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**

Annex Deliverable D45c
MARMARA Demonstration Mission

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

Start date of the Demonstration Mission: **April 2008** Duration: **30 months**

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PP	Restricted to other programme participants (including the Commission Services	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
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CONTENT

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ESONET MARMARA-DM PROJECT

Deliverable 1.1: Report on Piezometer and OBS results

Due date of deliverable: September 2010
Actual submission date: September 2010

Start date of project: **April, 1st 2007** Duration: **30 months**

Organisation name of lead contractor for this deliverable: CNRS/CEREGE
Lead authors for this deliverable: Pierre Henry

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Executive summary

Acoustic surveys carried out in the Sea of Marmara in 2007 and 2009 have revealed numerous sites of gas emissions on the slope bordering the Tekirdag Basin to the west, suggesting that gas from the Thrace Basin reservoir is presently leaking into the water column.

In addition, high resolution, seismic data collected with the sediment penetrator (3.5 kHz) during the Marmesonet cruise of R/V Le Suroit (from october 4th to december 14th, 2009), reveal the ubiquitous occurrence of gas in the sub-surface sediments covering the Marmara seafloor.

The present deliverable thus includes **two case studies** :

- For the **first case study**, focus was given to the relation between the micro-seismicity and other observations we had from the seafloor, most particularly: fluid sampling and analysis (performed by Pete Burnard and Sylvain Bourlange, from CRPG, Nancy, using samples collected in 2007 during the MarNaut cruise) and detailed micro-bathymetry (based on AUV data collected in 2009 during the Marmesonet cruise). After this work, there is now little doubt 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., 2011] ».*

- For the **second case study**, we decided to focus 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 unprecedented 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.

Submarine degassing processes may be either natural (continuous exploration efforts and progress in multi-beam sonar techniques in the recent years have shown that natural seafloor degassing is a wide spread phenomenon), either artificial resulting from human activities (e. g. sediment destabilization related to oil exploration, pipe leaking, etc). Whether natural or artificial, degassing processes require a number of generic tools for their detection and monitoring, a subject of critical importance for mitigating gas-related geohazards. However, the pre-requisite -prior to any step forward- is to gain more and more experience on the natural, background degassing activity in a variety of environments.

1. Case study 1 :

Tary, J.-B., **Géli, L.,** Henry, P., Natalin, B., Gasperini, L., Comoglu, M., Cagatay, N., & Bardainne, T., (2011), « Sea-bottom observations from the western escarpment of the Sea of Marmara », *Bull. Seism. Soc. Am.*, Vol. 101, No. 2, doi: 10.1785/0120100014, April 2011

Free copy can be downloaded on :
http://wwz.ifremer.fr/drogm/Presentation-GM/Pages-perso/Louis-Geli/Publications

2. Case Study 2 : Non-seismic micro-events observed on OBS recordings from the Sea of Marmara

Besides micro-earthquakes, the OBSs deployed during the MarNaut cruise recorded numerous non-seismic micro-events. These micro-events are very common on OBS recordings [*Buskirk et al.,* 1981; *Diaz et al.,* 2007], but generally not detected by the procedure described earlier for micro-earthquakes, as they are most of the time not recorded by more than one station. Micro-events differ from micro-earthquakes by several aspects (Fig. 1 and 2).

Micro-events have short durations of less than 0.8 s, a monochromatic frequency content between 5 and 30 Hz, and highly variable amplitudes (0.5-50 µm/s). Even though micro-earthquakes amplitudes are in the same range, they have a richest frequency spectrum and longer durations (3 s-few minutes). In addition, earthquakes are composed by different waves (P-wave, S-wave, surface waves…) while micro-events show only one arrival. Finally, while micro-earthquakes are well recorded by the hydrophones, micro-events are visible only on those hydrophones that are close enough to the sediment/water interface (<0.9 m).

Based on OBS recordings in various geologic contexts, *Buskirk et al.* [1981] and *Diaz et al.* [2007] proposed two explanations for the origin of the observed micro-events. Following the observations of micro-events distribution with depth, which could mimics the repartition of biomass in oceans, and observations of eggs of unknown biologic organism fixed on the frame of several instruments, *Buskirk et al.* [1981] proposed that micro-events could be produced by some living organisms "bumping" the instruments.

On the other hand, following the fluid-filled cracks modeling of *Chouet* [1988, 1996], *Diaz et al.* [2007] suggested that micro-events could be produced by pressure transients involving the resonance of fluid-filled cracks.

We propose that gas emissions on the seafloor through fractures, pre-existent or not, are likely the source of the micro-events.

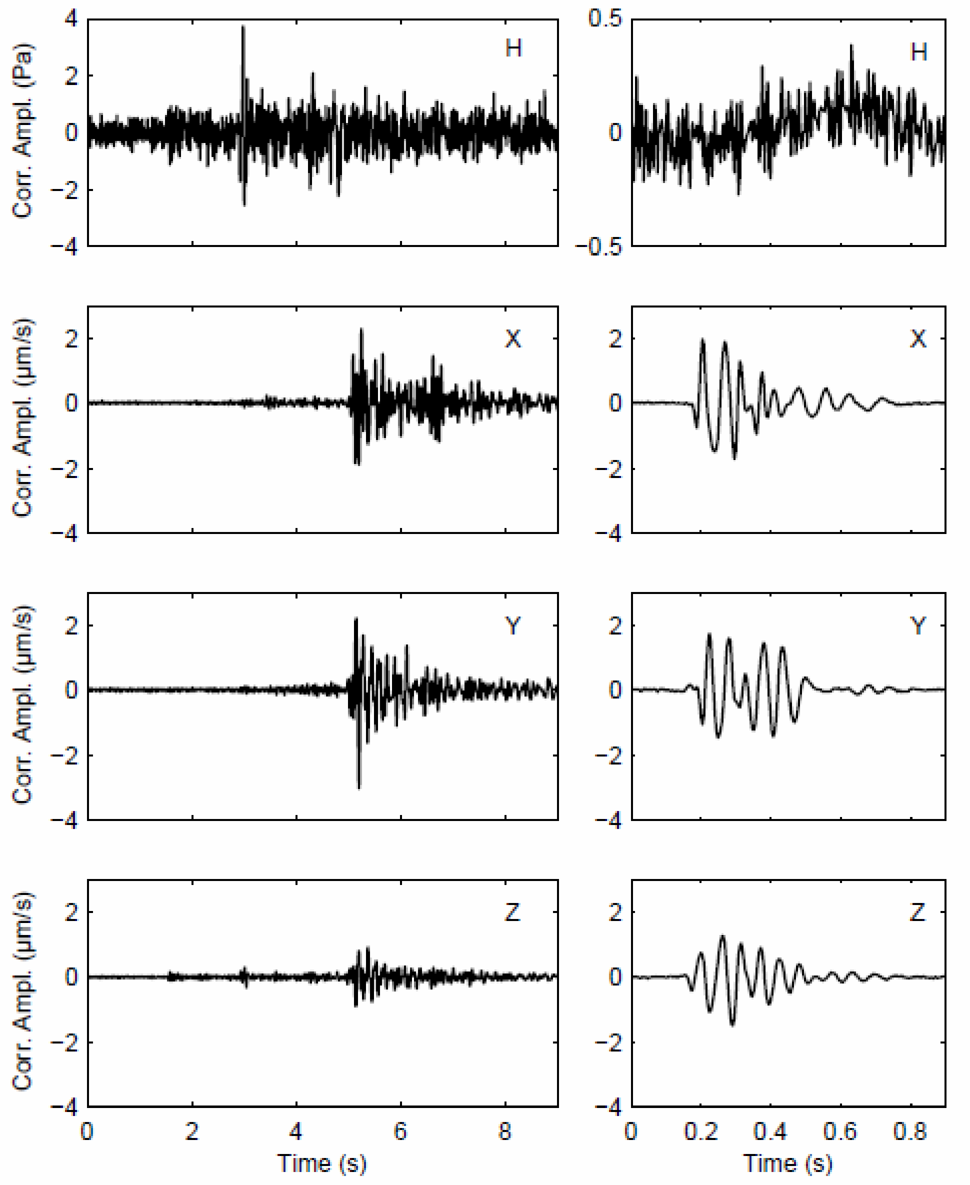

Fig. 1 OBS M recordings (H: hydrophone, X and Y: geophone horizontal components, Z: geophone vertical component), showing a micro-earthquake (M_w 1.98, May 14, 2007, 22:23:32) on the left and a micro-event on the right (May 14, 2007, 14:01:57).

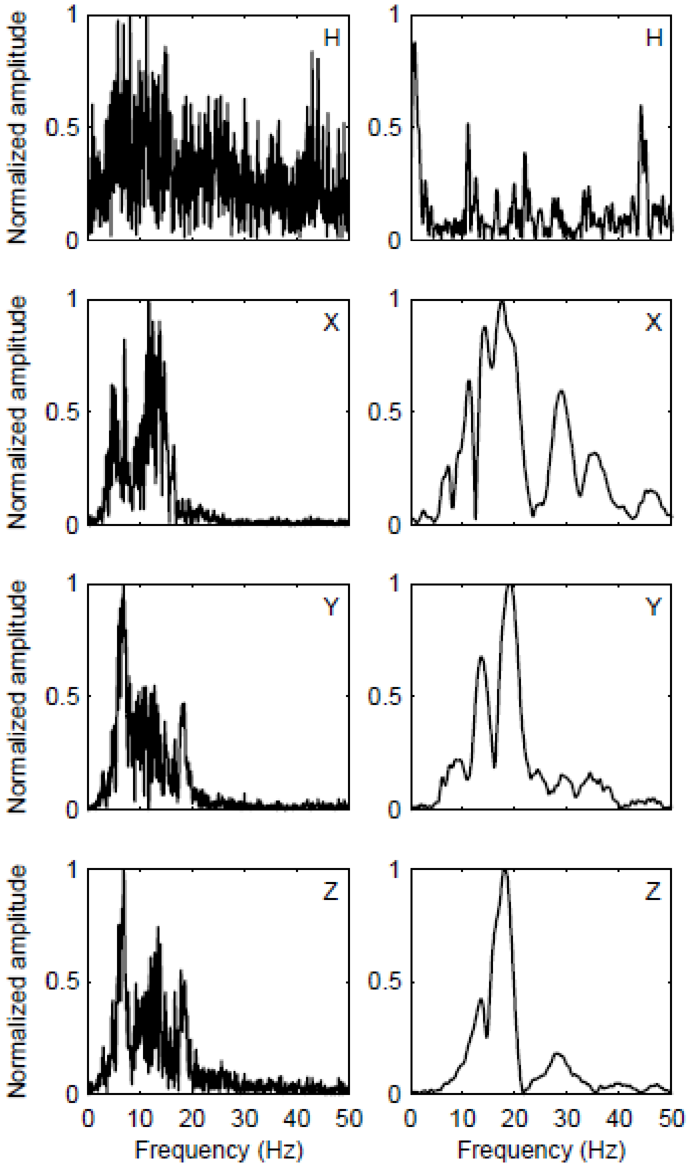

Fig. 2.Frequency spectrum of the micro-earthquake (left) and the micro-event (right) shown in Fig. 1 (H: hydrophone, X and Y: geophone horizontal components, Z: geophone vertical component).

An article will be submitted to the *Journal of Geophysical Research* in april 2011.

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ESONET

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

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

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

ESONET MARMARA-DM PROJECT

Deliverable 1.2: Fluid flux rates through the Marmara seafloor : Results from flowmeters and osmo-samplers

Due date of deliverable: September 2010
Actual submission date: September 2010

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Executive summary

The results presented in this deliverable help quantify the level of activity of venting sites along the submerged section of the North Anatolian Fault, and help identify 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.

The present deliverable shows that the submerged section North-Anatolian Fault within the Sea of Marmara is hydrologically active and exhibits a diversity of sources and processes. An important amount of work is still needed to assess the background fluxes and flows through the seafloor sediments, before practical applications can be found to assess the relationship between seismic activity and fluid migration.

Quantifying submarine fluid seep activity along the North Anatolian Fault Zone in the Sea of Marmara

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Components: 7,733 words, 2 tables, 8 figures.
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Index Terms: fluid seeps, marine geochemistry, hydrotectonics, fault zone processes
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Abstract

The Sea of Marmara presents the rare case where active seafloor venting sites are found on the surface trace of a major plate boundary fault: the North Anatolian Fault Zone. The objective of the 2007 MarNaut project was to quantify the level of activity of these venting sites, 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. Our work shows that submerged continental

transform plate boundaries can be hydrologically active and exhibit a diversity of sources and processes.

1.0 Introduction

The Sea of Marmara is an exceptional case were active seafloor venting sites are found on the surface trace of a major plate boundary fault: the North Anatolian Fault Zone (NAFZ). The distribution of seeps in convergent margins is often more complex with rare, if any, seeps at the frontal thrust and the bulk of fluid outflow distributed over the outer forearc at the surface traces of thrust faults, normal faults, and mud volcanoes. Our observations on the Main Marmara Fault (MMF), the northwestern extension of the NAFZ, suggest a simple pattern where the main strike-slip fault is the principal channel for fluid expulsion on the ridges, and the basin bounding faults are the main fluid channels in the basins (Géli et al., 2008; Tryon et al., 2010a). This simple pattern is complicated by the effects of turbidite channels which provide lateral conduits, local structural effects, such as anticlines which can act as traps, and by local bends in the MMF causing compaction or dilation driven flow. In addition, temporal influences such as recent earthquake activity may also affect emissions of fluids. For example, the region of the Central High seismic gap exhibits low gas emissions while the region west of the Kocaeli earthquake rupture, characterized by micro-seismic activity, exhibits extensive gas emissions (Géli et al., 2008). In order to extend these observations and gain a quantitative overview of the magnitude of flow occurring in this environment, we deployed six Chemical and Aqueous Transport (CAT) meters (Tryon et al., 2001) for a period of one year at three different sites of fluid seepage that spanned a range of hydrological, geochemical, and tectonic environments. These instruments monitored fluid flow rates for the entire deployment time as well as collected a time series of fluid samples including their dissolved gases. Additionally, piston cores were obtained for pore fluid chemical analysis at 13 sites covering both basins and ridges (Tryon et al., 2010a). Along with cores obtained from the Marmara-VT cruise (Zitter et al., 2008), profiles from the new cores were used to further extend the chemical record gained from the CAT meters.. The relative simplicity of the tectonic and hydrologic system along the NAFZ make this region a natural laboratory for studying relationships between tectonic activity and fluid migration. In this respect, a primary goal of this endeavor was to establish a baseline for hydrogeologic activity in the region for comparison with periods characterized by crustal unrest.

2.0 Essential Background

2.1 Hydrotectonic relationships

Fluid flow and pressure distribution within active faults are critical but poorly constrained parameters that affect fault zone processes. Observations on active margins have shown that manifestations of fluid seepage at the seafloor are commonly associated with active tectonic features and that episodic flow occurs in fault zones (Carson and Screaton, 1998). Notably, geochemical and geophysical evidence for rapid flow from seismogenic depths channeled along thrusts has been obtained in ODP drill holes on the Cascadia margin (Davis et al., 1995; Sample, 1996). A number of physical models have been proposed to explain pressure transients or fluid discharge associated with seismic (and aseismic) slip: poroelasticity and pressure diffusion (Davis et al., 2001; Ge and Stover, 2000; Muir-Wood and King, 1993), damage and fluidization due to ground shaking (Gavrilenko et al., 2000; Wang et al., 2001), fracturing/sealing cycles (Barton et al., 1995; Husen and Kissling, 2001; Renard et al., 2000; Sleep and Blanpied, 1994) and solitary waves (Henry, 2000; Rice, 1992). However, in general, the relationship between episodes of fluid flow and occurrences of fault sliding remains to be defined. While any or all above possibilities may occur, identification and/or rejection of a particular mechanism can potentially be made through long term flow monitoring. For example, permeability changes effect the tidal response of a seep while poroelastic effects do not (e.g., (Elkhoury et al., 2006; Tryon et al., 2002)).

Coupling between deformation and fluid flow may lead to post seismic fluid release, to precursory events, as well as to systematic variations of flow rates, fluid chemistry and pore pressure during inter-seismic phases. Evidence for changes in subsurface water chemistry associated with tectonic activity has been noted in a wide variety of geological environments (Biagi et al., 2004; Italiano et al., 2001; Sano et al., 1998). For example, significant progressive increases in Cl, Mg, SO_4, and Sr were observed prior to the Mw 6.9 1995 Kobe earthquake based on the analysis of bottled water taken from a 100 m deep water well drilled near the epicenter (Tsunogai and Wakita, 1995). Bottled water from the well preserved a multi-year record of changes in water chemistry, revealing an exponential change in chemistry leading up to the point of the earthquake event.

We hypothesize that fluid seeps fed by fault zone conduits are sensitive to the state of stress in the fault zone and, thus, may respond to processes occurring in the seismogenic zone (though the primary fluid sources will be shallower). Identifying and understanding this response will rely heavily on a comparative study of data from fault segments with different slip orientations and histories, bothfrom this project and any future monitoring studies. However, the current level of hydrologic activity and the composition of expelled fluid, along with critical observations (relative abundance of biological activity, relative abundance of carbonate crusts and structures), provide a means to test hypotheses on the relationship between fault activity and episodic fluid emission on the historic time scale.

2.2 Geologic and tectonic context

The Sea of Marmara lies to the south of Istanbul, Turkey, and connects the Black Sea to the Mediterranean Sea by way of Istanbul (Bosphorus) and Çanakkale (Dardanelles) Straits. It consists of three ~1200 m deep fault-bounded extensional basins where sediments, of a few kilometer thickness, have recently accumulated (Fig. 1). These basins are separated by compressional ridges that rise ~600 m above the basin floors. This part of the Sea of Marmara is crossed east to west by the Main Marmara Fault (MMF), which forms the northernmost branch of the North Anatolian Fault. It takes up most of the 23-27 mm/yr strike-slip motion between Eurasian and Anatolian plates (Le Pichon et al., 2003; Meade et al., 2002; Reilinger et al., 2006). The MMF joins the İzmit Fault in the east and the Ganos Fault in the west. The actual slip rate on the offshore MMF has mostly been estimated from modeling-based studies. Estimates for the dextral strike slip component vary between 12 and 23 mm/yr depending on the fault segment considered and the assumptions underlying each model (Flerit et al., 2003; Hergert and Heidbach, 2010; Le Pichon et al., 2003). Slip on secondary fault branches is much less (1-5 mm/yr) but, in the present context, this should not bias their hydrogeological significance. The trace of the MMF is linear on the ridges, and more complex in the basins. Each sector displays different structural characteristics and tectonic styles corresponding to trans-tension, partitioned strike-slip and extension, or, locally transpression. Earthquakes (Mw 7+) appear to occur in the region on a ~100 yr average time interval and, after the Kocaeli M7.4 earthquake (Barka et al., 2002) along the İzmit Fault, the MMF was proposed to be the likely source of a major earthquake (>M7) in the near future (Hubert-Ferrari et al., 2000; Parsons et al., 2000).

The Sea of Marmara was a freshwater lake isolated from both the Mediterranean and Black seas prior to the last glacio-eustatic sea level rise (Aksu et al., 1999; Çağatay et al., 2000; Ryan et al., 2003). Transition to a marine environment occurred progressively from 14.7 to 12.4 kyr BP, followed by a change in sediment cores lithology at about 12 kyr BP (Çağatay et al., 2000; Vidal et al., 2010). Sedimentation rates as high as 2.5 mm/yr in the basins has deposited up to 35 m of marine sediment above the lacustrine-marine transition zone with shelves and ridges receiving only 0.1-0.5 mm/yr (Armijo et al., 2005; Çağatay et al., 2000; Mercier de Lépinay et al., 2003). Presently, the water of the Sea of Marmara is strongly stratified with a 20-40 m thick layer of brackish Black Sea water entering through the Bosphorus capping warm saline Mediterranean water that enters through the Dardanelles and sinks below the cap.

2.3 Prior evidence for fluid emissions

Evidence of methane emissions associated with the Main Marmara Fault was found during the Meteor cruise M 44/1 (1999), as shown by black-grayish seafloor sediments with bacterial mats and by methane anomalies in the lower part of the water column (Halbach and Scientific Party, 2000). These observations were made where the fault crosscuts the Western High separating the Tekirdağ and the Central basins. In addition, a shallow sulfate-methane-reaction zone (SMRZ) was detected in sediment cores from the same area at depths of 4 to 5 meters below the seafloor and from the Çınarck Basin at 3 mbsf (Çağatay et al., 2004). High resolution seismic data (Le Pichon et al., 2001) and chirp profiles indicated the probable presence of trapped gases within the uppermost sedimentary sequences. Observations during the Marmarascarps cruise (2002) showed that bubbles (presumably of methane) are often present immediately beneath the seafloor at reduced sediment patches, notably on the Western High. More spectacular active chimneys were found in the Tekirdağ Basin and in the Central Basin (Armijo et al., 2005) but the fluids were not sampled. In the Tekirdağ Basin, fluid outflow is visible, due to a contrast in optical indices; however, the temperature is less than 0.5°C above bottom water temperature, implying that a fluid of very different salinity is expelled at this site. Water sampled below the SMRZ in cores taken in these basins and on the Western High exhibited decreasing salinity with depth. Zitter, et al. (Zitter et al., 2008) suggested that the burial of Lake Marmara fresh or brackish water was the source of the freshened endmember fluid seen at deep levels in cores from the Marmara-VT cruise and at the chimneys. This conclusion was based upon extrapolation of various mixing lines which, in turn, indicated a minimum chlorinity of 100 mM for the buried fluid, thought to be representative of the Marmara glacial lake. The Tekirdağ chimneys were found on the MMF outcrop and were located on a recent seafloor rupture (possibly of the 1912 Ganos earthquake), which broke older carbonate crusts. In the Central Basin, smaller chimneys and abundant carbonates were found on the subsidiary fault bounding the basin to the north. This fault does not display evidence of comparable recent surface rupture. Manifestations of fluid expulsion in the Çınarck Basin area have not been systematically investigated previously but intense expulsion of methane in the İzmit Gulf, near the 1999 Kocaeli earthquake rupture, has been reported (Alpar, 1999).

3. Methods

Details of the design and operational theory of the CAT meter (Fig. 2), including descriptions of the initial testing, are described in (Tryon et al., 2001). This instrument is designed to quantify both inflow and outflow fluid flow rates on the order of 0.01 to 1500 cm/yr. At moderate to high outflow rates, a time series record of the outflow fluid chemistry may also be obtained. These instruments have been in use since 1998 to monitor long-term fluid flow in both seep and non-seep environments (e.g., (Tryon, 2009; Tryon et al., 1999; Tryon et al., 2010b)). The instrument uses the dilution of a chemical tracer to measure flow through the outlet tubing exiting the top of a collection chamber. A tracer solution of similar density to, but different composition from, the seep fluid is injected at a constant rate by two osmotic pumps into the water stream as it moves through the outlet tubing. These same pumps withdraw a sample of the seep fluid/tracer mixture from downstream of the tracer injection port giving a serial record of the tracer dilution. The pump contains an osmotic membrane that separates chambers containing pure water and saline water, held at saturation levels by the presence of excess NaCl. Due to the constant concentration gradient, distilled water is drawn from the fresh water chamber through the osmotic membrane into the saline chamber at a rate that is constant for a given temperature. The saline output side of the pump system is rigged to inject the tracer while the distilled input side is connected to separate sample coils into which is drawn fluid from either side of the tracer injection point. Each sample coil is initially filled with deionized water. Fluids moving out of the sediment and through the collection chamber are collected in the coils, displacing the deionized water. Having two sample coils allows both inflow and outflow to be measured. A unique pattern of chemical tracer distribution is recorded in the sample coils allowing a serial record of the flow rates to be determined. Knowledge of the dilution factor of the tracer, collection chamber area, and osmotic pump rate are used to calculate the flow rate.

Upon recovery of the instruments, the 100 m long sample coils are dispensed into date-specific subsamples of 1-3 days duration. Tracer concentration is analyzed using an inductively coupled plasma optical emission spectrometer (ICP-OES) on a subset of these samples to quantify the rates and degree of variability. Some degree of "smoothing" of the record is induced by dispersion as the seep fluid is slowly drawn into and through the tubing over the deployment period. Also, while the two endpoints of the record are well fixed, there is an increasing temporal uncertainty toward the center of the record due to small additative errors in sampling (primarily variations in tubing diameter). This error is estimated to be ≤5 days for a one year record. For the

Marmara deployment, each CAT meter was also equipped with an auxiliary osmotic pump with copper tubing extending from the seafloor sample collection chamber through the sample collection coils and ending at the osmotic pump (Fig. 2). The sample coils included high pressure valves at each end which automatically closed when the instrument left the seafloor during recovery via acoustic release. In this manner, we were able to collect dissolved gas samples and hold them at in situ pressure for post recovery analysis.

After reconnaissance observations using sub-bottom geophysical surveys, multi-beam mapping, bubble plume mapping, and visual surveys using the submersible Nautile, three sites were chosen for CAT meter deployment that were thought to best span the tectonic, hydrologic, and geochemical environments of the region. The instruments were lowered to the seafloor via wire, released, and subsequently placed in specific locations using the Nautile submersible. Sites chosen were the southern Tekirdag Basin brackish water venting site, the Western High diapir site where extensive gas bubbling, oil droplets, and high-salinity fluids were observed, and the northern basin bounding escarpment of the Cinarcik Basin where extensive areas of black sulfidic sediment and microbial mats were observed.

4.0 Results and Discussion

The CAT meter fluid flow results are shown in Figure 3, the endmember pore fluid compositions are presented in Table 1, and the noble gas analysis results are presented in Table 2. As observed in other seep environments, significant fluid flow through sediment appears to be primarily an episodic phenomenum with background rates on the order of mm to cm/yr except at or very near focused vents (e.g., the Tekirdag Basin “Jack the Smoker” vent). Changes in flow rate and flow events can have a variety of causes. When free gas is present, associated processes such as filling and emptying of near subsurface gas reservoirs dominate this episodicity (e.g., (Tryon, 2004; Tryon et al., 1999)). In the absence of free gas, results of micro-tectonic and micro-seismic processes may be observed (e.g., (Tryon, 2009)). Gradual changes in flow rates can also be attributed to changes in Darcian or fracture permeability, for example due to mineral or hydrate precipitation in the pathways, and to migration of fluid pathways due to the same causes (Tryon et al., 2002). Notably, piston core profiles can be used to bracket flow rates (Fig. 4). Cores give a time-integrated rate indicative of the average rate over past months to years. Since piston core positions were not precise in this study (±25 m), we caution that core-derived rates should not be matched directly with seeps but considered as indicator of peripheral flows. In general, we find that the flow rates peripheral to the seeps, as estimated from the cores, are an order of magnitude lower than the background rates recorded at the seeps themselves.

4.1 Tekirdag Basin brackish water vents

The Tekirdağ Basin site is located at the southern margin of the basin at a depth of 1120 m, near the brackish water vent referred to as "Jack the Smoker" (Armijo et al., 2005). Figure 5 shows the spatial relationship between the vent, CAT meters, and cores. Core locations are estimated to be ±25 m. At this site, fluids could be seen visibly flowing from vent chimneys. Fluids emitted here are dominated by Lake Marmara brackish water with minor alteration resulting from silicate diagenesis (Tryon et al., 2010b; Zitter et al., 2008). In contrast to the high activity of Jack, visual observations here suggested that this site may not be particularly active at the present time.. There were a large number of black patches of sulfidic sediment but they typically lack evidence of live biology (bivalves, microbial mat). Patches of small white disarticulated shells suggest, rather, that these sites are mostly inactive or dead seep sites where the sulfidic sediment has persisted but the chemosynthetic communities have died out or moved on. The indicators of current fluid flow activity appear to be restricted to the fault scarp itself, typically exiting the face of the scarp or at the scarp to basin floor intersection. An upper carbonate cap of ~5-10 cm thickness could be seen on the exposed scarp face with seepage primarily coming from the base of this cap. It is thus likely that persistent fault zone flow has produced this impermeable cap that was ruptured during the last fault movement. Vertical flow within the fault zone will encounter this cap and be diverted laterally through permeable pathways to the scarp face or their intersection with the current fault plane. Hard substrate and carbonate prevented flow measurements at the vents themselves or directly on the fault scarp: however, an osmo-sampler was placed in the Jack the Smoker vent for time-series geochemical sampling. The fluid chemistry rapidly ramped up to the composition given in Table 1 with no resolvable change until the sampling port apparently plugged a few months into the deployment, presumably as a result of biofouling or carbonate precipitation. CAT K was deployed at the base of the fault scarp 100 m west of the vents on a ~1 m diameter patch of black sulfidic sediment. In contrast to the visual observations, flow rates were relatively high, reaching ~1 m/yr during high flow periods and with background rates of 5-20 cm/yr. Approximately 150 m basinward from the fault scarp, mm/yr downflow was observed with CAT N which showed some correlation with CAT K.

There is also a very clear trend in the piston core pore fluid composition profiles with distance from the fluid vent site (Tryon et al., 2010b) (Fig. 4, 5). Core KC-30 is located adjacent to the Jack vent and upward fluid velocity can be estimated from the shape of the Cl profile. Fluid velocity is determined to be 1 to 1.5 cm/yr for this core by fitting data below 2 m depth with a steady state advection-diffusion model (e.g., (Martin et al., 1996)). VT-2740, 150 m from the fault scarp, has nearly vertical profiles of Ca, Sr, and sulfate in the top ~500 cm followed by a concave upward lower section suggesting that there may be downward flow at this site on the order of a mm/yr. KC-17, 300 m out, exhibits only a slight curvature and minimal downflow, while VT-2737, 1500 m from the scarp, appears linear and diffusive indicating no flow. No free gas was observed at this site so the changes in flow may have a tectonic and/or micro-seismic source. However, there was a significant amount of dissolved gas present and sub-bottom seismics suggested buried free gas. The driving source for the background flow is therefore thought to be primarily basin consolidation which drives fluids toward high permeability turbidite layers that drain laterally up-dip toward the basin bounding fault. Buoyancy forces of the low salinity fluids augment the flow and may also be responsible for the apparent convection cell and associated down-flow adjacent to the fault and vents.

4.2 Western High hydrocarbon mounds

The Western High hydrocarbon mound site is located at 660 m depth where the MMF cuts across the structural high from the Central Basin to the Tekirdağ Basin (Fig. 1, 6). This section of the MMF has nearly vertical strike slip motion striking E-W and cutting a NE-SW trending anticline. The site produced a large bubble plume visible on the high frequency acoustics (Géli et al., 2008) and there was also an oil slick on the surface waters visible during multiple visits. Two small mounds were observed that have a high sonar back-scatter in a wide frequency range (at least 35 kHz- 200 kHz) and associated chirp profiles suggested that they were small mud volcanoes which formed along the anticlinal ridge north of the MMF (Henry and Marnaut Scientific Party, 2007). No mud breccia was found in the coreswhich instead appeared to be formed of hemipelagic sediment bearing several authigenic carbonate layers in the first 2.5 meters as well as barite. Although earlier stages may have involved mud extrusion, there is no evidence this is happening at present. The northern mound is circular, 150 m diameter, with a depressed center and irregular rim and the southern mound is similar in size and shape with a breach in its NE wall. Thus, this site appears as chemoherms formed on long-lived fluid conduits. The conduits are clearly defined in 3D seismics collected during the 2009 Marmara-DM program. These structures appear quite similar to the larger fluid escape mounds observed on the Costa Rica convergent margin (Klaucke et al., 2008). Bottom surveys with the Nautile submersible revealed extensive bubble streams and globules of oil coming from the sediment in many places. One of the main bubble fields was on the top of the northern mound, located 700 m north of the MMF trace, where CAT Q was deployed. On the southeast and south slopes of the mound, two sites of fluid expulsion were seen where the flow appeared to be focused through outlets <1 m across exhibiting flow of dense water, as evident from the downslope pattern of flow channels and white barite precipitate (Fig. 7). CAT S was deployed at the larger of these outlets. It contained two autonomous flow meters and one collection chamber was placed in the center of the outlet and the other at the apparent rim.

While the basin pore fluids appear to have a common source of Pleistocene Lake Marmara water that has been modified to various degrees by microbial and diagenetic processes, the chemical composition of pore fluids at this site suggests they are also influenced by gas hydrate formation and decomposition near the seafloor as well as deep sourced fluids possibly associated with natural gas reservoirs. Most notable in this respect is the occurrence of gas hydrate in some of the cores and the observance of oil seeping from the sediment in the area. At a depth of 660 m and a temperature of 14.5°C, these hydrates are well outside the stability field of methane hydrates. Analysis of the hydrates confirmed the presence of higher hydrocarbons at concentrations that allow the formation of structure II hydrates at the *in situ* P, T conditions, (Bourry et al., 2009). The analysis also suggests that the gas source is the same as that of the Kuzey Marmara gas field which is located on a NE trending anticline that appears to be a continuation of the Western High. The source rock for this field is the Eocene Hamitabat Formation which consists of sandstone, shale, and conglomerate and the reservoir rock is the limestone Sogucak Formation (Hosgormez and Yalcin, 2005). At the Kuzey Marmara field, the Hamitabat formation is absent and the reservoir lies unconformably over the metamorphic basement. Overlying formations consist primarily of shale, sandstone, siltstone, claystone, and conglomerates, and minor amounts of tuffite and is typically 1200-1500 m thick at the anticlinal crest (Hosgormez and Yalcin, 2005).

The flow meter on the summit of the diapir mound (CAT Q) was in the middle of the bubble field and indicated only rapidly oscillating flow. The rapid filling and emptying of near-subsurface free gas reservoirs causes rapid inflow and outflow of water through the sediment water interface. Unless the background flow rate is high enough to overcome these flow reversals, the tracer in the CAT meter is distributed equally on both the upflow and downflow sensor sides and no net flow rate can be resolved. The effect of oscillating flow is also seen in the core pore fluid profiles in gas-rich areas. In these areas, there is typically a ~1-5 m upper section where the pore fluid is dominated by a bottom water composition overlying a relatively linear gradient to the seep fluid composition. Significantly less gas was observed at the site on the side of the mound and a good flow rate record was recorded. The CAT meter in the center of the outlet (CAT S) recorded background flow rates on the order of 10 cm/yr with a strong outflow event occurring in November, 2007, as high as 1.4 m/yr. The CAT meter located at the rim of the outlet recorded no flow indicating the conduit is less than 1-2 m wide. The single event at this site suggests it may be driven by a deeper source than the rapid changes in the nearby bubble field. This longer term episodic nature is typical of mud volcano eruptions, the most spectacular of the spectrum of such deep-sourced structures that extends from chemoherms to mud volcanoes.

Southern mound core KC-27 contained gas hydrate and exhibited highly altered deep sourced fluid. The curvature of the chlorinity profile above the depth at which gas hydrates were sampled indicates upward fluid flow at a velocity of about 2 cm/yr (Fig. 4). In core KC-14 from approximately the same location as CAT Q, the advection rate is too low to cause significant curvature, and no hydrate was found.

The fluid and gas chemistry from CAT S followed a similar pattern to the flow rate with the most altered pore fluids seen during the expulsion event and a slow return to less altered fluids as bottom water influenced shallower fluids again began to dominate. Significantly, $^{3}He/^{4}He$ ratios in these fluids were the lowest (i.e., most radiogenic) of all values recorded during this study. However, the lowest ratio (0.6RA where RA = air 3He/4He) was found in a Mound sample with the lowest He concentration. This is consistent with high He concentration seawater and/or air bubble entrainment dominating the He inventory following an event with a transient pulse of low concentration He captured only during the expulsion event.

4.3 Cinarcik Basin northern bounding fault

The northern Cinarcik Basin site is located adjacent to the basin bounding fault at a depth of 1160 m. A well weathered low fault scarp was located basinward of the main basin escarpment with an area of black sulfidic sediment and patchy white and orange microbial mat extending ~50 m basinward of the scarp and laterally at least 100 m along the scarp. The only breaks in the sulfidic sediment cover appeared to be the locations of meter-sized boulders on and just beneath the sediment surface that blocked flow. These boulders are derived from erosion of the basin bounding escarpment that consists of Paleozoïc sedimentary rocks. Within the sediment cover, there appeared to be a ~15 cm cover of soft, high water content sediment overlying a hard layer that could not be penetrated by push cores. It is unknown whether this is a carbonate cemented layer or stiff sediments: however, the complete lack of outcrops of carbonate in the area suggests hard sediment. No gas bubbles were seen during the Nautile dives nor seen during the EK-60 surveys: however, this area was one of the most extensive plumes identified from the September 2000 R/V Le Suroit deep tow SAR survey. CAT meters J and M were deployed here on locations with microbial mats.

High rates of fluid flow were expected based on the observed extensive anoxia and microbial mat coverage. Background rates, however, appear to only be on the order of a few cm/yr, although outflow of up to a m/yr was observed during the first couple months of the deployment at the location of CAT M. The observed rates do not appear sufficient to maintain the pervasive anoxic environment at the sediment-water interface required to maintain the black sediment color and microbial mats. However, a surprising result on recovery of the instruments after a year on the bottom was that the copper coils for gas sampling still appeared new, without the usual thick coating of blue-green copper sulfate. We hypothesize, therefore, that the bottom water here is totally anoxic allowing the relatively low outflux of dissolved methane and sulfide to maintain a reducing seafloor chemical and biological environment. The major element fluid chemistry appears to be the same as that seen in the cores elsewhere in the Cinarcik and Central Basins: Marmara Sea bottom water with minor Lake Marmara water altered by local shallow redox reactions, carbonate precipitation, and barite dissolution.

No cores were successfully recovered at this location, likely due to the ubiquitous boulders, however a core recovered in an area in the southern Cinarcik Basin with comparable sulfidic sediment and microbial activity suggested background rates on the order of 0.1-1 cm/yr (Tryon et al., 2010b).

4.4 Results of gas sampling

Results of carbon gas analyses are reported in (Bourry et al., 2009). In summary, the basin margin seeps emit primarily shallow-sourced biogenic methane with a trace of thermogenic gas. The ridge sites emit deeper sourced thermogenic gas with methane dominating but with significant amounts of higher hydrocarbons at the Western High diapirs. A total of 7 sample aliquots of water from the Marmara Sea, collected in copper coils from CAT meters at each of the three sites, were analyzed for their helium isotope composition and concentrations of He and Ne (Table 2). For the most part, all samples have atmospheric (or close to atmospheric) ^{3}He/^{4}He ratios. The only exception was sample S-7-1 which recorded a ^{3}He/^{4}He ratio of 0.60 RA (RA = air ^{3}He/^{4}He). This sample therefore records a mixture of magmatic (mantle-derived) and radiogenic (crustal) He with the balance of crustal He far outweighing the mantle component. This sample was collected during the large outflow event at the hydrocarbon seep site (Fig. 8). Interestingly, this sample location on the Western High extends prior He isotope analysis of subaerial geothermal fluids associated with the NAFZ well off-shore (c.f., (De Leeuw et al., 2010; Gulec et al., 2002)). Thus, the NAFZ is emitting mantle-derived fluids along the entire length of its western segment albeit heavily diluted by crustally-derived He.

The atmospheric-like ^{3}He/^{4}He ratios and associated variations in He and Ne concentrations can be explained by the effects of gas stripping whereby He and Ne have been partitioned (lost) into a gas phase, presumably methane (see (Füri et al., 2010; Füri et al., 2009)). The only exception to this observation is sample S-8-2 which is oversaturated with He (with respect to air-equilibrated seawater): this may indicate air entrainment, likely indicative of contamination. In most cases, however, waters which have lost the majority of their dissolved atmospheric gas load to bubbles of methane would be highly susceptible to record the effects of addition of other gases which, in the present case, is likely atmospheric He and Ne from ambient seawater. However, during the outflow event recorded by CAT S there would be inhibited addition of near-surface gases and, thus, a greater sensitivity to record a minor input of He with a $^3He/^4He$ ratio more indicative of the deeper fluid reservoir. This is also evident in the aqueous chemistry which was the most altered and representative of the deep source during the outflow event.

5.0 Conclusion

The MarNaut project has established a baseline for the Sea of Marmara in terms of the distribution and rates of aqueous and gas flow and fluid chemistry. This baseline spans the unusually diverse tectonic, hydrologic, and geochemical environment of the region. These measurements, along with the results of associated research during the Marnaut mission and the ongoing Marmara-DM ESONET demonstration mission will help establish the Sea of Marmara as a natural laboratory for observing the relationship between tectonic activity, earthquakes, and fault zone hydrologic activity. Should preseismic, coseismic, and/or post seismic changes occur in Marmara seafloor hydrology, our instrumentation and analytical approach presents the means to capture/record such changes.. The high level of earthquake activity gives us confidence that the Sea of Marmara presents one of the best regions for achieving the long-term goal of understanding the relationship between tectono-seismic activity with fluid flow in faulted crust.

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Figure Captions

Figure 1: Map of the Sea of Marmara indicating: Inset) Regional reference frame and tectonic framework, A) the names and locations of major features, fault locations and bathymetry, and, B) the locations of the coring sites referenced in this manuscript.

Figure 2: Schematic of CAT meter (see Tryon, et al., 2001 for details of operation). Tracer is injected into the flow through the I/O tube and sampled continuously both upstream and downstream. Flow rate is determined from the dilution of the tracer in the downstream coil and the upstream coil is used for chemical analysis. An auxiliary osmo-sampler is also installed at the collection chamber and fluids collected in copper coils with a valve at each end that automatically closes on recovery. These latter fluids are used for dissolved gas analysis.

Figure 3: Plots of flow rate vs. time for the 5 CAT meters that recorded flow. See text for discussion.

Figure 4: Upward fluid velocity can be estimated from the shape of the Cl profile by fitting data with a steady state advection-diffusion model (e.g., Martin et al., 1996). Left: Tekirdağ site, Right: Mound site. Core KC-30 is located adjacent to the Jack vent and fluid velocity is determined to be 1 to 1.5 cm/yr. VT-2740, 150 m from the fault scarp, has nearly vertical profiles of Ca, Sr, and sulfate in the top ~500 cm followed by a concave upward lower section suggesting that there may be downward flow at this site on the order of a mm/yr. KC-17, 300 m out, exhibits only a slight curvature and minimal downflow, while VT-2737, 1500 m from the scarp, appears linear and diffusive indicating no flow. The curvature of the chlorinity profile of core KC-27 indicates upward fluid flow at a velocity of about 2 cm/yr. In core KC-14 the advection rate is too low to cause significant curvature.

Figure 5: Detail map of structure, CAT locations, and coring locations at the Tekirdağ Basin site.

Figure 6: Detail map of the hydrate and carbonate mound site. Inset is AUV high-resolution microbathymetry from the 2009 Marmara-DM cruise. The mounds are significantly offset from the Main Marmara Fault (MMF) which is easily traced in the bathymetry. CAT deployment sites and coring site locations from MarNaut and Marmara-VT are shown.

Figure 7: Seep site where CAT S was deployed showing downslope flow pattern of dense fluids (down is to the right in the photo). White material is barite precipitate, black ring is sulfidic sediment, and white halo outside that is microbial mat.

Figure 8: Plot of flow rate and $^{3}He/^{4}He$ ratio at CAT S, mound site. Bottom water or

atmospheric-like ratios are seen except during the flow event in December where a $^{3}He/^{4}He$ ratio of 0.60 Ra is seen, indicative of magmatic (mantle-derived) and radiogenic (crustal) He with the balance of crustal He far outweighing the mantle component.

Site	Cl (mM)	Na (mM)	Mg (mM)	Ca (mM)	Sr (μM)	K (mM)	Li (μM)	B (μM)	Ba (μM)
Tekirdag	100	50	5	13	35	1.8	1	20	30
Mounds	1050	590	100	120	2400	7.5	1100	250	2000
S. Cinarcik	450	380	43	1.5	55	8.0	15	380	50
N. Cinarcik	710	565	63	8.5	87	11.7	30	508	0
bottom water	600	514	59	11.2	100	11.2	29	472	0

Table 1: Endmember compositions of fluids from the Sea of Marmara sites.

