, the SN4-observatory site has been surveyed before deployment with geophysical imaging techniques and direct observations with a deep towed system, MEDUSA, that provided oceanographic data (CTD), methane content in the water column and visual inspection through a high-resolution video camera. MEDUSA exploration surveys were performed in different sites in order to detect methane anomalies and have direct observations of the seabed where SN-4 was planned to be deployed.

Recovery and redeployment of SN-4 (D2.2). INGV successfully recovered, re-conditionned and immediately redeployed SN-4 with R/V Yunuz in march 2010. SN-4 was eventually recovered in October 2010 with Urania, shortly after the official end of the Marmara-DM project, in order to collect a full year of data (Note : the R/V Yunuz, used for the second SN-4 deployment, had not dynamic positioning system and the capability to keep the position during the operations, so it was not possible to deploy SN-4 in the same site of the previous period, which was in a protected area inside a canyon. SN-4 station was therefore deployed in a narrow rectilinear valley that dissect the Darica basin and mark the North Anatolian Fault trace).

Data reduction and processing and preliminary interpretation of SN-4 (D2.3). Regarding the first mission, SN-4 station successfully recorded data from all sensors except current meter (10.5 Gbyte of data from methane and oxygen sensors, CTD, transmissometer and broad-band seismometer). The interpretation work of these data is presently under progress at INGV, mobilizing a group of 5 persons. During the first SN-4 monitoring mission, there were no significant earthquakes (M>3.4) within 100 km. SN-4 however revealed local microseismicity not recorded by land stations (Turkish network). Preliminary analysis shows an apparent correlation between non-seismic signals recorded on the Broad-Band seismometer and variations in bottom water temperature drop, methane concentration and turbidity. All data converge towards an hypothesis of episodic degassing from sediments in the SN-4 near field. Waiting for detailed and complete data elaboration and interpretation, we can anticipate that the SN-4 mission in Marmara Sea represented the longest monitoring of temperature + gas + seismicity at seabed, ever done. The success of the Marmara-DM project is thus now far beyond the initial expectations.

3.2.5 Partner 5 : CNRS

Coordination of WP1 (Marnaut data integration). Pierre Henry (CNRS) coordinated the Marnaut cruise which was conducted in 2007 with R/V L'Atalante and manned submersible Nautile. The data and samples acquired during Marnaut cruise were included in the Marmara-DM data set. These included processing of echo-sounder data, analysis of interstitial water and gas composition and deployments of flow meters, piezometers and of a mini OBS network. Analysis of these data was in great part funded by Marmara-DM as WP1 and conducted under the scientific supervision of Pierre Henry. 4 articles included in delivrables D1.1, D1.3 and D1.4 were published and one article, included in delivrable D1.2, is submitted.

GIS including all available data (D4.2). Data available to the CEREGE group were included in a GIS by Tiphaine Zitter. These included data from Marnaut (L'Atalante and Nautile), MarmaraVT (Marion-Dusfresne), Marmara 1 (Le Suroît), and part of the data from Marmarascarps (L'Atalante and ROV Victor) cruise. After Marmesonet cruise, the GIS was transferred to Ifremer for standardization and integration of Mamesonet data (AUV and Shipboard multibeam, sediment sounder).

Testing working hypotheses and validating concept of observatory (D4.3). Marmara-DM was driven by the following hypothesis: H1) *Physical and chemical properties of the fluids and deformation within the fault zone change systematically with time throughout an earthquake cycle, and some of these changes, or their consequences, can be recorded at the seafloor; H2) Strain rate variations induce pore pressure variations in* *subsurface sediments; H3) Fluids from the seismogenic depth reach (locally and episodically) the sediment surface.* Pierre Henry (CNRS) supervised the work to assess the results of the Marmara-DM with respect to this hypothesis testing approach, and to conclude on future observatory planning.

3.2.6 Partner 6 : DEU

Pirmarmara Cruise of Piri Reis (WP2, D2.1). The main contribution of DEU consisted in organizing and conducting the Pirmara Cruise of R/V Piri Reis, from June 4th to June 14th, 2011, to collect additional high resolution seismic data at the implementation sites of the future multidisciplinary seafloor observatories. Günay Çifçi was the coordinator of the PirMarmara Cruise, Bruno Marsset and Yannick Thomas from Ifremer and Dr. Seda Okay and also 12 researchers participated to the cruise. High Resolution (HR) seismic profiles were collected over the 3D box covered during the Marmesonet Cruise (Leg II) with a 1500-m long streamer having 240 traces, recently acquired by DEU, to provide velocity constrains and hence to improve 3D seismic imaging.

The second leg of the PirMarmara cruise aimed to complete the former 2D HR acquisition close to Istanbul, mainly in the Çınarcık basin. The Central High, Central Basin and Çınarcık Basin (area 4) where the Tamam data set recorded in 2008 on board R/V Piri Reis was completed. The southern shelf of the Marmara Sea (areas 1 and 3), with the investigation of the Messinian unconformity.

Processing of TAMAM data (WP2, D2.1 and D2.2b). The TAMAM cruise was carried out in june 2008 with R/V Piri Reis, in collaboration between DEU and Lamont Doherty Earth Observatory (LDEO). Although the TAMAM cruise is not part of MARMARA-DM, DEU spent considerable efforts in seismic data processing. This work helped the interpretation of the TAMAM lines, which, indirectly, helped the planning of the MARMARA-DM operations, most particularly the planning of the Marmesonet HR-3D seismic survey conducted with Le Suroit in december 2009 on the Western High (gas hydrates sites).

Interpretation of HR-3D seismic survey at site 3 (D3.3). Hakan Saritas (DEU) spent 10 months at Ifremer research center in Brest, from August 2010 to June 2011 to work on the interpretation of the HR-3D seismic seismic data, using Kingdom Suite for the seafloor imagery maps and drawing of first inperpretation of superficial horizons of 3D-cube in time domain and simultaneously comparison with chirp data of MarmEsonet data. This work also constitutes his Phd thesis and includes processing of long offset HR 2D seismic data provide by DEU new streamer and 3D time migration using the updated velocity model.

Burcu Barin and Orhan Atgin visited IFREMER during 17 October-17 November 2010 and worked with Bruno Marset and Yannick Thomas on PirMarmara data. The main objective of the visits was, the fundamentals of 3D high resolution Marine Seismic Acquisition, Quality Control and 3D High Resolution Seismic Data Pre-Processing and Quality Control. During the visits, the QC sequence for 2D HR DEU seismic equipment was adopted which derives from the one developed by using Matlab for its DEU seismic equipment. Also they have started to study on the data for their MSc Thesis in Sea of Marmara using PirMarmara data.

Gunay Cifci, Seda Okay, Burcu Barin, Orhan Atgin, have visited IFREMER Brest between last week of February and beginning of March for the 4th call Exchange of personel. The aim of the visit is, to work on the Marmara-DM project to evaluate the first results of MarmEsonet and PirMarmara data combining both data sets.