Sample name	Location	Weight H_2O (g)	$^3He/^4He$ (R_m/R_a)	^4He_m ($x10^{-9}$ cm^3 STP/g)	$^{20}Ne_m$ ($x10^{-9}$ cm^3 STP/g)
M-10-1	N. Cinarcik	1.29 ± 0.15	1.11 ± 0.07	6.56 ± 0.76	16.94 ± 1.95
M-2-25	N. Cinarcik	1.06 ± 0.12	1.08 ± 0.05	20.06 ± 2.31	71.35 ± 8.23
I-2-1	Tekirdag	1.19 ± 0.14	1.13 ± 0.04	54.29 ± 6.26	223.47 ± 25.94
S-8-2	Mounds	1.18 ± 0.13	1.04 ± 0.04	471.65 ± 54.39	1111.50 ± 128.17
S-7-1	Mounds	1.06 ± 0.12	0.60 ± 1.39	0.16 ± 0.02	2.07 ± 0.29
S-2-2	Mounds	1.12 ± 0.13	1.14 ± 0.04	22.35 ± 2.58	86.50 ± 9.97
S-2-1	Mounds	1.06 ± 0.12	1.09 ± 0.14	3.13 ± 0.36	20.51 ± 2.39

Table 2: Noble gas analytical results. R_a = $^3He/^4He$ of air. At 14.5°C, ^4He_m of sea water is $39.34*10^{-9}$ cm^3 STP/g and $^{20}Ne_m$ of sea water is $164.29*10^{-9}$ cm^3 STP/g

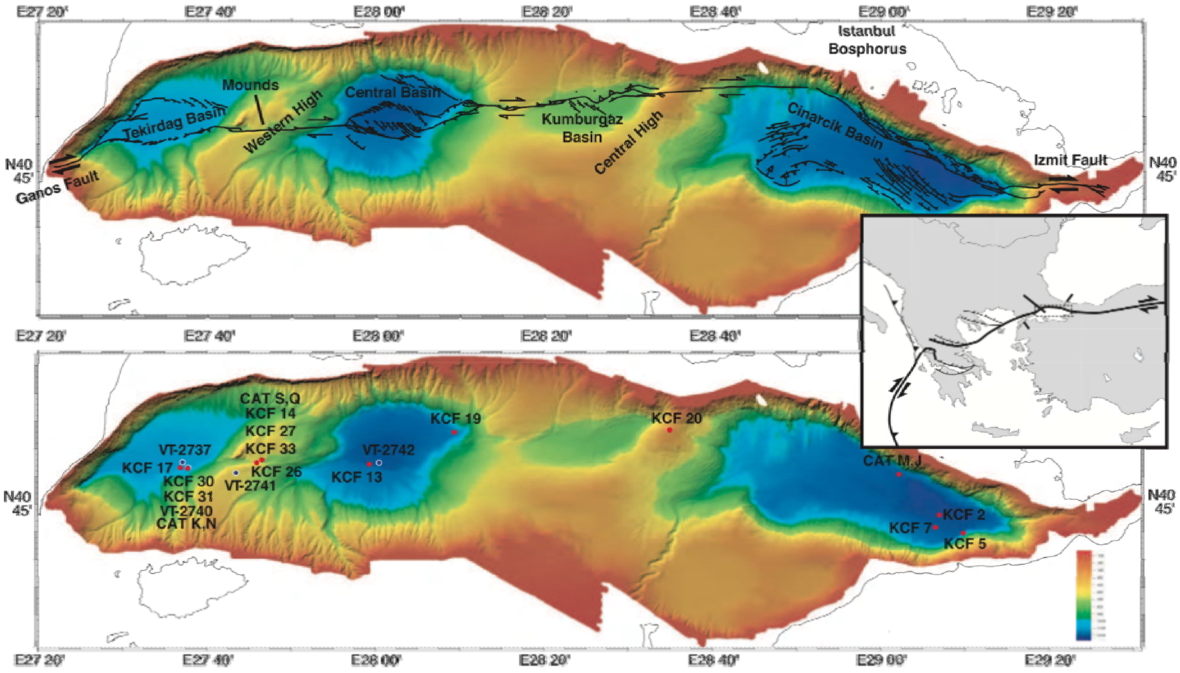


FIGURE 1

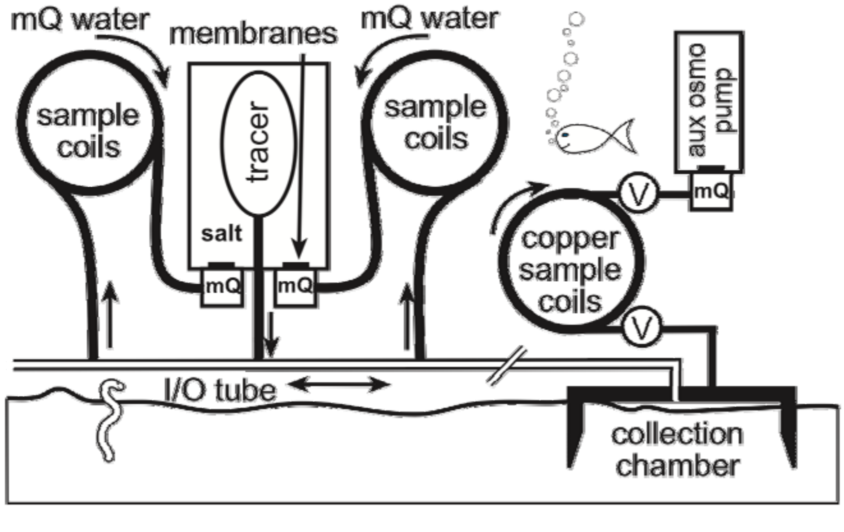


FIGURE 2

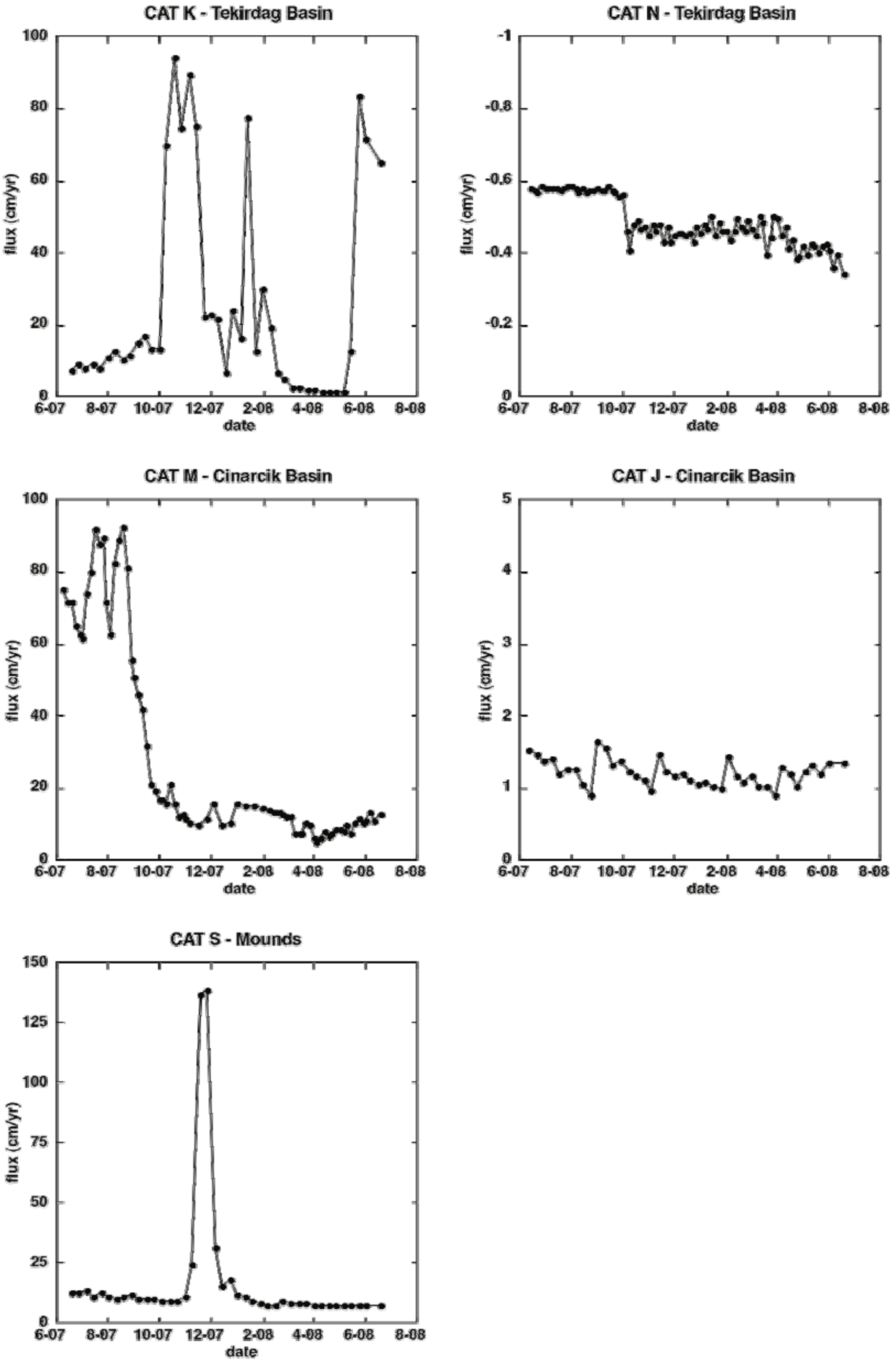

CAT K - Tekirdag Basin
flux (cm/yr)
date
CAT N - Tekirdag Basin
flux (cm/yr)
date
CAT M - Cinarcik Basin
flux (cm/yr)
date
CAT J - Cinarcik Basin
flux (cm/yr)
date
CAT S - Mounds
flux (cm/yr)
date
6-07 8-07 10-07 12-07 2-08 4-08 6-08 8-08

FIGURE 3

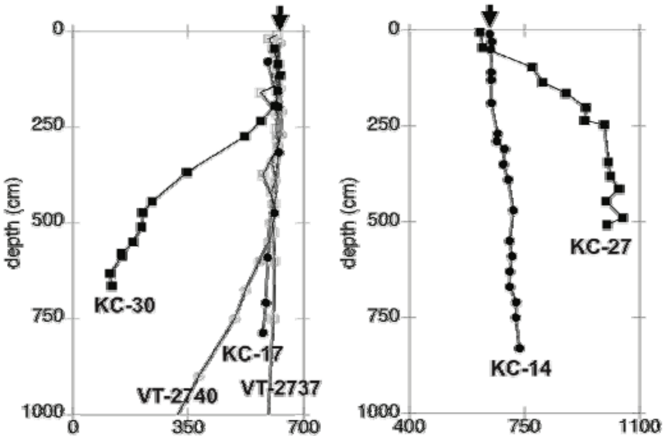


FIGURE 4

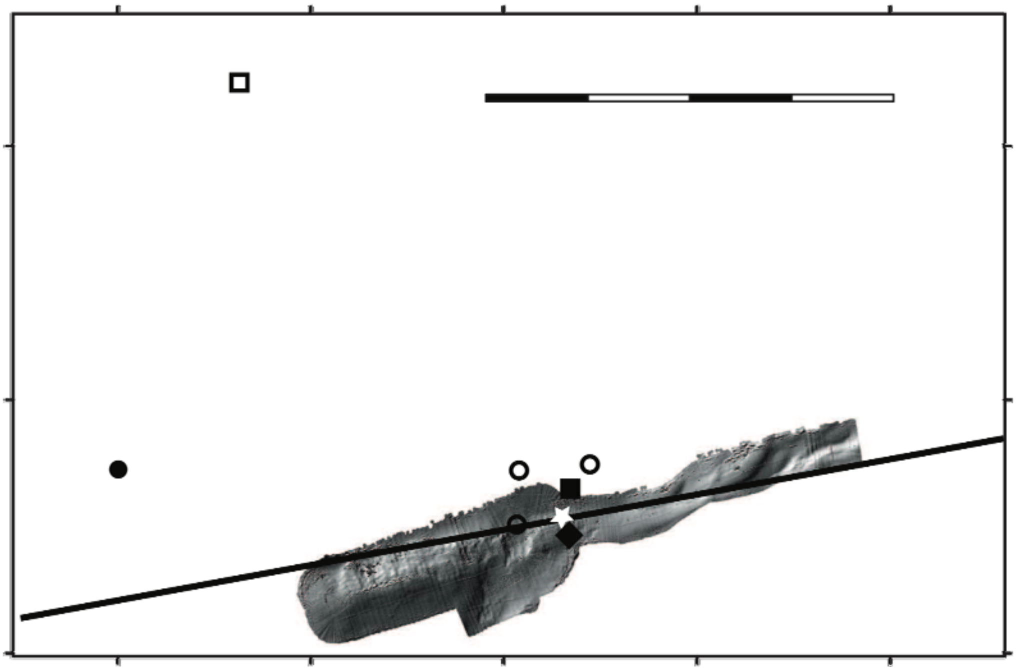
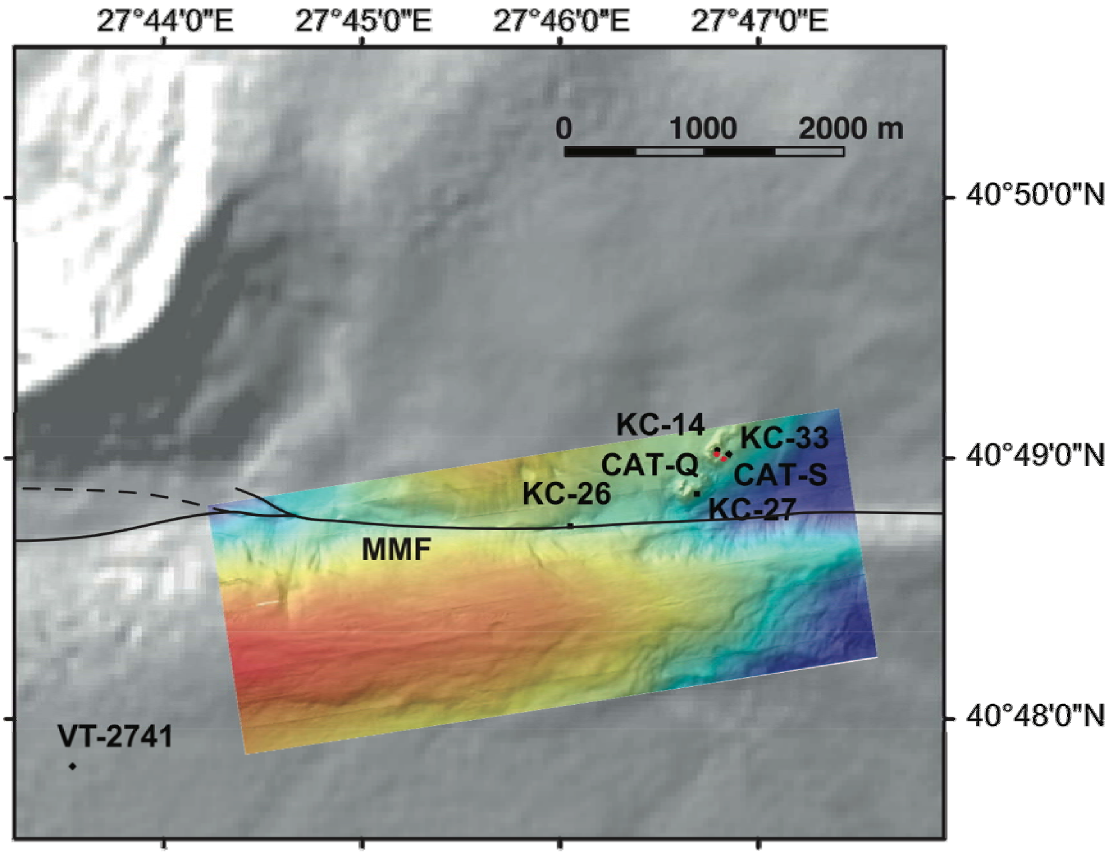


FIGURE 5


27°44'0"E
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27°46'0"E
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2000 m
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40°49'0"N
40°48'0"N
KC-14
KC-33
CAT-Q
CAT-S
KC-26
KC-27
MMF
VT-2741

FIGURE 6

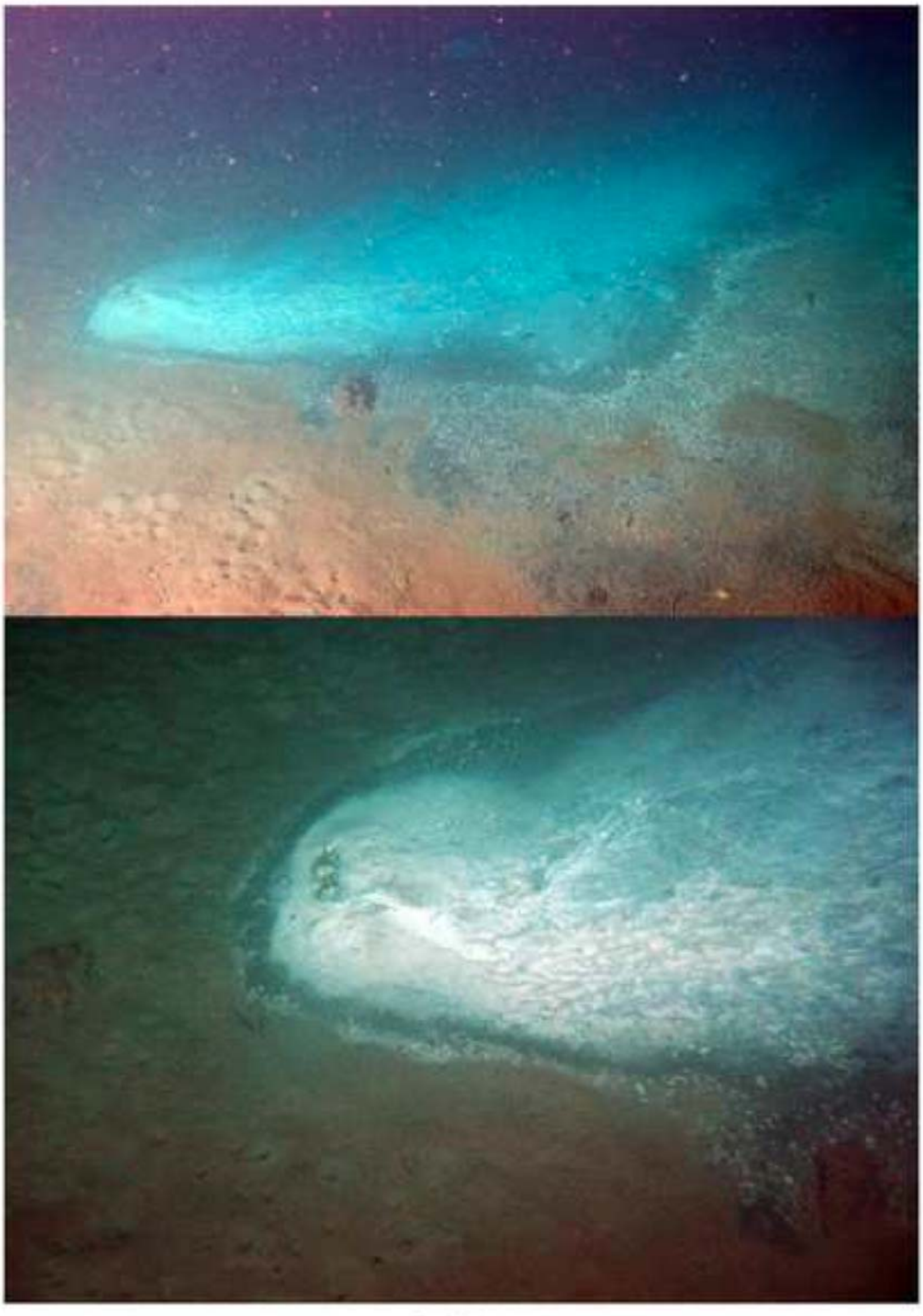

FIGURE 7

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 MARMARA-DM PROJECT

Deliverable 1.3: Origin of fluids escaping from the Marmara seafloor

Due date of deliverable: September 2010
Actual submission date: September 2010

Start date of project: **April, 1st, 2007** Duration: **30 months**

Organisation name of lead contractor for this deliverable: CNRS/CEREGE
Lead authors for this deliverable: Pierre Henry

Revision [final version]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	PU
PP	Restricted to other programme participants (including the Commission Services	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
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CONTENTS

Executive summary : Origin of fluids escaping from the Marmara seafloor

Introduction

Whether fluids come from shallow or deep sediments give important insight on fluids circulation from the surface to seismogenic depths. The most common gas in sediments is methane. Methane can be produced either in superficial sediments by carbon dioxide reduction or acetate fermentation (biogenic methane), or by thermal degradation of kerogen and oil in deeper sediments (thermogenic methane). The origin of methane can be determined by the analysis of carbon and hydrogen isotopic ratios.

1. Geochemical analyses: hydrocarbons and carbon isotopic ratio

-Structural highs (Western High and Central High)

Clusters of gas plumes have been detected in the Western High fault valley and on top of the Central High, about 1 km southward of the fault. Gas bubbles sampled on Western (PG-1662) and Central (PG-1664) Highs, and gas hydrates sampled on Western High (MNTKS27), show isotopic and molecular composition typical of a thermogenic origin [*Bourry et al.,* 2009] (Fig. 1). Consequently, the sources of these gases are petroleum or rocks filled by thermally mature organic matter.
The gas samples coming from the Western High have a composition similar to the *K.Marmara-af* natural gas field [*Gürgey et al.,* 2005; *Bourry et al.,* 2009]. The *K.Marmara-af* is one of the natural gas fields originating from the Thrace Basin. The similarities in gas composition between the Western High samples and the *K.Marmara-af* indicate that the North Anatolian Fault cross-cuts gas reservoirs from the southern continuation of the Thrace Basin gas field, and that gas probably follows the fracture network of the North Anatolian Fault to rise up to the sea floor.

- Çinarcik Basin

In contrast, gas samples taken from the southern part of the Çinarcik Basin (PG-1659, Fig. 1) show that the methane and ethane have a biogenic and thermogenic origin, respectively. It seems that between biogenic and thermogenic gases are mixed in this area [*Bourry et al.,* 2009].

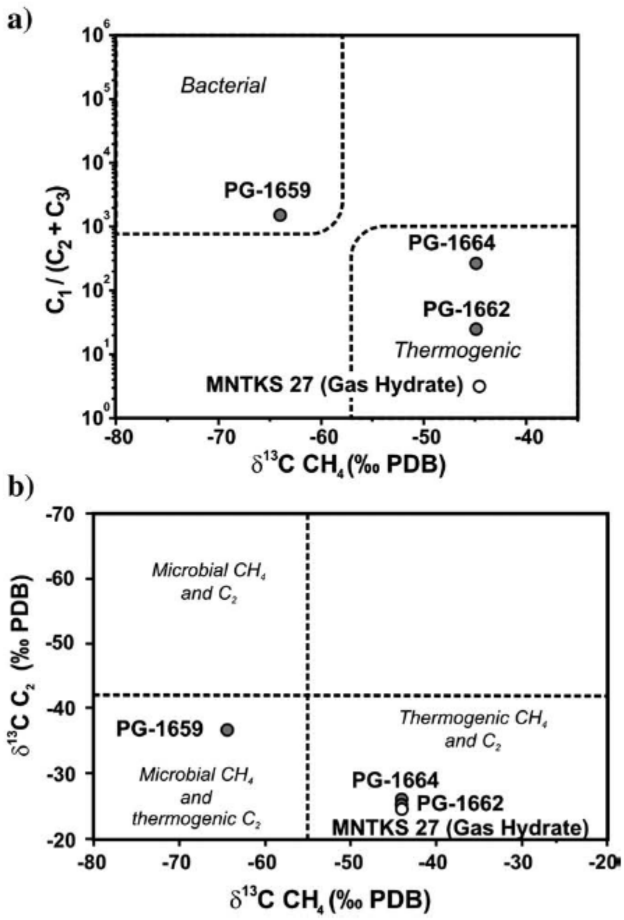

Fig. 1. Reproduced from Bourry et al. [2009]. Hydrocarbons and carbon isotopic ratio analysis for gas bubbles and gas hydrates origin determination. a) Stable carbon isotope composition ($\delta^{13}C$) of CH4 in function of the $C_1/(C_2+C_3)$ ratio. b) Stable carbon isotope composition ($\delta^{13}C$) of CH4 in function of the table carbon isotope composition ($\delta^{13}C$) of C2. Carbon isotopic ratio ($\delta^{13}C$) is given as parts per thousand (‰) relative to the PeeDee Belemnite standard (PDB).

2. Geochemical analyses: helium isotopes

Fluid samples from the Marnaut cruise have been analyzed for Helium isotopes and for Ne/He ratios. In nature, there are only 2 stable isotopes of helium, ^{3}He and ^{4}He. The only source of ^{3}He in geological fluids is the mantle (i.e. primordial He trapped in the earth during accretion). The isotope ^{4}He is produced over time by radioactive decay of Uranium and Thorium. The measurements are normalized to the ^{3}He/^{4}He ratio of atmosphere $((^3He/^4He)_{air} = 1.39 \times 10^{-6} = 1$ Ra). Atmospheric He escapes to space, so the Ne/He ratio is high for air and seawater, and low for the crust and the mantle. This ratio, combined with the Ne/He ratio, is a powerful tool for tracing the origin of fluids.
Fluid samples were recovered during the Marnaut cruise in 2007. Eight of the recovered samples have He/Ne ratios similar to the atmosphere, one has a ratio corresponding to pure crust, and the remaining 10 samples have variable amounts of mantle helium (Fig. 2). Almost all of these samples have less than 25 % of mantle helium. Only one sample, coming from the northwest corner of the Tekirdag Basin, is

composed of 70 % mantle helium. This ratio shows that the fluids of this site have a deep source [*Burnard et al.,* 2008; *Burnard et al.,* 2011 *in preparation*].

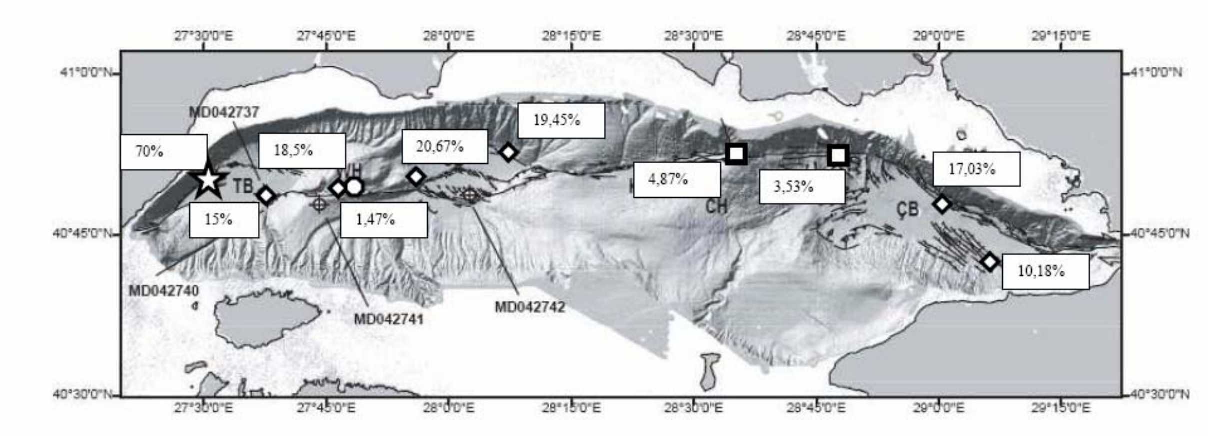

Fig. 2 Reproduced from Burnard et al. [2011 in preparation]. Helium isotope data analysis for fluids emanating from the North Anatolian Fault and related splays. The percentages correspond to the amount of mantle fluids. TB: Tekirdag Basin. WH: Western High. CH: Central High. CB: Cinarcik Basin.

3. Analysis of Sediment pore fluids

As part of the 2007 Marnaut cruise in the Sea of Marmara, an investigation of the pore fluid chemistry of sites along the Main Marmara Fault zone was conducted. The goal was to define the spatial Relationship between active faults and fluid outlets and to determine the sources and evolution of the fluids. Sites included basin bounding transtensional faults and strike slip faults cutting through the topographic highs. The basin pore fluids are dominated by simple mixing of bottom water with a brackish, low-density Pleistocene Lake Marmara end-member that is advecting buoyantly and/or diffusing from a relatively shallow depth. This mix is overprinted by shallow redox reactions and carbonate precipitation. The ridge sites are more complex with evidence for deep!sourced fluids including thermogenic gas and evidence for both silicate and carbonate diagenetic processes. 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 of up to twice seawater salinity with an exotic fluid chemistry extremely high in Li, Sr, and Ba. Oil globules were observed both at the surface and in cores, and type II gas hydrates of thermogenic origin were recovered. Hydrate formation near the seafloor contributes to increase brine concentration but cannot explain their chemical composition, which appears to be influenced by diagenetic reactions at temperatures of 75°C–150°C. Hence, a potential source for fluids at this site is the water associated with the reservoir from which the gas and oil is seeping, which has been shown to be related to the Thrace Basin hydrocarbon system.

1. Paper 1 :

Bourry, C., Chazalon, B., Charlou, J.-L., Donval, J.-P., Rufine, L., Henry, P., Géli, L., Çagatay, N., Inan, S., Moreau, M. (2009), Free gas and gas hydrates from the Sea of Marmara, Turkey : Chemical and structural characterization, *Chemical Geology*, doi: 10.1016/j.chemgeo.2009.03.007

http://wwz.ifremer.fr/drogm/content/download/17793/261337/file/49-Bourry2009.pdf

2. Paper 2 :

Tryon, M. D., Henry, P., Cagatay, M . N., Zitter, T., Géli, L., Gasperini, L., Burnard, P., Bourlange, S., Grall, C., (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

http://wwz.ifremer.fr/drogm/content/download/17796/261370/file/54-Tryon2010.pdf

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 MARMARA-DM PROJECT

Deliverable 1.4 : Synthesis Paper on MarNaut results

Due date of deliverable: September 2010
Actual submission date: September 2010

Start date of project: **March 2007** Duration: **30 months**

Organisation name of lead contractor for this deliverable: CNRS/CEREGE
Lead authors for this deliverable: Pierre Henry

Revision [final version]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
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CONTENTS

Summary :

Synthesis of MarNaut results : Relations between active faulting 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].* A systematic correlation was also found between active faulting and the acoustically detected gas escapes. Remarkably, the fault segment with the less acoustic anomalies found within the main fault trace corresponds to the Central High and Kumburgaz Basin area (see Fig. 1 in *[Géli et al, 2008]).* 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 found in the Thrace Basin are present on top of anticline structures, which indicate 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 occurence 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 in the crust: the hydrogeological system in submarine environment appears to be directly coupled to the tectonic system through the interaction of fluid pressure and stress state. 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. Because gas is very compressible, great quantities of gas can accumulate in sediment pores, until excess pressure fractures the overburden. In addition, gas bubbles in the water are very easy to detect via acoustic methods. Hence, a major challenge is to determine whether gas can generate **detectable** signals related to the stress building process during the seismic cycle. This is a major issue related to detection of precursory signals before an earthquake, and therefore of direct societal importance.

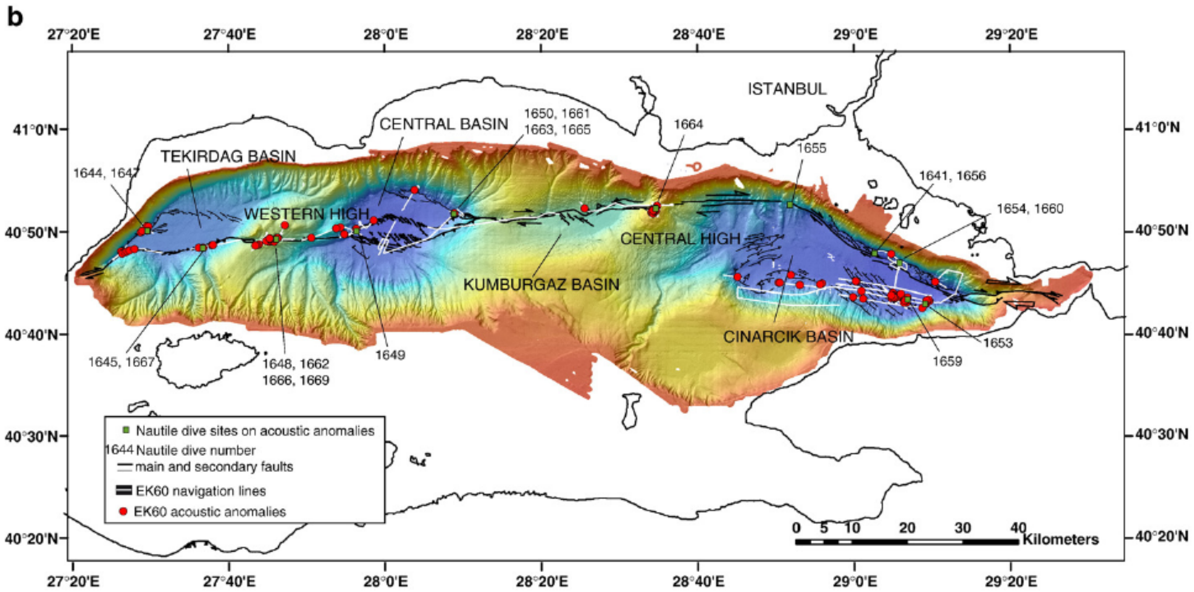

Fig. 1 Reproduced from Géli et al. [2008]. Bathymetric map of the Sea of Marmara with the acoustic anomalies (red dots) detected with an EK-60 sonar during the MarNaut cruise (May-June 2007). Black and white lines indicate active faults [Rangin et al., 2004] and the R/V L'Atalante tracks during the MarNaut cruise.

Synthesis Paper :

Géli, L., Henry, P., Zitter, T., Dupré, S., Tryon, M., Cagatay, N., Mercier de Lépinay, B., Le Pichon, X., Sengör, A. M. C., Görür, N., Natalin, B., Uçarkus, G., Volker, D., Gasperini, L., Burnard, P., Bourlange, S. & the MarNaut Scientific Party (2008), « Gas emissions and active tectonics within the submerged section of the North Anatolian fault zone in the Sea of Marmara », *Earth and Plan. Sci. Let*., **274**, 34-39, doi : 10.1016/j.epsl.2008.06.047

http://wwz.ifremer.fr/drogm/content/download/17792/261326/file/48-Geli2008.pdf

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 MARMARA-DM PROJECT

Deliverable 2.1:
Cruise report of DEU (PirMarmara) Cruise with R/V Piri Reis

Due date of deliverable: September 2010
Actual submission date: September 2010

Start date of project: **March 2007** Duration: **30 months**

Organisation of lead contractor for this deliverable: Dokuz Eylül Universitesi, Izmir, Turkey
Lead authors for this deliverable: Günay Çifçi,

Revision [final version]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	PU
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CONTENTS

Executive summary

The Pirmarmara cruise was conducted in the Marmara Sea from June 2 to June 12, 2010, on board R/V K. Piri Reis from Dokuz Eylül University (DEU, Izmir, Turkey), under the supervision of Dr Günay Çifçi, head of the Marine Seismic Laboratory SeisLab of DEU.

The cruise consists in the acquisition of High Resolution (HR) seismic profiles over 4 main targets. The Pirmarmara cruise completes two previous HR seismic surveys in cooperation with two other research institutes :

- The first one, is part of the Tamam project (Turkish-American MArmara Multichannel). This survey has allowed 2D HR data acquisition all over the Marmara Sea in 2008, using DEU 600 meters length streamer. The Tamam project, funded by the National Science Foundation (USA) gathers Dokuz Eylül Üniversitesi, Lamont-Doherty Earth Observatory and Istanbul Technical University. The second leg of the Pirmarmara cruise aims to complete the former 2D HR acquisition close to Istanbul, mainly in the Çınarcık basin.
- The second one, is part of the Marmara Demonstration Mission Program supported by EU ESONET project (European Seafloor Observatory Network). This survey has allowed 3D HR data acquisition over the Western High in December 2009 using Ifremer's equipment, dual 450 meters length streamers. The main objective of the Pirmarmara first leg was to record 2D long offset seismic profiles to provide velocity constrains and hence to improve 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.

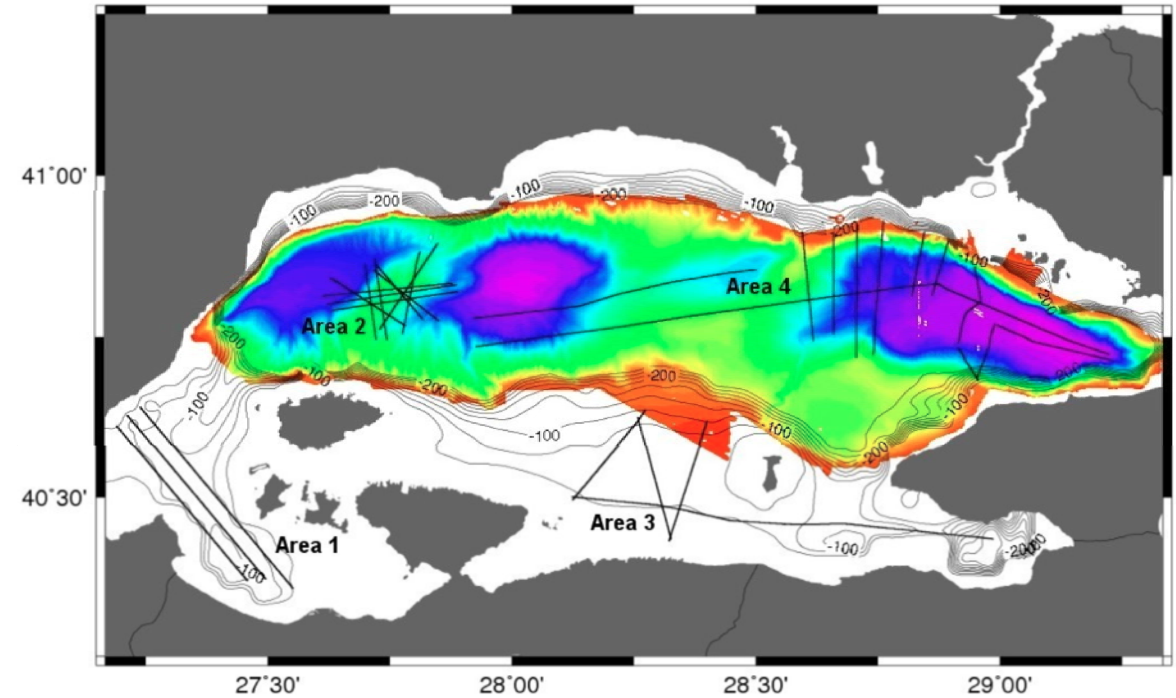
Ifremer and Genavir, have provided additional seismic equipment to the cruise with an active tail buoy and 10 depth controllers including compasses in order to enhance the security of the equipment in a heavy maritime traffic area.

The Pirmarmara cruise would not have been succesfull without the invaluable help of both the R/V Piri Reis ship crew and the Turkish Navy chase boats.

Objectives

Three geological targets were selected for the Pirmarmara cruise :

- The Western High (area 2) where 3D HR seismic data were acquired in December 2009 on board R/V Le Suroît. The objectives for area 2 are two fold :
    - a detailed site survey to constrain velocity model using long offset DEU's streamer;
    - AVO analysis on amplitude anomalies, which may bring new insights regarding fluid characterization;
- The Central High, Central Basin and Çınarcık Basin (area 4) to complement the Tamam data set recorded in 2008 on board R/V Piri Reis.
- The southern shelf of the Marmara Sea (areas 1 and 3), with the investigation of the Messinian unconformity.



Pirmarmara cruise profiles - R/V Piri Reis (DEU)

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 MARMARA-DM PROJECT

Deliverable 2.2a:

Cruise report of Marmesonet Cruise (Leg I) with R/V Le Suroit

Due date of deliverable: September 2010
Actual submission date: September 2010

Start date of project: **March 2007** Duration: **30 months**

Organisation of lead contractor for this deliverable: Ifremer
Lead authors for this deliverable: Louis Géli,

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CONTENTS

Executive summary

The MARMESONET cruise is part of the Marmara Demonstration Mission Program supported by ESONET Network of Excellence (**E**uropean **S**eafloor **O**bservatory **N**etwork), within the 6th European Framework Programme. Main partners are: Ifremer, CNRS/CEREGE, Istanbul Technical University, TUBITAK, Institute of Marine Science and Technology of Dokuz Eylül Universitesi (Izmir), INGV (Rom) and ISMAR (Bologna). Marmesonet is also the follow-on of the Franco-Turk collaborative programme that resulted in numerous cruises in the Sea of Marmara since 2000.

The objectives of the MARMESONET cruise were:

1) to study the relationship between fluids and seismicity along the Sea of Marmara fault system ;
2) to carryout site surveys prior to the implementation of permanent seafloor observatories in the Marmara Sea through ESONET.

The cruise is divided in 2 parts:

- 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) *Aster$_x$* 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 (from november 28th november to december 14th, 2009), for 3D, High Resolution Seismic imagery of the fluid conduits below the observatory site planned at the Western High.

The present deliverable only concerns Leg I.

A total of 19 dives were completed during Leg I: 16 with the multibeam echosounder SIMRAD EM2000 (200 kHz), among which 12 were successful and 4 failed ;3 with the CHIRP sédiment penetrator (1 test dive and 2 operational, both were unfortunately with early stop recording). Main results are:

- The absence of recent, visible deformation on the segment south of Istanbul. Wether or not this segment is locked or creeping remains an open question. The site south of Istanbul thus requires a massive effort to assess the deformation, particularly through submarine geodesy and piezometry.
- The plausible presence of a 4 km, right-lateral offset on the Western High, between N30 oriented structures related to cold seeps.
- Gas emission sites are systematically related to zones of High reflectivity mapped on the AUV imagery
- AUV imagery reveals the traces of intensive, human activity, which shows the necessity to ensure the security of the future cables by enforcing a clearance area
- Last but not least, the exact position of the future observatories is now established, at the Central High and at the Western High sites.

Some chirp profiles suggest that the 1912 earthquake probably extended up to the Western High, but not the fault is not visible on all of them. Further work is needed.

The SIMRAD EM-302 multibeam echosounder was used to map the water column, providing a complete coverage of slopes foot and of the central shear zone. Results require further analysis to establish the correlation between acoustic anomalies and active faults, as gas emissions appear to be a common feature in the the Sea of Marmara. A noticeable feature is the important gas emission activity along the base of thewestern of slope of the Tekirdag Basin, suggesting that the gas réservoirs from the Thrace Basin are presently leaking out into the Sea of Marmara.

In addition, shipboard CHIRP data were collected along with EM-302. 23 cores were taken (13 with gravity corer, 3 with Küllenberg and 7 with interface corers). A total of 24 additional heat flow measurementswere also collected. Finally, 2 OBSs were deployed to complete the coverage of the OBSs dropped with R/V Urania in september 2009.

The assistance of the Turkish Coast Guard largely contributed to the success of the operation. We greatly acknowledge the Coast Guard, as well as SHOD, the Department for Hydrography and Oceanography of Turkey, who made the cruise possible in a heavy trafic area. The captain, Jean-René Gléhen, and all crew members of R/V Le Suroit, are also greatly acknowledged.

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 MARMARA-DM PROJECT

Deliverable 2.2b:
Cruise report of Marmesonet Cruise (Leg II) with R/V Le Suroit

Due date of deliverable: September 2010
Actual submission date: September 2010

Start date of project: **March 2007** Duration: **30 months**

Organisation of lead contractor for this deliverable: Ifremer
Lead authors for this deliverable: Louis Géli,

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  - 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 (from november 28th november to december 14th, 2009), for 3D, High Resolution Seismic imagery of the fluid conduits below the observatory site planned at the Western High.

The present deliverable only concerns Leg II.

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).
Thanks to exceptionally favorable weather conditions (in december, the sea is usually rough), 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. Onboard results obtained using pseudo-3D migration (in 2 passes, along and across line) with constant velocity of 1500 m/s show the potential of the method that can be expected after application of finely-tuned signal processing.

Additional chirp data and multibeam (EM-302) bathymetry data were also collected during transits from Istanbul to the survey area and during periods of rough weather, mainly after december 10th, 2009. This dataset improves the systematic coverage achieved during Leg I.

The assistance of the Turkish Coast Guard largely contributed to the success of the operation. We greatly acknowledge the Coast Guard, as well as SHOD, the Department for Hydrography and Oceanography of Turkey, who made the cruise possible in a heavy trafic area. The captain, Jean-René Gléhen, and all crew members of R/V Le Suroit, are also greatly acknowledged.

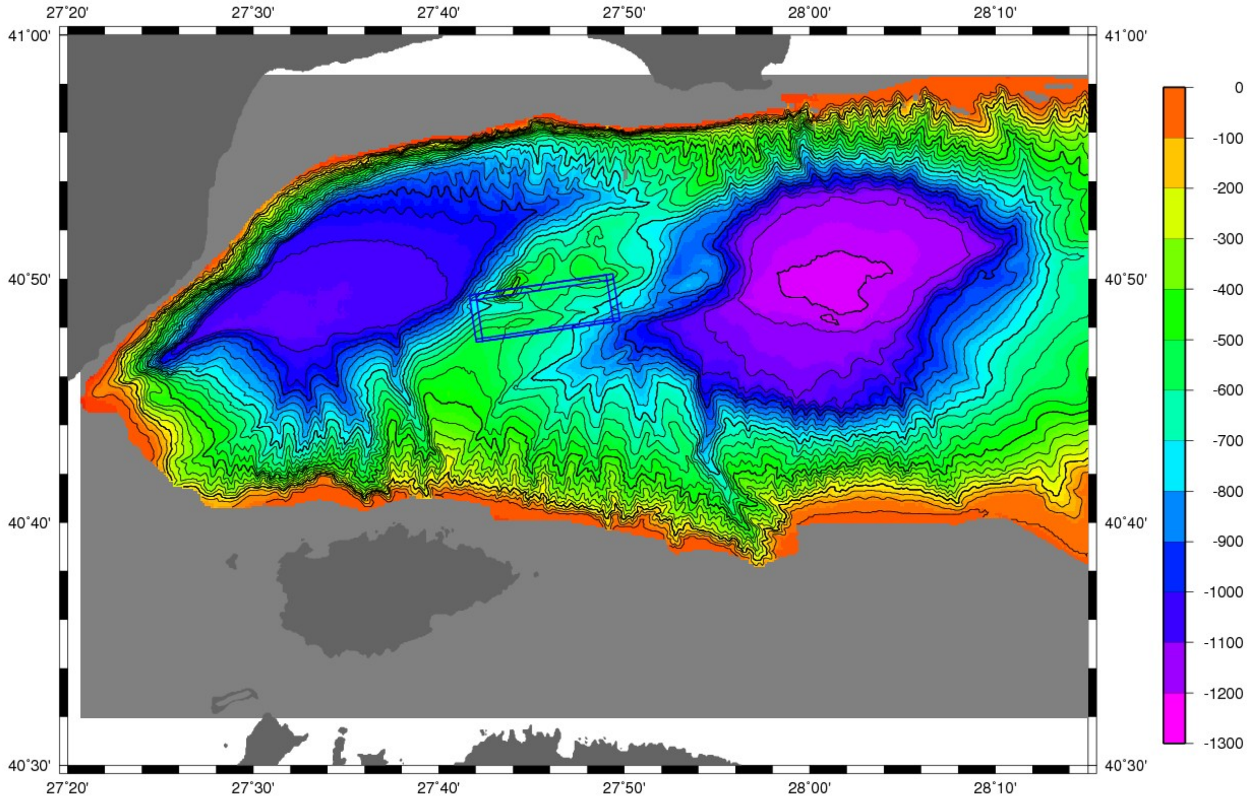
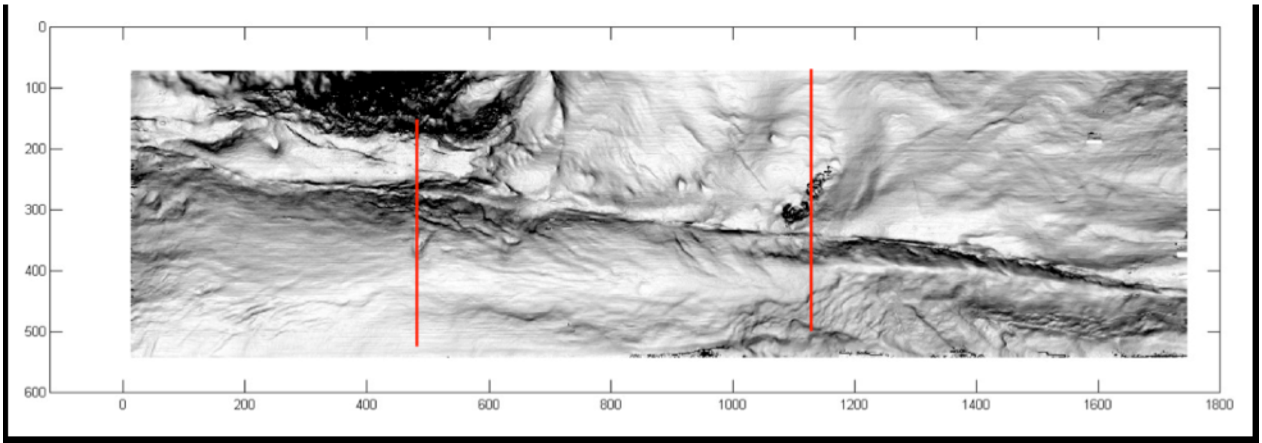
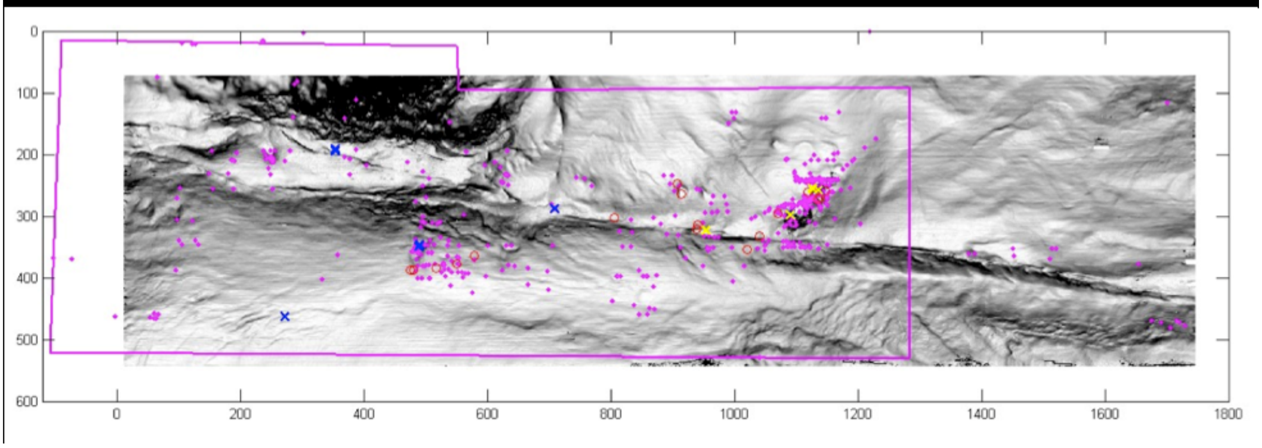


Fig. 1 : Rectangle shows the location of High Res 3D Seismic Survey area, on the Western High (Sea of Marmara)

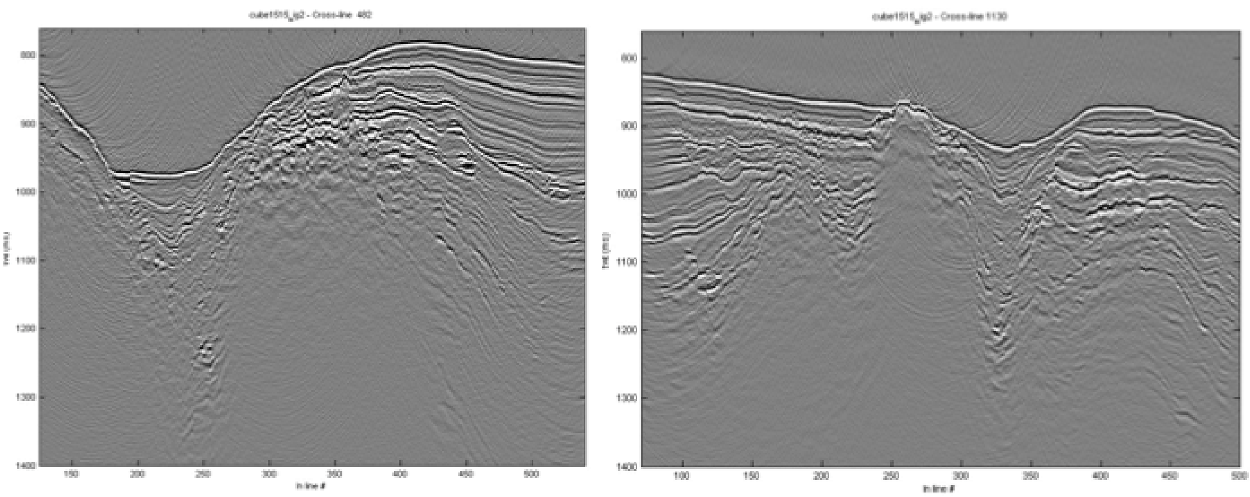




Upper figure : Seismic bathymetry (bin 6.25 m) obtained with High Res 3D system. Red lines indicate seismic cross-sections shown in the figure below. After Thomas, Marsset et al (in prep).

Middle Figure : Seismic bathymetry (bin 6.25 m) obtained with High Res 3D system. Violet dots indicate acoustically detected gas emissions. . After Thomas, Marsset et al (in prep).

Bottom Figure : Seismic profils (cross-lines) indicated as red lines in the upper figure. Note diapir rising up to th surface on right profile, indicating the présence of a mud volcano.



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**

Deliverable reference number and title

ESONET MARMARA-DM PROJECT

Deliverable 2.3: Cruise reports of SN4-related operations

- Marmara 2009 Cruise with R/V Urania

- Recovery and redeployment operations with R/V Yunuz

- Marmara 2010 Cruise with R/V Urania

Due date of deliverable: September 2010
Actual submission date: September 2010

Start date of project: **April 1st, 2007** Duration: **30 months**

Organisation of lead contractor for this deliverable: ISMAR
Lead authors for this deliverable: Luca Gasperini

Revision [final version]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	PU
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)	

CONTENTS

1. Executive summary

A major objective of the Marmara-DM was to collect long-term, multi-parameters time-series in order to study the relations between fluids and seismicity in the close vicinity of the Main Marmara Fault. To meet this objectives, the following cruises were conducted within WP2 of the present Demonstration Mission to deploy, recover and re-deploy, stand-alone instruments on the Marmara seafloor:

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

2) Yunuz-2010 cruise with R/V Yunuz for :
    - recovering and redeploying SN4, after a 6 months long deployment.
    - 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

3) Marmara-2010 cruise with R/V Urania (sept 29 – oct 18, 2010), during which the INGV-SN4 station was finally recovered, after the second, 6-months long deployment.

The brief summary of each of these cruises is retrieved hereafter :

Marmara-2009 cruise with R/V Urania. *A marine geological cruise, MARMARA2009, was carried out from september 23rd to october 12, 2009, in the frame of MARM- ESONET, a demo mission of the EC funded ESONET Network of Excellence (European Seafloor Observatory Network). Main objective of the project is attempting to assess and mitigate seismic hazards in the region close to Istanbul through geological/geophysical surveys carried out in the Sea of Marmara along the submerged track on the North Anatolian Fault (NAF) and through the de- ployment of seafloor observatories. During MARMARA2009 we collected multibeam bathymetry, side-scan sonar imagery and chirp sub-bottom data, together with carefully positioned core samples; we also deployed a submarine station of the GEOSTAR family (SN-4) that will collect multidisci- plinary data over a period of 1 year. Although selected prior of the cruise, the SN4-observatory site has been surveyed before deployment with geophysical imaging techniques and direct groundthrut- ing with a deep towed system, the MEDUSA, that provided oceanographic data (CTD), methane content in the water column and visual inspection through a high-resolution video camera. Together with the SN-4 station, 5 piezometers and 10 OBSs (Ocean Bottom Seismometers) were deployed.*

Yunuz-2010 cruise.

- *2010-03-27 08:30 R/V Yunus S. left Istynie harbour, with INGV, ITU-EMCOL and IFREMER teams onboard, heading to SN4 site. Ship arrives on SN4 station at 09:50 local. At 10:30 water sample cast with 2 bottles (bottom and 5 m above). At 11:47 Piezometer P2-D is recovered. SN4 release is recovered at 12:30. Ship heads to Tuzla and docks at 15:45.*
- *2010-03-28 09:07 Recovery of Piezometers and OBS*

- *2010-03-29 09:07 Recovery of Piezometers and OBS*
- *2010-03-31 09:07 R/V Yunus S. leaves Tuzla harbour*
- *2010-03-31 10:05 at the SN4 deployment site*
- *2010-03-31 14:34 SN4 release*
- *2010-03-31 15:15 water sample 2010-03-31 16:10 SN4 interrogation*
- *2010-03-31 16:40 leave area, heading to Istanbul*
- *2010-03-31 21:30 Docked at Istinye*

Marmara-2010 cruise with R/V Urania. *The objectives of this cruise, carried out from september 29 to october 18, 2010, were similar to those of the Urania-2009 cruise. Additional multibeam bathymetry, side-scan sonar imagery, chirp sub-bottom and ADCP data were collected, together with carefully positioned core samples. The INGV GEOSTAR family (SN-4) was recovered after second 6 month deployment. During Transits core and water samples were collected in the Western Ionian Sea. We recovered also two INGV OBS deployed during the February 2010 R/V Urania in the Southern Tyrrhenian Sea.*

2. List of available time series collected during Marmara-DM Demo Mission

Piezometers (Ifremer) :

Piezometer name	Deployment Date	Latitude	Longitude	Depth (m)	Near-by core	Near-by OBS	Chirp File	Recording period	Duration (days)
PZ-A	27/09/09 :15:36	40°45.505	28°47.866	1199	MPZ-01	OBS-7	MA09-066	27/09/09-27/02/10	153
PZ-B	28/09/09 :08 :42	40°43.159	29°07.024	1248	MPZ-02	OBS-9	MA09-103	28/09/09-01/10/09	3
PZ-C	28/09/09 :13 :06	40°44.045	29°07.202	1265	MPZ-03	OBS-9	MA09-109	28/09/09-12/01/10	106
PZ-D	29/09/09 :07 :48	40°43.693	29°23.157	168	MPZ-04	SN4	MA09-179	28/09/09-23/02/10	147
PZ-E	29/09/09 :12 :52	40°50.003	28°56.223	1219	MPZ-05	OBS-10	MA09-120	28/09/09-10/10/09	11

Sensor number	Sensor depth (m)
P1	0,79
P2	3,84
P3	5,39
P4	6 ,94
P5	7,74
P6	8,54

OBSs (Ifremer and Geomar)

OBS	**Latitude**	**Longitude**	**Depth (m)**	**Date of Start recording**	**Date, hour end recording**	**Commentaire**
OBS1	40°44.220	27°25.392	303	01-oct	15/03/10 12:00	
OBS-2	40°49.555	27°29.907	1118	01-oct	24/02/10 03:11	
OBS-3	40°51.090	27°42.033	1059	Corrupt	Corrupt	Non usable
OBS-4	40°44.409	27°49.723	668	01-oct	15/03/10 12:00	
OBS-5	40°46.575	28°18.557	428	1 day record only	Failure	Non usable
OBS-6	40°44.365	28°34.672	740	01-oct	28/01/10 00:05	
OBS-7	40°45.519	28°47.882	1200	01-oct	15/03/10 12:00	
OBS8	40°52.038	28°25.966	711	LOST		Non usable
OBS9	40°43.165	29°07.029	1248	01-oct	15/03/10 12:00	Very noisy after 01/11/09 00:00
OBS10	40°49.913	28°55.688	1211	01-oct	15/03/10 12:00	
OBS-GEOM1	40°7,883	28°52,131	366	07-nov	15/03/10 12:00	
OBS-GEOM2	40°53,350	28°4,100	1198	07-nov	15/03/10 12:00	

SN4 Multi-parameter station (INGV)

INSTRUMENT	***Fisrt mission 2009/10/05-2010/03/15***	***Second mission 2010/03/31-2010/10/06***	***Notes***
SEISMOMETER	All the period	All the period	The R/V Yunuz, used for the second SN-4 deployment, had not a pull-up buoy on board and when the acoustic release was released, it fell on the station breaking the system for seismometer release. So the seismometer acquired all the period but it wasn't coupled to the ground.
METS WITH PUMP	All the period	All the period	On September, 20, 2010, SN-4 was dragged from some sailor-ship and tipped over. Data are not reliable after that event.
METS WITHOUT PUMP	All the period	All the period	
CTD	All the period	All the period	
TURBIDITY METER	All the period	All the period	
OXYGEN	All the period	All the period	
CURRENT METER	2009/10/05-2009/10/14 2010/02/14-2010/02/23 2010/03/04-2010/03/13 there was a software problem in current data acquisition	Never	The R/V Yunuz, used for the second SN-4 deployment, had not a pull-up buoy on board and when the acoustic release was released, it fell on the station breaking the current meter. So we don't have any current data.

3. Preliminary analysis of SN-4 time (6 months) series

Preliminary Observations made on the SN4-datsets

Francesco Frugoni[1], Stephen Monna[1], Davide Embriaco[1] and Aybige Akinci[1]
INGV, Italy

I. General Observations from the Broad-Band OBS

1. Very high data quality on 3 components
2. 90% of local seismic event reported on Turkish bulletin (epicentre < 100 Km from SN-4) were recorded
3. Numerous, low-magnitude, local events recorded that are not reported on the land network Turkish bulletin.
4. Occurrence of 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. 1).
5. Simultaneously, high amplitude, long period signals (up to 30 seconds) are visible on horizontal components. Such signals often occur on the vertical component (Fig. 1).
6. Very common occurrence of short-duration (< 3 s), high-frequency (20 Hz), events, not reported on land stations (Fig. 2). 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.
7. The very long period (~3 hours) signals on the vertical component appear associated with very strong amplitude, non-seismic micro-events described in item 6 (Fig. 2).

II. Correlations between OBS recordings and non-seismic parameters

1. 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”.
2. No apparent correlation exists between the local seismicity occurrence and physico-chemical parameters trend (e.g Methane peaks)

III. Next step in seismic data analysis also in comparison with non-seismic sensors

1. Systematic detection of long period signals on vertical component and of high amplitude signals on horizontal components.
2. Check when the gas outburst occurs relatively to the long period event : is it before, during the ascending phase or at the paroxysmus of the rising seafloor?
3. Check if the perturbations on the piezometer correlate with the occurrence of the long period/high amplitude signals observed on the 3-component seismometer .

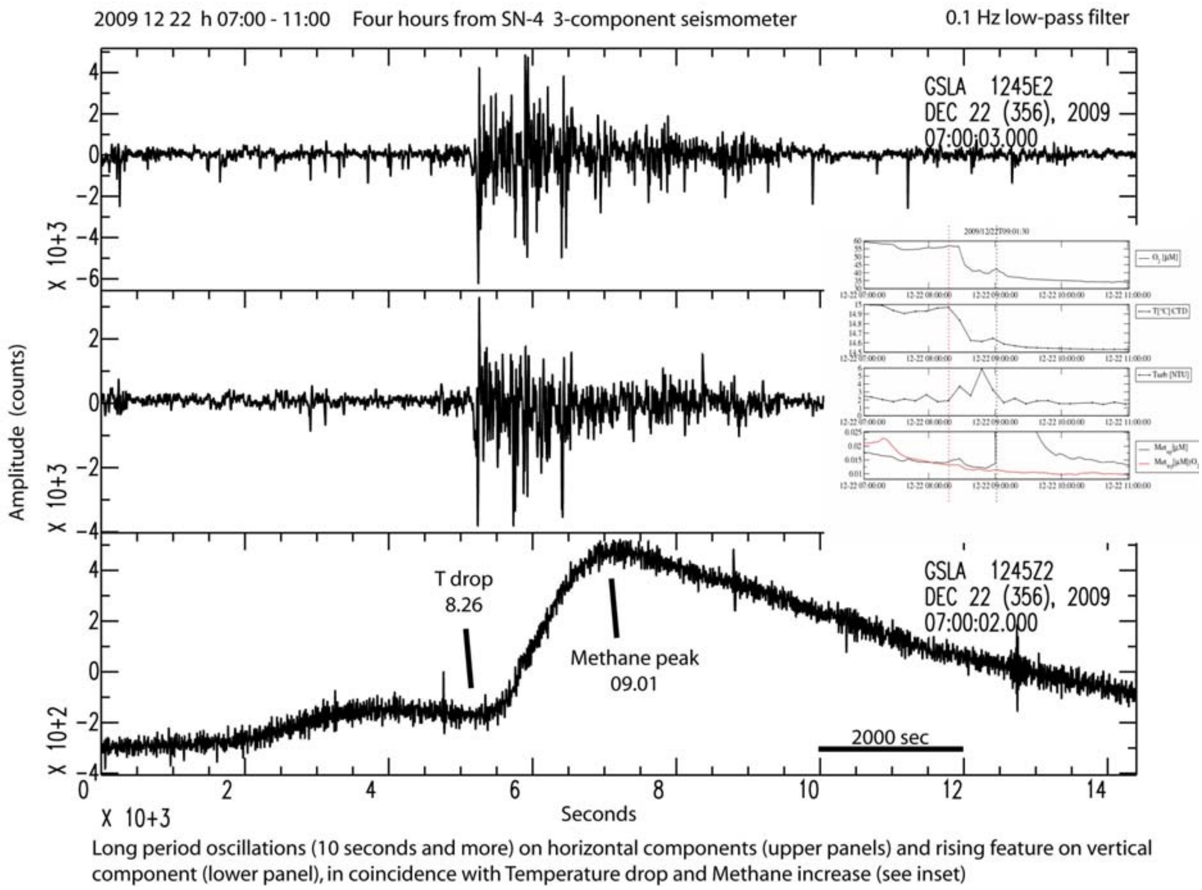


Fig. 1 : Figure summarizing the observations on SN-4 : very long period (~3 hours) signals are observed on the vertical component, appearing like an arch, with an episode of rising seafloor and then an episode of dropping seafloor suggesting return to equilibrium. Simultaneously, high amplitude, long 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.

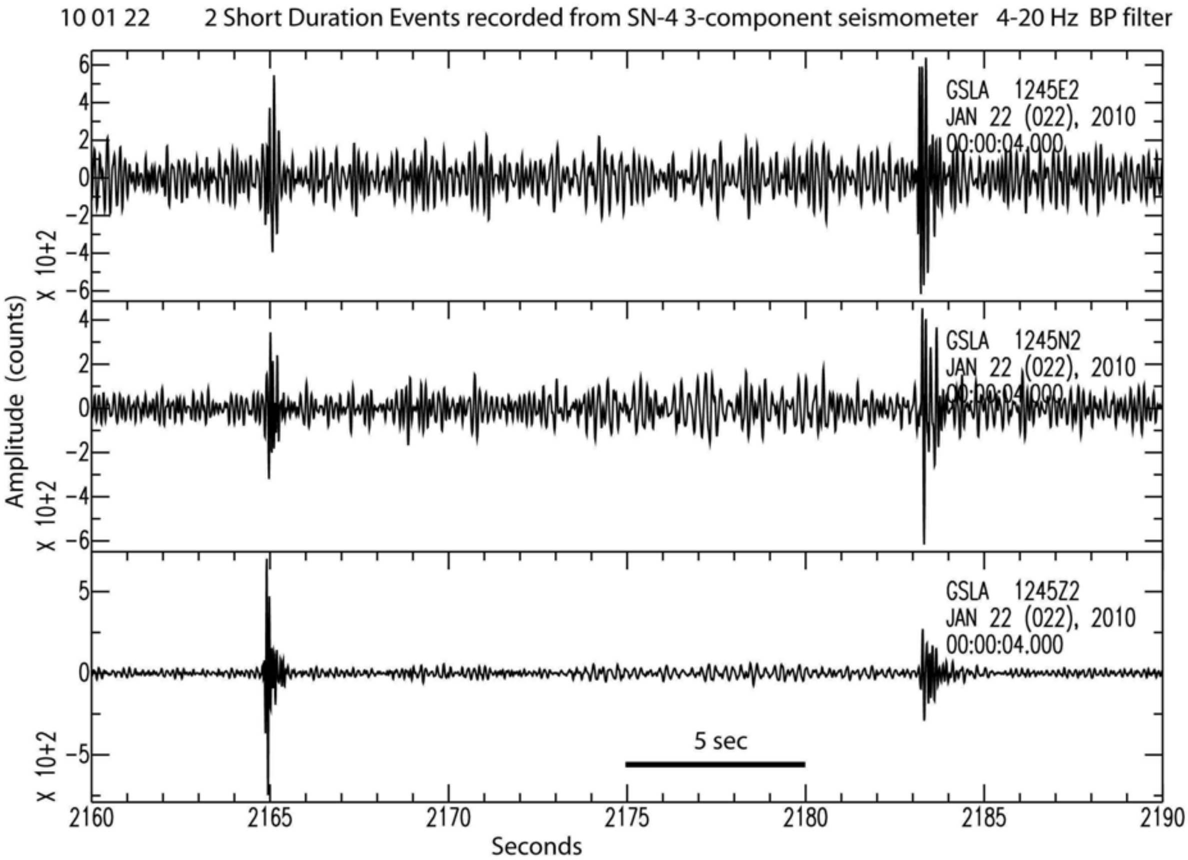


Fig.2a Example of two short duration events recorded on the BB-OBS (Guralp CGM-3). Signals are band-pass filtered 4-20 Hz.

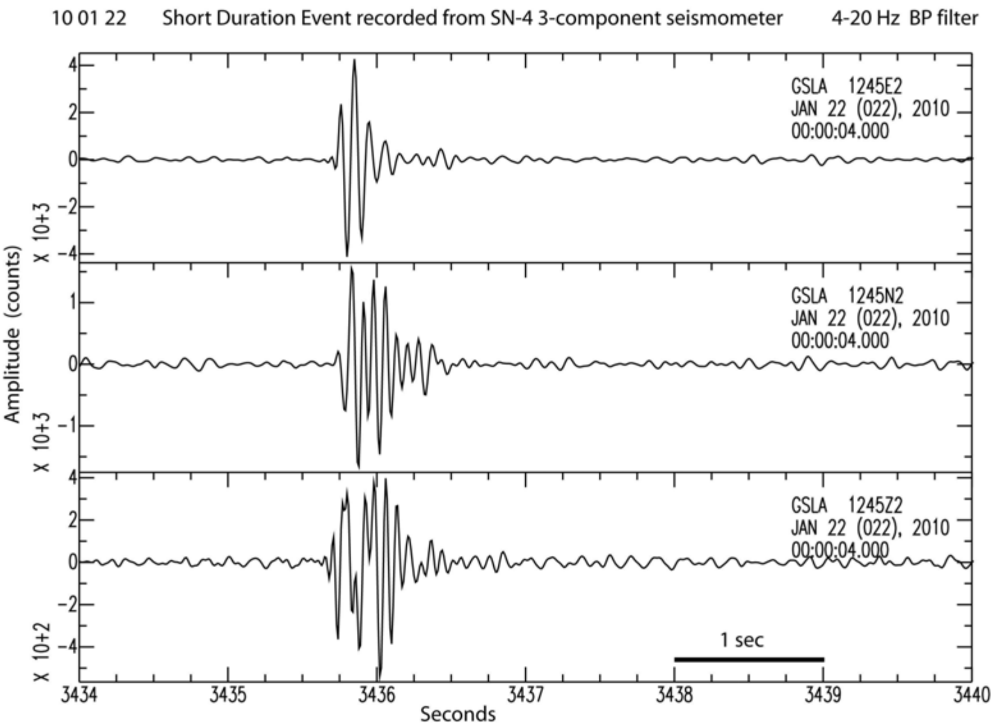


Fig. 2b : Zoom on one short-duration event recorded on the BB-OBS Guralp CGM-3 installed on SN-4. Signal is band-pass filtered [4-20] Hz. The upper plot represents the vertical component.

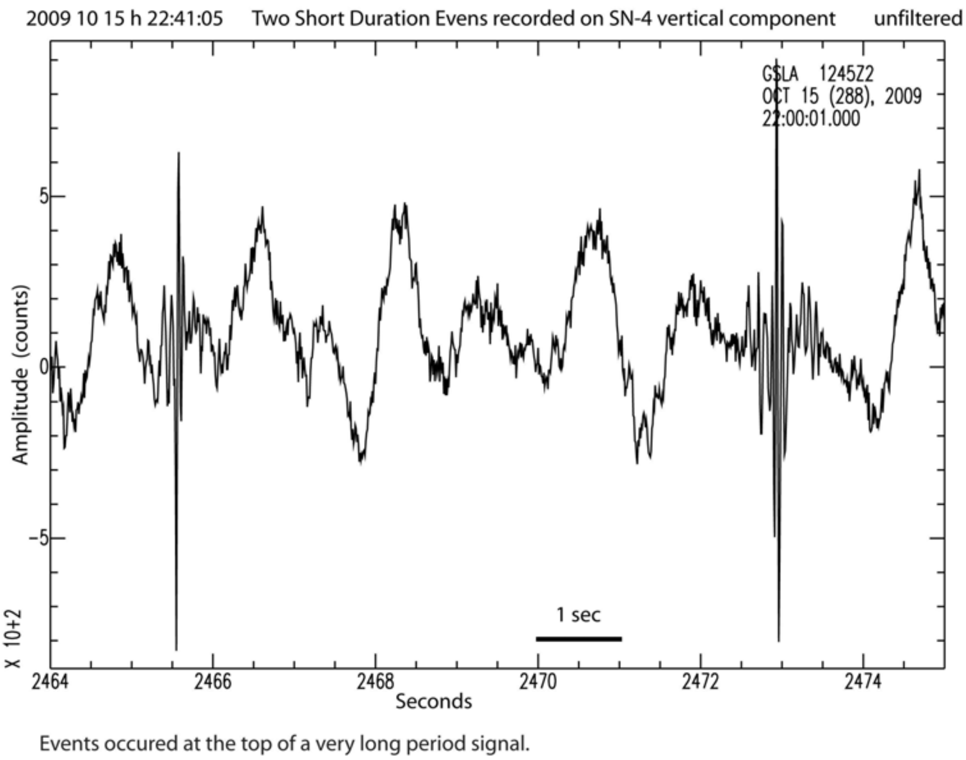


Fig 2c : Example of two short duration events recorded on the vertical component of the BB-OBS, when no filter is applied. These events occur at the top of the very long period signal shown in Figure 2.

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 MARMARA-DM PROJECT

Deliverable 3.1: Report combining marine and land seismological datasets

Due date of deliverable: September 2010
Actual submission date: September 2010

Start date of project: **April 1st, 2007** Duration: **30 months**

Organisation name of lead contractor for this deliverable: Ifremer
Lead authors for this deliverable: Louis Géli & Jean-Baptiste Tary

Revision [final version]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
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CONTENTS

Report combining marine and land seismological dataset

1. Executive summary :

The subject of the present delivrable was fully addressed during Jean-Baptiste Tary's *PhD* work (defended on march 15th, 2011), entitled *"Case studies on fluids and seismicity in submarine environments based on Ocean Bottom Seismometers (OBS) recordings from the Sea of Marmara and from to the Niger Delta"*.

Part of this work is subject to a publication in press :
Tary, J.-B., **Géli, L.,** Henry, P., Natalin, B., Gasperini, L., Comoglu, M., Cagatay, N., & Bardainne, T., (2011), Sea-bottom observations from the western escarpment of the Sea of Marmara, *Bull. Seism. Soc. Am*., in press (april 2011).
http://wwz.ifremer.fr/drogm/Presentation-GM/Pages-perso/Louis-Geli/Publications

Based on this PhD work, the following recommendations are made for the future, permanent, mutli-disciplinary seafloor observatories for earthquake monitoring in the Sea of Marmara:

1.1 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**.

1.2 To improve the real-time, absolute locations of hypocenters near the submerged fault zone and enhance the search for seismic tremors [*Bouchon et al.,* 2010 *in press*], 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.

1.3 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.

1.4 Multi-parameters approaches must be developed. Our work clearly shows that for each measured parameter, the background variability must be assessed. In addition, data processing and research on the physics of the phenomena should be intimately related.

2. Extract of Chapter 2.7 of Jean-Baptiste Tary's Ph. D. Thesis

2.7. MarNaut cruise (May-August, 2007): OBS data analysis

2.7.2. Network configuration and instrument characteristics

During the MarNaut cruise, 8 short-period OBSs were deployed for various periods in the Tekirdag Basin (western part of the Sea of Marmara, Fig. 2.26 and 2.27). Five OBSs, called J, J2, K, L and M, were provided by IFREMER and three by CGG-Veritas, called ARMSS, NEEDLE and SPAN. All OBSs were 3 components velocity sensors with a hydrophone. Except the ARMSS, in which the geophones are in Galperin configuration, all other OBSs have their sensors set orthogonally. The clock drift was linearly corrected for all instruments. The instruments recording periods are listed in Table 2.1 and their technical characteristics are detailed in Appendix B.

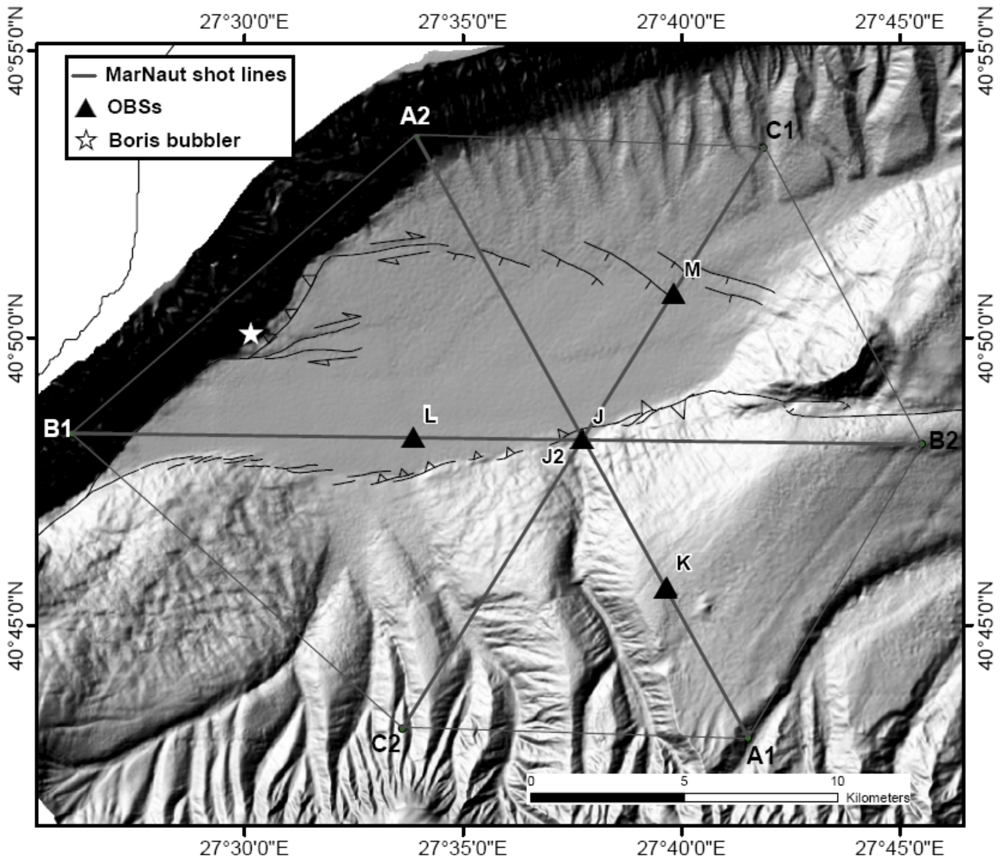


Fig. 2.26. Tectonic map of the Tekirdag Basin. The OBSs deployed during the MarNaut cruise are indicated by black triangles. Gray lines show the location of the wide-angle seismic profiles acquired during the MarNaut cruise by the R/V Sismik-1. OBSs J2, ARMSS, NEEDLE and ARMSS are situated close to OBS J (see Fig. 2.27).

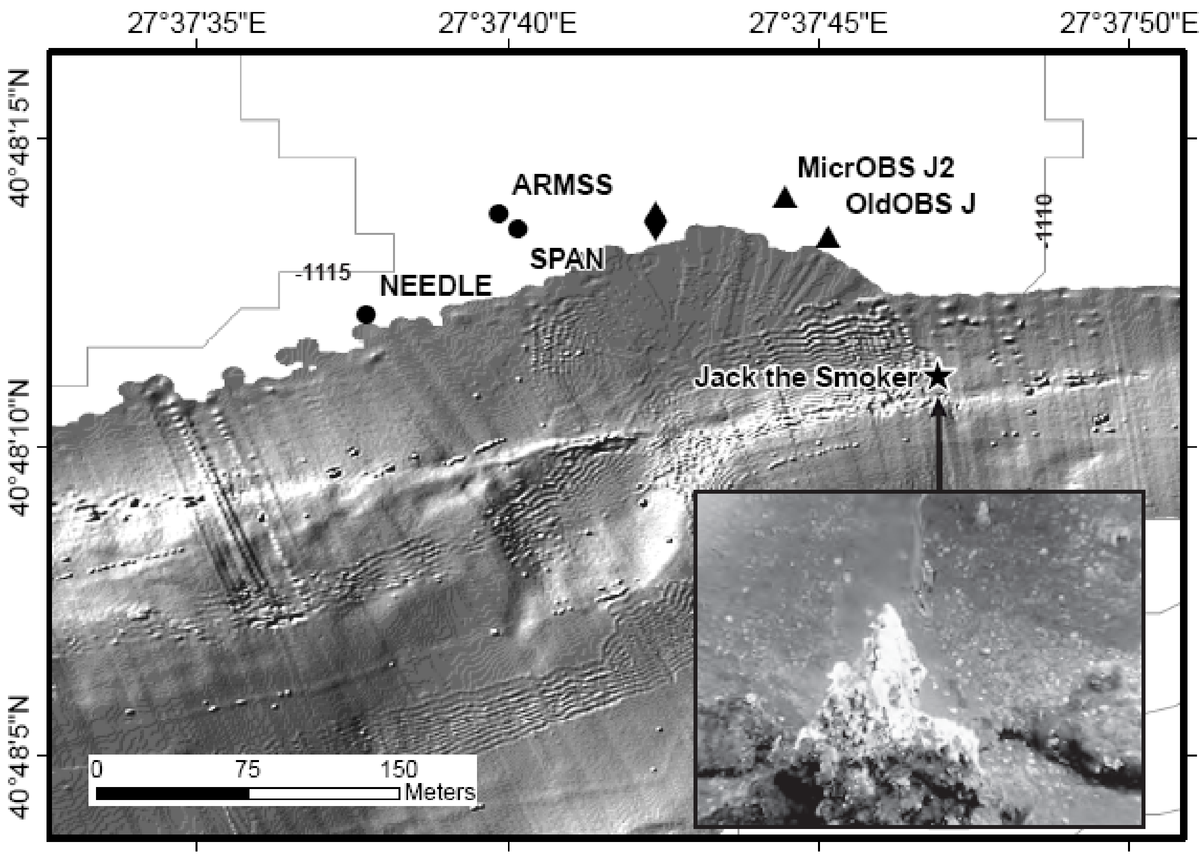


Fig. 2.27. Zoom in the area close to OBS J. Microbathymetric data were acquired during the MARMARASCARPS cruise in 2002 by the R.O.V. Victor. OBS provided by IFREMER and CGG-Veritas are indicated by black triangles and black dots respectively. The black star shows the location of "Jack the Smoker" site where fresh water escapes from the seafloor through carbonate chimneys. The seismic shot used for OBSs amplitude inter-calibration is indicated by the black diamond (Fig. 2.26).

Stations	Longitude (deg)	Latitude (deg)	Depth (m)	Recorded period used	F_0 (Hz)	Fs(Hz)
J	E 27.62921	N 40.80372	1112	14 May - 30 Aug. 2007	4.5	250
J2	E 27.62902	N 40.80390	1112	22 May - 28 May 2007	4.5	250
K	E 27.6608	N 40.7613	546	14 May - 19 Aug. 2007	4.5	250
L	E 27.5645	N 40.8044	1132	14 May - 09 June 2007	4.5	250
M	E 27.6637	N 40.8466	1110	14 May - 26 Aug. 2007	4.5	250
ARMSS	E 27.62774	N 40.80382	1115	14 May - 09 June 2007	14	500
SPAN	E 27.62782	N 40.80376	1117	14 May - 28 May 2007	4.5	500
NEEDLE	E 27.62714	N 40.80337	1115	14 May - 28 May 2007	4.5	500

Table 2.1. OBS position, main technical characteristics and recording period. F_0: geophones natural frequency; Fs: sampling frequency.

During the first period, from May 14 to June 9, 2007, between 4 and 8 OBSs worked simultaneously. However, during the second period, from June 9 to August 28, 2007, only 3 instruments worked. In our configuration, three stations are not enough to locate micro-earthquakes with reasonable uncertainties. Consequently, the recordings of the 2nd period were not used for locating earthquakes.

During the MarNaut cruise, 5 types of OBS have been layed down to the sea floor: OldOBS (J, K, L, and M), MicrOBS (J2), ARMSS, SPAN, and NEEDLE. Each one is equipped with different coupling devices. Thereby, an inter-comparison of OBSs response to known solicitations as well as a noise analysis has been carried out to determine the performance of each instrument (Appendix B).

2.7.3. Tentative calibration for hydrophones and geophones (section 2.9, Appendix A)

Each OBS type has a specific descaling factor to convert digital (counts) into physical (µm/s or Pa) amplitudes, which depends on the ADC coefficient (counts to volts), on the pre-amplifier and amplifier gains, and geophone or hydrophone sensibility. Unfortunately, the descaling factors of the different instruments are not known, except for the hydrophone of the MicrOBS and the geophones of the OldOBS, which will be used hereafter as references. To compare the amplitudes of the signals recorded by the different instruments, we have used seismic shots fired with a surface vessel above the OBSs (Fig. 2.27). Conversion factors were derived, assuming that the amplitude of the first P-arrival peak in response to one given shot is the same for all different OBSs (Fig. 2.28, Table 2.2)

	Hydrophone	Geophone (Z)
OldOBS (J, K, L, M)	4.822E-06	2.286E-04
MicrOBS (J2)	5.813E-06	2.125E-04
ARMSS	-7.170E-05	1.058E-05
NEEDLE	2.847E-05	1.996E-03
SPAN	No signal	2.870E-04

Table 2.2. Conversion factors for vertical geophones (counts to µm/s) and hydrophones (counts to Pa) of all OBSs.

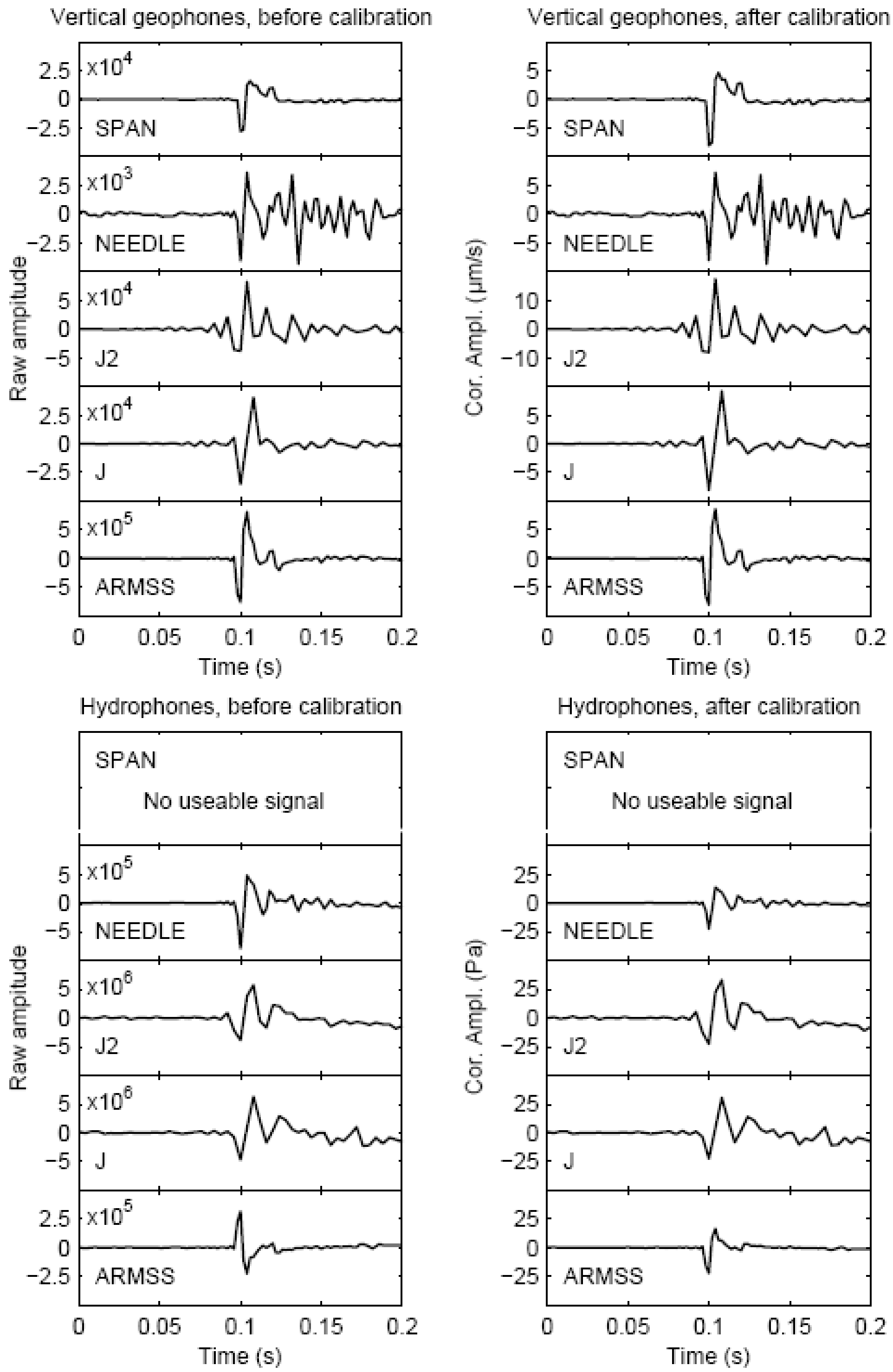


Fig. 2.28. Recordings of a seismic shot (May 24, 2007, 07:04:21.6) by the 5 OBSs before and after inter-calibration (see Fig. 2.27 for locations). Despite the resonance of OBS J2 geophones, the seismic shot amplitudes on OBSs J2 and J are in the same order of magnitude. Cor. Ampl., Corrected amplitudes.