3.3 Input to and from ESONET Work Packages

The Marmara-DM demonstration mission greatly benefited from the input of ESONET WP1, WP3 and WP5. For WP1 (Programme for Exchange and Training of personnel, within ESONET Work Package 1) the exchanges performed during Marmara-DM are listed in the table hereafter:

Institutions concerned FROM	Institutions concerned FROM	Name of scientist	Date	Objective and Marmara-DM Work Package
ITU	Ifremer	Cengiz Cabzi	Jan-feb 2011	Completion of Project GIS (WP6)
ITU	Ifremer	Namik Cagatay Umut B. Ülgen Dursun Acar	Jan-Feb 2010	- Work on seafloor observatory design (WP5) - Work on GIS, Project database and project web page (WP4). - Training on sediment coring and preparation of cores for analyses (WP1).
ITU	CNRS-CEREGE	Namik Cagatay	September 2009	Work on core samples and integration of all data (WP4)
		Umut B. Ülgen Dursun Acar	December 2010	Work on core samples and integration of all data (WP4)
		Devrim Tezcan	January 2011	Work on GIS database for the Sea of Marmara and transfer the available data obtained during various cruises (WP6)
		Caner Imren	January 2011	Work on seismic data and data integration (WP4)
ITU	ISMAR	Namik Cagatay Umut B. Ülgen Dursun Acar	May 2010	- Discussion on URANIA 2010 cruise plan - Review of the results of SN-4 station and its recovery and possible redeployment in October 2010 - Work on 2 papers : 1) Sedimentary; 2) slip rate along NAF
		Namik Cagatay Emre Dabci Gülsen Uçarkus	Feb 2011	Work on core samples from Marmara 2010 cruise and integration of all data (WP4)
ITU	INGV	Umut B. Ülgen Dursun Acar	May 2010	Land and marine seismological data integration from the Sea of Marmara region (WP3)
		Namik Cagatay Emre Dabci Gülsen Uçarkus	Feb 2011	- discussed the *MARDEP* project proposal - work on SN-4 data obtained during one year of deployment, with INGV scientists - compare the earthquake and tsunami record results of core studies in the Sea of Marmara and Ionian Sea - work on database management system to be built up for Marmara Sea Observatory.

Institutions concerned FROM	Institutions concerned FROM	Name of scientist	Date	Objective and Marmara-DM Work Package
ISMAR	ITU	Luca Gasperini Giovanni Bortoluzzi Alina Polonia Giuliana Panieri	March-April/Nov 2010	Work on core samples and integration of all data (WP4) Collect data from the SN4 station, and share data and results with the Turkish team (WP1)
CNRS-CEREGE	ITU	Pierre Henry Céline Grall	September 2010	Work on core samples and integration of all data (WP4)
Ifremer	DEU	Bruno Marsset Yannick Thomas Louis Géli	June 2009	Preparation of Pirmara Cruise (WP2)
Ifremer	KOERI	Jean-Baptiste Tary	August 2009	Merging KOERI land and marine stations (WP3)
DEU	Ifremer	Günay Cifci	Jan. 2010	Preparing PIRMARMARA cruise (WP2) and Work on TAMAM seismic data (WP4)
KOERI	Ifremer	Mustafa Comoglu	April 2009	Merging KOERI land and marine stations (WP3)
Ifremer	ITU	Louis Géli	October 2010	Completion of project deliverables – Preparation of MARDEP Proposal (WP6)
Ifremer	ITU	Yves Auffret	August 2009	Observatory Design (WP5)
HCMR	Ifremer	Christos Tsabaris	January 2011	Work on Underwater Radon Measurements
DEU	Ifremer	Günay Cifci Seda Okay Orhan Atgın Burcu Barin	February-March 2011	MarmEsonet Days meetings and to discuss the future publications on the data from PirMarmara cruise

4. Data Management

4.1 MARMARA-DM Data Management

The main objective of the Marmara-DM Demo Mission was to conduct site surveys and preliminary studies to test the feasibility of multi-parameters seafloor observatories for monitoring earthquake hazards in the Sea of Marmara. Only a few continuous, short-term (< 6 months) time series were collected using MARMARA-DM using autonomous instruments:

- SN-4 recorded 12 months of data, including: oxygen, methane, 3 component broad-band seismometers (D2.3)
- 4 short-period (4.5 Hz) OBSs and one piezometer recorded data continuously during 3 months (may-september 2007).

All data collected during the Marmara-DM project were deposited on ITU-EMCOL Network Attached Storage (NAS). NAS is a solution for safe and platform independent file storage over Internet. According to Wikipedia, "NAS is a file-level computer data storage connected to a computer network providing data access to heterogeneous network clients".

ITU-EMCOL NAS allows SSH and FTP protocols for sake of security and can be accessed from any kind of OS (Windows, Linux, Unix, Mac OS X). Each MARMARA-DM member has been notified about his or her username or password. The procedure to connect to ITU-EMCOL NAS is described hereafter in terms of both SSH and FTP protocols. Username and password may be provided on request to the project coordinator Dr. Louis Geli (Louis.Geli@ifremer.fr).

4.2 Design of the future observatory Data Center / Data management and archiving system

To prepare the MARDEP Proposal, a preliminary, undisclosed study was made by Ocean Works Canada (www.oceanworks.com) to determine the main characteristics and costs of the data management and archiving system, based on the experience acquired for the Neptune Project (www.neptunecanada.ca). These characteristics are described in Deliverables D5.1, D5.2 and D5.3.

The Observatory Data Center (ODC) consists of the hardware and software elements required to sustain long term observatory operations and user interaction with the data. The ODC computer hardware includes a system server to host the Data Management and Archiving System (DMAS) software, database, and web applications. The DMAS is a scalable operational software system, which consists of two main components:

1) The Data Acquisition Framework (DAF) takes care of the interaction with instruments in terms of control, monitoring as well as data acquisition and storage. The framework also contains operation control tools. Those functions are typically run at the shore station. The other key element of the DAF is its archival function. The archival function gathers all the data produced by the various instruments and stores them either in the database for selected scalar values or in a structured file system for all other data.
2) The user interaction features (UIFs) include data search and retrieval, data distribution. Current developments in the Web 2.0 area will provide a complete research environment where users will have the ability to work and interact on-line with colleagues, process and visualize data, establish observation schedules and pre-program autonomous, event detection and reaction.

DMAS provides services that perform both user functions (such as data retrieval, data visualization, metadata discovery) and observatory operation support functions such as: observatory maintenance and management (monitor and control of junction boxes and instruments from a power point of view and monitor and control of instruments from a data flow point of view); science users interfacing; service segmentation (if special categories of instruments need to be isolated from one another for security reasons); system security (to prevent accidental damage to the infrastructure and limit malevolent activities); etc.

User access control and monitoring for such large infrastructure is an important requirement. Control will help prevent accidental damage to the infrastructure and limit malevolent activities. Monitoring/auditing will allow the managers of the system and their stakeholders to see how much the system is being used and how. The cost of the infrastructure and its public nature, the need to provide as much as possible an uninterrupted service (in e.g., a response to a service level agreement) impose the set up of a controlled access policy and of its enforcement. Control will take the form of the determination of who is allowed to do what on the system through the definition of roles. Monitoring of the activities will serve purposes of understanding changes that have occurred in the system configuration and their impact but also will help demonstrate to funding agencies and sponsors how much the facility is being used and for what purposes. Monitoring will therefore require auditing changes to the infrastructure configuration and activity recording. A typical implementation of the control and monitoring can be done through the definition of accounts, groups of users as well as privileges that can be granted or revoked.

5. Project Management

Note : The approximate costs are not given here, because the final, exact costs will be stated in the partners management report.