2.7.4. Microseismicity location

2.7.4.1. Detection and location programs

- Micro-earthquakes detection

The dataset was first converted from continuous SAC files to SEG-2 files of 10 minutes including all the OBSs. The events were then detected using dedicated software developed by Magnitude (Aix-en-Provence, France), a company specialized in microseismicity monitoring in relation with the petroleum and mining industries (http://www.magnitude-geo.com/).

The event detection procedure follows these steps:

(1) Events detection with seiscreen program (Magnitude©). The detection algorithm is based on the ratio between the short-term and long-term average convolved by chirplets (sinusoids of different shapes and frequency contents, [*Bardainne*, 2005]), the duration of events, and the number of stations. In our case, a pick is made if the STA/LTA ratio exceeds 20 at a minimum of 3 stations and at least 5 seconds after the previous pick (Fig. 2.29).

The aim of the STA/LTA ratio is to detect sudden changes in the signal amplitude. This technique computes the ratio between the mean for a short window (STA) and the mean for a long window (LTA). A wave is detected when the ratio exceeds a given threshold.
To improve the detection program efficiency, the signal is decomposed in a sum of chirplets before the STA/LTA ratio computation. As most of the earthquakes energy is below 30 Hz (Fig. 2.30), the triggering has been made over the frequency bandwidth 7 – 50 Hz;

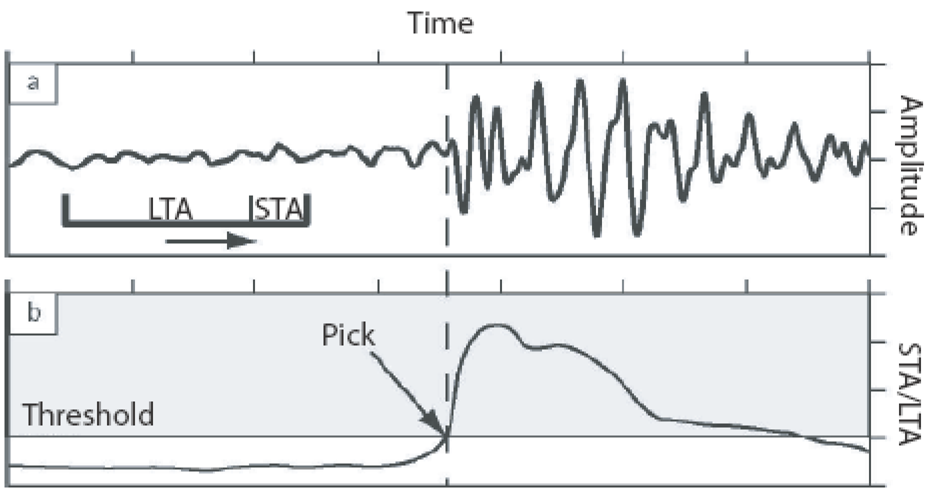


Fig. 2.29. Modified from Bardainne [2005]. STA/LTA ratio computation. (a) Seismograms with the 2 windows STA and LTA. (b) STA/LTA ratio, a picks is made when the ratio exceeds a given threshold.

(2) Manually inspect all detections and picked arrivals, assigning a subjective incertitude to each pick. Unclear events or events with picks for only one phase type (P or S) have been removed.

For events with a low signal-to-noise ratio, a band pass filter (4 – 25 Hz) has been applied. Sometimes the waveforms were too litigious to be picked independently. In some cases, a "master" event with clear picks and very similar waveforms (i.e. with the same source and ray path) has been used to remove the ambiguity and pick at the litigious station(s);

Based on the above, 270 events have been picked, including 110 events for the first period (May 14 to June 9, 2007).

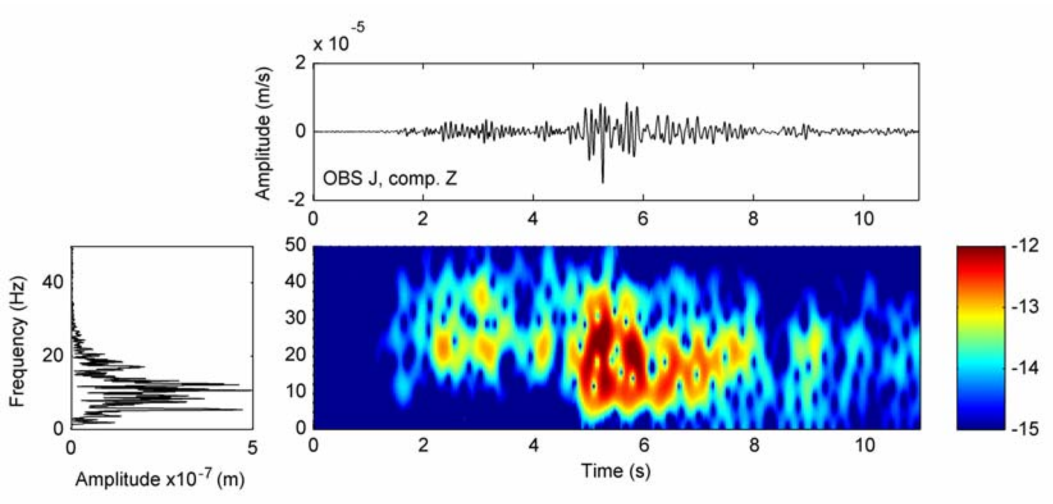


Fig. 2.30. Top: Micro-earthquake recorded by OBS J (Component Z) on 14 May, 2007 at 20:50:35 (M_w 2.9). Bottom left: micro-earthquake frequency content. Bottom right: temporal evolution of the micro-earthquake frequency content.

<u>- Location programs</u>

With P and S waves picks, several programs can be used to solve the earthquake location problem. We have therefore compared different software, thanks particularly to Mustafa Çomoğlu, working for the KOERI (Kandilli Observatory and Earthquake Institute). The day-to-day earthquakes location in Turkey is done by the KOERI with the program zSacWin based on HYPO-71. This program minimizes iteratively the residues between calculated and observed travel times.

Given an *a priori* hypocenter and a 1D velocity model, the algorithm follows the steepest slope of decreasing residues. This is the linearized least-squares solution to the earthquake location problem. However, the parameters space in the location problem is not linear. Thereby, this method is very sensitive to local minima and is highly dependent on the *a priori* hypocenter. HYPO-71 does not take into account the station elevation. This obviously introduces time shifts in the calculated travel times. Furthermore, *Lienert et al.* [1986] shown that the capability of the location algorithm to locate shallow events is enhanced when stations elevations are included.

To avoid those problems the program LOC3D has been used. It takes into account the elevation and uses a non-linear algorithm. The LOC3D program is similar to the program NonLinLoc [*Lomax, et al.,* 2000], which is a non-linear earthquake location program. It follows the probabilistic formulation of inversion presented in *Tarantola and Valette* [1982]. First the program computes the travel times for all x-y-z nodes using a finite-difference code based on the 3D Eikonal equation developed by *Podvin and Lecomte* [1991].
Then LOC3D proceeds to a probability grid search with a 3D or 1D velocity model, using P and S waves arrival times and/or wave polarisation. The hypocenter is positioned on the local probability maximum. As probability density functions are calculated for all grid points, local minima are avoided. Since probability distributions obtained are rarely Gaussian, they cannot be approximated by an ellipsoid (Fig. 2.31). The uncertainties computed by LOC3D correspond to 68 % of the probability integral.

The wave polarization has not been used for the location owing to a noise level too important (i. e. filtering) and a lack of information about the orientation of OBSs horizontal components. Therefore, earthquakes location was performed using only P and S waves picks.

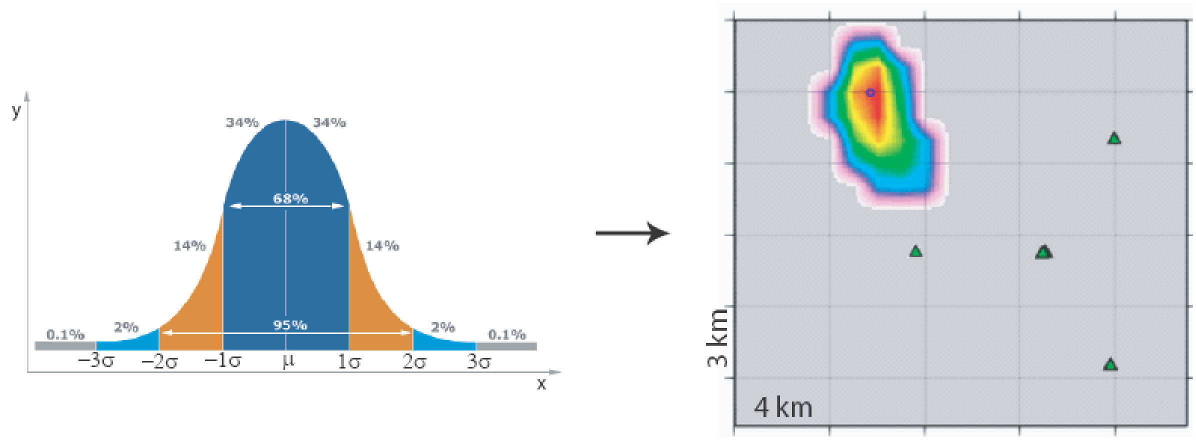


Fig. 2.31. (Left) Normal distribution of a parameter x with the 1, 2 and 3 standard deviations (σ). (Right) A located event with its uncertainty. The red and white-pink colours correspond to the maximum of probability and the 68 % contour of the probability integral, respectively. It can be seen that the shape of the probability distribution is not Gaussian.

- Micro-earthquakes magnitude

As specified by *Lee and Stewart* [1981] for microseismicity, the micro-earthquakes magnitude have been determined by

$$M = \frac{2}{3}\log(M_0) - 10.7\,.$$

Following *Brune* [1970], the seismic moment M_0 (N.m) can be estimated from the source and ray path parameters:

$$M_0 = \frac{4\pi\rho\Omega_0 R\beta^3}{0.85}$$

With:

ρ: earth density (2700 kg/m^3)

Ω_0: long period limit of the shear displacement spectrum (m.s; Fig. 2.32)

R: distance (m)

β: S-wave velocity (3000 m/s)

0.85 takes into account an average radiation pattern factor

- Magnitude detection threshold

Out of the 110 micro-earthquakes detected during the first period (May 14 to June 9, 2007), the 30 events with picks for P and S waves at a minimum of 4 stations were selected. Their magnitudes range from 1.5 to 2.9. During the same period, the KOERI located 6 earthquakes with magnitudes between 2.1 and 2.9 in the same area (Fig. 2.33). This highlights the ability of OBSs to lower the magnitude detection threshold in the Sea of Marmara.
In Fig. 2.34 is shown the differences between the locations made by the KOERI using land stations, and our locations using seabottom stations. For the three examples shown, the distance between KOERI and our locations ranges from ~5 to ~10 km. Hence, using seabottom stations close to the micro-earthquakes hypocenters significantly improve the locations accuracy.

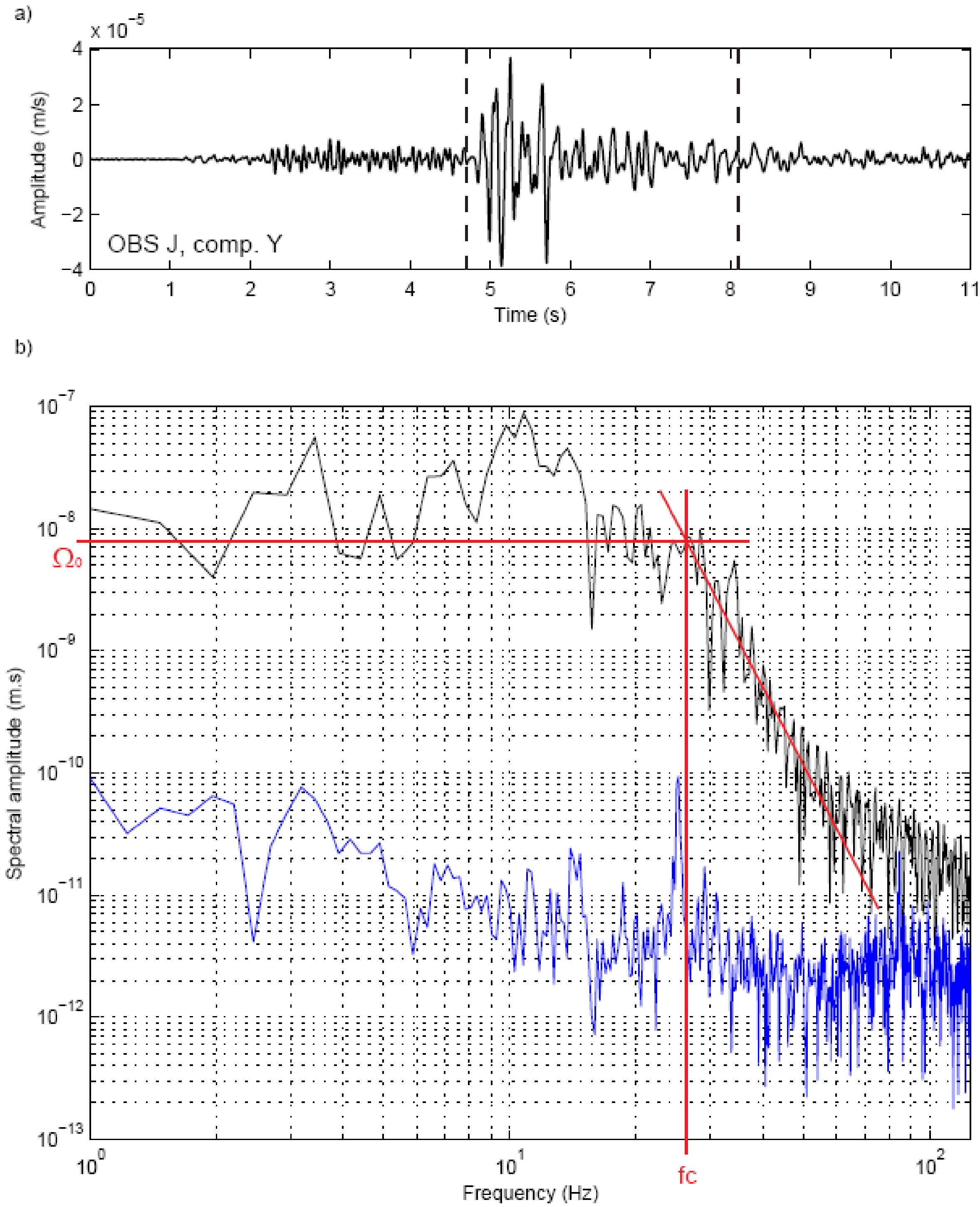


Fig. 2.32. a) Seismogram of a micro-earthquake recorded by OBS J (component Y) on 14 May 2007 (M_w 2.9). The part of the seismogram used to calculate the S-wave displacement spectra presented in b) is included between the two dashed lines. b) S-wave displacement spectra of the micro-earthquake shown in a) (black line). The blue line shows the noise displacement spectra (over 6 s taken before the micro-earthquake). Ω_0: long period limit of the S-wave displacement spectrum; fc: S-wave spectrum corner frequency.

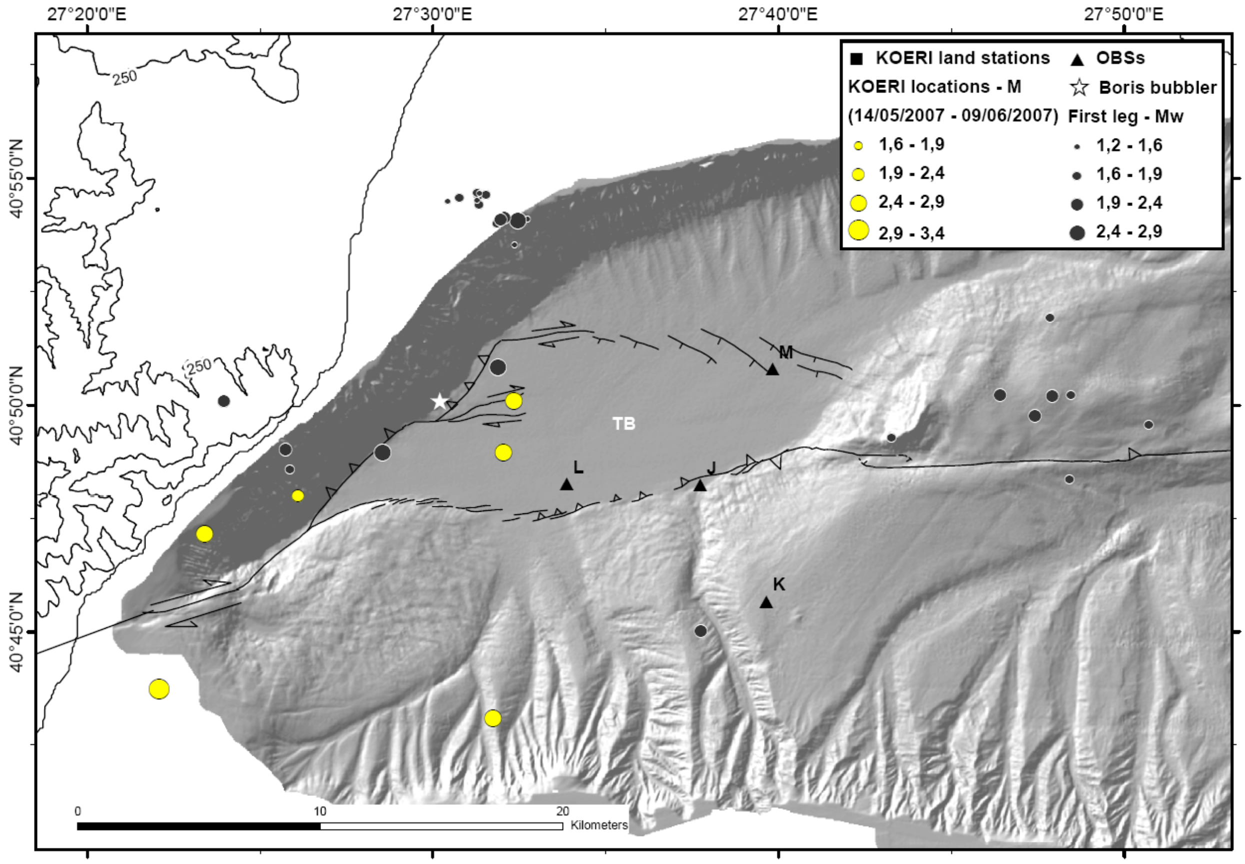


Fig. 2.33. Microseismicity distribution in the Tekirdag Basin (TB). The location of the selected earthquakes using LOC3D and the composite 1D model are indicated by gray dots. KOERI locations are indicated by yellow dots. The dots size depends on the magnitude. Boris's bubbler site is shown by the white star.

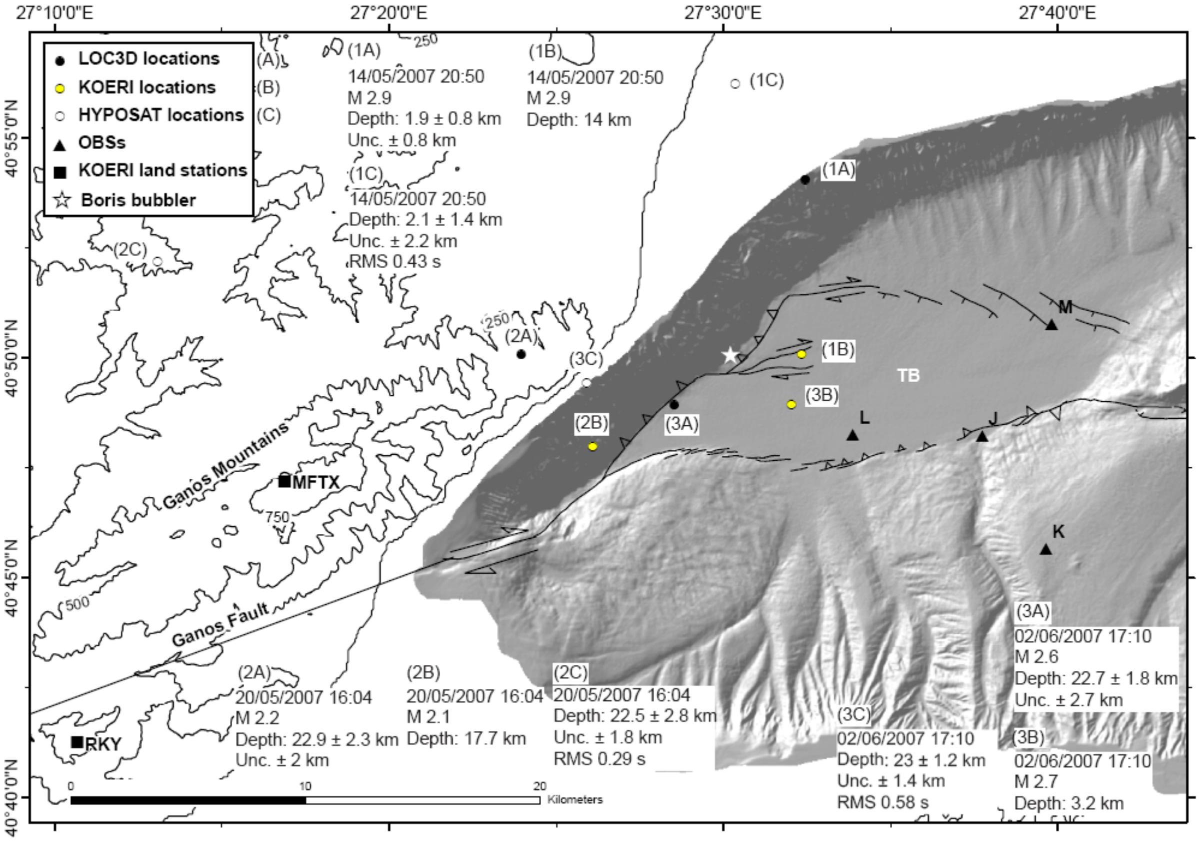


Fig. 2.34. Comparison between locations of three micro-earthquakes. KOERI locations, obtained using land stations data, are indicated yellow dots. Our locations, obtained using only seabottom stations data, are shown by black dots. HYPOSAT locations (white dots) performed using seabottom and land stations data are also indicated (see section 2.7.4.3).

2.7.4.2. Velocity models

Previous workers used three different 1D velocity models for earthquakes location in the Sea of Marmara.

(1) First the NEMC model [*Kalafat et al.,* 1987], used by the KOERI for day-to-day location, is a standard model for the whole Turkey (Fig. 2.35). This very simple model does not consider the specific velocity structure of the Sea of Marmara region due to the presence of deep troughs filled by low-velocity sediments.

(2) The Gürbüz 1D velocity model [*Gürbüz et al.,* 2000; *Sato et al.,* 2004] has been obtained by the simultaneous inversion (VELEST) of the hypocenters (October – December 1995 period) and the velocity structure. Station corrections were also calculated. The *a priori* velocity model came from an earlier refraction data modelling [*Gürbüz et al.,* 1992]. This model has been performed specifically for the Sea of Marmara region. It has a better precision

than the NEMC model and a lower supracrustal velocity. However, like the NEMC model, this model is still dedicated to land networks.

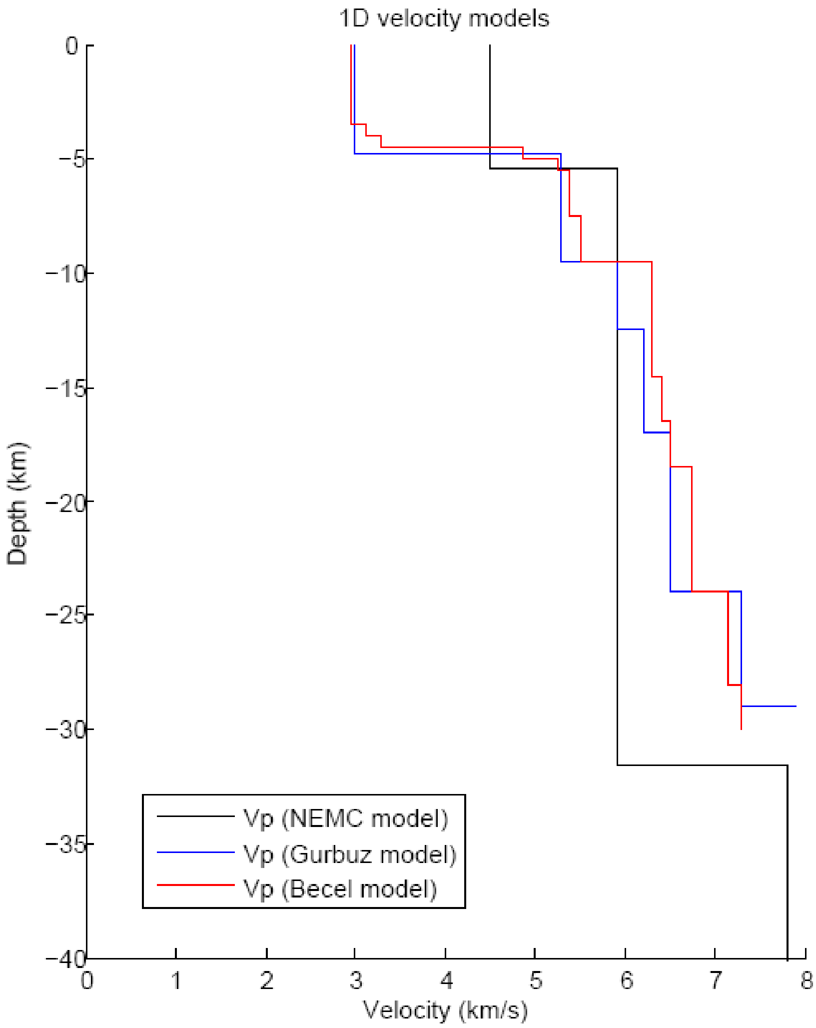


Fig. 2.35. Three 1D velocity models for the region of the Sea of Marmara, in black the NEMC model [Kalafat et al., 1987], in blue the Gürbüz model [Gürbüz et al., 2000], and in red the model of Bécel [2006].

(3) The model of *Bécel* [2006] is based on the simultaneous 1D inversion of the hypocenters, seismic shots and the velocity structure (Seismarmara cruise in 2001). The *a priori* velocity model is the model of *Gürbüz et al.* [2000]. Both P and S waves velocity structure have been inversed. The Vp/Vs ratio is about 1.79 and almost constant with depth. Therefore, in the present study a constant Vp/Vs ratio of 1.79 is assumed.

While this model has the advantage to take into account the specific structure of the Sea of Marmara, the averaged velocity structure of the upper 5 km does not correspond to the one of the sedimentary basins. Then, wide-angle profiles acquired during the MarNaut cruise by the R/V Sismik-1 in the Tekirdag Basin were modelled to obtain its velocity structure in the upper 4 km (see Appendix A in the published paper in section 2.8). Finally, the deep velocity structure of the model of *Bécel* [2006], and the modelled superficial structure were combined in a composite 1D model (Fig. 2.36). This composite model was used in the present study for locating micro-earthquakes.

The influence of the velocity model in the micro-seismicity location is shown in Fig. 2.37. In Fig. 2.37, selected earthquakes were located twice with the program LOC3D and two different 1D velocity models: the NEMC velocity model, and the composite velocity model. Relatively to the locations using the composite velocity model (gray dots), the locations using the NEMC model (black squares) are pushed away from the OBS network (up to 10-15 km). This arises from the fact that the NEMC model has higher velocities than the composite model in the upper layers. Thus, at the scale of the Tekirdag Basin, major errors can be introduced by the velocity model.

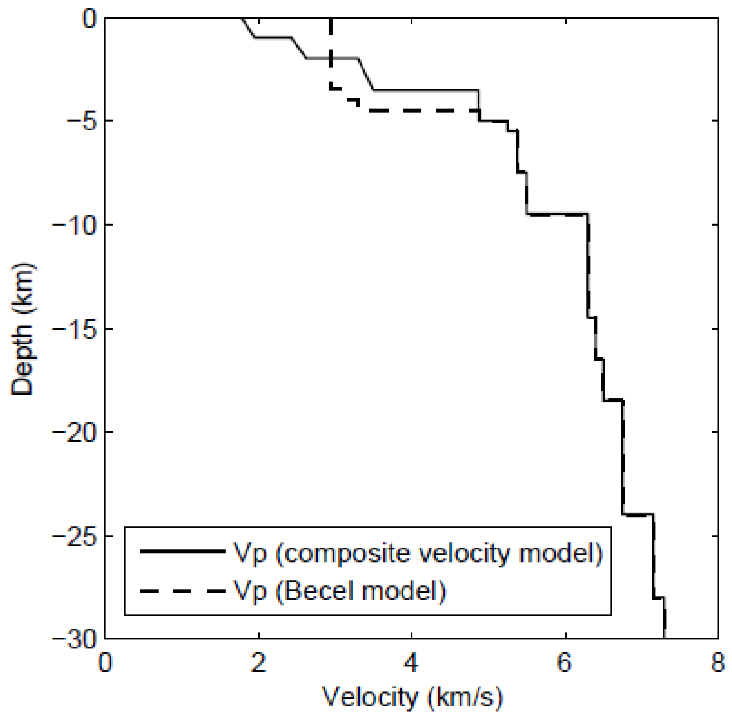


Fig. 2.36. Composite 1D velocity model (solid black line) in the upper 30 km of the Tekirdag Basin. The velocity model of Bécel [2006] is indicated by the dashed black line.

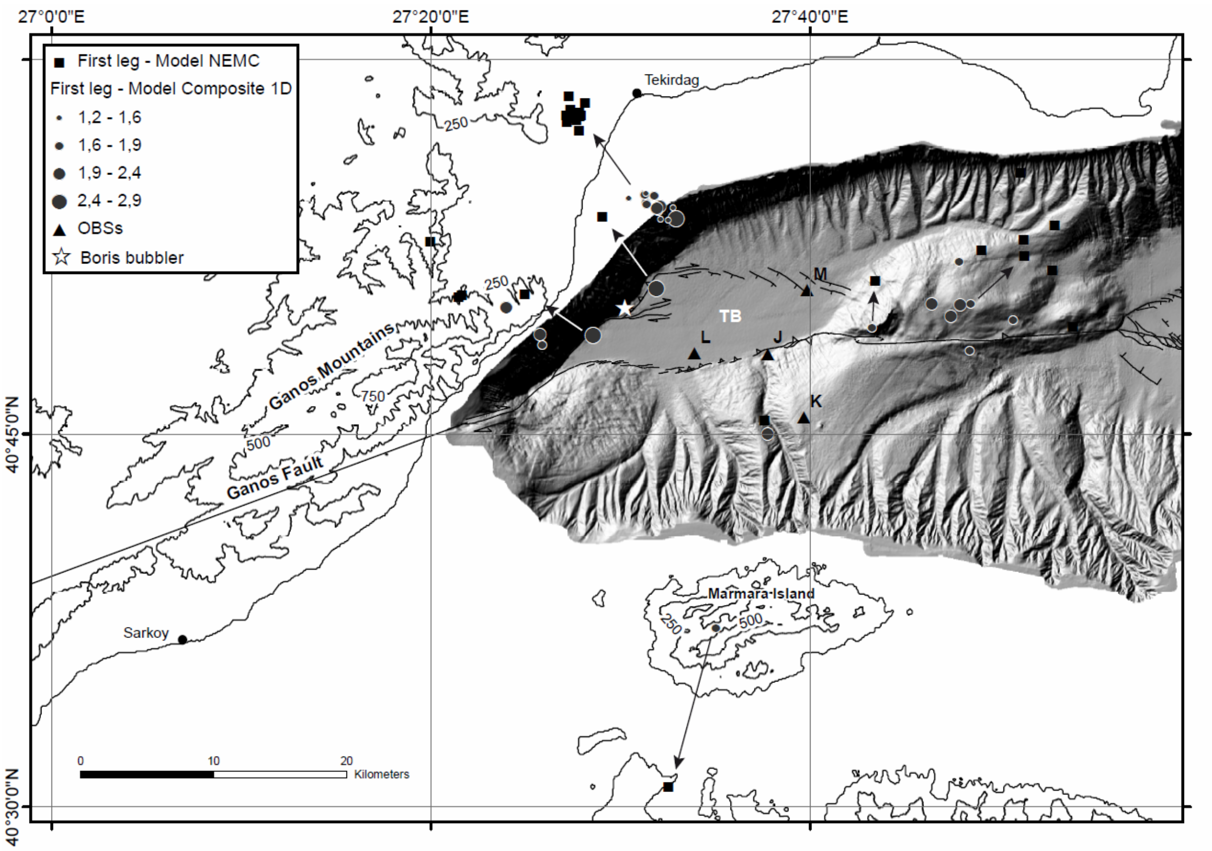


Fig. 2.37. Influence of the velocity model in hypocenter determination. Selected earthquakes have been located using either the composite 1D model (gray dots), or the NEMC model (black squares). The locations have been performed using the same program, LOC3D, and the same P and S waves picks. Black triangles show the OBSs position. Boris's bubbler site is indicated by the white star. TB: Tekirdag Basin.

2.7.4.3. Coherency problems when merging land and sea networks

<u>- Microseismicity location</u>

To improve the location precision, we tried to combine the datasets coming from land (KOERI) and sea networks (Fig. 2.38). However, velocity structures below land and sea stations are greatly different, and inconsistencies in travel times have frequently been observed. Fig. 2.39 represents a micro-earthquake strong enough to be recorded by the two networks. It can be seen that the P waves arrive sooner at the sea stations (J, K, L and M) than at the land station (MRMX). Typically, this indicates that the micro-earthquake is closer to the OBS than the land station. On the other hand, the difference between S and P waves arrival times, proportional to the distance source-receiver, is larger for sea stations, indicating that the land station is closer to the micro-earthquake hypocenter. This incompatibility arises from the waves propagation in low-velocity sediments in the Tekirdag Basin, which involves a time delay on sea stations recordings.

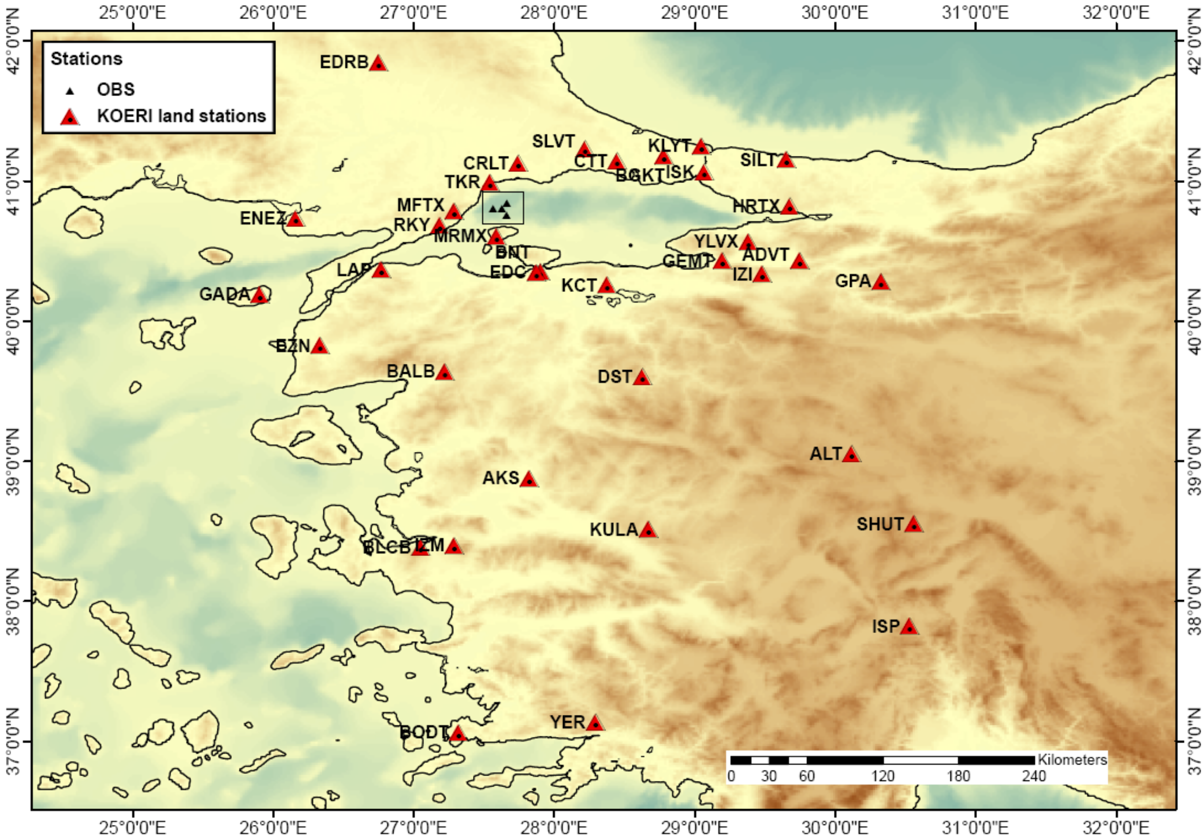


Fig. 2.38. Location of KOERI land stations (red triangles) in western Turkey and MarNaut OBSs (black triangles).

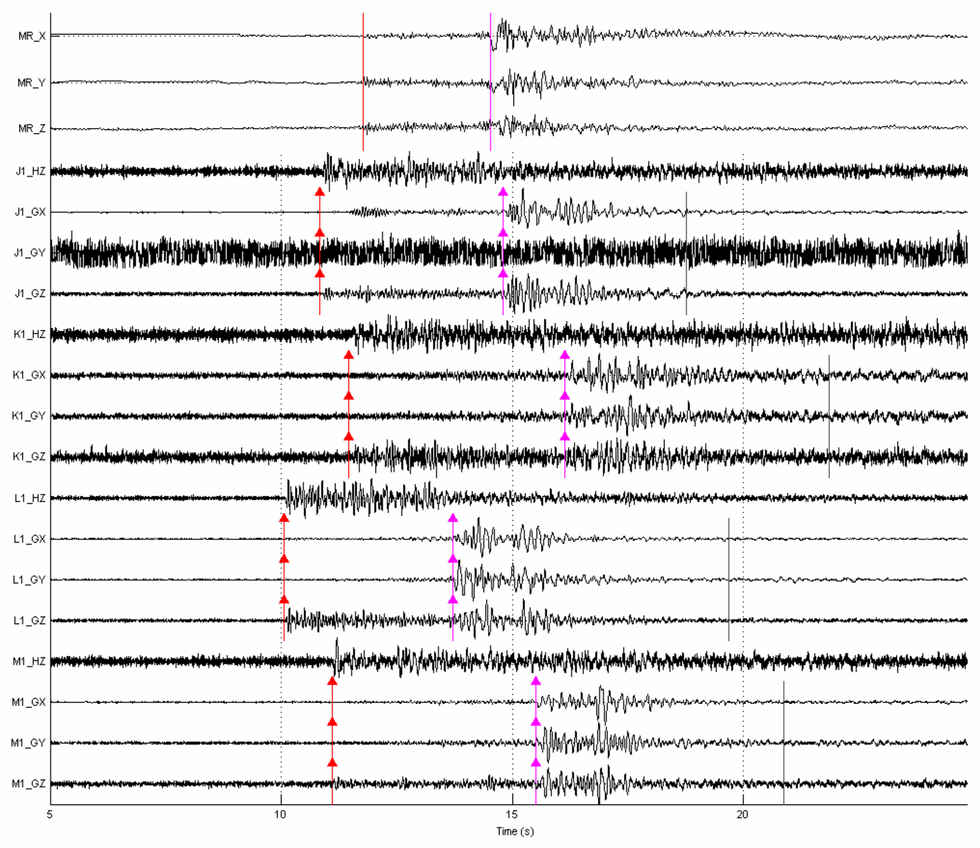


Fig. 2.39. Seismograms of MRMX (MR_) land station, and OBS J, K, L, M for the same event (origin time: 01/06/2007 12:40:32). X and Y are horizontal components, Z is vertical and H is hydrophone. Seismograms are not filtered. P (red lines) and S (purple lines) wave arrivals are indicated. Vertical black lines indicate the end of the time windows used for displacement spectrum and magnitude calculations. Note that the P waves are clearly visible on the hydrophone, which is very helpful for phase picking.

Therefore, with a 1D velocity model and a unique Vp/Vs ratio, we do not recommend a joint location using land and seabottom stations because it introduces important location errors. In large networks, velocity structure heterogeneities can be compensated by the removal of stations with large travel-times residues. When we deal with 3D velocity structure heterogeneities, stations corrections would solve only partly this problem, as they are dependent on micro-earthquakes position.

A 3D velocity model or several 1D velocity models could be used to perform a combined location. The 2nd solution was tested, as no 3D velocity model of the Sea of Marmara was available when the micro-earthquakes location was performed. LOC3D does not allow to use different 1D models for land and seabottom stations. Therefore, we used instead HYPOSAT, which assigns a 1D local velocity model below every single epicenter [*Schweitzer*, 2001]. The local model is assigned to the stations near the epicenter, while a global model is assigned to the stations located away from the epicenter (Fig. 2.40). The size of the area around the epicenter, where the local model is prescribed, is defined by the user. The algorithm used in HYPOSAT is similar to the one used in HYPO-71 (HYPOSAT takes into account the station elevation, while HYPO-71 does not). HYPOSAT solves the non-linear problem of earthquake location with a stepwise linearized least-squares algorithm and needs *a priori* locations. Depending on the locations reliability, either LOC3D or KOERI locations have been used as *a priori* locations. For events that were not located by the KOERI or events located by LOC3D with uncertainties inferior to 10 km, we used LOC3D locations as *a priori* locations. In the other cases, mainly for events situated too far from the OBS network, we used KOERI locations as *a priori* locations.

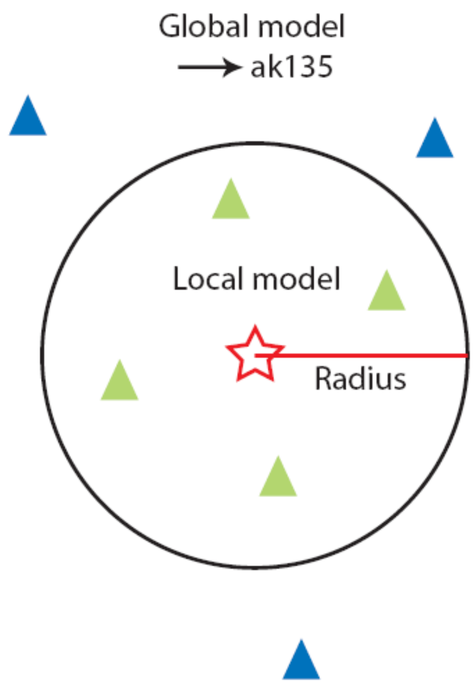


Fig. 2.40. Sketch illustrating how velocity models are prescribed in HYPOSAT. The disk defined by the epicenter (red star) and the radius corresponds to the influence of the local model. The global (ak135, [Kennet et al., 1995]) and local models are assigned to the stations located outside the circle (blue triangles) and inside the circle (green triangles), respectively.

Three different local models have been used. The composite 1D model has been used for the events located in the Tekirdag Basin and its vicinity. Either the NEMC or Gürbüz models have been assigned to epicenters situated close to the land stations. The global model, called ak135 [*Kennet et al.,* 1995] (Table 2.2), corresponds to the velocity structure of an average continental crust. Elevation corrections are applied at each OBS.

Finally, 67 events were located with uncertainties ranging from 0.5 to 8 km horizontally (mean 1.6 km), and from 0.5 and 7 km in depth (mean 2.4 km). The RMS range from 0.03 to 0.65 s, with a mean of 0.2 s (Fig. 2.41). These events were located using 3 or 4 OBSs and between 1 and 37 land stations. Among those 67 events, 25 were recorded only by OBSs, and thus located using only OBSs. In Fig. 2.42 are shown the HYPOSAT locations of these 25 events together with their locations performed by LOC3D. As the 25 events are close enough to the OBS network, the two locations sets were performed using the same velocity model, i. e. the composite 1D model. In average, the distance between the two locations sets is about 3.8 km. This shows that the choice of the location software has significant influence on the locations.