Expected Men-Month

	Researcher		Engineer		Technician		Post-Doc		Ph. D.		SUM	
	TC	EC	TC	EC	TC	EC	TC	EC	TC	EC	TC	EC
ITU	39	0	18	12	20		16		36	24	87	36
DEU	24		18		18		36	0	72	0	168	0
Ifremer	16	0	12	6	12	6	18	0	72	0	130	12
CNRS	33				0		26	18			59	18
INGV	33		3		15		24				75	0
ISMAR	16	0	0	0	10	0	22	22	0	0	48	22
TOTAL	161	0	51	18	75	6	142	40	180	24	567	88

Man-Month DISTRIBUTION BY WP, 1st Reporting period (April 1st, 2008 - Sept 30th, 2008)

	WP1		WP2		WP3		WP4		WP5		WP6		TOTAL	
	1st P.	Total	1st P.	Total	1st P.	Total	1st P.	Total	1st P.	Total	1st P.	Total	Total 1st	Total Expected
ITU	1,5	12	0,5	15	1,5	8	0	10	0	10	3,5	36	7	91
DEU	0	0	9	60	0	72	0	14	0	10	9	12	18	168
Ifremer	14,5	36	12	42	2	16	0	14	0	8	1	12	29,5	128
CNRS	5	30		7	0,5	10	0	8	0	0	1,5	3	7	58
INGV	0	4	12	30	0	15	0	12	0	7	1	7	13	75
ISMAR	2	8	0,5	12	0	12	0	10	0	1	0,5	4	3	47
Total	23	90	34	166	4	133	0	68	0	36	16,5	74	77,5	567
													77,5	

Man-Month DISTRIBUTION BY WP, 2nd reporting period (Oct 1st , 2008 - May 30th, 2009)

	WP1		WP2		WP3		WP4		WP5		WP6		TOTAL		
	2nd P.	Total	2nd P.	Total	2nd P.s	Total	2nd P.	Total	2nd P.	Total	2nd P.	Total	Total 2nd	Total 1st+2nd	Total Expected
ITU	0	12	1,5	15	1,5	8	14	10	0	10	8	36	25	32	91
DEU	0	0	4	60	0	72	10,5	14	0	10	0,5	12	15	33	168
Ifremer	2	36	9,3	42	2	16	1	14	0	8	2	12	16,3	45,8	128
CNRS	4	30	1,5	7	0	10	7	8	0	0	0,5	3	13	20	58
INGV	0,5	4	6	30	0	15	0	12	0	7	0	7	6,5	19,5	75
ISMAR	0	8	2	12	0	12	2	10	0	1	0	4	4	7	47
Total	6,5	90	24,3	166	3,5	133	34,5	68	0	36	11	74	79,8	157,3	567
													79,8		

Man-Month DISTRIBUTION BY WP, 3dd reporting period (June 1st, 2009 - January 31st, 2010)

	WP1		WP2		WP3		WP4		WP5		WP6		TOTAL		
	3rd P.	Total	3rd P.	Total	3rd P.s	Total	3rd P.	Total	3rd P.	Total	3rd P.	Total	Total 3rd	otal 1s+2ndt+3r	Total Expected
ITU	2,5	12	5,5	15	0,5	8	10,5	10	3	10	11,5	36	33,5	65,5	91
DEU	0	0	5,5	60	0,5	72	21	14	0	10	0,2	12	27,2	60,2	168
Ifremer	1	36	20	42	2	16	1	14	2	8	1	12	27	72,8	128
CNRS	4	30	4	7	1	10	3	8	0	0	0,5	3	12,5	32,5	58
INGV	3	4	24	30	1	15	0	12	0	7	0	7	28	47,5	75
ISMAR	0,5	8	12	12	2	12	1	10	0	1	0	4	15,5	22,5	47
Total	11	90	71	166	7	133	36,5	68	5	36	13,2	74	143,7	301	567
													143,7		

Man-Month DISTRIBUTION BY WP, 4th reporting period (February 1st, 2010 - Septmeber 30th, 2010)

	WP1		WP2		WP3		WP4		WP5		WP6		TOTAL		
	4th P.	Total	4th P.	Total	4th P.s	Total	4th P.	Total	4th P.	Total	4th P.	Total	Total 4th	al Total (1+2+3+	Total Expected
ITU	4	12	2,5	15	1	8	10	10	4	10	4	36	25,5	91	91
DEU	0	0	61,8	60	26	72	14	14	4	10	2	12	107,8	168	168
Ifremer	10	36	14	42	9	16	12	14	6,2	8	4	12	55,2	128	128
CNRS	12	30	3,5	7		10	5	8	5	0		3	25,5	58	58
INGV	0,5	4	4	30	10	15	5	12	4	7	4	7	27,5	75	75
ISMAR	4	8	13	12	2,5	12	3	10	1	1	1	4	24,5	47	47
Total	30,5	90	98,8	166	48,5	133	49	68	24,2	36	15	74	266	567	567

6. Results

6.1 Introduction

The major result of the Marmara-DM is to have collected important data to address the question on the predictability of earthquakes in the Istanbul area, one of the most exposed to earthquake hazards in Europe. The predictability of earthquakes is *per se* a subject that needs massive efforts and adapted, large-scale means concentrated on one well-studied seismic area, where the probability of occurrence is high. For many reasons, the Istanbul area is one of the most suitable areas for this purpose.

The first two reasons are well known: i) there is a high probability that an earthquake of $M_w > 7.0$ will strike within the next decades along the NAF in the Sea of Marmara, directly affecting the heavily populated Istanbul area; ii) the segment having the highest probability to rupture is relatively well determined (Fig. 6.1).

The two other reasons are less known, both result from recent findings :

1) Recent work has reported the observation of the nucleation phase of the *Mw 7.4* Izmit earthquake, which devastated part of northwestern Turkey in 1999, and the fact that this nucleation was accompanied by tremors at least 44 minutes before the main shock *[Bouchon et al, 2011]*.
2) Gas emissions were found in the water column near the surface expression of known active faults *[Géli et al, 2008]*. Based on geochemical analysis, it is shown that the NAF in the Sea of Marmara strikes across hydrocarbon gas reservoirs from the Thrace Basin gas province *[Bourry et al, 2009]*.

The first discovery is of fundamental importance, as the presence of very characteristics tremors during the nucleation phase of a large earthquake may yield direct information on the timing and location of the preparing rupture, before the earthquake strikes *[Bouchon et al, 2011]*. This clearly supports the imperious necessity to deploy ocean bottom seismometers close to the fault zone, most particularly close to the fault segment having the highest probability to rupture.

This discovery and the finding that gas reservoirs are connected to the fault zone opens new perspectives that were not even imaginable a few years ago, and supports the necessity to monitor gas emission activity along with seismicity. If seismic tremors are found to be associated with clear anomalies in gas emission activity, then we will have more criteria for characterizing and identifying the recorded signals as indicators that the probability of occurrence of an impending earthquake is increasing. In this respect, the work proposed is meant to improve the preparedness of the authorities in charge of civil protection.

Hence the concept: to improve the predictability of the next large earthquake in the Istanbul area, we propose to continuously collect geochemical and geophysical data from the immediate vicinity of the fault zone, most particularly by implementing permanent seafloor observatories in the Sea of Marmara and developing methods and tools for data processing, integration and analysis. The submarine stations deployed during the Marquake Project will provide high quality data from the close vicinity of the submerged fault, within the Sea of Marmara and benefit to the improvement of the ongoing early warning systems in the Istanbul area *[e. g. Oth et al, 2010]*.

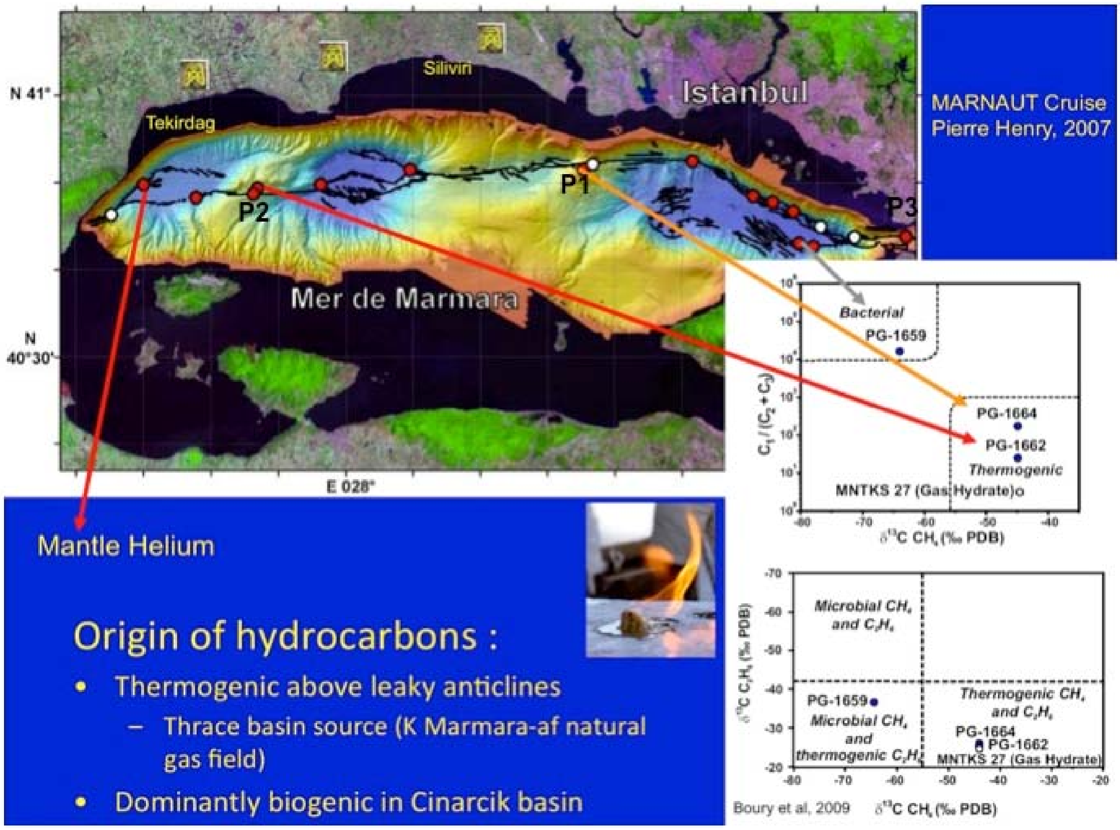


Fig.6.1 Map showing the most active northern branch of the North Anatolian Fault (NAF; black line), gas emission sites (red dots). The inset diagrams show the composition plots of gases showing the thermogenic and deep origin (Géli et al., 2008; Bourry et al., 2009). P1, P2 and P3 indicate potential sites that were identified for multi-disciplinary seafloor observatories during Marmara-DM Demonstration Mission of Esonet.

6.2 Relations with fluids and gas emissions

In the Gulf of Izmit, repeated surveys showed that the intensity of methane emissions increased after the August 17, 1999 earthquake *[Alpar, 2000 ; Kuscu et al, 2005]*. In the deeper parts, cold seeps and the associated manifestations, such as carbonate crusts, black patches, and bacterial mats, are present along the fault *[Armijo et al, 2005]*. Based on the results of the Marmara-DM project, a systematic correlation was also found between active faulting and the acoustically detected gas escapes (cf Deliverable D4.4). Geochemical analysis of gases and fluid flux rates through the Marmara seafloor using flowmeters and osmo-samplers were performed during Marmara-DM, within work packages 1 (cf D1.2 and D1.3, respectively). This segment is the most dangerous, as it is the only one that did not rupture since at least 1766. Thermogenic hydrocarbons having the same geochemical signature as those from the Thrace Basin have been found on top of anticline structures (cf Deliverable D1.3), suggesting that the North Anatolian Fault cross-cuts gas reservoirs from the southern continuation of the Thrace Basin gas field *[Bourry et al, 2009]*.

Cold seeps are often observed in association with active faults [e.g. *Moore et al., 1990 ; Henry et al., 2002*]. Furthermore, gas expulsion from pockmarks is also reported to occur in such submarine zones in relation to the occurrence of earthquakes. This has lead the scientific community to hypothesize that at least some of these faults channel fluids from deep levels within the sediments and, possibly, from the seismogenic zone. Coupling between deformation, pore pressure transients, and fluid flow may lead to post seismic fluid release, precursor events, and/or systematic variations of flow rates, fluid chemistry and pore pressure during inter-seismic phases. In addition, gas bubbles in the water are very easy to detect via acoustic methods. Hence, a major challenge addressed within the Marmara-DM was is to determine whether gas can generate **detectable** signals related to the stress building process during the seismic cycle, an issue related to detection of precursory signals before an earthquake, and therefore of direct societal importance. This issue is widely discussed in Deliverable D4.3, which consists in a report to test working hypothesis and to validate the concept of seafloor observatories.

6.3 Dataset used in the Marmara-DM project

The results of the Marmara-DM are based on the data collected during the 6 following cruises, which were conducted within Work Package 2:

- 2 Cruises with R/V Le Suroit of Ifremer, from november 4th to december 14th, 2009. The first for acoustic detection of gas emissions, AUV microbathymetry and seabottom deployment of BOB (acoustic gas bubble detector); the second cuise for high resolution, 3D seismic site survey on the Western High.
- 2 cruises with R/V Urania (Italy) in september 2009 and september 2010, for deploying and recovering the multiparameter sea-bottom observatory SN-4 of INGV at the entrance of the Gulf of Izmit, together with autonomous OBSs and piezometers from Ifremer.
- 2 cruises with Turkish vessels, respectively R/V Yunuz (from ITU) and R/V Piri Reis (from DEU) were respectively conducted in march 2010 to recover and redeploy SN-4 and to recover the Ifremer instruments and in june 2010 to collect additional high resolution, 2D seismic profiles to complete the different site surveys.

In addition, data and samples acquired in 2007 with R/V L'Atalante and manned submersible Nautile during Marnaut cruise were included in the Marmara-DM data set. These included echo-sounder data, analysis of interstitial water and gas composition and deployments of flow meters, piezometers and of a mini OBS network.

6.4 Best site selection (D4.4)

Three sites are identified as priorities for the future multi-parameters sea-floor observatories (Fig. 6.1):

- 1) The Istanbul-Silivri segment, in the seismic gap immediately south of Istanbul
- 2) The Western High / Gas Hydrates area.
- 3) Entrance of Izmit Gulf.

It is important to note that the detection of transient crustal events now appears as a scientific objective *per se*. The identification of seismic tremors and low frequency earthquakes –and of their relation with episodic "silent" slip– has been progressing very rapidly, first at subduction zones [e.g. *Shelly et al., 2006*], and now at strike-slip faults [*Nadeau and Dolenc, 2009; Bouchon et al., 2011*]. These progresses lead to consider the identification of slipping zones on the edges of seismic gaps or at the upper/lower limits of the seismogenic zone, as the next objectives to be achieved in the SoM. Work performed on Marmara-DM data met difficulties in the precise determination of the depth of offshore earthquakes and in the identification of tremors from noise analysis in the marine environment. Emphasis could now be given to focused, small-scale networks and to the identification of repeating earthquakes. Repeating earthquakes were recognized in the Central Basin area, which appears as an hypothetical nucleation site for a rupture on the Istanbul-Silivri segment. The gas hydrate site is remarkable as the only site next to the main fault where a relatively deep source is recognized for both interstitial water and hydrocarbons. The ideal monitoring network at Site 2 should span the Central Basin and the gas hydrates area on the western high.