The other 42 events were located using OBSs and land stations. The resulting locations are generally very different (with an offset ranging from 1 and 47 km) from the *a priori* locations (Fig. 2.41). These results clearly show the influence of, by order of consequence: 1) the velocity structure; 2) the addition of new data; and 3) the location software.

Depth (Km)	P velocity (Km/s)	S velocity (Km/s)
0.0	5.800	3.460
20.0	6.500	3.850
35.0	8.040	4.480
77.5	8.045	4.490
120.0	8.050	4.500

Table 2.2. Ak135 model [Kennet et al., 1995] corresponding to HYPOSAT global model.

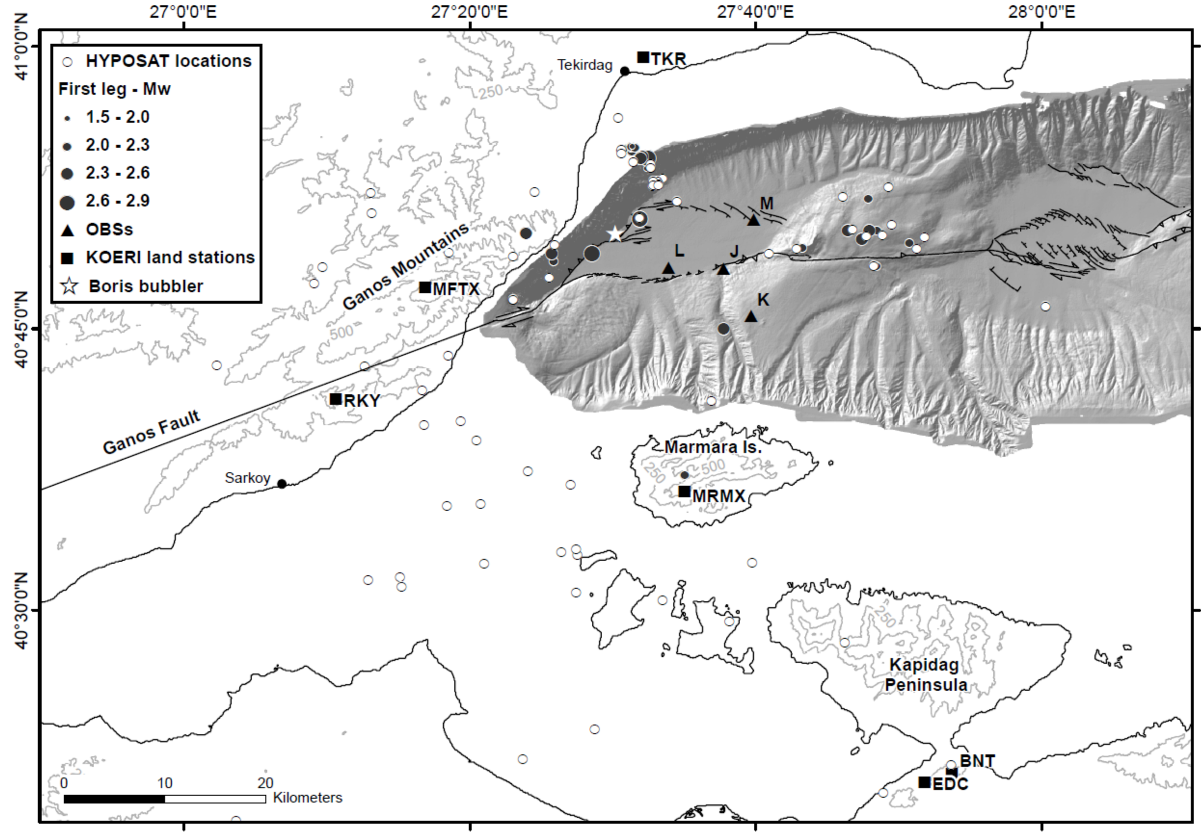


Fig. 2.41. HYPOSAT locations (white dots) using seabottom and land stations, and LOC3D locations (gray dots) using only OBSs data (the symbol size depends on the magnitude). The black triangles and black squares indicate the OBSs and KOERI land stations, respectively. TB: Tekirdag Basin; Is: Island.

In summary, HYPOSAT locations with only OBSs data show a good agreement with the LOC3D locations. Adding land stations allows to locate more earthquakes. However, these earthquakes have to be strong enough to be recorded by the two networks.

In addition, the definition of the local velocity model below the epicenters is not convenient in our case. It would have been better to define the local models at stations locations. Except for large events with a lot of stations, the gain in precision obtained by the addition of 1 or 2 land stations is lower than the errors introduced by the software and the combination of 2 very different velocity models. Whether land stations are useful or not depends on the objective.

In the present study, we focus on micro-earthquakes within or around the Tekirdag Basin which are generally recorded by less than 2 land stations. Then, from our point of view, it is more rigorous to show locations based on a consistent dataset, along with representative uncertainties, than locations based on land and seabottom stations.

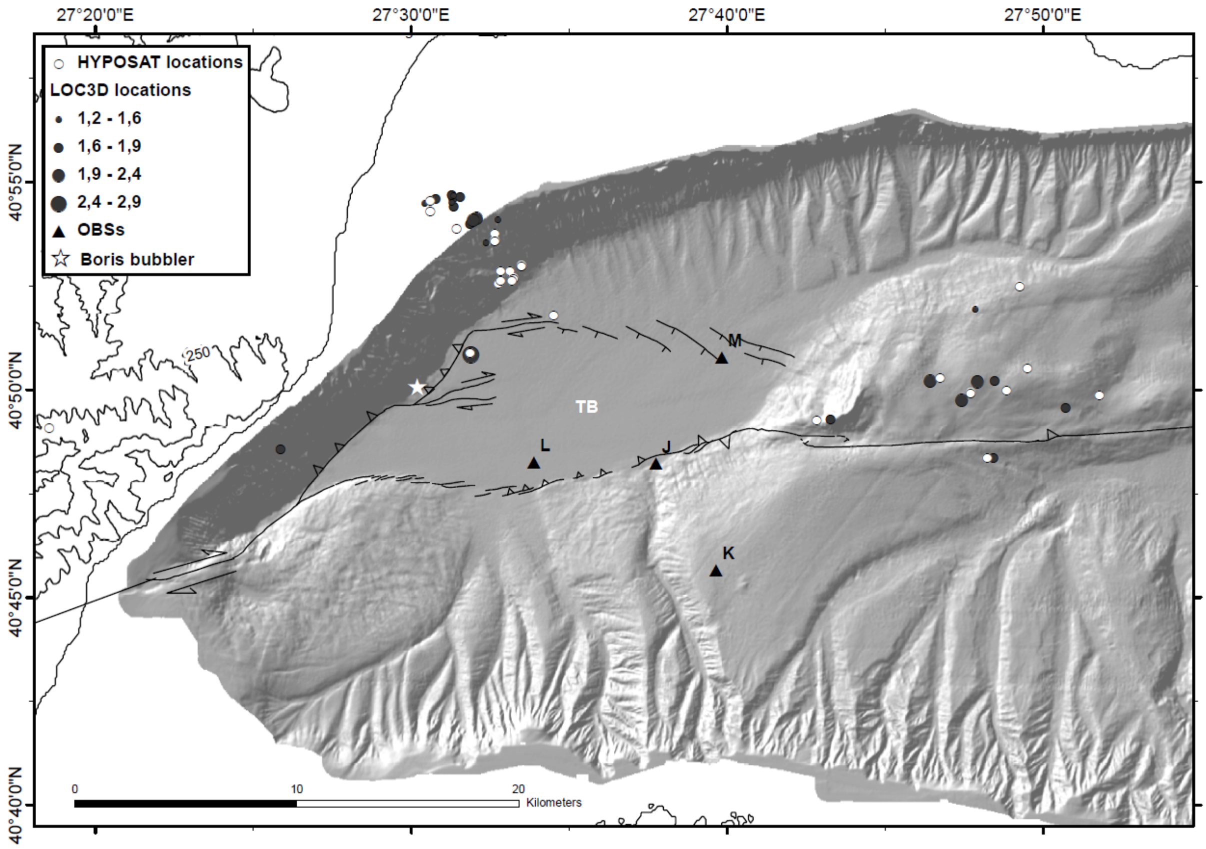


Fig. 2.42. HYPOSAT (white dots) and LOC3D (gray dots) locations using only seabottom stations. The gray dots size depends on the magnitude. The black triangles indicate the OBSs stations.

<u>- Focal mechanisms calculation</u>

The focal mechanisms have been calculated using land and seabottom networks in order to improve the azimuth coverage for each given events. To determine the stability of the focal mechanism calculations regarding the velocity model problem, we have performed two calculations: one with our composite 1D velocity model and one with the NEMC velocity model (Fig. 2.43).

Because focal mechanisms calculations mainly depend on the geographical distribution of stations, the 2 solutions are relatively similar (Fig. 2.43). This conclusion holds even if we use the velocity model of *Gürbüz et al.* [2000], which is known to be more appropriate for the Sea of Marmara region. The velocity model is of critical importance for locating earthquakes, but it has less impact on focal mechanism calculations in our 2 cases (M_w 2.9 May 14, 20:50:35 and M_w 2.6 June 2, 17:10:34).

Hence, we here consider that it is adequate to merge land and sea-bottom stations for deriving focal mechanisms, whereas it is not adequate to do so for locating earthquakes.

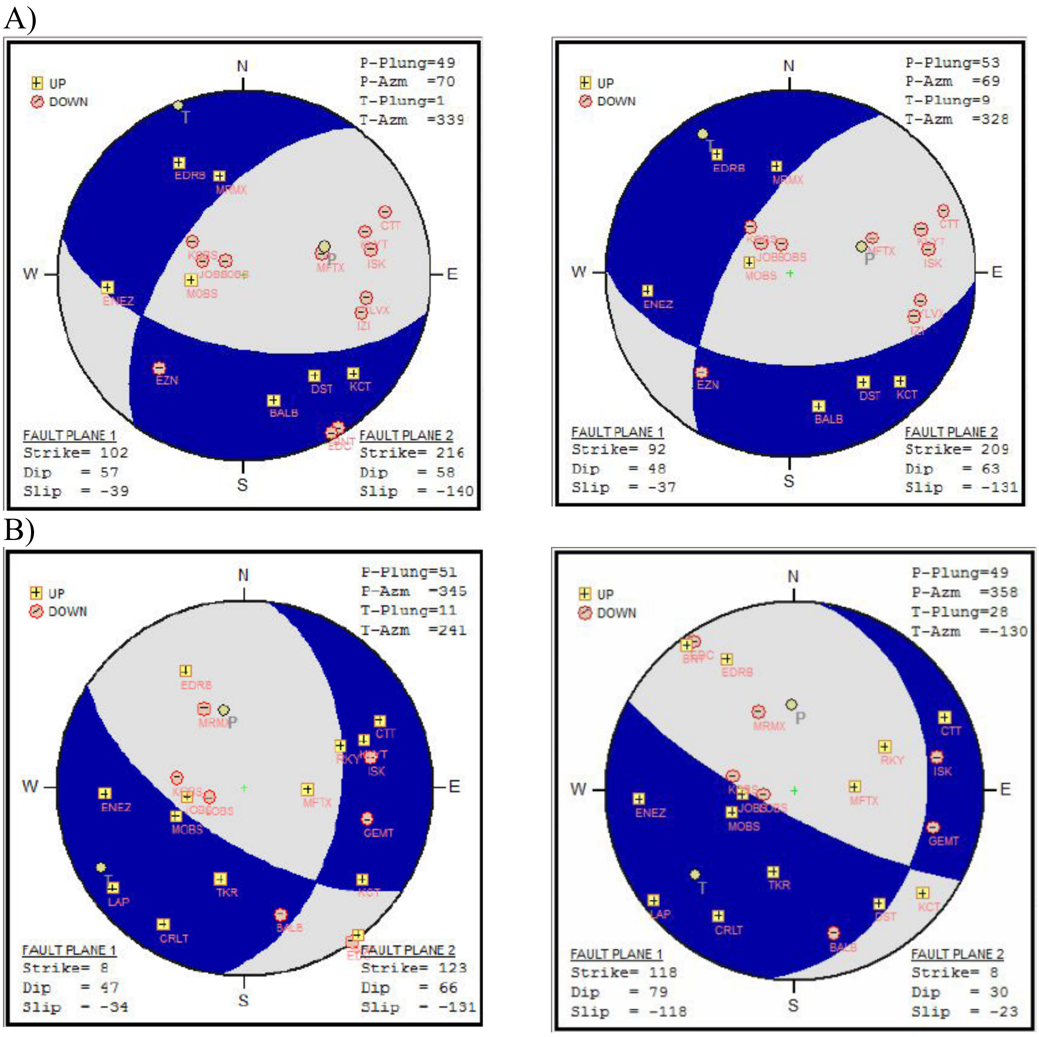


Fig. 2.43. Focal mechanisms of (A) the largest micro-earthquake (northern event in Fig. 2.36, May 14, 2007, 20:50:35) and (B) the micro-earthquake located close to the western escarpment of the Tekirdag Basin, ~10 km south of the one presented in (A) (June 2, 2007, 17:10:34), lower hemisphere projection. On the right are the focal mechanisms calculated with our composite 1D velocity model, and on the left the focal mechanisms calculated with NEMC velocity model. (+) indicates Upward and (-) Downward first motion at a given station.

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 MARMARA-DM PROJECT

Deliverable 3.2: Report on ambient noise and recommendations for implementing permanent seabottom stations

Due date of deliverable: September 2010
Actual submission date: September 2010

Start date of project: **April, 1st 2007** Duration: **30 months**

Organisation name of lead contractor for this deliverable: Ifremer
Lead authors for this deliverable: Louis Géli & Jean-Baptiste Tary

Revision [final version]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	PU
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)	

CONTENTS

Report

1. Executive summary :

The subject of the present delivrable was fully addressed during Jean-Baptiste Tary's *PhD* work (defended on march 15th, 2011), entitled *"Case studies on fluids and seismicity in submarine environments based on Ocean Bottom Seismometers (OBS) recordings from the Sea of Marmara and from to the Niger Delta".*

Part of this work is subject to a publication in preparation for submission to *J. Geophys. Res.* : Tary J.-B., Géli L., Henry P., Sultan N., Guennou C., Çagatay N.,4 and Vidal V., Micro-events produced by gas migration and expulsion at the seabed: a study based on sea bottom recordings from the Sea of Marmara.

Our 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.

Submarine degassing processes may be either natural (continuous exploration efforts and progress in multi-beam sonar techniques in the recent years have shown that natural seafloor degassing is a wide spread phenomenon), either artificial resulting from human activities (e. g. sediment destabilization related to oil exploration, pipe leaking, etc). Our study clearly shows that OBSs represent powerful tools to study these processes.

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.

Recommendations. For permanent, mutli-disciplinary seafloor observatories for earthquake monitoring in the Sea of Marmara, we thus recommand to deploy Broad-Band OBSs. To improve the real-time characterization of earthquakes within the submerged fault zone, specific networks of permanent, cabled, sea-bottom BB-seismometers are required. In addition, multi-parameters approaches must be developed 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.

2. Extract of Chapter 2.8 of Jean-Baptiste Tary's Ph. D. Thesis

Besides micro-earthquakes, the OBSs deployed during the MarNaut cruise (may to september 2007) recorded numerous non-seismic micro-events. These micro-events are very common on OBS recordings [*Buskirk et al.,* 1981; *Diaz et al.,* 2007], but generally they are not detected by the procedure described earlier for micro-earthquakes, as they are most of the time not recorded by more than one station. Micro-events differ from micro-earthquakes by several aspects (Fig. 2.44). Micro-events have short durations of less than 0.8 s, a monochromatic frequency content between 5 and 30 Hz, and highly variable amplitudes (0.5-50 µm/s). Even though micro- earthquakes have peak amplitudes in the same range, they have a richest frequency spectrum and longer durations (3 s-few minutes) than micro-events. In addition, earthquakes are composed by different waves (P-wave, S-wave, surface waves...) while micro-events show only one arrival. Finally, while micro-earthquakes are well recorded by the hydrophones, micro-events are visible only on those hydrophones that are close enough to the sediment/water interface (<0.9 m).

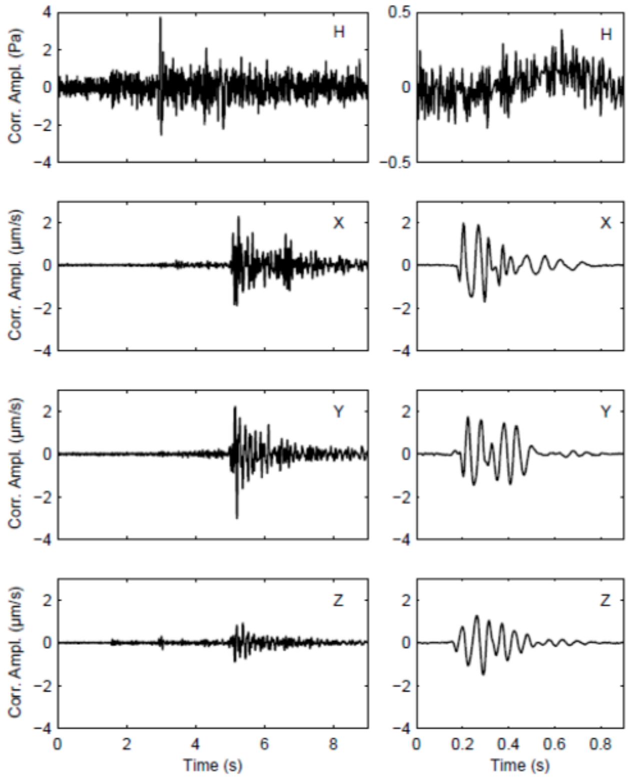


Fig. 2.44. OBS M recordings (H: hydrophone, X and Y: geophone horizontal components, Z: geophone vertical component), showing a micro-earthquake (M_w 1.98, May 14, 2007, 22:23:32) on the left and a micro-event on the right (May 14, 2007, 14:01:57).

3. Preliminary analysis of SN-4 data (see also D2.3, Chapter 3)

General observations from non-seismic sensors :

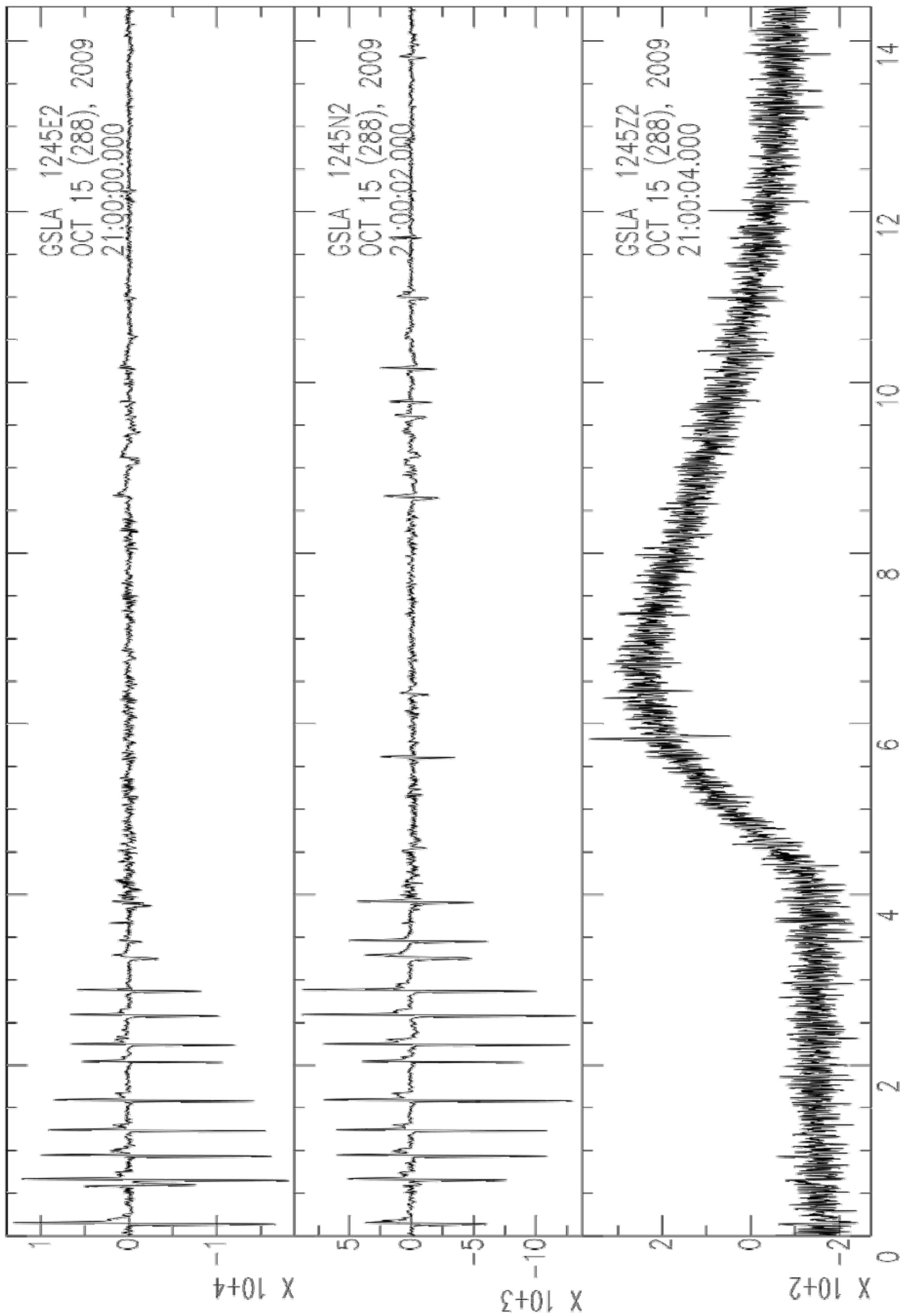
1. A quasi-systematic coïncidence between methane peak, temperature drop, oxygene decreases, turbidity peak.
2. Temperature most often drops before methane peaks
3. Turbidity event occurs after methane peaks

General Observations from OBSs :

1. Very high data quality on 3 components
2. Numerous, low-magnitude, local events recorded that are not reported by the land network. Low detection threshold.
3. Occurrence of 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 (return to equilibrium).
4. The very long period event is sometimes preceded (~ 1 hour before) by high amplitude 30-seconds period signals, visible on the horizontal components.
5. Very common occurrence of short-duration (< 3 s), high-frequency (20 Hz), events, not reported on land stations. 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.
6. The very long period (~3 hours) signals on the vertical component appear associated with very strong amplitude, non-seismic micro-events described in item 5.

Correlations between OBS recordings and non-seismic parameters and future work

1. The very long period (~3 hours) signals apparently occur simultaneously with the following sequence : temperature drop, methane peak and oxygen decrease, and turbidity increase and “short duration, gas outburst signal”.
2. Check when the gas outburst occurs relatively to the long period event : is it before, during the ascending phase or at the paroxysmus of the rising seafloor.
3. Check if the perturbations on the piezometer correlate with the occurrence of the sequence observed on the OBS.



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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 MARMARA-DM PROJECT

Deliverable 3.3: High Resolution, 3D Seismic Images from Western High Site

Start date of project: **April 1st, 2007** Duration: **30 months**

Organisation name of lead contractor for this deliverable: Ifremer
Lead authors for this deliverable: Bruno Marsset & Yannick Thomas
Revision [final version]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	PU
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)	

CONTENTS

1. Executive summary :

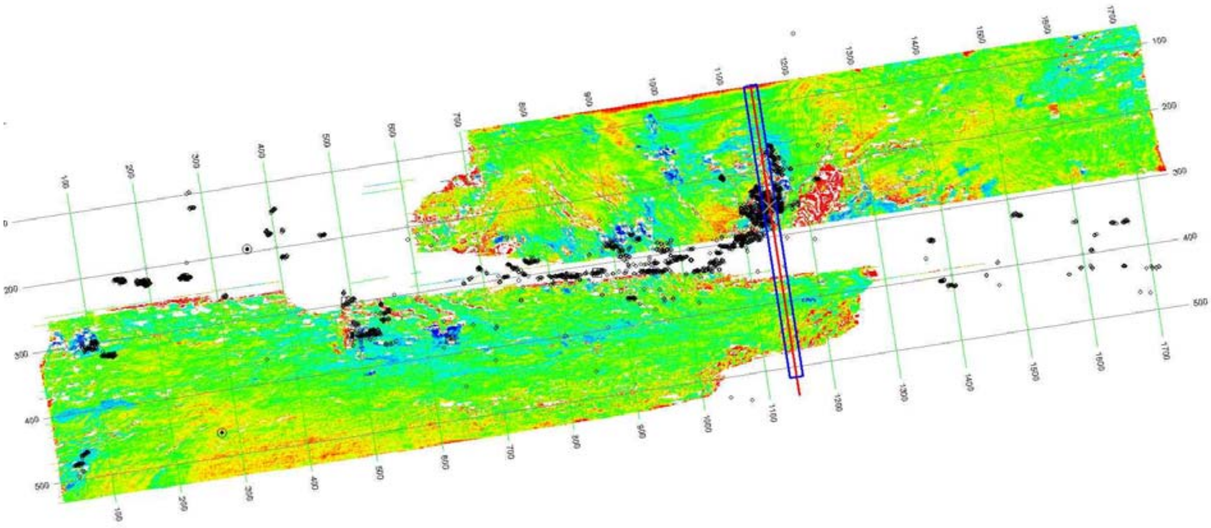
The MARMESONET cruise is part of the Marmara Demonstration Mission Program supported by ESONET Network of Excellence (**E**uropean **S**eafloor **O**bservatory **N**etwork), within the 6th European Framework Programme. Main partners are : Ifremer, CNRS/CEREGE, Istanbul Technical University, TUBITAK, Institute of Marine Science and Technology of Dokuz Eylül Universitesi (Izmir), INGV (Rom) and ISMAR (Bologna). Marmesonet is also the follow-on of the Franco-Turk collaborative programme that resulted in numerous cruises in the Sea of Marmara since 2000.

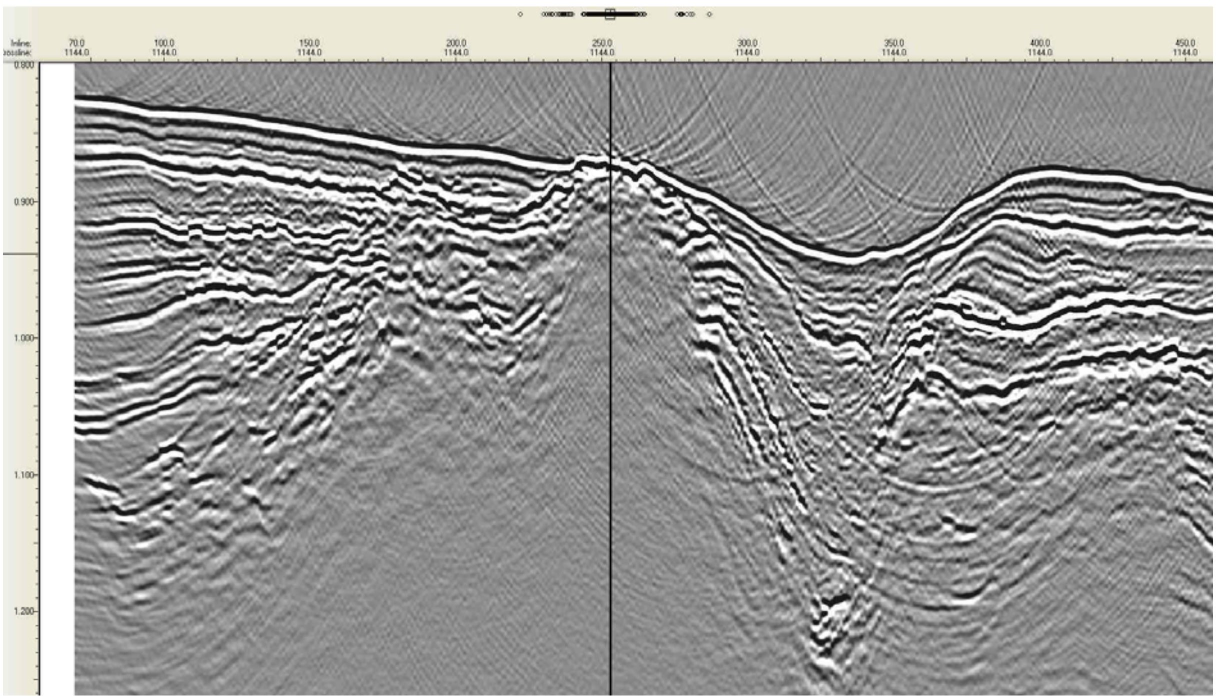
The objectives of the MARMESONET cruise were : 1) to study the relationship between fluids and seismicity along the Sea of Marmara fault system ; 2) to carry out site surveys prior to the implementation of permanent seafloor observatories in the Marmara Sea through ESONET. The cruise is divided in 2 parts :

- 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) *Aster$_x$* 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 (from 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.





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 seps were found, together with outcropping gas hydrates.

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 MARMARA-DM PROJECT

Deliverable 4.1 Report on the data repository system including a fully integrated data base

Due date of deliverable: September 2010
Actual submission date: September 2010

Start date of project: **April, 1st 2007** Duration: **30 months**

Organisation name of lead contractor for this deliverable: ITU
Lead authors for this deliverable: Cengiz Zabci (ITU)

Revision [final version]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	PU
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)	

Executive summary : 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 ITU-EMCOL NAS has the following characteristics:

- It is constructed on FreeBSD based FreeNAS 0.7.1 OS; which provides benefits of an Unix-like operating system and multi-protocol file sharing
- Settings are easily adjusted over a web-based graphical user interface by the administrator
- The 4x2 TB HDD in a RAID-5+1 array provides a secure 6 TB of capacity at the moment
- It allows connecting to the Internet over 100Mbit ethernet interface and is continuously online within the network facility of ITU. A high capacity UPS for any electricity shortage also assists the hardware.

Because EMCOL NAS is attached to the Internet, it can be reached from anywhere on the earth. It uses an IPv4 number (160.75.30.57) as the server’s address. Moreover, a DNS record such as emcolnas.geol.itu.edu.tr is planned in the near future.

FreeNAS uses a wide-range of protocols for file sharing such as; SAMBA (CIFS), NFS, FTP, TFTP, AFP, and SSH. However, ITU-EMCOL NAS allows SSH and FTP protocols for sake of security and is 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:

SSH Protocol:

For Windows users:

- Run WinSCP
- Enter the IP of EMCOL NAS server as host name 160.75.30.57
- Port number is 22
- Enter username and password in the relevant fields
- Choose SFTP as file protocol and click Login (or Save if you want to save these settings)

For Linux and MacOSX users:
Expert users can easily access and operate EMCOL NAS by using (command prompt): ssh username@160.75.30.57 or sftp username@160.75.30.57 commands.

- Graphical User Interface (GUI) gnome users can use Nautilus as a SSH client
- Or one can use a SFTP client with a GUI such as Fugu (http://rsug.itd.umich.edu/software/fugu/) and/or Cyberduck (http://cyberduck.ch/) .

FTP Protocol:

FTP server is also enabled in EMCOL NAS to provide a more user-friendly interface. It can be accessed from any web browser by entering the FTP address (ftp://160.75.30.57). Moreover, Windows users can use Windows Explorer for a more convenient usage.

Linux users can use Nautilus (gnome) or KFTPgrabber (KDE) to easily access to the EMCOL NAS. Accessibility through command prompt is always possible for expert users.

MAC OS X users have only read-only access to the FTP servers due to the MAC OS X default features. Users who will upload data must use third-party software such as open-source software Cyberduck (http://cyberduck.ch/).

Cengiz Zabci (ITU; zabci@itu.edu.tr) is assigned to the task-leader of EMCOL NAS. For further explanations and instructions you can visit the EMCOL-NAS section of the Marmara DM web page (http://www.esonet.marmara-dm.itu.edu.tr/). You can also contact with Cengiz Zabcı (zabci@itu.edu.tr) or Umut B. Ülgen (ulgenum@itu.edu.tr) for further assistance. To ask for username and password, please contact with the project coordinator Dr. Louis Geli (Louis.Geli@ifremer.fr) or Umut B. Ülgen (ulgenum@itu.edu.tr).

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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 MARMARA-DM PROJECT

Deliverable 4.2: GIS including all available data collected during the Marmara-DM project

Due date of deliverable: September 2010
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Organisation name of lead contractor for this deliverable: ITU & Ifremer
Lead authors for this deliverable: Cengiz Cabci (ITU) & Stéphanie Dupré (Ifremer)
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Dissemination Level		
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Note : 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. 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. You can find further instructions about data repository in the Marmara_DM web page (http://www.esonet.marmara-dm.itu.edu.tr/) EMCOL-NAS section.

Geographical Information System (GIS) Database of the Marmara-DM Demonstration Mission

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1. Introduction

The disastrous 1999 Izmit (Mw=7.6) and Duzce (Mw=7.1) earthquakes immediately directed attentions of both social and scientific communities towards the Marmara region, Turkey. The poor data for submarine fault geometry and seismic gap which was determined to be ruptured in near future by Coulomb failure criteria (Çakır et al., 2003; Parsons, 2004; Parsons et al., 2000; Pondard et al., 2007) triggered many and continuous scientific projects in the Marmara region. The majority of these studies were carried out by marine cruises in the Sea of Marmara.

Scientists also started to realize that the Sea of Marmara constitute a unique opportunity to study seismogenic behavior of the one of the most important continental strike fault, the North Anatolian Fault (NAF). It is clear that this also would create a great contribution to studies of other active faults of the Earth. To achieve this aim, many national and international campaigns were carried out to understand, form and conclude hypothesizes on the structure and the behavior of the NAF. Many scientific papers were published on various subjects such as the mapping of fault (Armijo et al., 2005; Demirbag et al., 2003; Le Pichon et al., 2003; Le Pichon et al., 2001; Okay et al., 2000; Rangin et al., 2004; Yaltirak, 2002), historical earthquakes (Beck et al., 2007; McHugh et al., 2006; Sari and Cagatay, 2006), tsunamis (Hayir et al., 2008; Hébert et al., 2005; Kilinc et al., 2009; Ozeren et al., 2010; Yalçıner et al., 2002) and fluid/gas interaction with the active fault (Bourry et al., 2009; Geli et al., 2008; Tryon et al., 2010) in the Sea of Marmara.

It is obvious that there is a huge accumulated data acquisition at the background of all these studies. This richness of both type and quantity of data created the necessity to form a geodatabase. Geographical Information System (GIS) is known to be a very effective tool to organize data in spatial sense. On the other hand attribute tables can be designed to give information in many aspects such as temporal concept, data acquisition type, results after preliminary or final processes, and many more. In the framework of ESONET NoE -

Marmara Demo Mission, it is decided to create a GIS database as the main target of the Deliverable 4.2.

The job is decided to be integrated into the IFREMER's GIS architecture, which had designed on the basis of many years marine studies' experience. A lot of data had been already submitted to GIS onboard or just after cruises. Moreover, there were already processed shape files by Dr. Devrim Tezcan and researchers of IFREMER (Dr. Stephanie Dupré and Cartographie division). My contribution to Marmara DM`s GIS was mainly about converting processed preliminary shape files into the desired format, creating missing ones from available raw navigation data or cruise reports, filling missing attributes, constructing hyperlinks to images of processed data, and integration of some published studies during 7 weeks of stay in IFREMER, Brest in the framework of personal exchange program of ESONET. Moreover, the entire job is checked and corrected by precise and professional eyes of Mr. Sylvain Bermell. This report summarizes the work which is formed by works of many contributors and gives information on the GIS architecture and details of integrated data from the Marmara cruises.

Table 1. **The Sea of Marmara cruises fully or partly covered in the GIS database**

Campaign	Acronym	Campaign No	Ship	Leaders	Start Date	End Date
Marmara 97	MAT97	9999	Sismik-1			
Marmara 99	MAT99	9999	Sismik-1			
Marmara	MAR	2000010200	Le Suroit	X. Le Pichon, A.M.C. Sengor, E. Demirbag	12/09/00	03/10/00
Seismarmara	SEM	2001080050	Le Nadir	A. Hirn, S. Singh	11/08/01	09/09/01
Marmarascarps	SCA	2002010140	L`Atalante	R.Armijo, J. Malavielle	16/09/02	15/10/02
Marmara VT		2004200080	Le Marion Dufresne	P. Henry, G. Leicolais, G. Delaygue	04/05/04	07/05/04

Marnaut	MNT	2007010070	L`Atalante	P. Henry, A.M.C. Sengor, N. Cagatay	12/05/07	12/06/07
TAMAM	TAM		Piri Reis	G. Çifçi	01/07/2008	19/07/2008
Marmesonet	MET	2009020040	Le Suroit	L. Geli, P. Henry, N. Cagatay	04/11/09	12/06/07

Table 1. (continue)

Marmara 2009	MA09		Urania	L. Gasperini	23/09/09	12/10/09
Marmrescue	MRES		Yunus	P. Pelleau	26/03/10	31/03/10
Pirmarmara	PIM		Piri Reis	G. Çifçi	02/06/10	07/06/10
TAMAM-II	TAMII		Piri Reis	G. Çifçi	08/06/10	11/06/10
Marmara 2010	MA10		Urania	L. Gasperini	29/09/10	18/10/10

2. General Structure of the GIS Database: Main Folders

The general structure or main folders of the GIS database is designed to be exactly in IFREMER's GIS architecture. The major folders are "01_CAMPAGNES", "02_PROFILS", "03_STATIONS_PRELEVEMENTS", "04_PLONGEES", "05_BATHY", "06_IMAGERIE" "07_HYPERLIENS", 08_INTERPRETATION", "09_TERRE", and "10_REGLEMENTATION" (Table 2). Data from the Sea of Marmara cruises are processed and integrated into above folders according to their data type. Each associated shape file and their attribute tables will be explained in details as subfolders of these main titles.

Table 2. **The general structure of Marmara DM`s GIS**

MAIN FOLDERS	NOTES
01_CAMPAGNE	All recorded points and lines are presented as separate shp files for each cruise

02_PROFILS	Profiles (lines) are presented as separate shp files for each cruise and data type (Chirp, Seismic, etc.)
03_STATIONS_PRELEVEMENTS	Stations (points) are presented as separate shp files for each cruise and data type (CTD, OBS, Cores, etc.)
04_PLONGEES	Data related to dives are presented as separate shp files for each cruise and data type (Chirp, EM2000, etc)
05_BATHY	Processed and gridded bathymetry is presented under this main folder
06_IMAGERIE	All raster images are presented in this folder
07_HYPERLIENS	Processed files such as chirp and seismic profiles are located in this folder
08_INTERPRETATION	Interpreted and other published data are stored under many sub-folders such as GEOCIHIMIE, GEOPHYSIQUE, MORPHOLOGIE, SEDIMENTOLOGIE, and STRATIGRAPHIE_SISMIQUE
09_TERRE	All data related to land such as geological maps, DEMs, coast lines, etc…
10_REGLEMENTATION	Contains data related to regulations such as navigation routes

2.1 Main Folder : CAMPAGNE

Point and polyline type shp files which are generated from ships` navigation of each campaign are stored in this main folder. The nomenclature of each shp file is designed to be in [Campaign].shp form for lines and [Campaign]_points.shp form for points. The main target is to give information about campaign name, campaign number, dates, leaders and data type in attribute tables (Table 3 and Table 4). The Fig. 1 shows the entire navigation lines of processed campaigns in this study.

Table 3. **The attribute table of point type campaign file**

LAYER NAME	DATA TYPE	SCALE
[Campaign]_points.shp	VECTOR-POINT	-

FIELD	FULL NAME	COMMENTS	FIELD TYPE
NUMPCAMP	Campaign number	The number of the campaign (e.g. : 2000020100)	DOUBLE (Precision: 10)
CAMPAGNE	Campaign name	The name of the campaign (e.g.: Marmesonet)	TEXT (Length: 20)
NAVIGATION	Navigation	Navigation source (e.g.: Bateau)	TEXT (Length: 20)
DATE	Date	The date of point data acquisition in DAY/MONTH/YEAR format (e.g.: 22/09/2000)	TEXT (Length: 10)
HEURE	Hour	The exact hour of point data acquisition in HH:MM:SS format (e.g.: 22:19:06)	TEXT (Length: 8)
LATITUDE	Latitude in decimal degrees	Geographical latitude in decimal degrees and WGS84 map datum (e.g.: 41.2345769)	DOUBLE (Precision:11 / Scale: 7)
LONGITUDE	Latitude in decimal degrees	Geographical longitude in decimal degrees and WGS84 map datum (e.g.: 27.5158963)	DOUBLE (Precision:11 / Scale: 7)

Table 4. **The attribute structure of the line type campaign file**

LAYER NAME	DATA TYPE	SCALE
[Campaign].shp	VECTOR-POLYLINE	-

FIELD	FULL NAME	COMMENTS	FIELD TYPE
NUMPCAMP	Campaign number	The number of the campaign (e.g. : 2000020100)	DOUBLE (Precision: 10)
CAMPAGNE	Campaign name	The name of the campaign (e.g.: Marmesonet)	TEXT (Length: 20)
NAVIRE	Ship	Ship’s name (e.g.: Le Suroit)	TEXT (Length: 30)

NOMCHEF	Chief names	Name list of campaign leader and co-leaders (e.g.: LE PICHON Xavier SENGOR Celal DEMIRBAG Emin)	TEXT (Length: 100)
TRAVAUX	Collected data types	Data acquisition types of the campaign (e.g.: bathymetry (EM300), seismic, chirp)	TEXT (Length: 254)
DATEDEBUT	Date start	The starting date of the campaign in DAY/MONTH/YEAR format (e.g.: 22/09/2000)	TEXT (Length: 10)
DATEFIN	Final Date	The final date of the campaign in DAY/MONTH/YEAR format (e.g.: 12/10/2000)	TEXT (Length: 10)
ANNEE	Year	The campaign year (e.g.: 2000)	TEXT (Length: 4)

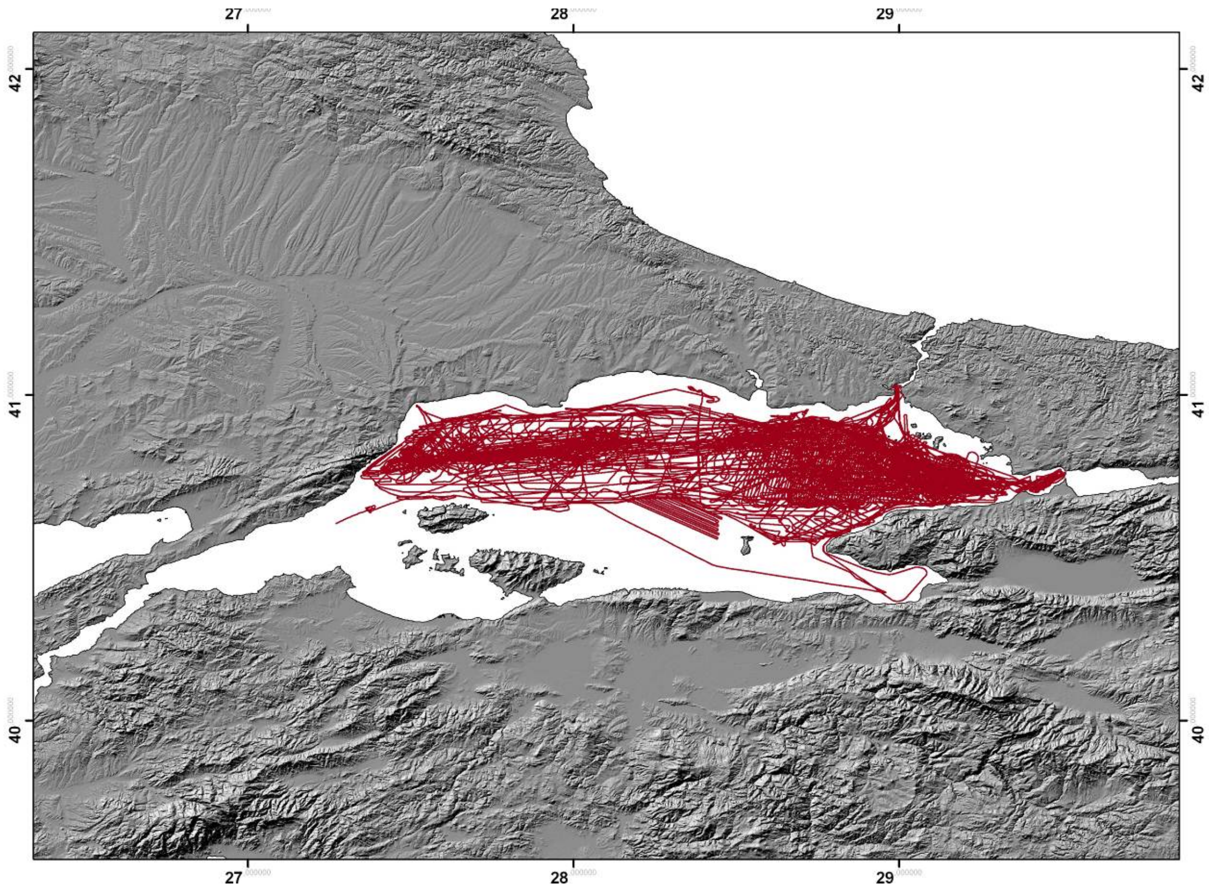

Figure 1. Navigation profiles of processed campaigns. The hillshade image of the terrestrial Marmara Region is created by using SRTM v2 data.