6.5 Concept

Based on the Marmara-DM results, the MARDEP project is to be proposed to the Turkish authorities in June 2011 (Deliverable D6.1). The concept behind the MARDEP project is to improve earthquake predictability by combining microseismic monitoring (including the search for tremors) and fluid emission monitoring (including gas released in the water column).

- The tremor-like signal that was recently documented by *[Bouchon et al, 2011]* prior to the Izmit earthquake shows the existence for that earthquake of a nucleation phase which is both detectable and identifiable. The search of seismic tremors in the Istanbul area is hence a challenge of dramatic importance, which requires not only the collection of seismological data from the near vicinity of the fault, but also the development of specific methods, including the precise, real-time location and characterization of events and the real-time identification of tremors. We still must learn on these tremors. The context in which they occur needs to be analyzed and understood, in order to draw general conclusions on their capacity to provide clear indications on the occurrence of an impending earthquake.

• The fact that emissions of thermogenic gases, and, in some places, hydrocarbon seepages have been found on the seafloor in the close vicinity of the main fault, within the fault valley or on top of neighbouring anticlines, clearly indicates that there is a direct connexion between the sediment surface and the hydrocarbon reservoirs at depth. In addition, high-resolution 3D seismic data reveal a 300 meters wide, chimney-like conduit, rising from below the Western High, up to the site where gas hydrates were sampled at the sea surface. The existence of this structure, located less than 600 m away from the main fault suggest that shear movement along the fault perturbs the hydrogeological system, likely affecting the precarious equilibrium of over-pressured units, and thereby allowing fluids to be flushed along the fault pathway.

More generally, focused fluid expulsion structures (such as vent complexes, pockmarks and mud volcanoes) are often associated with faults in various geological settings. To explain these observations, it has been proposed that the critical fluid pressure required to induce sediment deformation is reduced when strike-slip faulting is active [*Mazzini et al, 2009*]. Fluid expulsion then occurs when overpressure at depth is sufficient to fracture the overburden sedimentary units [e.g. *Kopf, 2002* and references therein]. When a threshold is reached due to continuous generation of fluids (e.g. water, hydrocarbons, gas) at depth, a system of fractures propagates towards the surface breaching the seal.

Inversely, one can reasonably expect that when the total stress approaches the failure strength immediately prior to an earthquake (reaching 90 to 95 % of the yield stress), the critical overpressure to fracture the overburden layers is reduced, causing fluids to escape along the fault. We hypothesize that the intensity of thermogenic hydrocarbon emission is related to the coulomb stress on the fault, and that information of fault criticality, and hence earthquake probability, could be derived from long-term records. On a shorter time-scale, observation of precursory fluid emissions during earthquake nucleation would presumably require interaction between the slipping patch and the fluid reservoir or conduit. Coupled seismological and fluid monitoring would be needed to detect such events.

6.6 Design of future Multi-Disciplinary Seafloor Observatories (MDSOs)

- At sites 1 and 2 (both located on anticlines where numerous sites of gas emissions of thermogenic origin were found), the shore station will be cabled to one node, itself connected to four junctions boxes : one on each side of the fault (JBN and JBS), one to the east (JBE) and one to the west (JBW) of Central High. Junction boxes will have the same requirements[1] as those produced by Oceanworks[2] (Canada), the provider of the Neptune Project[3], allowing the connexion of 10 instrument packages each (Table 1). At JBE and JBW, we will deploy, respectively: an array of 4 seismometers, at distances < 500 from the junction box; one piezometer, one BOB, one methane

[1] ***Junction Box Requirements***
Depth requirements : 200, 450,700m
Maximum power : 1800W
Input voltage : 375VDC (nominal)
Input data interface : 100 BaseTX
Number of ports : 8 science, 2 expansion/high power
Science power interface : software configurable 12, 15, 24VDC at 75W
Science data interface : ideally RS232/485 and Ethernet ports on same connector
Expansion port : 375VDC at 1800W, 100BaseTX (allows connection of high power instrument system or another junction box for expansion)
Monitoring capabilities : voltage, current, ground fault (internal and science interfaces)
Science control/monitoring : fully integrated, secure operator web interface ; disconnect breakers for each Science port Operating distance from Node : 70m without additional media converter modules.

[2] *http://www.oceanworks.com/*
[3] *http://www.neptunecanada.ca/*

sensor. At JBN and JBS, we will deploy 2 OBSs, 3 distance meters, one BOB, one methane sensor, one piezometer. Clusters of seismometers will allow the ultra-precise characterization of earthquakes near the fault zone, using array-based methods for hypocenter determination.

- At site 3, one junction box, directly cabled to the shore station, will be sufficient to meet the project requirements, due to the proxility to the shore.

A significant research effort has been made during Marmara-DM for developing innovative sensors for monitoring variations in the geochemical and geophysical properties of gas emissions:

- *Pore-pressure sensors.* The piezometer we propose to use is a free-fall device with a 15-m long sediment-piercing lance equipped with sensors for measuring the differential pore pressure at 5 different depths (< 15 m) below the seafloor. This device has been shown to be very powerful for detecting and monitoring episodes of free gas accumulation and release in surficial sediments [Sultan et al, 2010, in review].
- *Gas-bubble monitoring.* We will use standard and well known acoustic technology, such as high directivity single beam or multibeam echo-sounders, to map and quantify gas bubbles emissions from the seafloor and monitor their temporal variability *[Greinert, 2008]*. These echo-sounders are ideally combined with 70 to 300 KHz ADCPs systems to identify different seeps in the data sets and to determine the horizontal and vertical velocity of the bubbles.
- *Methane sensor.* Based on one-year long tests performed by INGV for measuring variations in methane concentrations in the Gulf of Izmit, we will use the methane sensor METS developed by the German FRAMATECH company, which has provided satisfactory results.
- *Distance meters network:* an array of 6 geodetic stations to monitor displacements along the active fault, in order to determine the fault behaviour with regard to the existence (or not) of a creep component and the accumulation of elastic deformation before faulting, a critical, first order information.
- Arrays of Broadband Ocean Bottom Seismometers ((BB-OBS)[4] having bandwith of 0.03 - 30 Hz. In order to improve real-time event localization (within less than a few hundreds of meters), we will deploy an array of 4 seismometers –spaced by ~ 500 m) connected to each junction box.

Connectors	*Supplier*	*Availability of instrument/ Manufacturer*	*Interface*	*Power (Approx)*
1	*OBS*	*Guralp*	*RS-232*	*< 10 W*
2	*Piezometer*	*NKE*	*RS-232*	*< 10 W*
3	*BOB (Bubble Observatory)*	*Ifremer*	*100BaseTX*	*< 10 W*
4	*Methane sensor*	*FRAMATECH*	*RS-232*	*< 10 W*
5	*Accelerometer*	*On-the-shelf*	*RS-232*	*< 10 W*
6	*Absolute Bottom Pressure Recorder*	*Paroscientific*	*RS-232*	*< 10 W*
7	*CTD/Oxygen/Turbidity*	*On-the-shelf*	*RS-232*	*< 10 W*
8	*Current meter / ADCP*	*On-the-shelf*	*RS-232*	*< 10 W*
9	*Time Lapse Camera*	*On-the-shelf*	*100BaseTX*	*< 10 W*
10	*Strong Motion Accelerometer*			
11	*Distance Meter*	*Sonardyne*	*RS-232*	*< 10 W*

Table 3.1: List of the 11 sensor packages tested during EC-funded programmes, e.g.: the ESONET NoE Programme (for slots 1 to 10) and ASSEM (for slot 11).

[4] *There are two leading manufactures of BB sensors used in Ocean Bottom Seismology: Guralp (www.guralp.com) and Kinemetrics (www.kinemetrics.com).*

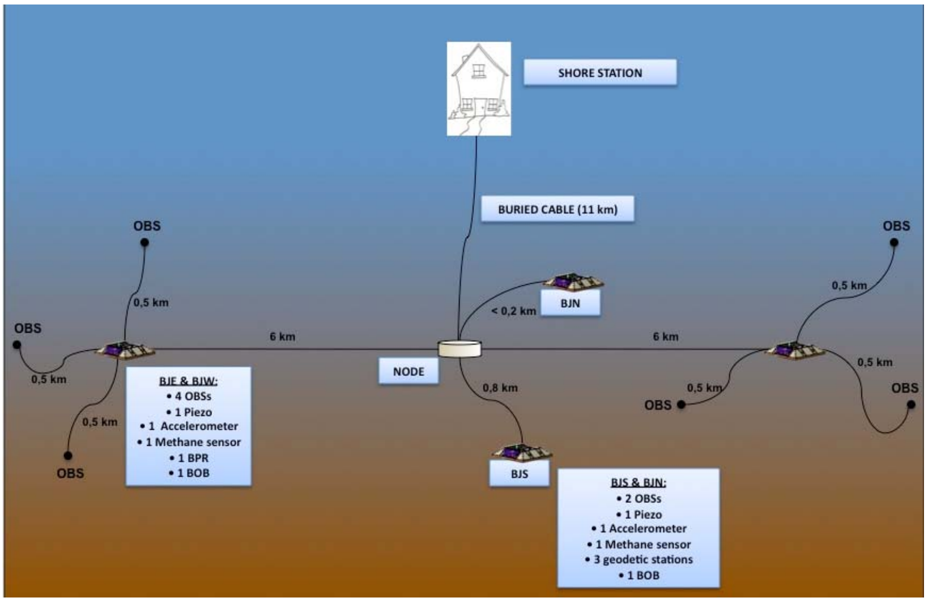


Fig. 3.4: Example of ideal multi-parameter seafloor observatory of TYPE I. The shore station should be cabled to one node, itself ideally connected to four junctions boxes : one on each side of the fault (JBN and JBS), one to the east (JBE) and one to the west (JBW). Clusters of seismometers will allow the ultra-precise characterization of earthquakes using array-based methods for hypocenter determination. The cable between the node and the land stations will be deeply buried. The cables from the node to the JBs will be deployed on the seafloor using Remote Operated Vehicles (ROVs).

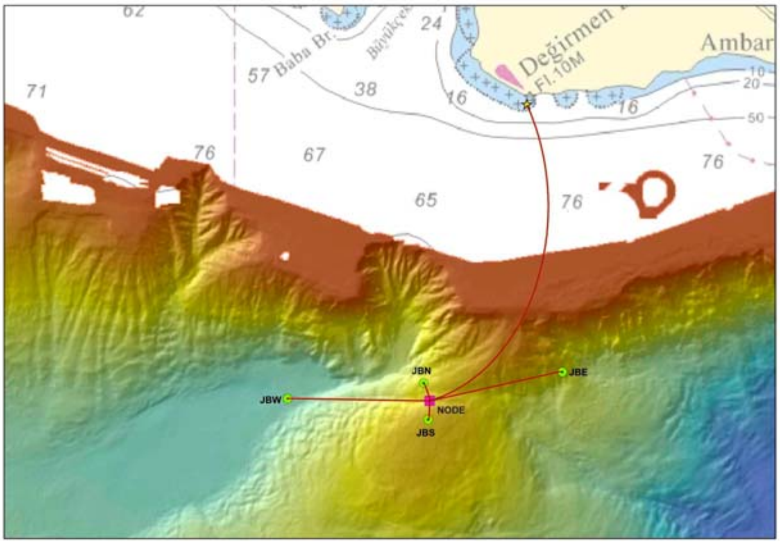


Fig. 6.3: Detailed set up of the multi-disciplinary observatory, example given for site1, located south of Istanbul on the Silivri-İstanbul segmen), with the cable routes and nodes south and north of the fault. Juction Boxes North and South are shown (black squares). Thecable is located near, but outside the anchoring area.

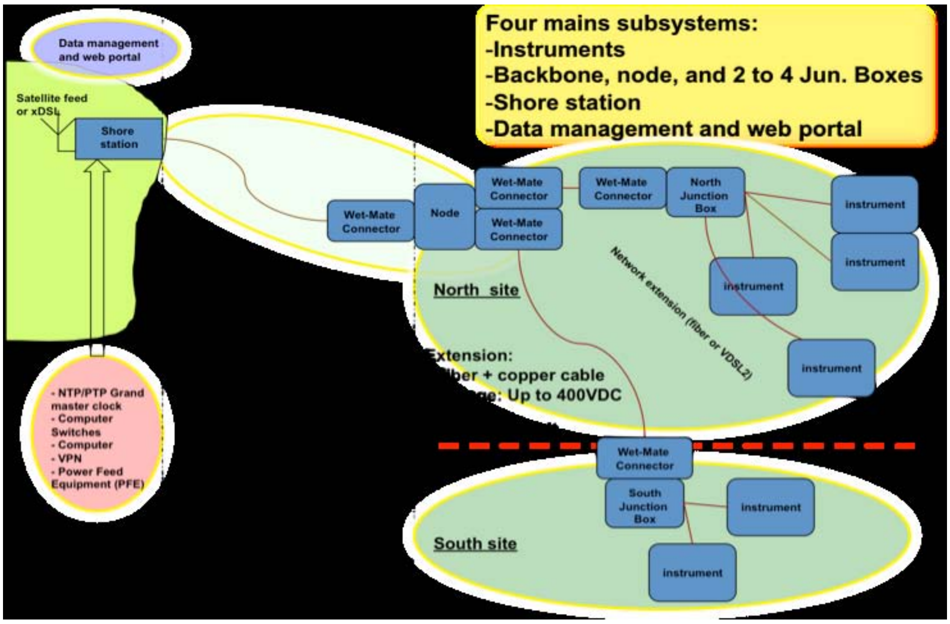


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Fig. 4d : Design of the modular seafloor observatory, based on the study perfomed during the Esonet/Marmara-DM Demonstration mission.

6.7 Autonomous, mobile seafloor equipments to enhance the multi-parameter approach

Additional geophysical and geochemical time series from autonomous, mobile seafloor instruments are critically needed for at least two reasons :

- the installation of a permanent multidisciplinary seafloor observatory will take time (~ 36 to 40 months) ; hence, it is necessary to collect data from the very beginning of the project, in order to start the work on data processing and analysis as early as possible;
- data from other sites are required, in order to assess the background variability of gas emissions and improve our ability to identify and detect anomalous variations.

Some physical parameters are relatively well understood, like seismicity in relation with fault creeping. Other parameters (e. g. sediment pore pressure or gas bubble acoustic response) require further research. Additional time series are needed to evaluate the real significance of each gas emission anomaly and its relevance to earthquake occurrence.

These general statements are illustrated by the results obtained by INGV with SN-4 SN-4 (the multi-parameter, autonomous seafloor observatory developed by INGV, Italy), which was deployed at the entrance of the Gulf of Izmit between october 2009 and march 2010 (Figures 6 and 7) :

- the Broad-Band OBS recorded very long period (~3 hours) signals on the vertical component, appearing like an arch, with an episode of rising seafloor and then an episode of dropping seafloor suggesting return to equilibrium (Fig. 6). Simultaneously, high amplitude, long period signals (up to 30 seconds) are visible on horizontal components. Such signals often occur on the vertical component (Fig. 7a, b, c). The very long period (~3 hours) signals on the vertical component appear associated with very strong amplitude, non-seismic micro-events of short-duration (< 3 s) and high-frequency (20 Hz) (Fig. 7).