2.2 Main Folder: PROFILS

Profiles are one of the main data acquisition type during cruises in the Sea of Marmara. Chirp, seismic, EM300, SAR, EM2000 data can be given as examples. The main purpose of profile's attribute table is to differentiate them according to campaigns and to give full information on the temporal and spatial patterns. Table 5 shows the attribute table details of profiles and its major fields. Moreover, additional columns show each data type and hyperlinks to processed product (if it exists). Figure 2 shows a sample profile file which indicates seismic lines of Pirmarmara cruise with its attribute table.

Table 5. The attribute structure and field details of profiles

LAYER NAME	DATA TYPE	SCALE
[Campaign]_profiles_[datatype].shp	VECTOR-POLYLINE	-

FIELD	FULL NAME	COMMENTS	FIELD TYPE
NUMPCAMP	Campaign number	The number of the campaign (e.g. : 2000020100)	DOUBLE (Precision: 10)
CAMPAGNE	Campaign name	The name of the campaign (e.g.: Marmesonet)	TEXT (Length: 20)
PROFIL	Profile name or number	Profile's name with the acronym of the campaign(e.g.: MRN_101)	TEXT (Length: 15)
NAVIGATION	Navigation source	The source of the navigation data (e.g.: bateau or engin)	TEXT (Length: 15)
DATEDEBUT	Date start	The starting date of the campaign in DAY/MONTH/YEAR format (e.g.: 22/09/2000)	TEXT (Length: 10)
HEUREDEBUT	Hour start	The exact start time of the profile in HH:MM:SS format (e.g.: 10:47:26)	TEXT (Length: 8)
DATEFIN	Final Date	The final date of the campaign in DAY/MONTH/YEAR format (e.g.: 12/10/2000)	TEXT (Length: 10)
HEUREDEBUT	Final Hour	The exact final time of the profile in HH:MM:SS format (e.g.: 10:47:26)	TEXT (Length: 8)
X_DEBUT	X coordinate of line start	The starting X coordinate of the line in decimal degrees and WGS84 map datum (e.g.: 27.4569877)	DOUBLE (Precision:11/Scale:7)
Y_DEBUT	Y coordinate of line start	The starting Y coordinate of the line in decimal degrees and WGS84 map datum (e.g.: 39.7456981)	DOUBLE (Precision:11/Scale:7)
X_FIN	X coordinate of line end	The ending X coordinate of the line in decimal degrees and WGS84 map datum (e.g.: 29.5489654)	DOUBLE (Precision:11/Scale:7)
Y_FIN	Y coordinate of line end	The ending Y coordinate of the line in decimal degrees and WGS84 map datum (e.g.: 40.5479877)	DOUBLE (Precision:11/Scale:7)
LONGUEUR	Length	Length of line in meters (e.g.: 1258.125)	DOUBLE (Precision:10/Scale:3)

Table 5 (continue). **Next columns are added to each different profile according to their data types and availability;**

CHIRP/EM300/ SISMIQUE/ EM2000/EM302/	Data type	Indication for the data type of the profile. 1 is used for “yes” and 0 is for “no”	SHORT INTEGER (Precision:1)
LINK2PDF	Hyperlink to profile’s processed image	Length of line in meters (e.g.: 1258.125)	DOUBLE (Precision:10/Scale:3)

Table 6. Integrated profiles from each campaign to GIS database

CAMPAIGN	ACRONYM	PROFILE TYPE	HYPERLINK
Marmara 97	MAT97	Seismic	Yes
Marmara 99	MAT99	Seismic	Yes
Marmara	MAR	SAR	No
Seismarmara	SEM	Seismic	Yes
Marmarascarps	SCA	Chirp	Yes
Marnaut	MNT	Chirp / EK60	Yes/No
TAMAM	TAM	Seismic	No
Marmesonet	MET	Chirp / EM302 / EM2000 /Seismic HR	Yes/No/Yes/No
Marmara2009	MA09	Chirp, Multibeam, Medusa	No
Marmrescue	MRES	None	-
Pirmarmara	PIM	Seismic	Yes
Marmara2010	MA10	Chirp, Medusa	No
TAMAM-II	TAMII	Seismic	No

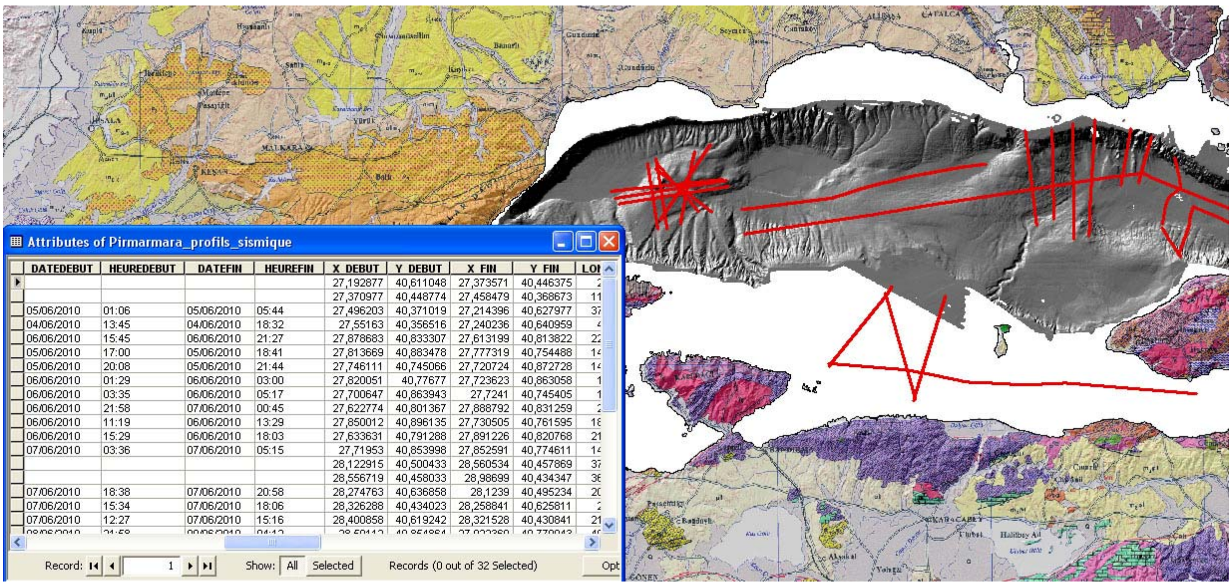

Figure 2. A screen shot as an example for a profile shp and its attribute table. The lines are from Pirmarmara cruise.

2.3 Main Folder: STATIONS_PRELEVEMENTS

All stationary type (point) observations, sampling and measurement sites are integrated into the GIS as point type shape files. The main part of the attribute table is designed to give basic information such as the campaign name, station number, date, coordinates, depth, length, the type of positioning, tool and the site name (Table 7). Moreover, each station type may have more columns which are reserved to include additional information according to data type. For example columns related with XRF outputs are added to each core shp file. The integrated stationary data to the Marmara DM GIS database are summarized in Table 8. The screen shot of Marmara2009 cruise's core locations and their attribute table is given as a sample view (Figure 3).

Table 7. The attribute structure and field properties of stationary shp files

LAYER NAME	DATA TYPE	SCALE
[Campaign]_[datatype].shp	VECTOR-POINT	-

FIELD	FULL NAME	COMMENTS	FIELD TYPE
NUMPCAMP	Campaign number	The number of the campaign (e.g. : 2000020100)	DOUBLE (Precision: 10)
CAMPAGNE	Campaign name	The name of the campaign (e.g.: Marmesonet)	TEXT (Length: 20)
NUMPREL	Station name or number	Station's name with the acronym of the campaign(e.g.: MRN_101)	TEXT (Length: 15)
DATE_	Date	The exact date of the observation / sampling / measurement in DAY/MONTH/YEAR format (e.g.: 22/09/2000)	TEXT (Length: 10)
ANNEE	Year	The year of the campaign (e.g.: 2000)	TEXT (Length: 4)
LATITUDE	Latitude	Latitude in decimal degrees and WGS84 map datum (e.g.: 40.2364238)	DOUBLE (Precision:11/Scale:7)
LONGITUDE	Longitude	Longitude in decimal degrees and WGS84 map datum (e.g.: 27.4569877)	DOUBLE (Precision:11/Scale:7)
PROFONDEUR	Depth	Observation / measurement / sampling depth of the	DOUBLE (Precision:0/Scale:0)

		station in meters (e.g.: 273.89)	
LONGUEUR	Length	The length of cores or samples in meters (e.g.: 3.225)	DOUBLE (Precision:0/Scale:0)

Tablo 7. (continue)

TYPE_POSIT	Type of positioning	The method of positioning (e.g.: D-GPS)	TEXT (Length: 50)
OUTIL	Tool	Used tool in sampling / measurement / observation (e.g.: Gravity core)	TEXT (Length:25)
SITE	Site	Operation site's name (e.g.: Çınarcık basin)	TEXT (Length: 50)

Table 8. Integrated stationary data per each campaign

CAMPAIGN	ACRONYM	STATION TYPE	HYPERLINK
Marmara 97	MAT97	None	-
Marmara 99	MAT99	None	-
Marmara	MAR	None	-
Seismarmara	SEM	None	-
Marmarascarps	SCA	None	-
Marnaut	MNT	Core / CTD / Heat Flux / OBS / Piezometers	No / Yes / Yes / No / No
TAMAM	TAM	None	-
Marmesonet	MET	BOB / Core / CTD / Heat Flux / OBS / Sippican	No / No / Yes / No / No / No
Marmara2009	MA09	CTD, OBS, Piezometers, SN4	No
Pirmarmara	PIM	None	-
Marmrescue	MRES	Piezometers / SN4 / OBS	No
Marmara2010	MA10	Core /CTD / SN4	No
TAMAM-II	TAMII	None	No

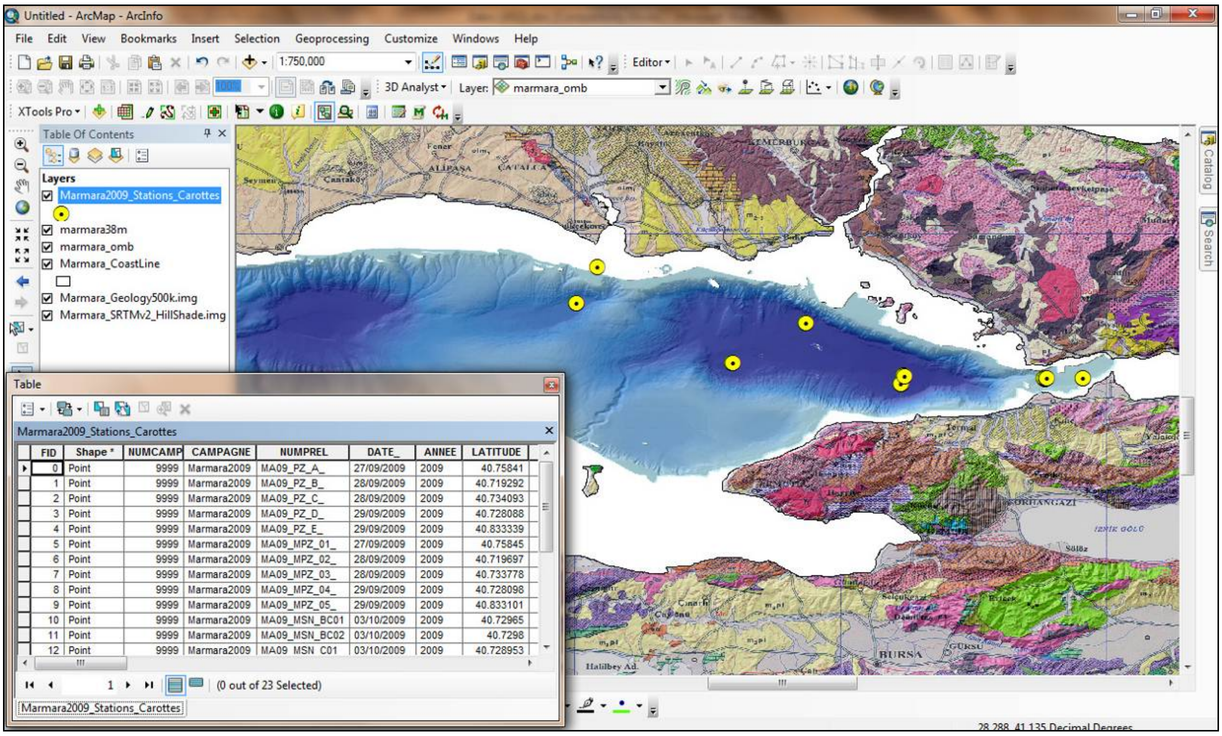

Figure 3. The screen shot showing the core sampling sites of the Marmara2009 cruise and part of their attributes.

2.4 Main Folder: PLONGEES

This folder is designed to include navigation information for each dive during various cruises. There is no standard attribute table design for this section, but the main aim is to give the device based navigation profiles for each job. Moreover, additional products such as images and minifilms are added as subfolders to each separated dives. Table 9 summarizes the included dives, while Figure 4 and Figure 5 show samples of a dive profile and an attached image.

Table 9. Integrated dive data to the Marmara DM GIS

CAMPAIGN	ACRONYM	NO of DIVES	IMAGES
Marmarascarps	SCA	12	Yes
Marnaut	MNT	30	Yes

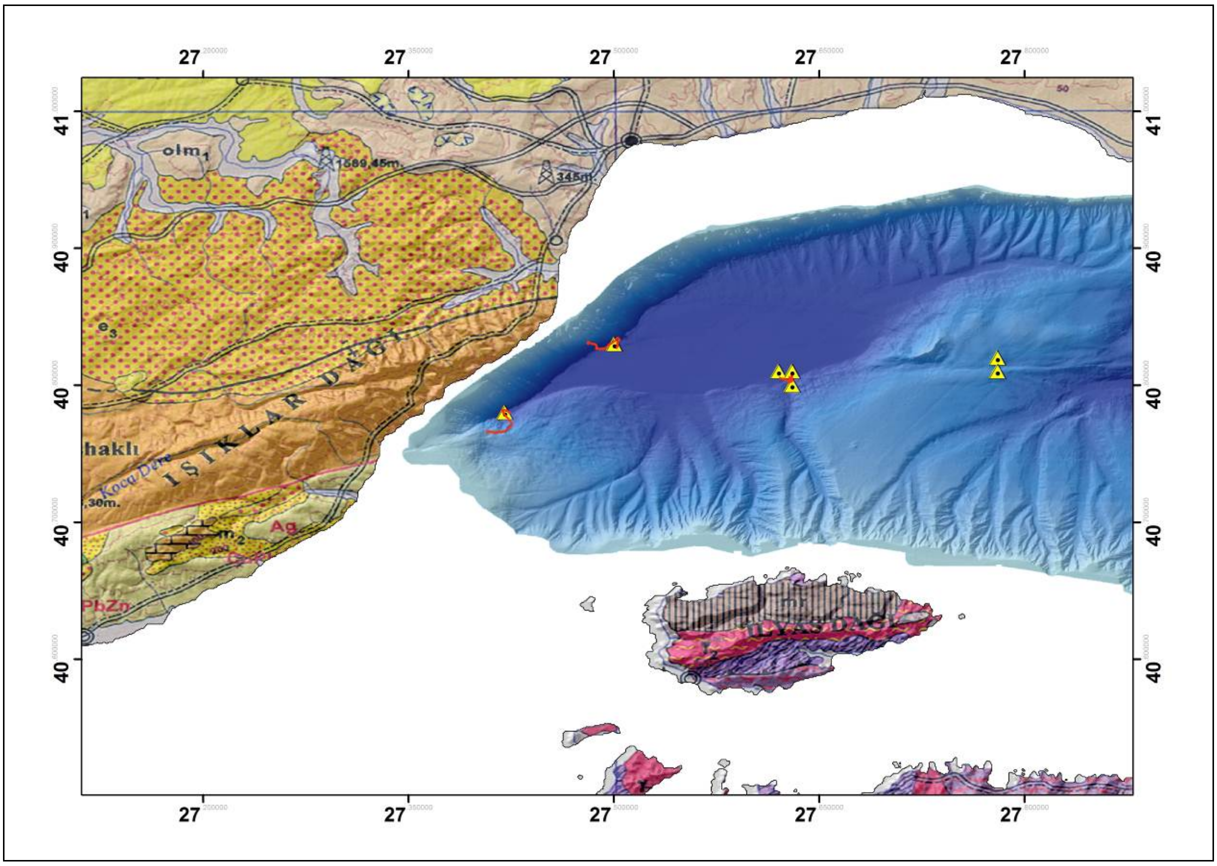

Figure 4. A sample close up to Tekirdağ Basin to show exact locations (yellow triangles) of dives during the Marnaut cruise. Red lines indicate the Nautile’s navigation.

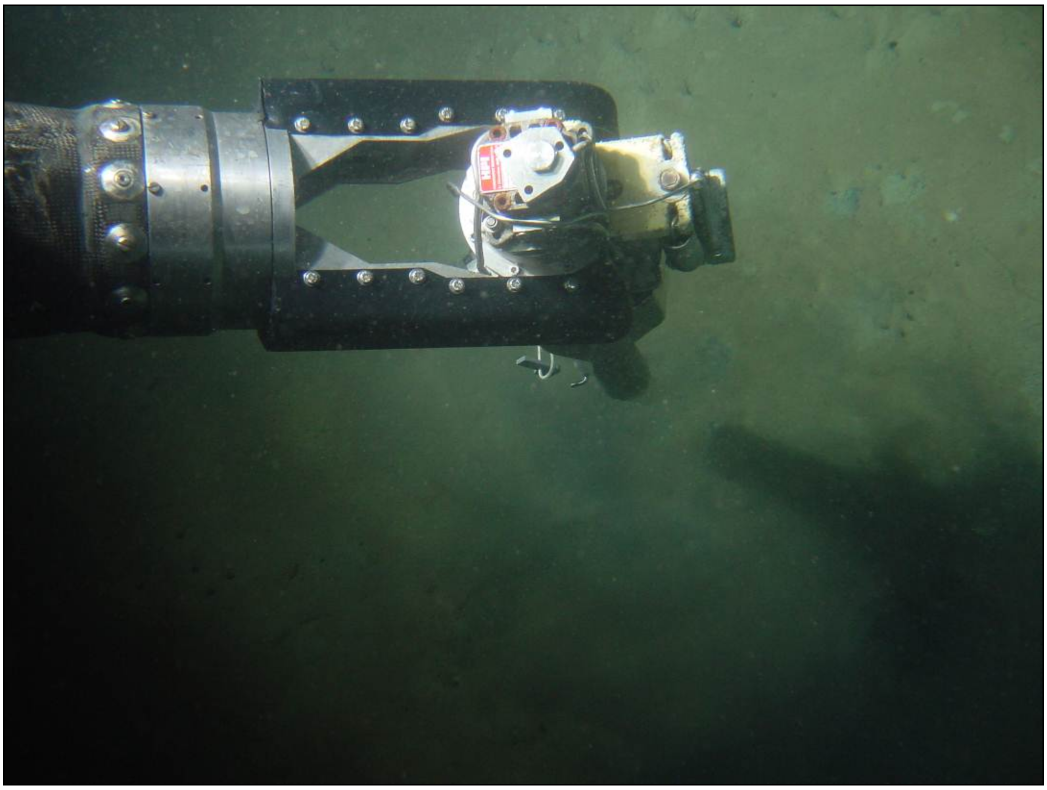

Figure 5. A sample image from the image gallery of Marnaut dives.

2.5 Main Folders: BATHY

This folder includes the gridded bathymetry data from various cruises. Moreover, there are isobaths which are derived from these grid data (Table 10). The isobaths are classified to have different contour intervals such as 5, 10, 20, 100 and 500 meters. There is also a hill shade image which is produced by using the bathymetry data of the Marmara cruise (Figure 6).

Table 10. The isobaths and grids in the BATHY folder

CAMPAIGN	ACRONYM	GRIDS	ISOBATHS
Marmara	SCA	Yes	Yes
Marmesonet	MET	Yes	-

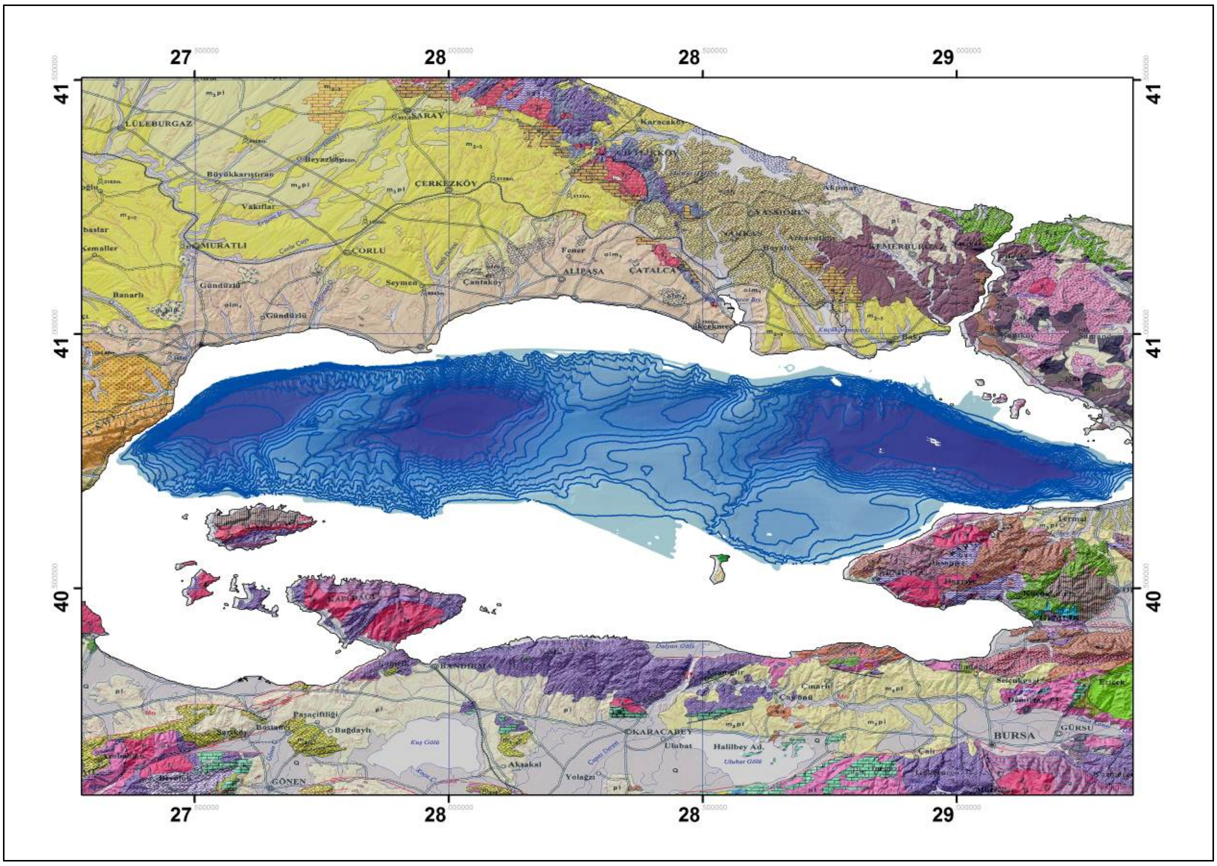

Figure 6. Hillshaded bathmetry grid and isobaths with 100 m contour interval from the Marmara cruise.

2.6 Main Folder: IMAGERIE

This folder is reserved to include raster type data (images) which are obtained by various tools. All images have a georeference frame and it can be directly visualized in its correct position with other shp files.

While there is no precise file format for included images, referenced “bmp” file types are preferred mostly. There are also many ESRI grid and ERDAS Imagine type files included in the Imagerie folder.

2.7 Main Folder: HYPERLIENS

The preliminary or final image products of collected various type of data are stored in this folder. These all images are linked in their host shape files with a reserved column named “LINK2PDF”. All images are set to be in “PDF” file format. The usage of the pdf is to have a less file length and its general usage.

The major hyperlink folders in Marmara DM GIS project are ACOUSTIQUE COLONNE EAU, FLUX CHALEUR, LOGS CAROTTE, PROFILS CHIRP and PROFILS SISMIQUE. Included hyperlinked cruises and type of data are shown in Table 11.

Table 11. Hyperlinked data and their cruises

CAMPAIGN	ACRONYM	HYPERLINKS
Marmesonet	MET	Acoustic Anomalies, Multibeam, Chirp, CTD,
Marnaut	MNT	Heat flux, Chirp, CTD
Seismarmara	SEM	Seismic profiles
Pirmarmara	PIM	Seismic profiles
TAMAM_II	TAMII	Seismic profiles
Marmara97	MAT97	Seismic profiles
Marmara99	MAT99	Seismic profiles
Marmarascarps	SCA	Chirp

2.8 Main Folders: INTERPRETATION

Interpreted data are stored in different fields of disciplines under this main folder. The major sub-folders are GEOPHYSIQUE, GEOCHIMIE, MORPHOLOGIE, SEDIMENTOLOGIE, and STRATIGRAPHIE-SISMIQUE. Each interpreted data is implemented in one of these related sub-folders in this section.

There are shp files which show stationary coordinates of acoustic anomalies with hyperlinks in the GEOPHYSIQUE section. GEOCHIMIE folder includes files which are generated from published papers by various authors showing some sample/observation locations. Although they are not products of the Marmara cruises, these informative studies are decided to be included by referring authors. MORPHOLOGIE sub-section covers all shp files which are related with the sub-marine morphology such as canyons, channels, seeps and slides. It also includes morpho-tectonic structures such as active faults of the Marmara Sea.

2.9 Other Folders: TERRE and REGLEMENTATION

The folder TERRE is designed to be used to store all data relevant to land. The subfolders Carottes, Couches_AV, Geologie, MNT, Orthopohotos, Reseau_Hydrographique and Trait_Cote are all created to host different type of land data.

The main digital elevation model (DEM) used for the Marmara region is obtained from open access Shuttle Radar Topographic Mission (SRTM) data of USGS (Figure 7). Also shaded relief of SRTM data is created and added to the database. The geological map of the Marmara region with scale 1:500k is stored under TERRE (Türkecan and Yurtsever, 2002). The general coast line for the coverage of the Marmara region is also added to this collection.

The folder REGLEMENTATION includes the navigation map of the Marmara Sea and the shp files showing navigation routes.

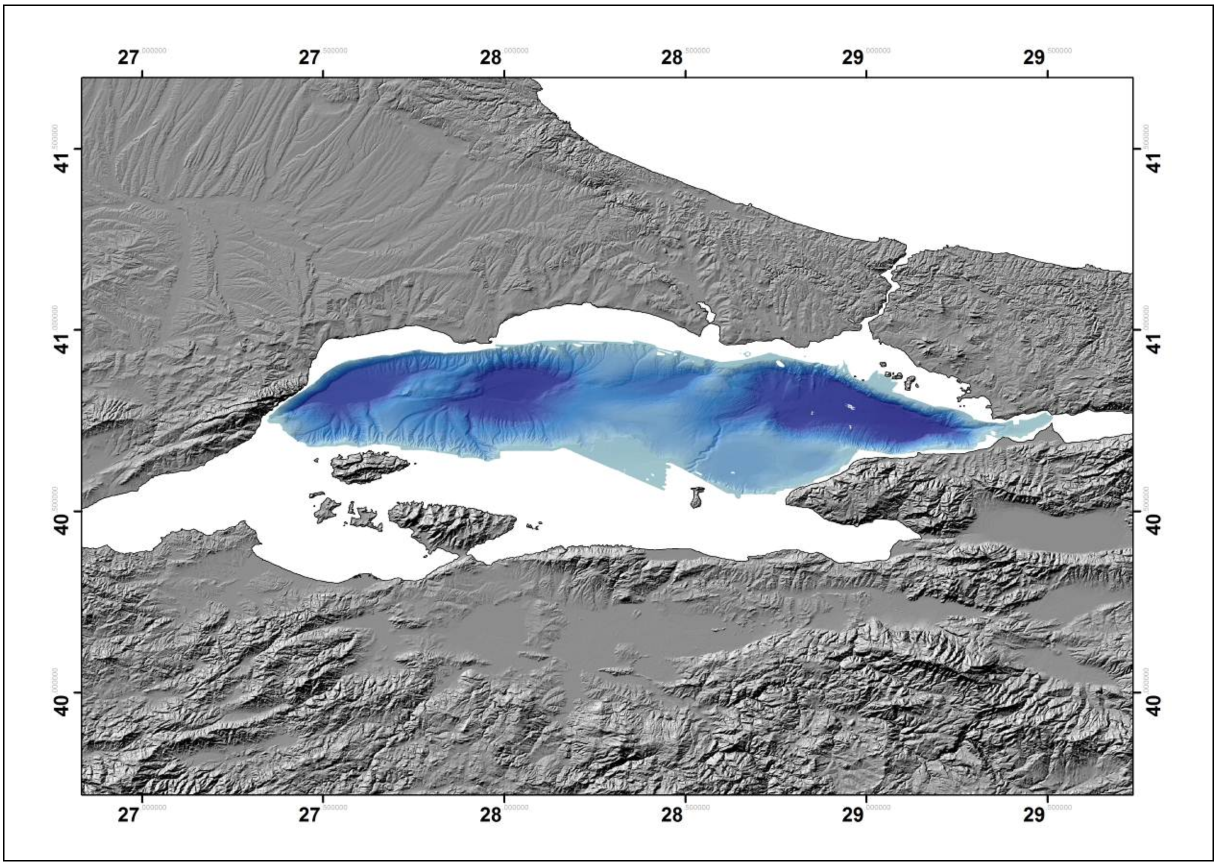

Figure 7. SRTM v2. Hill shade image with the shaded bathmetry of the Marmara cruise

3. Conclusion

Majority of ESONET Marmara DM data is processed and integrated in the GIS of IFREMER by many contributors. The checking of all processed data is also performed and all products are copied in their proper folders. The minor modifications can be done with arrival of new data or exposure of mistakes.

This all data will be 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. 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. You can find further instructions about data repository in the Marmara_DM web page (http://www.esonet.marmara-dm.itu.edu.tr/) EMCOL-NAS section.

Acknowledgments

The Marmara GIS entirely constructed on the IFREMER GIS architecture. This system was designed and is continuously developed with the experience of long marine studies. The major part of data were already constructed or prepared to be processed before my arrival to IFREMER in the framework of the ESONET personal exchange program. I am so thankful for all helps, guidance and corrections done by Dr. Stephanie Dupre and Mr. Sylvain Bermell during my visit. Dr. Louis Geli created a perfect working environment by his great hospitality. I also give my thanks to the people of the Cartographie division for their hospitality and helps during my stay.

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Geographical Information System (GIS) Database of the Marmara Sea Cruises: The personal report on the exchange programme of the European Sea Observatory Networks (ESONET)

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1. Introduction

The disasterous 1999 Izmit (Mw=7.6) and Duzce (Mw=7.1) earthquakes immediately directed attentions of both social and scientific communities towards the Marmara region, Turkey. The poor data for submarine fault geometry and seismic gap which was determined to be ruptured in near future by Coulomb failure criteria (Çakır et al., 2003; Parsons, 2004; Parsons et al., 2000; Pondard et al., 2007) triggered many and continuous scientific projects in the Marmara region. The majority of these studies were carried out by marine cruises in the Sea of Marmara.

Scientists also started to realize that the Sea of Marmara constitute a unique opportunity to study seismogenic behavior of the one of the most important continental strike fault, the North Anatolian Fault (NAF). It is clear that this also would create a great contribution to studies of other active faults of the Earth. To achieve this aim, many national and international campaigns were carried out to understand, form and conclude hypothesizes on the structure and the behavior of the NAF. Many scientific papers were published on various subjects such as the mapping of fault (Armijo et al., 2005; Demirbag et al., 2003; Le Pichon et al., 2003; Le Pichon et al., 2001; Okay et al., 2000; Rangin et al., 2004; Yaltirak, 2002), historical earthquakes (Beck et al., 2007; McHugh et al., 2006; Sari and Cagatay, 2006), tsunamis (Hayir et al., 2008; Hébert et al., 2005; Kilinc et al., 2009; Ozeren et al., 2010; Yalçıner et al., 2002) and fluid/gas interaction with the active fault (Bourry et al., 2009; Geli et al., 2008; Tryon et al., 2010) in the Sea of Marmara.

It is obvious that there is a huge accumulated data acquisition at the background of all these studies. This richness of both type and quantity of data created the necessity to form a geodatabase. Geographical Information System (GIS) is known to be a very effective tool to organize data in spatial sense. On the other hand attribute tables can be designed to give information in many aspects such as temporal concept, data acquisition type, results after preliminary or final processes, and many more. In the framework of ESONET NoN - Marmara Demo Mission, it is decided to create a GIS database as the main target of the Deliverable 4.2.

The job is decided to be integrated into the IFREMER's GIS architecture, which had designed on the basis of many years marine studies' experience. A lot of data had been already submitted to GIS onboard or just after cruises. Moreover, there were already processed shape files by Dr. Devrim Tezcan and researchers of IFREMER (Dr. Stephanie Dupre and Cartographie division). My contribution to Marmara DM`s GIS was mainly about converting processed preliminary shape files into the desired format, creating missing ones from available raw navigation data or cruise reports, filling missing attributes, constructing hyperlinks to images of processed data, and integration of some published studies during 7 weeks of stay in IFREMER, Brest in the framework of personal exchange program of ESONET. Moreover, the entire job is checked and corrected by precise and professional eyes of Mr. Sylvain Bermell. This report summarizes the work which is formed by works of many contributors and gives information on the GIS architecture and details of integrated data from the Marmara cruises.

Table 1. The Sea of Marmara cruises fully or partly covered in the GIS database

Campaign	Acronym	Campaign No	Ship	Leaders	Start Date	End Date
Marmara 97	MAT97	9999	Sismik-1			
Marmara 99	MAT99	9999	Sismik-1			
Marmara	MAR	2000010200	Le Suroit	X. Le Pichon, A.M.C. Sengor, E. Demirbag	12/09/00	03/10/00
Seismarmara	SEM	2001080050	Le Nadir	A. Hirn, S. Singh	11/08/01	09/09/01
Marmarascarps	SCA	2002010140	L`Atalante	R.Armijo, J. Malavielle	16/09/02	15/10/02
Marmara VT		2004200080	Le Marion Dufresne	P. Henry, G. Leicolais, G. Delaygue	04/05/04	07/05/04
Marnaut	MNT	2007010070	L`Atalante	P. Henry, A.M.C. Sengor, N. Cagatay	12/05/07	12/06/07
TAMAM	TAM		Piri Reis	G. Çifçi	01/07/2008	19/07/2008
Marmesonet	MET	2009020040	Le Suroit	L. Geli, P. Henry, N. Cagatay	04/11/09	12/06/07

Table 1. (continue)

Marmara 2009	MA09		Urania	L. Gasperini	23/09/09	12/10/09
Marmrescue	MRES		Yunus	P. Pelleau	26/03/10	31/03/10
Pirmarmara	PIM		Piri Reis	G. Çifçi	02/06/10	07/06/10
TAMAM-II	TAMII		Piri Reis	G. Çifçi	08/06/10	11/06/10
Marmara 2010	MA10		Urania	L. Gasperini	29/09/10	18/10/10

2. General Structure of the GIS Database: Main Folders

The general structure or main folders of the GIS database is designed to be exactly in IFREMER's GIS architecture. The major folders are "01_CAMPAGNES", "02_PROFILS", "03_STATIONS_PRELEVEMENTS", "04_PLONGEES", "05_BATHY", "06_IMAGERIE" "07_HYPERLIENS", 08_INTERPRETATION", "09_TERRE", and "10_REGLEMENTATION" (Table 2). Data from the Sea of Marmara cruises are processed and integrated into above folders according to their data type. Each associated shape file and their attribute tables will be explained in details as subfolders of these main titles.

Table 2. The general structure of Marmara DM`s GIS

MAIN FOLDERS	NOTES
01_CAMPAGNE	All recorded points and lines are presented as separate shp files for each cruise
02_PROFILS	Profiles (lines) are presented as separate shp files for each cruise and data type (Chirp, Seismic, etc.)
03_STATIONS_PRELEVEMENTS	Stations (points) are presented as separate shp files for each cruise and data type (CTD, OBS, Cores, etc.)
04_PLONGEES	Data related to dives are presented as separate shp files for each cruise and data type (Chirp, EM2000, etc)
05_BATHY	Processed and gridded bathymetry is presented under this main folder
06_IMAGERIE	All raster images are presented in this folder
07_HYPERLIENS	Processed files such as chirp and seismic profiles are located in this folder
08_INTERPRETATION	Interpreted and other published data are stored under many sub-folders such as GEOCIHIMIE, GEOPHYSIQUE, MORPHOLOGIE, SEDIMENTOLOGIE, and STRATIGRAPHIE_SISMIQUE
09_TERRE	All data related to land such as geological maps, DEMs, coast lines, etc…
10_REGLEMENTATION	Contains data related to regulations such as navigation routes

2.1 Main Folder : CAMPAGNE

Point and polyline type shp files which are generated from ships` navigation of each campaign are stored in this main folder. The nomenclature of each shp file is designed to be in [Campaign].shp form for lines and [Campaign]_points.shp form for points. The main target is to give information about campaign name, campaign number, dates, leaders and data type in attribute tables (Table 3 and Table 4). The Fig. 1 shows the entire navigation lines of processed campaigns in this study.

Tablo 3. The attribute table of point type campaign file

LAYER NAME	DATA TYPE	SCALE
[Campaign]_points.shp	VECTOR-POINT	-

FIELD	FULL NAME	COMMENTS	FIELD TYPE
NUMPCAMP	Campaign number	The number of the campaign (e.g. : 2000020100)	DOUBLE (Precision: 10)
CAMPAGNE	Campaign name	The name of the campaign (e.g.: Marmesonet)	TEXT (Length: 20)
NAVIGATION	Navigation	Navigation source (e.g.: Bateau)	TEXT (Length: 20)
DATE	Date	The date of point data acquisition in DAY/MONTH/YEAR format (e.g.: 22/09/2000)	TEXT (Length: 10)
HEURE	Hour	The exact hour of point data acquisition in HH:MM:SS format (e.g.: 22:19:06)	TEXT (Length: 8)
LATITUDE	Latitude in decimal degrees	Geographical latitude in decimal degrees and WGS84 map datum (e.g.: 41.2345769)	DOUBLE (Precision:11 / Scale: 7)
LONGITUDE	Latitude in decimal degrees	Geographical longitude in decimal degrees and WGS84 map datum (e.g.: 27.5158963)	DOUBLE (Precision:11 / Scale: 7)

Table 4. The attribute structure of the line type campaign file

LAYER NAME	DATA TYPE	SCALE
[Campaign].shp	VECTOR-POLYLINE	-

FIELD	FULL NAME	COMMENTS	FIELD TYPE
NUMPCAMP	Campaign number	The number of the campaign (e.g. : 2000020100)	DOUBLE (Precision: 10)
CAMPAGNE	Campaign name	The name of the campaign (e.g.: Marmesonet)	TEXT (Length: 20)
NAVIRE	Ship	Ship's name (e.g.: Le Suroit)	TEXT (Length: 30)
NOMCHEF	Chief names	Name list of campaign leader and co-leaders (e.g.: LE PICHON Xavier SENGOR Celal DEMIRBAG Emin)	TEXT (Length: 100)
TRAVAUX	Collected data types	Data acquisition types of the campaign (e.g.: bathymetry (EM300), seismic, chirp)	TEXT (Length: 254)
DATEDEBUT	Date start	The starting date of the campaign in DAY/MONTH/YEAR format (e.g.: 22/09/2000)	TEXT (Length: 10)
DATEFIN	Final Date	The final date of the campaign in DAY/MONTH/YEAR format (e.g.: 12/10/2000)	TEXT (Length: 10)
ANNEE	Year	The campaign year (e.g.: 2000)	TEXT (Length: 4)

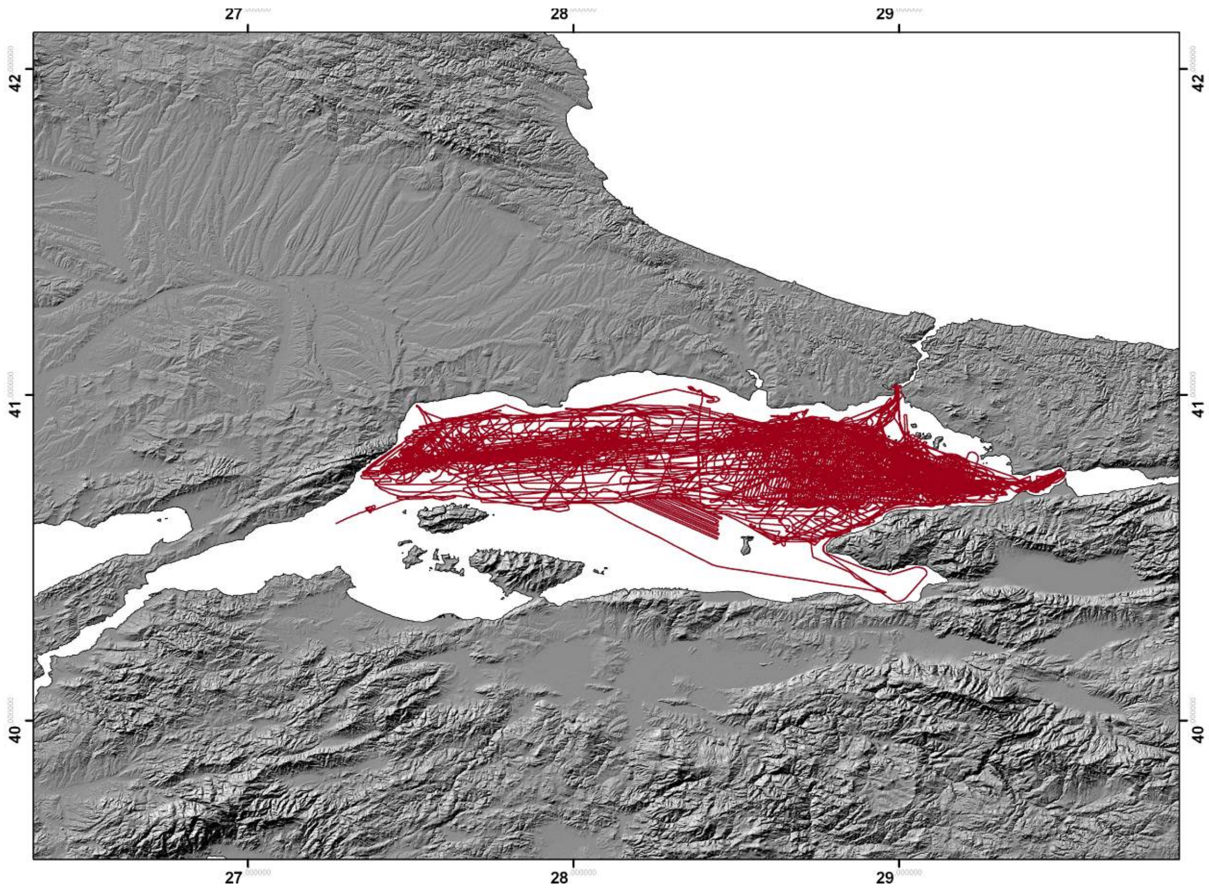

Figure 1. Navigation profiles of processed campaigns. The hillshade image of the terrestrial Marmara Region is created by using SRTM v2 data.

2.2 Main Folder: PROFILS

Profiles are one of the main data acquisition type during cruises in the Sea of Marmara. Chirp, seismic, EM300, SAR, EM2000 data can be given as examples. The main purpose of profile's attribute table is to differentiate them according to campaigns and to give full information on the temporal and spatial patterns. Table 5 shows the attribute table details of profiles and its major fields. Moreover, additional columns show each data type and hyperlinks to processed product (if it exists). Figure 2 shows a sample profile file which indicates seismic lines of Pirmarmara cruise with its attribute table.