- The very long period (~3 hours) signals apparently occur simultaneously with the following sequence: temperature drop, methane peak oxygen decrease, turbidity variation and "short duration, gas outburst signal" (Fig. 6). No apparent correlation exists between the local seismicity occurrence and physico-chemical parameters trend (e.g Methane peaks).

These data are encouraging, but long-term observations and further research are needed to confirm the causality link between the two observations: are the observed methane pulses «significant»? In other words: do methane pulses occur randomly or preferentially prior to earthquakes? What are the characteristics of these earthquakes (exact location, magnitude)? What is the optimal duration of the time windows for the short and long term averages of methane concentration?

The above example clearly shows that for each measured parameters, data processing and research on the physics of the phenomena are intimately related. The better our understanding on the physics, the better our ability to determine the appropriate criteria for data processing, such as, for instance, the time durations for the short and long term average analysis.

At each site (P1, P2 and P3), it is recommended to deploy autonomous equipments, including SN-4 (the autonomous, multi-parameter observatory developed by INGV), additional seismometers, piezometers, and acoustic bubble detector. Detailed site surveys have already been carried out during the ESONET/Marmara-DM demonstration mission. The geological structures and the hydro-geological system are thus well known, as well as the exact position of the instruments at each site.

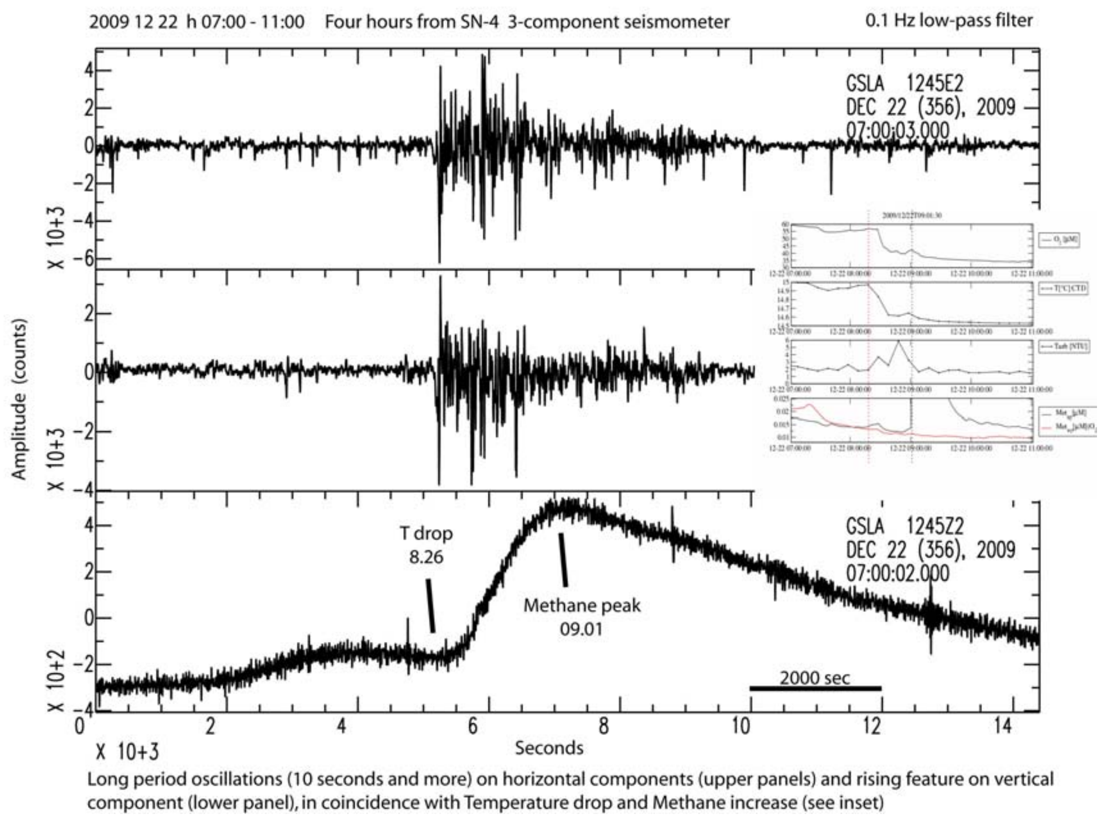

Fig. 6 : Figure summarizing the observations on SN-4 (courtesy of Francesco Frugoni and colleagues, INGV) : very long period (~3 hours) signals are observed on the vertical component, appearing like an arch, with an episode of rising seafloor and then an episode of dropping seafloor suggesting return to equilibrium. Simultaneously, high amplitude, long period signals (up to 30 seconds) are visible on horizontal components during the rising phase of the vertical component. Short-duration (< 3 s), high-frequency (20 Hz), events, are also recorded during the rising phase. Based on other experience from the Sea of Marmara (Ph. D. work of JB Tary), these events are interpreted as gas outbursts from the upper, gassy, sediment layers. Inset shows that the very long period (~3 hours) signals apparently occur simultaneously with temperature drop, methane peak oxygen decrease and turbidity variation.

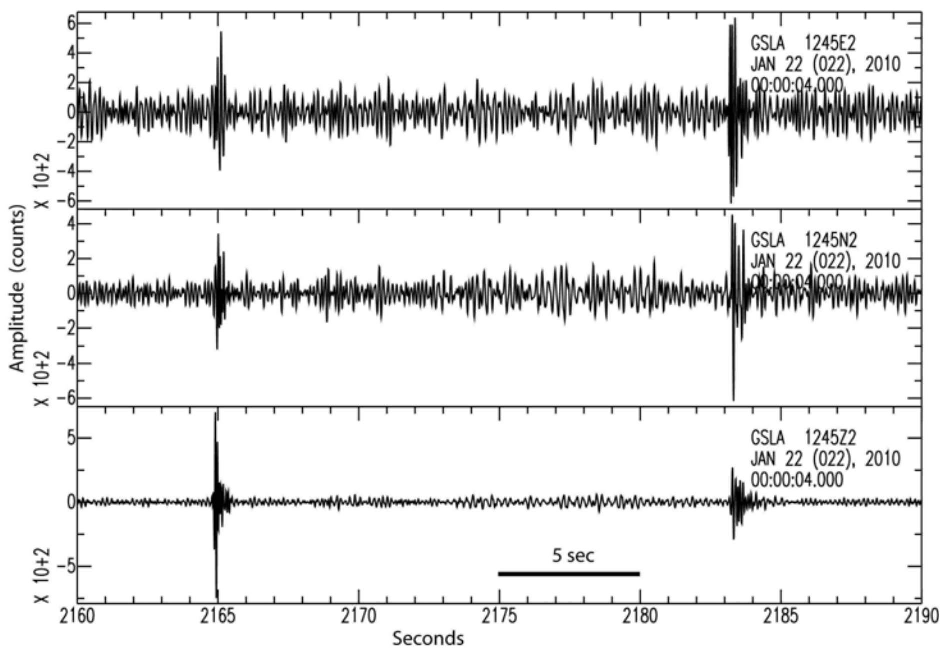

Fig.7a Example of 2 short duration events recorded on the BB-OBS (Guralp CGM-3). Signals band-pass filtered 4-20 Hz. Courtesy Frugoni and INGV colleagues.