Table 5. The attribute structure and field details of profiles

LAYER NAME	DATA TYPE	SCALE
[Campaign]_profiles_[datatype].shp	VECTOR-POLYLINE	-

FIELD	FULL NAME	COMMENTS	FIELD TYPE
NUMPCAMP	Campaign number	The number of the campaign (e.g. : 2000020100)	DOUBLE (Precision: 10)
CAMPAGNE	Campaign name	The name of the campaign (e.g.: Marmesonet)	TEXT (Length: 20)
PROFIL	Profile name or number	Profile's name with the acronym of the campaign(e.g.: MRN_101)	TEXT (Length: 15)
NAVIGATION	Navigation source	The source of the navigation data (e.g.: bateau or engin)	TEXT (Length: 15)
DATEDEBUT	Date start	The starting date of the campaign in DAY/MONTH/YEAR format (e.g.: 22/09/2000)	TEXT (Length: 10)
HEUREDEBUT	Hour start	The exact start time of the profile in HH:MM:SS format (e.g.: 10:47:26)	TEXT (Length: 8)
DATEFIN	Final Date	The final date of the campaign in DAY/MONTH/YEAR format (e.g.: 12/10/2000)	TEXT (Length: 10)
HEUREDEBUT	Final Hour	The exact final time of the profile in HH:MM:SS format (e.g.: 10:47:26)	TEXT (Length: 8)
X_DEBUT	X coordinate of line start	The starting X coordinate of the line in decimal degrees and WGS84 map datum (e.g.: 27.4569877)	DOUBLE (Precision:11/Scale:7)
Y_DEBUT	Y coordinate of line start	The starting Y coordinate of the line in decimal degrees and WGS84 map datum (e.g.: 39.7456981)	DOUBLE (Precision:11/Scale:7)
X_FIN	X coordinate of line end	The ending X coordinate of the line in decimal degrees and WGS84 map datum (e.g.: 29.5489654)	DOUBLE (Precision:11/Scale:7)
Y_FIN	Y coordinate of line end	The ending Y coordinate of the line in decimal degrees and WGS84 map datum (e.g.: 40.5479877)	DOUBLE (Precision:11/Scale:7)
LONGUEUR	Length	Length of line in meters (e.g.: 1258.125)	DOUBLE (Precision:10/Scale:3)

Table 5 (continue). Next columns are added to each different profile according to their data types and availability;

CHIRP/EM300/ SISMIQUE/ EM2000/EM302/	Data type	Indication for the data type of the profile. 1 is used for "yes" and 0 is for "no"	SHORT INTEGER (Precision:1)
LINK2PDF	Hyperlink to profile's processed image	Length of line in meters (e.g.: 1258.125)	DOUBLE (Precision:10/Scale:3)

Table 6. Integrated profiles from each campaign to GIS database

CAMPAIGN	ACRONYM	PROFILE TYPE	HYPERLINK
Marmara 97	MAT97	Seismic	Yes
Marmara 99	MAT99	Seismic	Yes
Marmara	MAR	SAR	No
Seismarmara	SEM	Seismic	Yes
Marmarascarps	SCA	Chirp	Yes
Marnaut	MNT	Chirp / EK60	Yes/No
TAMAM	TAM	Seismic	No
Marmesonet	MET	Chirp / EM302 / EM2000 /Seismic HR	Yes/No/Yes/No
Marmara2009	MA09	Chirp, Multibeam, Medusa	No
Marmrescue	MRES	None	-
Pirmarmara	PIM	Seismic	Yes
Marmara2010	MA10	Chirp, Medusa	No
TAMAM-II	TAMII	Seismic	No

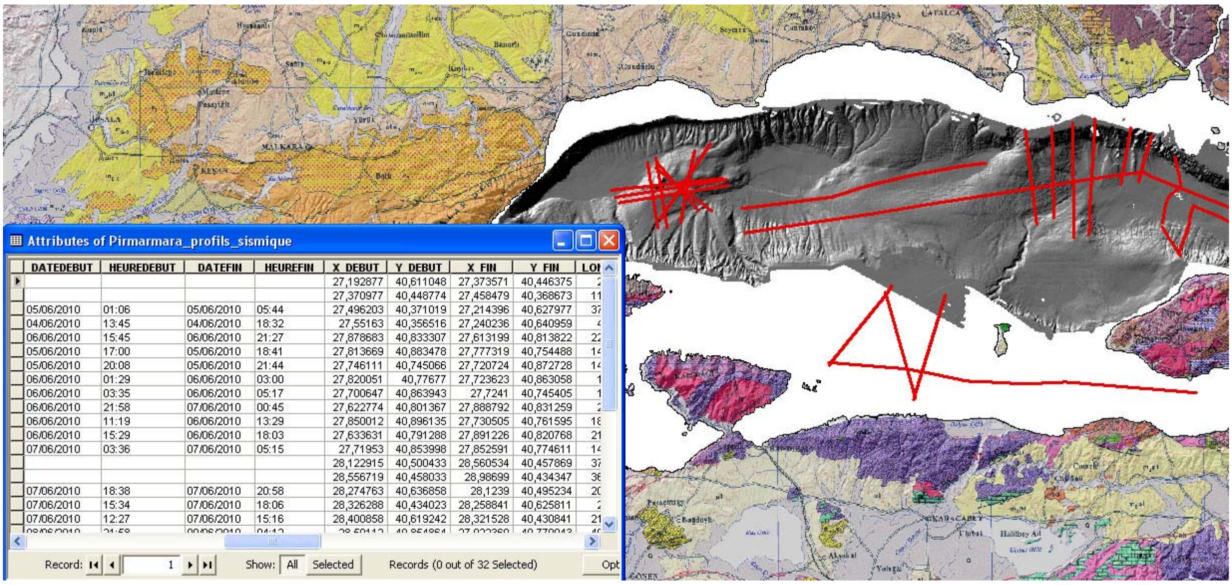

Figure 2. A screen shot as an example for a profile shp and its attribute table. The lines are from Pirmarmara cruise.

2.3 Main Folder: STATIONS_PRELEVEMENTS

All stationary type (point) observations, sampling and measurement sites are integrated into the GIS as point type shape files. The main part of the attribute table is designed to give basic information such as the campaign name, station number, date, coordinates, depth, length, the type of positioning, tool and the site name (Table 7). Moreover, each station type may have more columns which are reserved to include additional information according to data type. For example columns related with XRF outputs are added to each core shp file. The integrated stationary data to the Marmara DM GIS database are summarized in Table 8. The screen shot of Marmara2009 cruise's core locations and their attribute table is given as a sample view (Figure 3).

Table 7. The attribute structure and field properties of stationary shp files

LAYER NAME	DATA TYPE	SCALE
[Campaign]_[datatype].shp	VECTOR-POINT	-

FIELD	FULL NAME	COMMENTS	FIELD TYPE
NUMPCAMP	Campaign number	The number of the campaign (e.g. : 2000020100)	DOUBLE (Precision: 10)
CAMPAGNE	Campaign name	The name of the campaign (e.g.: Marmesonet)	TEXT (Length: 20)
NUMPREL	Station name or number	Station's name with the acronym of the campaign(e.g.: MRN_101)	TEXT (Length: 15)
DATE_	Date	The exact date of the observation / sampling / measurement in DAY/MONTH/YEAR format (e.g.: 22/09/2000)	TEXT (Length: 10)
ANNEE	Year	The year of the campaign (e.g.: 2000)	TEXT (Length: 4)
LATITUDE	Latitude	Latitude in decimal degrees and WGS84 map datum (e.g.: 40.2364238)	DOUBLE (Precision:11/Scale:7)
LONGITUDE	Longitude	Longitude in decimal degrees and WGS84 map datum (e.g.: 27.4569877)	DOUBLE (Precision:11/Scale:7)
PROFONDEUR	Depth	Observation / measurement / sampling depth of the station in meters (e.g.: 273.89)	DOUBLE (Precision:0/Scale:0)
LONGUEUR	Length	The length of cores or samples in meters (e.g.: 3.225)	DOUBLE (Precision:0/Scale:0)

Tablo 7. (continue)

TYPE_POSIT	Type of positioning	The method of positioning (e.g.: D-GPS)	TEXT (Length: 50)
OUTIL	Tool	Used tool in sampling / measurement / observation (e.g.: Gravity core)	TEXT (Length:25)
SITE	Site	Operation site's name (e.g.: Çınarcık basin)	TEXT (Length: 50)

Table 8. Integrated stationary data per each campaign

CAMPAIGN	ACRONYM	STATION TYPE	HYPERLINK
Marmara 97	MAT97	None	-
Marmara 99	MAT99	None	-
Marmara	MAR	None	-
Seismarmara	SEM	None	-
Marmarascarps	SCA	None	-
Marnaut	MNT	Core / CTD / Heat Flux / OBS / Piezometers	No / Yes / Yes / No / No
TAMAM	TAM	None	-
Marmesonet	MET	BOB / Core / CTD / Heat Flux / OBS / Sippican	No / No / Yes / No / No / No
Marmara2009	MA09	CTD, OBS, Piezometers, SN4	No
Pirmarmara	PIM	None	-
Marmrescue	MRES	Piezometers / SN4 / OBS	No
Marmara2010	MA10	Core /CTD / SN4	No
TAMAM-II	TAMII	None	No

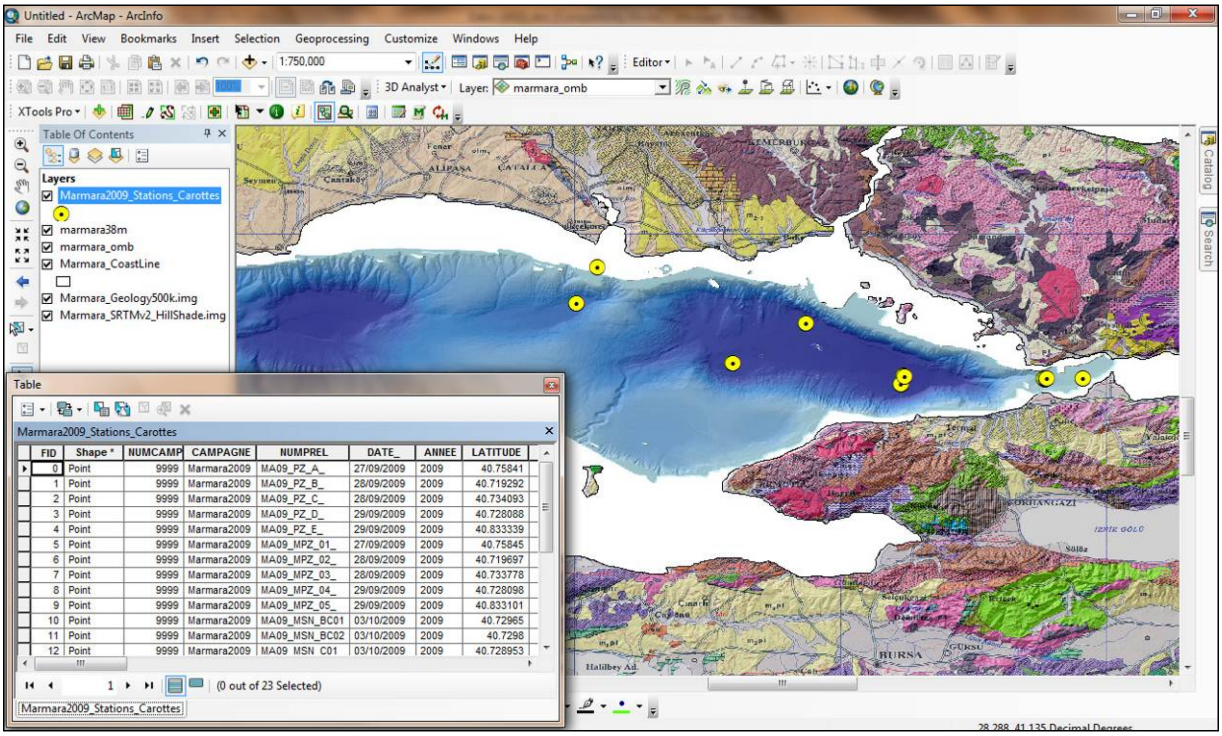

Figure 3. The screen shot showing the core sampling sites of the Marmara2009 cruise and part of their attributes.

2.4 Main Folder: PLONGEES

This folder is designed to include navigation information for each dive during various cruises. There is no standard attribute table design for this section, but the main aim is to give the device based navigation profiles for each job. Moreover, additional products such as images and minifilms are added as subfolders to each separated dives. Table 9 summarizes the included dives, while Figure 4 and Figure 5 show samples of a dive profile and an attached image.

Table 9. Integrated dive data to the Marmara DM GIS

CAMPAIGN	ACRONYM	NO of DIVES	IMAGES
Marmarascarps	SCA	12	Yes
Marnaut	MNT	30	Yes

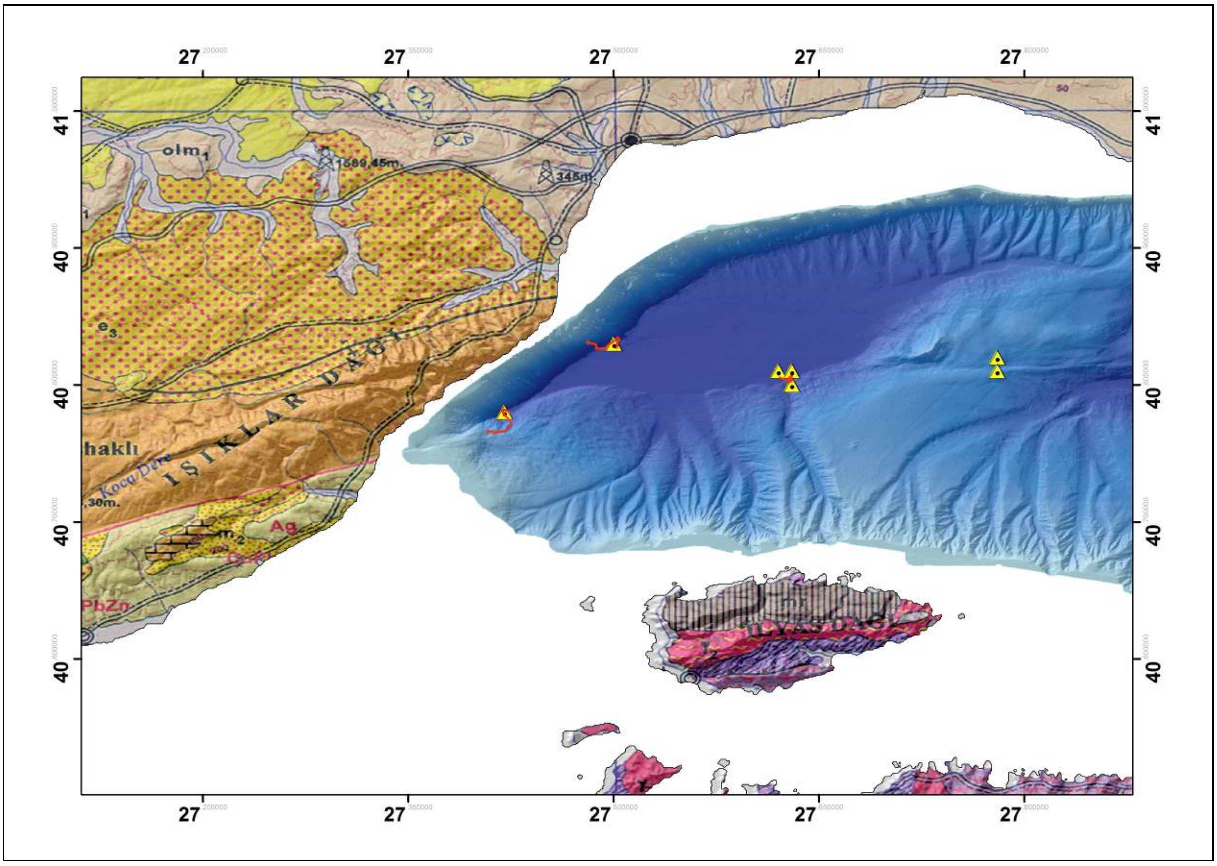

Figure 4. A sample close up to Tekirdağ Basin to show exact locations (yellow triangles) of dives during the Marnaut cruise. Red lines indicate the Nautile's navigation.

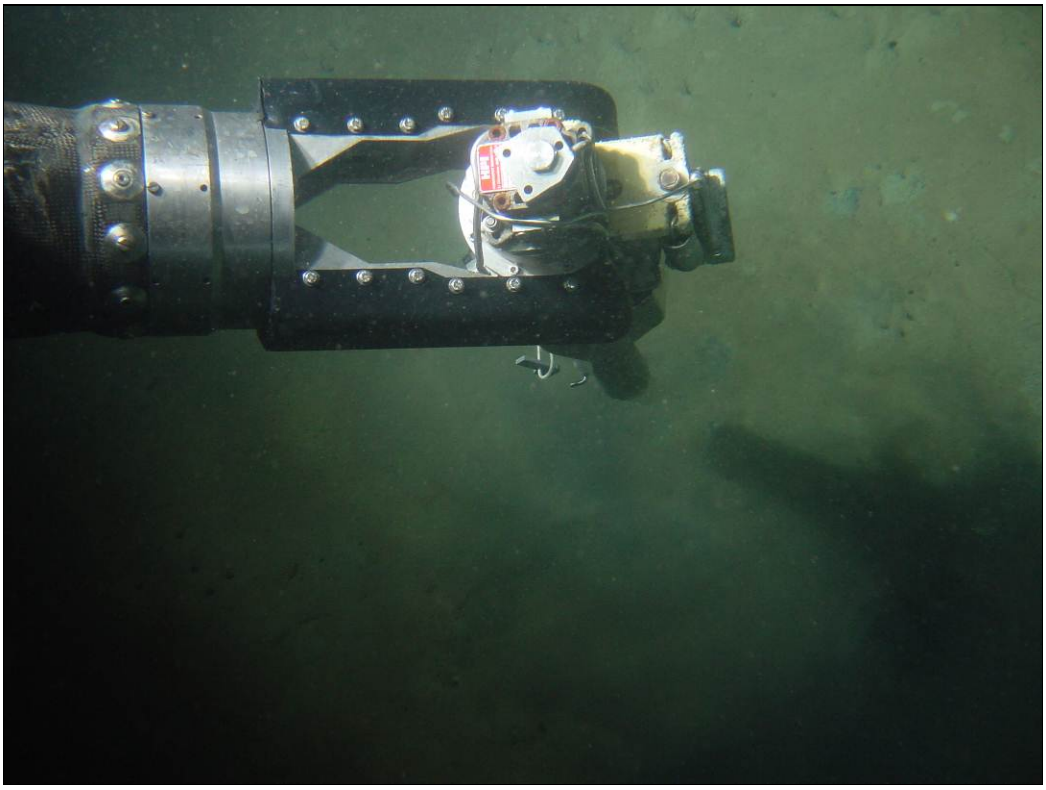

Figure 5. A sample image from the image gallery of Marnaut dives.

2.5 Main Folders: BATHY

This folder includes the gridded bathymetry data from various cruises. Moreover, there are isobaths which are derived from these grid data (Table 10). The isobaths are classified to have different contour intervals such as 5, 10, 20, 100 and 500 meters. There is also a hill shade image which is produced by using the bathymetry data of the Marmara cruise (Figure 6).

Table 10. The isobaths and grids in the BATHY folder

CAMPAIGN	ACRONYM	GRIDS	ISOBATHS
Marmara	SCA	Yes	Yes
Marmesonet	MET	Yes	-

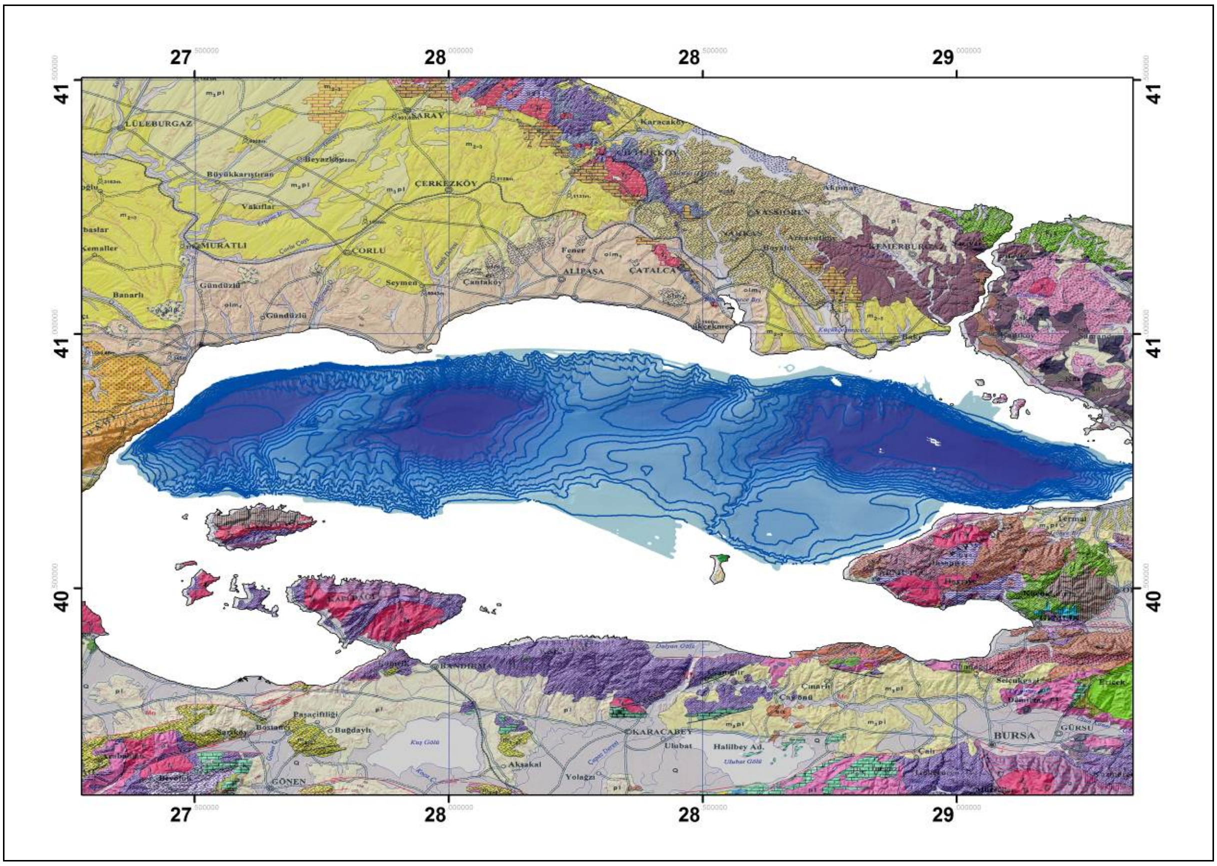

Figure 6. Hillshaded bathmetry grid and isobaths with 100 m contour interval from the Marmara cruise.

2.6 Main Folder: IMAGERIE

This folder is reserved to include raster type data (images) which are obtained by various tools. All images have a georeference frame and it can be directly visualized in its correct position with other shp files.

While there is no precise file format for included images, referenced “bmp” file types are preferred mostly. There are also many ESRI grid and ERDAS Imagine type files included in the Imagerie folder.

2.7 Main Folder: HYPERLIENS

The preliminary or final image products of collected various type of data are stored in this folder. These all images are linked in their host shape files with a reserved column named “LINK2PDF”. All images are set to be in “PDF” file format. The usage of the pdf is to have a less file length and its general usage.

The major hyperlink folders in Marmara DM GIS project are ACOUSTIQUE COLONNE EAU, FLUX CHALEUR, LOGS CAROTTE, PROFILS CHIRP and PROFILS SISMIQUE. Included hyperlinked cruises and type of data are shown in Table 11.

Table 11. Hyperlinked data and their cruises

CAMPAIGN	ACRONYM	HYPERLINKS
Marmesonet	MET	Acoustic Anomalies, Multibeam, Chirp, CTD,
Marnaut	MNT	Heat flux, Chirp, CTD
Seismarmara	SEM	Seismic profiles
Pirmarmara	PIM	Seismic profiles
TAMAM_II	TAMII	Seismic profiles
Marmara97	MAT97	Seismic profiles
Marmara99	MAT99	Seismic profiles
Marmarascarps	SCA	Chirp

2.8 Main Folders: INTERPRETATION

Interpreted data are stored in different fields of disciplines under this main folder. The major sub-folders are GEOPHYSIQUE, GEOCHIMIE, MORPHOLOGIE, SEDIMENTOLOGIE, and STRATIGRAPHIE-SISMIQUE. Each interpreted data is implemented in one of these related sub-folders in this section.

There are shp files which show stationary coordinates of acoustic anomalies with hyperlinks in the GEOPHYSIQUE section. GEOCHIMIE folder includes files which are generated from published papers by various authors showing some sample/observation locations. Although they are not products of the Marmara cruises, these informative studies are decided to be included by referring authors. MORPHOLOGIE sub-section covers all shp files which are related with the sub-marine morphology such as canyons, channels, seeps and slides. It also includes morpho-tectonic structures such as active faults of the Marmara Sea.

2.9 Other Folders: TERRE and REGLEMENTATION

The folder TERRE is designed to be used to store all data relevant to land. The subfolders Carottes, Couches_AV, Geologie, MNT, Orthopohotos, Reseau_Hydrographique and Trait_Cote are all created to host different type of land data.

The main digital elevation model (DEM) used for the Marmara region is obtained from open access Shuttle Radar Topographic Mission (SRTM) data of USGS (Figure 7). Also shaded relief of SRTM data is created and added to the database. The geological map of the Marmara region with scale 1:500k is stored under TERRE (Türkecan and Yurtsever, 2002). The general coast line for the coverage of the Marmara region is also added to this collection.

The folder REGLEMENTATION includes the navigation map of the Marmara Sea and the shp files showing navigation routes.

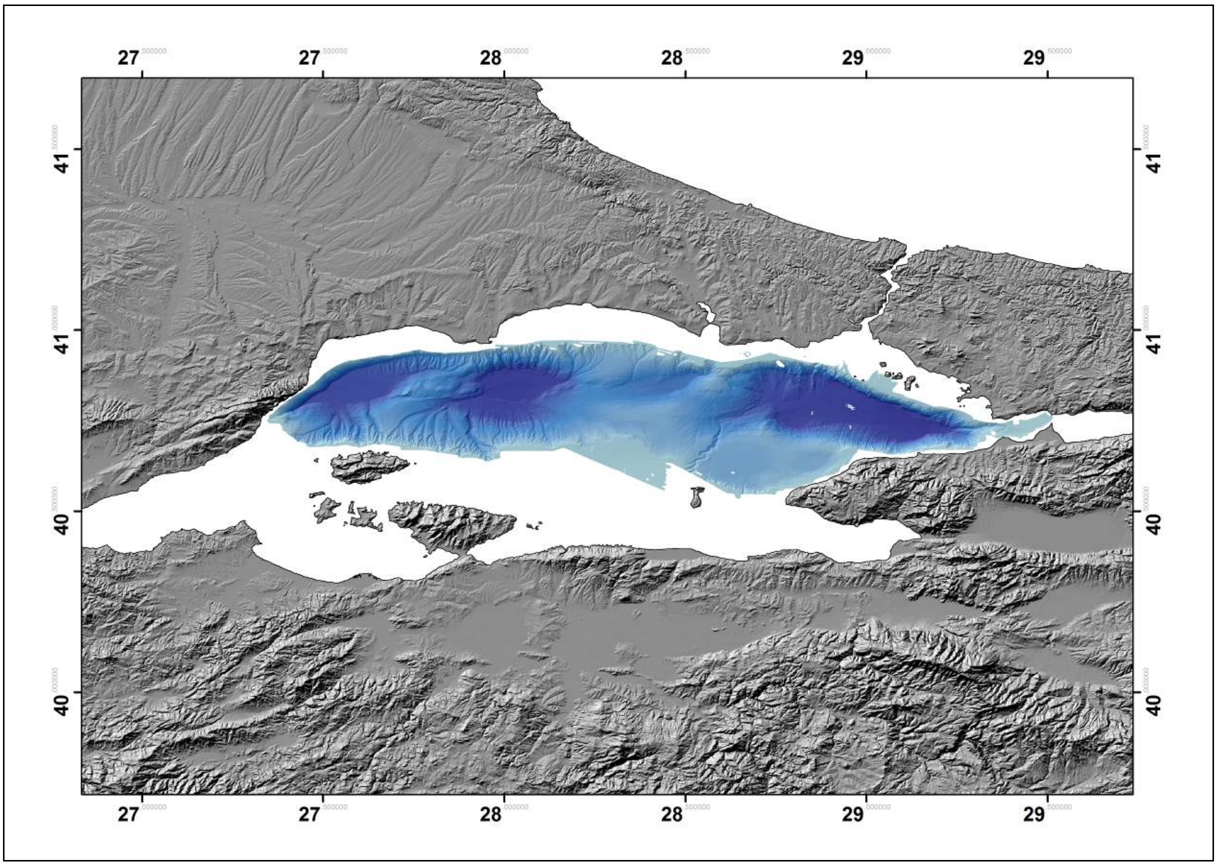

Figure 7. SRTM v2. Hill shade image with the shaded bathmetry of the Marmara cruise

3. Conclusion

Majority of ESONET Marmara DM data is processed and integrated in the GIS of IFREMER by many contributors. The checking of all processed data is also performed and all products are copied in their proper folders. The minor modifications can be done with arrival of new data or exposure of mistakes.

This all data will be 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. 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. You can find further instructions about data repository in the Marmara_DM web page (http://www.esonet.marmara-dm.itu.edu.tr/) EMCOL-NAS section.

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The Marmara GIS entirely constructed on the IFREMER GIS architecture. This system was designed and is continuously developed with the experience of long marine studies. The major part of data were already constructed or prepared to be processed before my arrival to IFREMER in the framework of the ESONET personal exchange program. I am so thankful for all helps, guidance and corrections done by Dr. Stephanie Dupre and Mr. Sylvain Bermell during my visit. Dr. Louis Geli created a perfect working environment by his great hospitality. I also give my thanks to the people of the Cartographie division for their hospitality and helps during my stay.

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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 MARMARA-DM PROJECT

Deliverable 4.3: Report to test working hypothesis and validate concept of seafloor observatories

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CO	Confidential, only for members of the consortium (including the Commission Services)	

Marmara-DM Delivrable D4.3

« Report to test working hypothesis and validate concept of seafloor observatories »

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Introduction

The Marmara Demonstration Mission (DM, April 2008 to October 2010) was conducted within the EU-funded European Seas Observatory NETwork - Network of Excellence project (ESONET-NoE): i) to characterize the temporal and spatial relations between fluid expulsion, fluid chemistry and seismic activity in the Sea of Marmara (SoM) ; ii) to test the relevance of permanent seafloor observatories for an innovative monitoring of earthquake related hazards, appropriate to the SoM specific environment ; and iii) to carry out a feasibility study to optimise the submarine infrastructure options (fibre-optical cable, buoys with a wireless meshed network, autonomous mobile stations with wireless messenger).

Cold seeps are often observed in association with active faults [e.g. *Moore et al., 1990; Henry et al., 2002*]. 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 in the crust. Furthermore, gas expulsion from pockmarks and mud volcanoes is reported to occur in relation to the occurrence of earthquakes. 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.

Numerous fluid vents and related features have been discovered along the North Anatolian Fault (NAF) system in the Sea of Marmara (SoM). In the Gulf of Izmit, repeated surveys showed that the intensity of methane emissions increased after the August 17, 1999 earthquake [*Alpar, 1999; 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 [*Zitter et al., 2008; Armijo et al, 2005*]. The SoM thus appeared as a unique area to test hypothesis on the relations between strike-slip deformation, seismic activity, fluid flow and gas expulsion within the water column. Hence, Marmara-DM was driven by the following hypothesis, which we consider testable with long term multi-parameter observatories (H1):
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.*
More specific hypotheses that could be at least be partly tested by Marmara-DM were derived:
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 this report is to assess the results of the Marmara-DM with respect to this hypothesis testing approach, and conclude on future observatory planning.

Two recent findings have important implications for the long-term observatory strategy:

1. Recent work (outside ESONET and Marmara-DM) 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 has been shown that the NAF in the SoM strikes across hydrocarbon reservoirs from the Thrace Basin [*Bourry et al, 2009; Tryon et al., 2010*] and that variable amounts of mantle derived ^{3}He is carried with the hydrocarbon gasses.

The first finding is of fundamental importance in seismology and opens the possibility to detect and identify ongoing earthquake nucleation before the earthquake occurs. This clearly supports the imperious necessity to deploy ocean bottom seismometers close to fault zones, most particularly close to fault segments having the highest probability to rupture. The second finding is a Marmara-DM result, which opens unexpected perspectives and supports the need to monitor gas emission activity along with seismicity.

Here, we will first summarize evidence that lead to define the Istanbul-Silivri segment of the NAF as a dangerous seismic gap, and the implication of the recent observations on the nucleation of Izmit 1999 earthquake. We then present an overview of the operations performed in Marmara-DM, and discuss the main results in relation with the working hypothesis. Some recommendations can be issued for observatory design in order to improve data quality and relevance. We conclude by presenting general observatory concepts and a brief overview of project MARDEP, which will be submitted to Turkish authorities in 2011.

Seismological characteristics of the NAF and evidence for extended nucleation before the Izmit 1999 earthquake.

The SoM developed along the highly active, right lateral strike-slip NAF, which produced devastating historical earthquakes along its 1600 km length [e.g. *Ambraseys and Finkel, 1995*]. Since 1940, the earthquake events along this fault zone had a westward progression with sixty-years sequence of rupturing towards Istanbul, with –more or less– one event promoting the next [e.g. *Stein et al, 1997; Barka, 1996*]. The last destructive earthquake occurred at the eastern end of the SoM (1999 Izmit and Düzce earthquakes) and therefore the next large (Mw> 7) earthquake is expected to nucleate in the SoM close to Istanbul. Earthquake related landslide and tsunami hazards are also very high (most of the 30 major tsunamis with waves > 6 m that have occurred during the past two millennia have been caused by submarine landslides triggered by earthquakes; e.g. [*Görür and Çağatay, 2010*; and references therein].

Historical evidence [*Ambraseys and Jackson, 2000*] indicates that a major earthquake occurred in the central part of the SoM in 1509. A series of earthquakes with estimated $M_w \geq 7$ occurred in 1719, 1754, and in May and August 1766, but the distribution of damage cannot resolve the exact geometry of the associated segment fault ruptures [e.g. *Ambraseys, 2002; Parson, 2004*]. The next series of Mw ~ 7 events comprises three earthquakes in 1894, 1912 and 1999. The 1894 earthquake affected the Cinarcik Basin and Izmit Gulf, but it is unclear which fault ruptured in the Cinarcik Basin. The 1912 earthquake ruptured the Ganos fault on land and extended some distance offshore [*Armijo, 2005*], but this distance may have been quite short [*Ambraseys, 2002*]. Whatever the interpretations, a consensus exists that the Istanbul-Silivri segment in the central part of the Sea of Marmara, which did not break since 1766, is the segment having the highest probability to rupture in the near future.

Following the earthquakes that struck the areas of Izmit and Düzce in 1999, intensive seismological studies were carried out during the last decade, which clearly have implications on the location and dynamics of the future Marmara earthquake. The Izmit earthquake nucleated near a long-lasting swarm of events related to the Aegean extension –which is not uniform along the NAF. This micro-seismicity indicates local extensional strain that, in turn, could result in a decrease of normal stress on the strike-slip fault and, eventually, cause the unclamping of the strike-slip fault. This leads to hypothesize that the next large earthquake could nucleate near a zone of long-term microseismicity [*Durand et al, 2010*]. Fault zone heterogeneity may be another factor controlling the nucleation site. Düzce and Izmit earthquakes both present important variations of rupture speed defining sub-rayleigh (slow) and supershear (fast) segments [*Bouchon and Karabulut, 2008*]. Segments with different rupture speed also have contrasting geometrical characteristics [e.g. *Pucci et al, 2006*] and distributions of aftershocks [*Aktar et al, 2004; Bouchon and Karabulut, 2008*]. Remarkably, both Düzce and Izmit earthquakes nucleated near the junction between the slow and fast segments.

Increases in seismic activity preceded the Izmit and Düzce earthquakes [*Bouchon and Karabulut, 2003*] and, last but not least, evidence was found of repeating earthquakes and tremors about 44 minutes prior to the Izmit rupture. These signals originate within less than 300 m from the hypocenter [*Bouchon et al, 2011*]. These authors conclude, ”the relatively long duration of the (Izmit) nucleation and the observation that it emits a characteristic signal are encouraging for possible early warning systems, but it remains to be seen whether this behavior is applicable to other large earthquakes. The next steps include re-examining the near-fault seismic records of other large, well-recorded earthquakes for similar signals. Continued seismic monitoring networks will also be necessary to understand if such extended nucleation events apply beyond this example.”

Marmara-DM operations and results

A total of 6 cruises were conducted within the Marmara-DM:

- 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-October 2009 and September-October 2010, for deploying and recovering the multiparameter sea-bottom observatory SN-4 of INGV at the entrance of the Gulf of Izmit on the fault trace and at the end of the rupture of the 1999 earthquake, 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 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.
- 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 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.

The systematic mapping of fluid emission sites in the SoM during Mamara-DM showed that although a number of them are associated with active fault traces [*Zitter et al., 2008; Géli et al., 2008*], they are widespread and found in diverse contexts, which do not systematically relate with active faults. Remarkably, the fault segment with the lowest occurrence of acoustic anomalies on the main fault trace corresponds to the Istanbul-Silivri seismic gap [*Géli et al, 2008*]. The geochemistry of the fluids expelled also appears diverse, notably considering the depth inferred for the fluid source [*Bourry et al., 2009; Tryon et al., 2010*]. Shallow fluid sources are widespread (biogenic gasses and brackish water), but a few of the sites analyzed expel fluids from Thrace basin reservoirs (hydrocarbons phases and aqueous fluids), originating from the oil window (temperature range of 75-150°C). Analysis of $^{3}He/^{4}He$ ratios showed that a minor contribution of mantle fluid is often present in the gasses and, in the absent of recent volcanism, it appears likely that the helium is extracted from the mantle by shearing below the seismogenic fault zone [*Burnard et al., 2008*]. At a site located on the Western edge of the Tekirdag Basin along a splay of the NAF and associated with microseismic activity [*Tary et al., in press*], it is estimated 70 % of the helium originates from a mantle source. However, the dataset presently available suggests that fluids expelled from the topographic highs (on the western high and on the Istanbul-Sliviri segment) are strongly influenced by the Thrace oil and gas system, with no evidence for a mantle contribution.

On the gas hydrate area on the Western High, 3D high-resolution seismic data reveal an acoustically chaotic zone below carbonate and hydrate mounds that expel gas, oil and brines. This zone extends from the NAF to about 1 km north in the core of a curved anticline and likely corresponds to a buried mud volcano or mud diapir structure. This association suggests that strike-slip movement along the fault could influence fluid escape from the reservoir. Mud volcano eruptions occur when overpressure at depth is sufficient to fracture the overburden sedimentary units [e.g. *Kopf, 2002* and references therein] and modeling shows this threshold is reduced when strike-slip faulting is active [*Mazzini et al, 2009*].

Deployment of instruments on the seafloor where performed for durations varying from one month to a year. Some clusters of microseismic activity appear spatially correlated with fluid migration through the crust [*Tary et al., in press*]. Flow-meters [*Tryon et al., 2011 (D1.2)*], and physical and chemical sensors deployed at SN-4 measured temporal variations related to episodic fluid emissions through the seafloor. A test deployment of the Bubble Observatory (BOB) and experiments in the laboratory demonstrated that quantification of bubble fluxes could be done. It was also found that seismometers (both broadband and conventional ones) record signals produced locally by gas migration in the shallow sediments, and correlated with methane emissions at the seafloor. These results open interesting perspectives for modeling the dynamics of fluid emission but no temporal correlation between fault activity and fluid parameters could be demonstrated with the data available, and analysis performed so far. One reason is that no important earthquake (M>3) occurred in the vicinity of the sites monitored within the time span of instrumental deployments. Furthermore, there is an internal cycle in the emission of methane from the subsurface that needs more analysis. Processes in the first 2 to 10 meters around active emission sites appear complex, and include convection processes resulting in seawater downflow through the water-sediment interface around fluid emission conduits.

Hypothesis assessment

Hypotheses H2 and H3 were directly addressed by Marmara-DM work and will be examined first. Hypothesis H1, of more general implications will be examined next.

Hypothesis H2 relates strain and pore pressure variations. As underwater geodesy is not operational (at least not with the $<10^{-6}$ strain accuracy required for this experiment), the concept proposed was to use pore pressure as a proxy for volumetric strain. While this approach has met some success in IODP with the use of CORK type (Circulation Obviation Retrofit Kit) hydrogeological observatories [e.g. *Davis and Villinger, 2006*], these devices were generally installed on boreholes a few hundred meters deep. It appears that the theoretical sensitivity to strain of seafloor piezometers (<12 m) is lower because of the high poisson ratio of seafloor sediments, and may be further decreased by the presence of gas. When installed near a vent site, piezometers more readily record the consequences of local fluid movements in conduits. From the results of deployments performed during MarmaraDM (and elsewhere by Ifremer) it appears that these devices can provide valuable information of fluid venting processes when installed in permeable conduits, and also have a potential to investigate relationships between pore pressure and gravity driven instabilities. However, recording of crustal strain by this method should, in most cases, require deeper sensors.

Hypothesis H3, regarding composition and origin of fluids, has been thoroughly addressed by Marmara-DM data and the spatial formulation of this hypothesis (*fluids from seismogenic depths reach locally the sediment surface*) can be considered proven to some extent. Evidence relies on the sampling of thermogenic hydrocarbons and associated brines, and on the presence of mantle helium. Strictly speaking, these observations point to sources respectively above and below the seismogenic zone. However, the temperature range of the oil window overlaps the temperature range proposed for the upper limit of the seismogenic zone (100-150°C). Furthermore, the conduit feeding the gas hydrate site on the Western High appears structurally related with the NAF, and episodic variations of the deep fluid flux were recorded at this site [*Tryon et al., 2010 (D1.2)*]. Mantle helium must travel through the seismogenic portion of the crust to reach the seafloor. We proposed that along the western edge of Tekirdag Basin, fluids travels through a network of microseismically active faults in the crust rather than along the main fault plane, and hypothesize that this flow system is coupled with crustal deformation [*Tary et al., in press*]. At this stage both Tekirdag and Western High sites appear promising for coupled monitoring of fluid flux, composition and seismicity. It also follows from Marmara-DM that a better definition of the seismogenic depth range at these sites is required, and may be achieved by the deployment of closely spaced OBS networks.

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.

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) 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*], repeating earthquakes occur, and fluid emissions are observed may also be considered.
- 2) The 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. 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) On the Istanbul-Silivri segment, 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.

Transient slip at depths may indicate earthquake nucleation or, at least, that the probability of occurrence of an earthquake is rapidly increasing. In this respect, the work proposed is meant to improve the preparedness of the authorities in charge of Civil Protection. If seismic tremors or other anomalous seismic activity are found to be associated with anomalies in fluid emission activity, then, we will have more criteria for characterizing and identifying transient slip events on an offshore fault. We hypothesize that the intensity of thermogenic hydrocarbon emission may be related to the Coulomb stress on the faults, and that information of fault criticality, and hence earthquake probability, could be derived from long-term records. On a shorter time-scale, interaction during nucleation between the slipping patch and the fluid reservoir could result in precursory fluid emissions.

Observatory concept and expected progress

The concept behind the MARDEP observatory 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) - along the Istanbul-Silivri fault segment, the most potentially dangerous segment in Western Turkey.

• The tremor-like signal –and an unusual scaling relationship between repeating earthquakes– 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. "Izmit is the first time we see the fault slipping at depth before the earthquake and the distinctive nature of the first couple of foreshocks tells a seismologist — or a computer program monitoring a fault — that there's a probability that something big is coming."

The search of seismic tremors in the Istanbul area is hence a challenge of great 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. However, the context in which these occur needs to be better understood before they could be used as indicators of an impending large earthquake.

• Marmara-DM has shown that several conduits channeling flow to the sea floor root at least to the depth of the oil window and are structurally related to the main active NAF or to secondary active faults. This includes: (1) gas vents along the Western edge of Tekirdag basin, which carry a fluid component originating from mantle; (2) a gas, oil and brine seep on the Western High (also referred to a the gas hydrate site) which, according to 3D high resolution data, is fed by a conduit of mobilized sediment adjacent to the NAF; (3) several other sites where emission of methane gas is found on the seafloor in the close vicinity of active faults. Gas bubbles in the water are easy to detect via acoustic methods. Hence, a major challenge is to determine whether gas can generate detectable signals related to transient strain or slip events. This is a major issue related to detection of precursory signals before an earthquake, and therefore of direct societal importance.