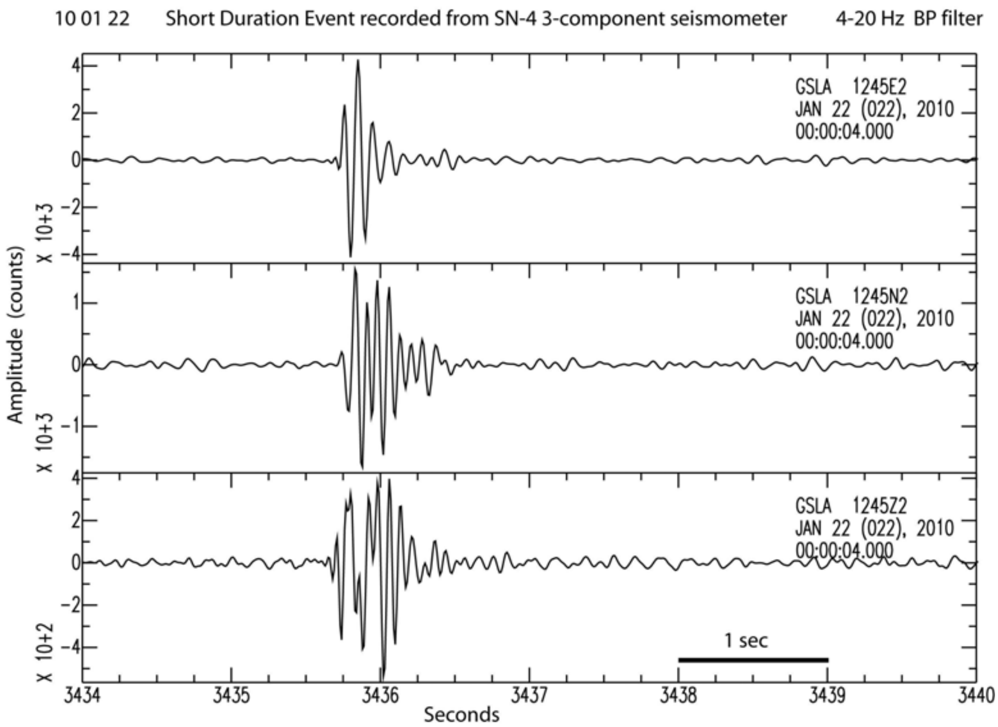

Fig. 7b : Zoom on one short-duration event recorded on the BB-OBS Guralp CGM-3 installed on SN-4. Signal is band-pass filtered [4-20] Hz. The upper plot represents the vertical component. Courtesy of Francesco Frugoni and colleagues, INGV.

6.12 Outreach and communication

During the 30 months of the Marmara-DM project several activities were carried out in Turkey to obtain funding for the establishment of seafloor observatories in the Sea of Marmara. For this, first we increased the visibility of the ESONET and EMSO projects' activities in the Sea of Marmara by special presentations in scientific meetings and by organizing an ESONET training course and a symposium in August 2009 (Deliverable D6.3). A public conference gathering the principal mass media in Turkey was held at the French General Consultate in Istanbul on December 15th, 2009. A public project website is now hosted at the Istanbul Technical University (Deliverable D6.2).

Second, we held meetings of Turkish institutions of marine and geohazard studies to reach a consensus on the establishment of the seafloor observatories and agree on a project proposal to obtain funding from the Turkish authorities, under the acronym "*MARDEP"(Marmara Seafloor Observatory Infrastructure for Earthquake and Environmental Research and Modeling)*. This proposal was ready to be submitted to the Turkish authorities (initially TUBITAK) by June 2010 (Deliverable D6.1). However, the submittal was postponed, to be submitted for funding to the Prime Ministry of Turkey State Planning Department's (DPT) call that will be either in April or June 2011.

The *MARDEP project* is designed as a national project with participation of all concerned marine institutions, as well as the Turkish Geological Survey (MTA), Undersecretariat for Maritime Affairs, Department of Hydrography Navigation Oceanography (SHOD), Istanbul Metropolitan Municipality (IBB), and Coast Guards General Command in the meetings. The Istanbul Metropolitan Municipality will be a user of the MARDEP project (see Annex 2). MTA (Mineral Research and Exploration General Directorate: Turkish Geological Survey) also strongly supports the project (Annex 3) If funded, we plan the completion of the infrastructure by 2014, and thereafter start its operation as regional department of the EMSO science infrastructure. In Turkey there are 11 stakeholders in the MARDEP proposal including the MTA (Turkish Geological Survey), Istanbul Municipality, and all Marine Sciences Institutes. The European partners include: IFREMER, CNRS, INGV and ISMAR, (French EMSO and Italian EMSO) all providing support letters (Annexes 4 and 5). Furthermore the ESONET and EMSO partners of the Marmara node applied to a recent EC FP 7 call: ENV.2011.1.3.1-1: Towards real-time earthquake risk reduction with a proposal: "MARQUAKE: Earthquake Predictability in the Sea of Marmara areas" in November, 2010.

The details of the activities concerning fund raising and preparation of the *MARDEP project* are extensively described in D6.1 The Sea of Marmara Node group (ITU, AFAD, IFREMER, CEREGE, ISMAR, DEU-IMST) also applied on 16 November 2010 to call ENV.2011.1.3.1-1 Towards real-time earthquake risk reduction with the MARQUAKE: Earthquake Predictability in the Sea of Marmara areas proposal.

6.13 List of publications resulting from the MARMARA-DM project

Peer Reviewed, International Journals

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7. Conclusion and perspectives

The Marmara Demonstration Mission (april 2008 to september 2010) was conducted within the EU-funded ESONET Network of Excellence programme: i) to characterize the temporal and spatial relations between fluid expulsion, fluid chemistry and seismic activity in the SoM ; ii) to test the relevance of permanent seafloor observatories for an innovative monitoring of earthquake related hazards, appropriate to the Marmara Sea specific environment ; and iii) to conduct a feasibility study to optimize the submarine infrastructure options (fiber optic cable, buoys with a wireless meshed network, autonomous mobile stations with wireless messenger). A total of 6 cruises were conducted, allowing the selection of the optimum sites for the future multi-parameters sea-floor observatories: i) on the Istanbul-Silivri segment, located in the seismic gap immediately south of Istanbul where intense bubbling is observed; ii) on the Western High, where gas hydrates, oil and gas seeps from the Thrace Basin were found; and iii) at the entrance of Izmit Gulf near the western end of the surface rupture associated with the 1999 Izmit earthquake. A significant research effort has also been made during Marmara-DM for testing innovative sensors for monitoring variations in the geochemical and geophysical properties of gas emissions.

The conclusions of the Marmara-DM project were used to build a full implementation plan, submitted to two funding agencies as 2 different proposals, respectively MARQUAKE and MARDEP:

- the MARQUAKE Proposal was submitted on november, 16th, 2010, to the FP7 Cooperation Work Programme 2011for Environment, Sub-Activity 6.1.3 « Natural Hazards », Area 6.1.3.1 « Hazard assessment, triggering factors and forecasting », Topic ENV.2011.1.3.1-1 « Towards real-time earthquake risk reduction ». Partners re : Ifremer (coodinator), ITU, AFAD, Ismar-CNR, CNRS and DEU. This proposal (see appendix in deliverable D5.3) received a mark of 10 out of 15, the negociation phase is still pending.
- The MARDEP Proposal will be submitted in june 2011 to the Disaster and Emergency Management Presidency (AFAD) of the Republic of Turkey (see Deliverable 6.1).

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