The expected progress beyond the state-of-the-art is summarized hereafter :

Progress in the detection of seismic tremors and of other seismic activity specific to transient "silent" slip events occurring on active faults. Seismological data from Izmit 1999 earthquake on the North Anatolian Fault let to the first detection of slip during nucleation of a major earthquake Confirming the existence of a detectable nucleation phase before earthquakes is a fundamental question for earthquake predictability. The MARDEP project will help by setting instruments on the adjacent fault segment of the North Anatolian Fault, which has high probability of a major earthquake.

Progress in real-time characterization of events from the Sea of Marmara. 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 and this leads to uncertainties in offshore earthquake location. The MARDEP project will allow absolute locations of hypocenters near the fault zone with an accuracy of less than a few hundred meters. This will considerably improve the characterization of events from the fault zone and enhance the search for seismic tremors.

Progress for early warning systems in the Sea of Marmara. It has been proposed that warnings of only minutes could make a difference in the overall effect of hazardous events. Solid earth wave physics has achieved sufficient understanding and technical ability to determine almost in real-time if the intensity and character of seismic events are hazardous. If such evaluations could be automated at some level, valuable warnings could be provided to citizens living some distance away of seismic activity [e. g. *Allen & Kanamori, 2003*]. The submarine stations will provide high quality data from the close vicinity of the underwater portion of the fault, within the SoM, and benefit to the improvement of the early warning systems under development in the Istanbul area [e. g. *Oth et al, 2010*].

Progress in understanding relations between fluid-related transients and seismicity. There is a wide literature, but no bullet proof evidence supporting the concept that variations in stress state and strain rate at seismogenic depths in the crust may cause variations of fluid outflow rates and fluid chemistry at the surface, a fundamental question for earthquake predictability. At the end of this project, we will have an unprecedented dataset to fully address this question, not only for the Sea of Marmara, but for other hydrogeological systems.

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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 MARMARA-DM PROJECT

Deliverable 4.4: Report on best site selection

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Report on best site selection

1. Objectives.

The main result of the MARMARA-DM demonstration mission is that we now have the arguments to build a project (MARDEP) focusing 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. Hence the idea of presenting a large-scale integrated project, with a core group of partners that have been working together for long, and who have shown their ability to integrate efforts towards a common goal.

The reasons justifying this approach are many. The first two reasons are well known: i) there is a high probability that an earthquake of Mw > 7.0 will strike within the next decades along the NAF in the Sea of Marmara, directly affecting the heavily populated Istanbul area; and ii) the segment having the highest probability to rupture is relatively well determined (Fig. 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]*[1].
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 has been 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, 2010, in press]*. 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 that 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 MARDEP Project will provide high quality data from the close vicinity of the submerged fault, within the Sea of

[1] Michel Bouchon*, et al.,* Extended Nucleation of the 1999 *M*w 7.6 Izmit Earthquake *Science* 331, 877 (2011); DOI: 10.1126/science.1197341

Marmara and benefit to the improvement of the ongoing early warning systems in the Istanbul area *[e. g. Oth et al, 2010].*

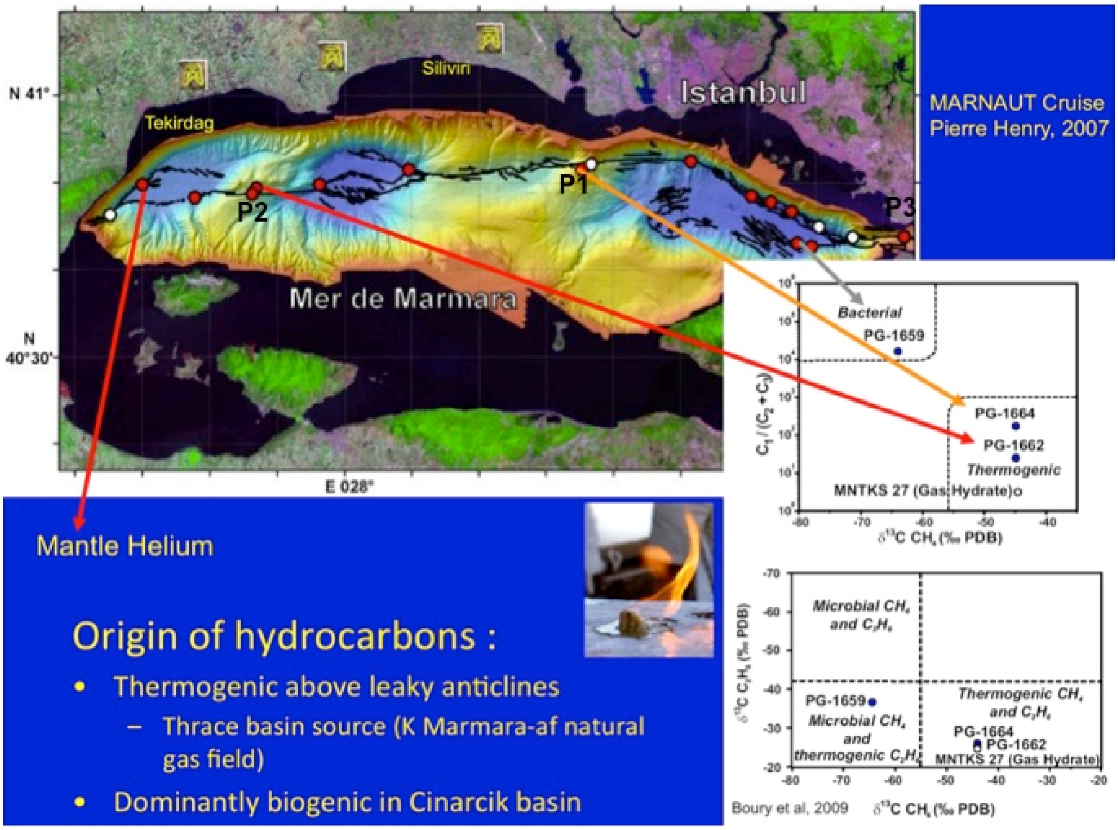

Fig.1 Map showing the most active northern branch of the North Anatolian Fault (NAF; black line), gas emission sites (red dots). The inset diagrams show the composition plots of gases showing the thermogenic and deep origin (Géli et al., 2008; Bourry et al., 2009). P1, P2 and P3 indicate potential sites that were identified for multi-disciplinary seafloor observatories during Marmara-DM Demonstration Mission of Esonet.

2. Tectonic setting

The Sea of Marmara developed along the highly active, right lateral strike-slip North Anatolian Fault (NAF), which produced devastating historical earthquakes along its 1600 km length [e.g., *Ambraseys and Finkel, 1995*]. Since 1940, the earthquake events along this fault zone have a westward progression with a sixty year sequence of rupturing towards Istanbul, with -more or less - one event promoting the next [*e.g. Stein et al, 1997*]. The last destructive earthquake occurred at the eastern end of the Sea of Marmara (1999 Izmit and Düzce earthquakes) and therefore the next large (Mw> 7) earthquake is expected to nucleate in the Sea of Marmara close to Istanbul. Earthquake related landslide and tsunami hazards are also very high (most of the 30 major tsunamis with waves > 6 m that have occurred during the past two millennia have been caused by submarine landslides triggered by earthquakes; e.g., *[Görür and Çağatay, 2010]* and references therein).

Historical evidence [*Ambraseys and Jackson, 2000*] indicates that a major earthquake occurred in the central part of the Sea of Marmara in 1509. A series of earthquakes with estimated moment magnitude close to or greater than 7 occurred in 1719, 1754, and in May and August 1766 in the Sea of Marmara region, but the distribution of damage cannot resolve the exact geometry of the associated segment fault ruptures [e.g. *Ambraseys, 2002; Parson, 2004; Pondard et al., 2007*]. The next series of Mw ~ 7 events comprises three earthquakes in 1894, 1912 and 1999. The 1894 earthquake affected the Cinarcik Basin and Izmit Gulf, but it is unclear which fault ruptured in the Cinarcik Basin. The 1912 earthquake ruptured the Ganos fault on land and extended some distance offshore *[Armijo, 2005]*, but this distance may have been quite short *[Ambraseys, 2002].* Whatever the interpretations, a consensus exists that the Istanbul-Siliviri segment in the central part of the Sea of Marmara, which did not break since 1766, is the segment having the highest probability to rupture in the next future (Fig. 1).

3 Seismological characteristics of the NAF – Evidence for Seismic tremors

Following the earthquakes that devastated the areas of Izmit and Düzce in 1999, intensive seismological studies were carried out during the last decade, which clearly have implications on the location and dynamics of the future Marmara earthquake.

The Izmit earthquake nucleated near a long-lasting swarm of events related to the Aegean extension -which is not uniform along the NAF. Swarms of seismicity could indicate that the release of normal stresses could allow strike slip to occur along the fault, supporting the hypothesis that the next large earthquake could nucleate near a swarm of seismicity *[Durand et al, 2010].*

Based on detailed field studies [e. g. *Pucci et al, 2006],* it has been recognized two different sections of the Düzce segment: a western section where the coseismic fault trace has a staircase trajectory; an eastern section, where the co-seismic fault trace shows a straight trajectory [*Aktar et al, 2004].* In addition, detailed seismological studies have shown that different fault segments may break at different speeds and that both Izmit and Düzce started near the junction between supershear and sub-Rayleigh segments. These results suggest that the fault zone characteristics and the rupture dynamics are likely linked: Düzce earthquake occurred where the simple supershear segment was the most loaded in Coulomb stress – the rupture was apparently triggered by the passage of a stress pulse of about 1 bar one day earlier *[Bouchon and Karabulut, 2008].*

Increases in seismic activity preceded the Izmit and Düzce earthquakes *[Bouchon and Karabulut, 2003].* Last but not least, evidence was found of low frequency earthquakes (tremors) about 44 minutes prior to the Izmit rupture. These very characteristics and recognizable signals originate within less than 300 m from the hypocenter *[Bouchon et al, 2010, submitted]. These authors recognize that «the existence or not of a detectable nucleation phase before earthquakes is understandably a fundamental question».* This statement, by itself, justifies the necessity to deploy seismometers near the fault zone.

The design of the seafloor observatory network that we propose to install along the Istanbul-Siliviri is entirely based on these results and on the results described in the following section.

4 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].* A systematic correlation was also found between active faulting and the acoustically detected gas escapes. Remarkably, the fault segment with the less acoustic anomalies found within the main fault trace corresponds to the Central High and Kumburgaz Basin area (see Fig. 1 in *[Géli et al, 2008]).* 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 found in the Thrace Basin are present on top of anticline structures, which indicate 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 occurence 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 in the crust: the hydrogeological system in submarine environment appears to be directly coupled to the tectonic system through the interaction of fluid pressure and stress state. 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. Because gas is very compressible, great quantities of gas can accumulate in sediment pores, until excess pressure fractures the overburden. In addition, gas bubbles in the water are very easy to detect via acoustic methods. Hence, a major challenge is to determine whether gas can generate **detectable** signals related to the stress building process during the seismic cycle. This is a major issue related to detection of precursory signals before an earthquake, and therefore of direct societal importance.

5 Results from the Marmara-DM project within ESONET : best sites selection

The Marmara Demonstration Mission (april 2008 to september 2010) was conducted within the EU-funded ESONET 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).

The partners involved in the Marmara-DM Demo Mission were almost the same as those in the present proposal, except KOERI: Ifremer, CNRS/INSU, CNR/ISMAR, INGV, ITU and DEU (Dokuz Eylül University, Izmir).

A total of 6 cruises were conducted[2], allowing the selection of the optimum sites for the future multi-parameters sea-floor observatories *(Fig.1)*:

- Site P1, on Istanbul-Silivri segment. This site located in the seismic gap immediately south of Istanbul where 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 is of critical importance to monitor micro-seismic activity, with a view to determine if the fault segment is locked or creeping. Due to the presence of the

[2] ***These cruises are listed hereafter:***

- *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 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, together with autonomous OBSs and piezometers from Ifremer.*
- *2 cruises with Turkish vessels, respectively R/V Yunuz (from ITU) and R/V Piri Reis were 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.*

anchoring area characterized by intense shipping zone, the cable must be buried all along the way (~ 13 km) deeply below the seafloor. ***Due to its proximity to the Istanbul, first priority (P1) is assigned to this site.***

- Site 2, on the Western High / Gas Hydrates area. This site is located where oil and gas seeps from the Thrace Basin were found and where the connections between the fluid migration conduits and the main fault system were imaged using 3D, High-Resolution seismics. Site 3 is thus a priority (P2), as we may there expect gas emissions resulting from pressure increases in the gas reservoirs. However, the distance from the coastline (~ 23 km) considerably increases the cost of the cable lay-out and burial.

- Entrance of Izmit Gulf (Site P3). At this site, the principal deformation zone of the North Anatolian Fault is less than some tens of meters wide. In addition, the site is close to the western end of the surface rupture associated with the 1999 Izmit earthquake, where the next earthquake affecting the fault strand towards Istanbul may nucleate. It is relatively accessible area, at shallow depth (200 m) and less than 5 km from the coastline.

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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 MARMARA-DM PROJECT

Deliverable 5.1 : Recommendation on the preferred option

Due date of deliverable: September 2010
Actual submission date: September 2010

Start date of project: **April, 1st 2007** Duration: **30 months**

Organisation name of lead contractor for this deliverable: Ifremer
Lead authors for this deliverable: Yves Auffret

Revision [final version]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	PU
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)	

Recommendation report on preferred option for Multi-disciplinary Seafloor Observatories (MDSO) in the Sea of Marmara

Based on the conclusions of the Marmara-DM project, two different designs are recommended for the future, cabled multi-disciplinary seafloor observatories :

Type I observatories (sites P1 and P2)

Type I observatories are recommended for sites P1 (Istanbul-Silivri fault segment) and P2 (Western High), both located on anticlines where numerous sites of gas emissions of thermogenic origin have ben 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). 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 up to 12 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 sensor. At JBN and JBS, we will deploy 2 OBSs, 3 distance meters, one BOB, one methane sensor, one piezometer and one CTD. Clusters of seismometers will allow the ultra-precise characterization of earthquakes near the fault zone, using array-based methods for hypocenter determination.

Type II observatory (site P3)

This type of observatory is recommended for site P3, which is located at shallow depth (200 m) at the entrance of the Gulf of Izmit. Deploying a node is not necessary, due to the short distance to the shore station (< 2 km). In addition, one single junction box is necessary with one OBS, 3 distance meters, one BOB, one methane sensor, one piezometer and one CTD.

[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. Operating distance from Node : 70m without additional media converter modules.

[2] ***http://www.oceanworks.com/***

[3] ***http://www.neptunecanada.ca/***

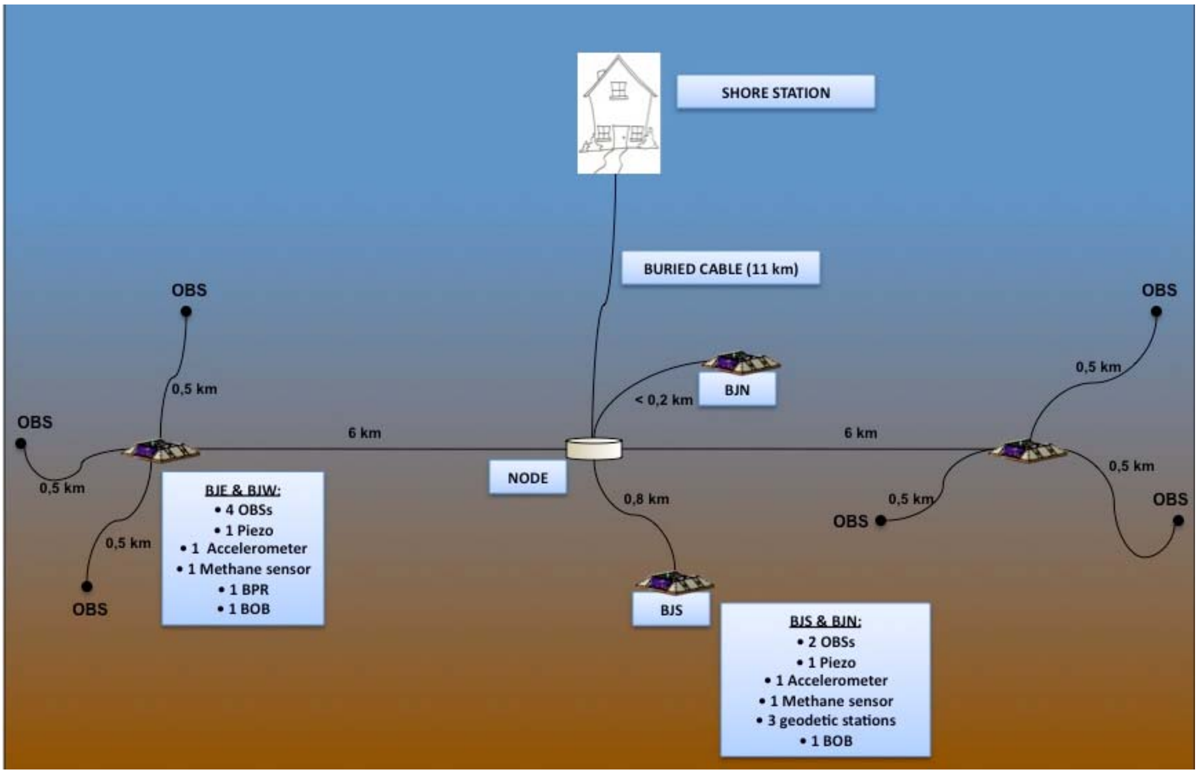

Fig. 1 : Example of multi-parameter seafloor observatory of TYPE I. The shore station will be cabled to one node, itself connected to four junctions boxes : one on each side of the fault (JBN and JBS), one to the east (JBE) and one to the west (JBW). Clusters of seismometers will allow the ultra-precise 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). Hence, the necessity to obtain clearance of the area, a critical issue of the project.

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 (HydroC™/ CH_4, Hydrocarbon & Methane Sensor), which has provided satisfactory results.
- *Distance meters network:* we will deploy 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. (see details hereafter).

- 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.

We recommend to leave open some connectors, offering the possibility to other potential end-users (profit or non-profit) to propose specific experimentation.

All sensors have been tested during MARMARA-DM, therefore all can be considered as being operational. The geodetic stations we propose to use were tested during the EC-Funded (FP5) ASSEM Programme in 2004 in the Gulf of Corinth. They consist in two or more different frequency acoustic transponders that measure the two-way travel time of sound between them with an accuracy of about one microsecond. Such geodetic experiments are commonly led onland, using GPS station networks. Offshore, an experience similar to the one we propose was conducted in 2007 in Japan, showing a standard deviation of 25 mm over a baseline of 750 m (Osada et al., 2008). This method, in combination with pressure sensors, is yet the most suitable for 2D displacements and seafloor deformation monitoring and quantification. Distancemeters will be combined with pressure gauges[5] for a full assessment of the 3-component (x, y, z) deformation through time.

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 1: List of the 11 sensor packages tested during previous 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).

[5] Pressure sensors only record vertical motion. They are generally used for measuring the deformation of volcano flanks, such as the Kilauea volcano (Phillips & Chadwell, 2008).Two pressure gauges are currently implemented since 2006 on the Lucky Strike segment of the Mid-Atlantic (MOMAR project, Ballu et al., 2009a,b). The accuracy is 0.5 mbar or 5 mm vertically.

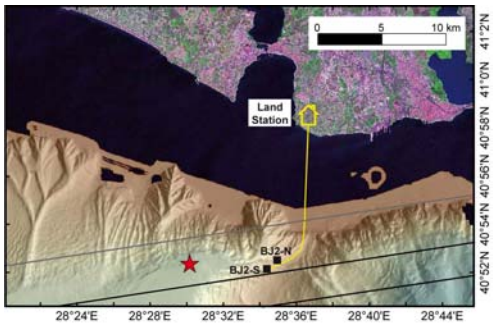

Figure 2 : View of the cable (yellow line) linking the observatory to the node at site P1. The cable will be deeply buried all the way from shore to main node. The area between the two SW-NE oriented, black lines is the separation zone between the upgoing and downgoing naviagtion corridor. The northern limit of the downgoing corridor is indicated as a thin grey line. The red star indicate the planned location of a cabled, permanent OBS to be deployed by KOERI in 2011.

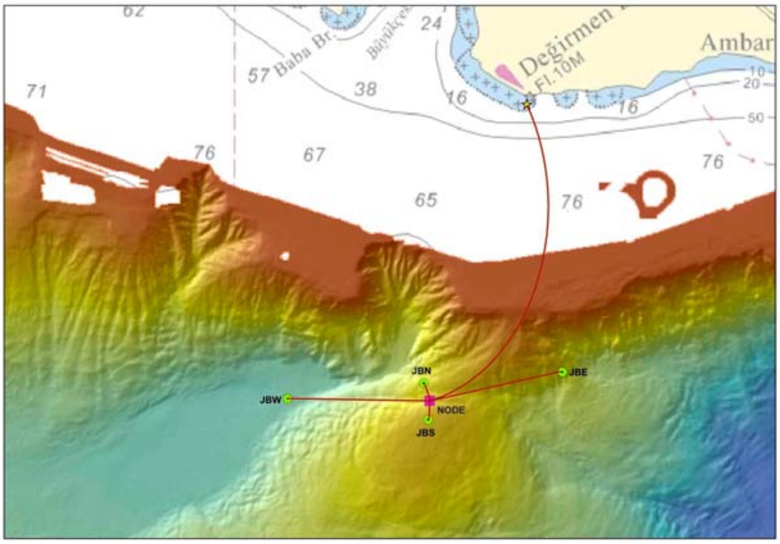

Fig. 3: Detailed set up of the multi-disciplinary observatory, south of Istanbul on the Silivri-İstanbul segmen), with the cable routes and nodes south and north of the fault. Juction Boxes North and South are shown (black squares). Thecable is located near, but outside the anchoring area.

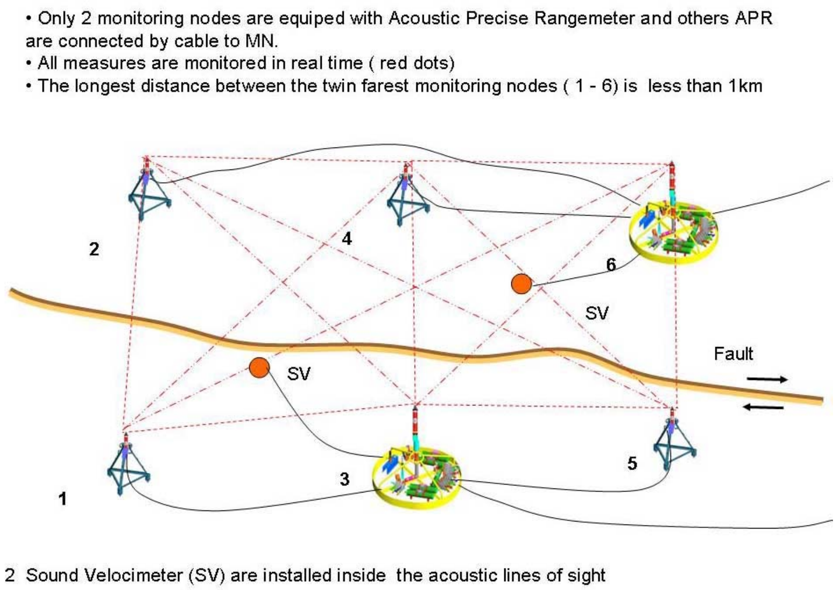

Fig. 4: Specific design of the geodetic experiment : 6 distancemeters + pressure gauges + sound velocimeters will be deployed, linked to 1 or 2 junction boxes (depending on the distance between JBs). Two additionnal sound velocimters are deployed in between to control sound velocity in between instruments.

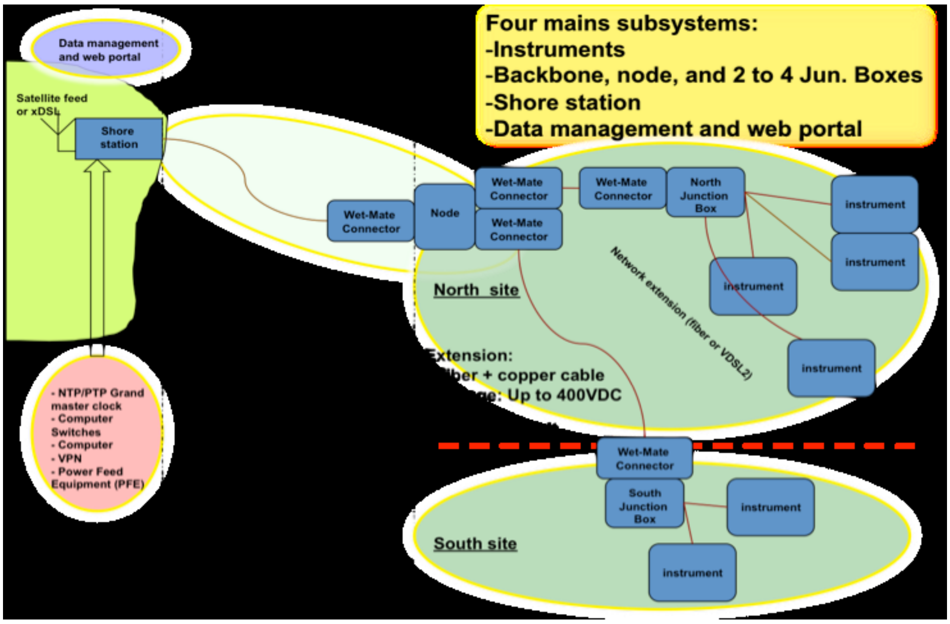

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Fig. 4d : Design of the modular seafloor observatory, based on the study perfomed during the Esonet/Marmara-DM Demonstration mission.

Observatory Data Center / Data management and archiving system

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 briefly summarized hereafter.

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.

The Shore Station Infrastructure will include the subsystems located at the cable landing location required to operate the observatory locally, remotely or autonomously. The shore station enclosure will be designed to contain the power and fiber optic terminations of the observatory cable, main utility power breakers, electrical panel service for shore station, telecommunications panel for backhaul, observatory power feed equipment, observatory local control computer, shore station observatory server, UPS and network equipment.

The shore station computer hardware will include a system server to host the DMAS shore station data acquisition software that is controlled remotely by system operators. It will also include a GPS-based timing system, such as the Meinberg LANTIME M600/GPS/PTPv2 IEEE1588-2008 provides a suitable PTP master clock. The shore station will operate an instance of the DMAS Shore Station software. Once communications with the ODC are severed, the DMAS Shore Station software continues to acquire and store observatory data on the local RAID drives autonomously. The shore station will have two instances of the DMAS DAF code base running: the first one deals with communication with the instrumentation (instrument drivers) and is hardly ever disturbed to minimize disruptions in the data flow. The second one executes the functions of parsing, calibration and event detection.

User access control and monitoring for such large infrastructure as MarQuake is a 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.

Real-time data processing and analysis

A major challenge for real time monitoring is to propose tools and methods for combining all different datasets and detecting anomalous signals that could be correlated with seismic activity and eventually be identified as indicators that a potentially dangerous situation is under way. The real-time processing of the full dataset thus represents a critical issue that comprises different phases, e.g. data correction and reduction, event detection and characterization, anomaly identification, data cross-correlation, and eventually earthquake predictability.

1. from raw data to physical measurement
- Data correction
- Data reduction

2. Detect relative variations for one single parameter and isolate anomalies

=> analyze background signals
=> research for better understanding of gas emissions and improvement of processing methods
=> e. g. improve assessment of parameters for time windows STA and LTA

3. For each detected anomaly, cross-correlation between different parameters

=> for each anomaly in gas emissions, determine correlation with seismicity
=> define criteria for real-time assessment of correlations
=> determine the actual “significance” of gas emission anomaly and its relevance to earthquake predictability

4. Earthquake Predictability

If seismic tremors are observed together with” significant” gas emissions, then the probability of occurrence of an impending earthquake naturally increases

Fig. 5 : Data Processing Work Flow chart

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 MARMARA-DM PROJECT

Deliverable 5.2 : Cost estimation report

Due date of deliverable: September 2010
Actual submission date: September 2010

Start date of project: **April, 1st 2007** Duration: **30 months**

Organisation name of lead contractor for this deliverable: Ifremer
Lead authors for this deliverable: Yves Auffret

Revision [final version]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	PU
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)	

Cost estimation report

The cost estimation presented here concerns the three selected sites described here below :

1. Entrance of Izmit Gulf. At this site, the principal deformation zone of the North Anatolian Fault is < of some tens of meters wide. In addition, the site is close to the western end of the surface rupture associated with the 1999 Izmit earthquake, where the next earthquake affecting the fault strand towards Istanbul may nucleate. It is relatively accessible area, at shallow depth (200 m) and less than 5 km from the coastline.
2. Istanbul-Siliviri segment. This site located in the seismic gap immediately south of Istanbul where intense bubbling is observed on a structural high 200-1 km south of the main fault trace, while no evidence of fluid expulsion is found on the fault itself. Here, it is of critical importance to monitor micro-seismic activity, with a view to determine if the fault segment is locked or creeping. Due to the presence of the anchoring area characterized by intense shipping zone, there is no direct available pathway for a cable on the seafloor. The minimum distance from shore to site is ~ 23 km.
3. Western High / Gas Hydrates area. This site is located where oil and gas seeps from the Thace Basin were found and sampled during the MarNaut cruise. In addition, a high-resolution seismic survey was conducted in December 2009 to image the connections between the fluid migration conduits and the fault system. Hence, fluids from the seismogenic depth could reach (at least locally and episodically) the sediment surface. Site 3 is thus a priority, as we may there expect gas emissions prior to earthquakes. The distance from the coastline is ~ 23 km.

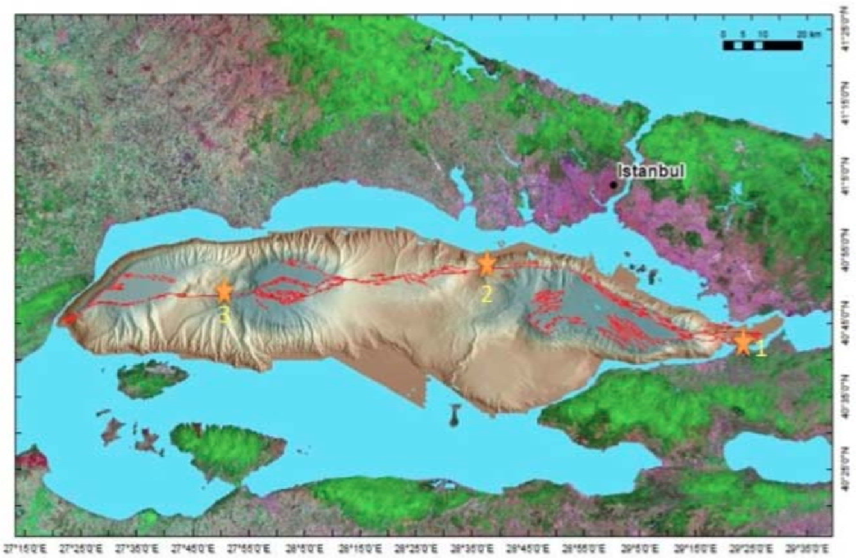


Fig. 1a : General map of the Sea of Marmara Area. Planned observatory sites are indicated by orange stars.

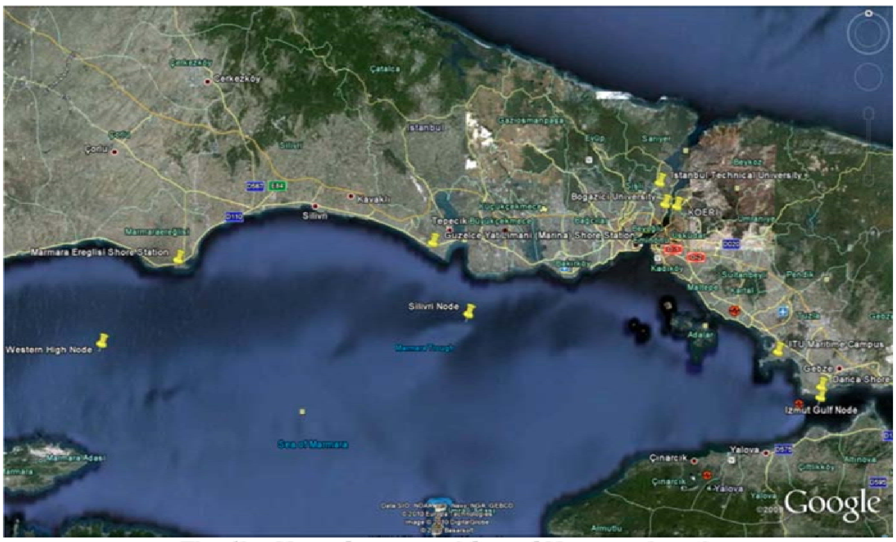


Fig. 1b : Map of proposed Sea of Marmara locations.

Observatory design and instrumentation.

Each observatory will include one or two junction boxes , connected to the 9 instrument packages listed in Table 1.

	Instrument	*Supplier*	*Interface*	*Power (approx)*
1	*OBS*	*Guralp*	*RS-232*	*<10W*
2	*Bottom Pressure Recorder (BPR)*	*Paroscientific*	*RS-232*	*<10W*
3	*Methane sensor*	*To be developed for long term monitoring*	*RS-232*	*<10W*
4	*CTD/Oxygen/Turbidity*	*On-the-shelf*	*RS-232*	*<10W*
5	*BOB (Bubble Observatory)*	*Ifremer*	*100BaseTX*	*<100W*
6	*Piezometer*	*Ifremer/NKE*	*RS-232*	*<10W*
7	*Accelerometer*	*On-the-shelf*	*RS-232*	*<10W*
8	*Current meter / ADCP*	*On-the-shelf*	*RS-232*	*<10W*
9	*Time Lapse Camera*	*On-the-shelf*	*100BaseTX*	*<10W*

Table 1 : List of the 9 instrument packages. The Bubble Observatory (BOB) is a standalone observation module equipped with a Simrad ER60 echosounder and a 120 kHz split-beam transducer mounted on a pan & tilt for horizontal insonification. It must be deployed at the sea floor close to a gas source located less than 60 m away.

Junction Box Requirements :

Depth requirements : 200, 450,700m
Maximum power : 1800W
Input voltage : 375VDC (nominal)
Input data interface : 100BaseTX
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.

Node Requirements
Node requirements driven by site location and system design. Trawl resistance is required.

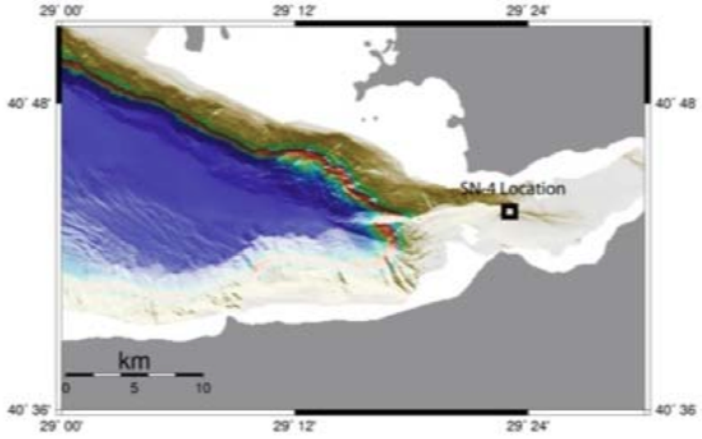


Fig. 2a : Detailed view of Site 1. The square indicates the location of the seafloor observatory (SN-4 was deployed at this site by Urania in september 2009, serviced in march 2010 and redeployed until september 2010).

Site 1 : Izmut Gulf Site
Approximate node location: 40 44' 8.70"N 29 23' 20.63"E
Approximate shore station location (Darica*): 40 45' 13.05"N 29 23' 26.00"E*
Approximate distance 2-3km
Approximate node depth: 200m

*shore station sites are not necessarily practical locations and are subject to detailed site analysis

Fig. 2b : Map of approximate Site 1 locations

Sites 2 and 3. In constrast, seafloor observatories at Sites 2 and 3 will include, respectively, one node and 2 junction boxes, with 9 instrument packages each (Fig. 3 and 4).

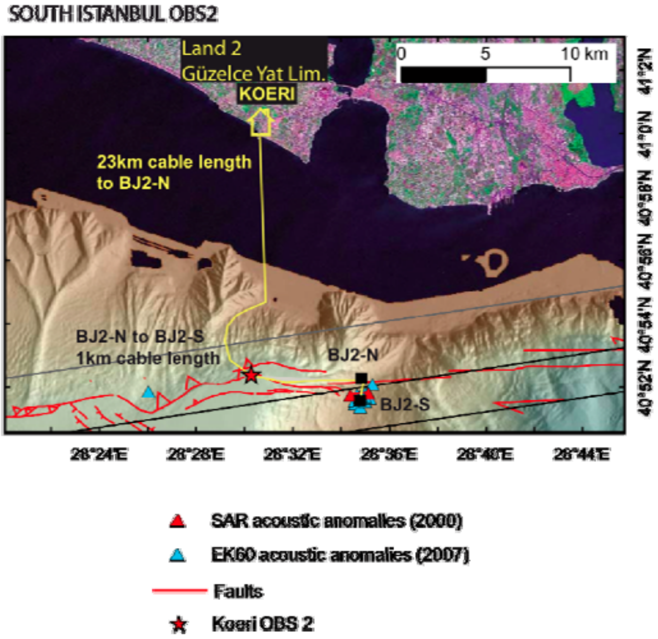


Fig. 3a : Cable routes for seafloor observatory at Site 2. This potential route avoids a major ship anchorage sites to the west.

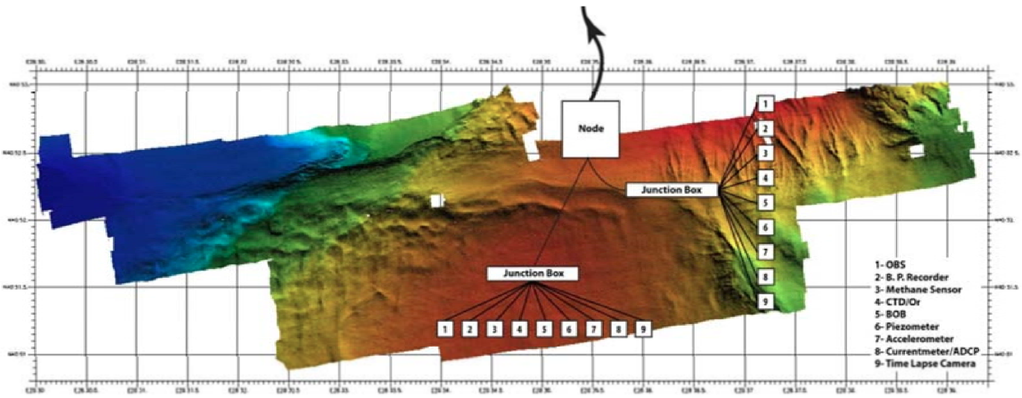


Fig. 2b : Observatory Design at site 2 (close up)

Site 2 : Silivri Site
Approximate node location: 40 52' 39.0"N 28 35' 30.0"E
Approximate shore station location (Guzelce Marina*): 40 51' 34.70"N 28 36' 50.95"E*
Approximate distance 23km
Approximate node depth: 450m

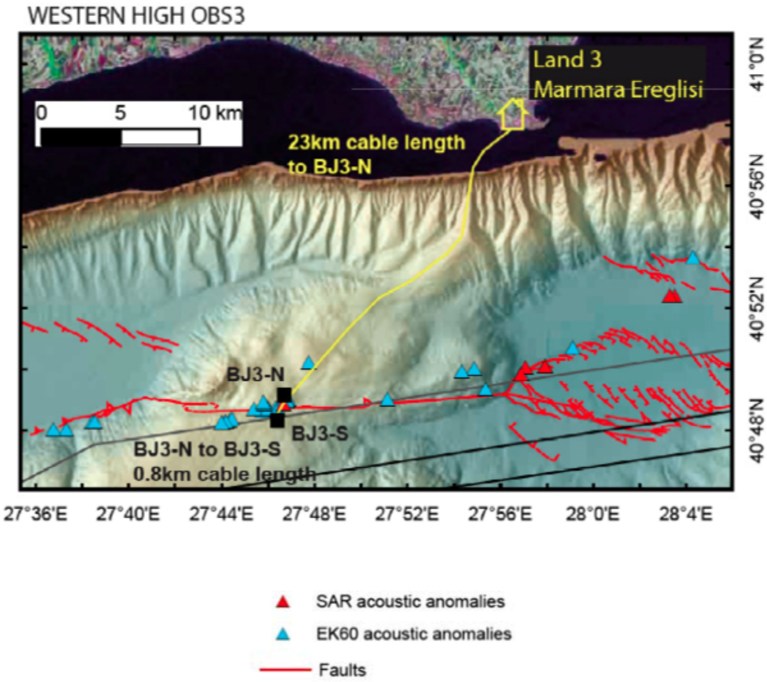


Fig. 3a : Cable routes for seafloor observatory at site 3.

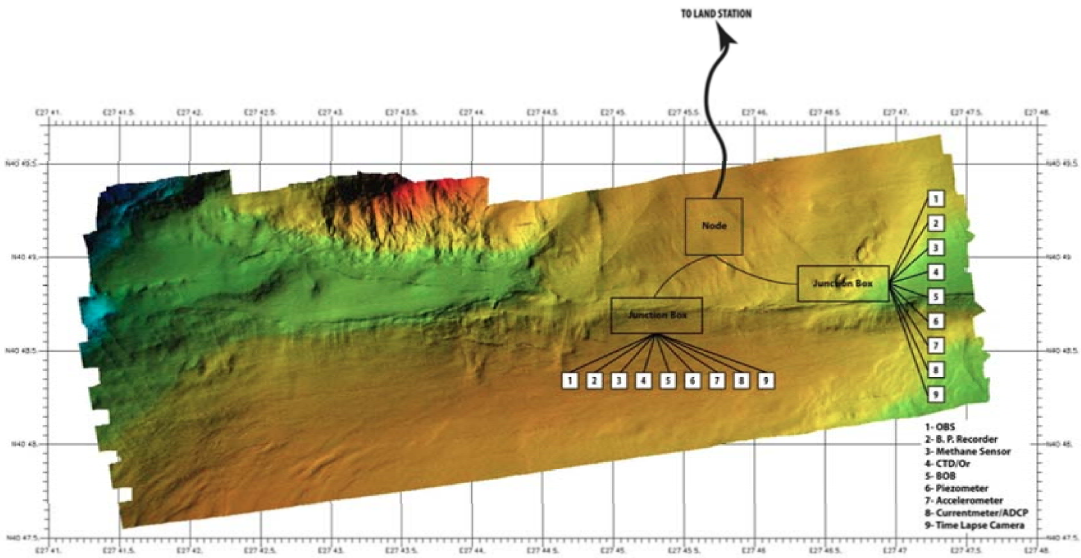


Fig. 3b : Observatory Design (close up) at site 3 (Western High / Gas Hydrates)

Site 3 : Western High Site
Approximate node location: 40 49' 06.0"N 27 45' 45.0"E
Approximate shore station location (Marmara Ereglisi*): 40 51' 34.70"N 28 36' 50.95"E*
Approximate distance 23km

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€

Cost of investments

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€

Indicative annual operating costs & training

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 MARMARA-DM PROJECT

Deliverable 5.3 : Implementation Plan

Due date of deliverable: September 2010
Actual submission date: September 2010

Start date of project: **April, 1st 2007** Duration: **30 months**

Organisation name of lead contractor for this deliverable: Ifremer & ITU
Lead authors for this deliverable: Louis Géli (Ifremer) & Namık Çagatay (ITU)
Revision [final version]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	PU
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)	

Contents

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 attached appendix in the present deliverable) 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. This proposal will be re-submitted in june 2011.

In the present Deliverable D5.3, we recall the implementation plan proposed in the Marquake Proposal, which only concerns site P1, along the Istanbul-Siliviri Segment. Five work packages are proposed to meet the project objectives:

WP1: Project management (coordinator: Ifremer). To provide an effective management and to ensure the high quality of the work to be performed and of the reports to be produced. Marquake Project aims at activating public EU investments to initiate an observatory structure that is aimed to be eventually managed by Turkish Institutions. Hence, the transfer from the EU to the national Turkish level will also be an important objective.

WP2: Implementation of multidisciplinary seafloor observatory (coordinator: ITU). This work package is based on the results of the Marmara-Demonstration mission of the EU-funded ESONET Programme within FP7, during which a great number of contacts have been taken with the Turkish authorities and with potential providers, industrial manufacturers and operators. This WP will be particularly complex, as the multidisciplinary seafloor observatory (MDSO) includes many components: the Observatory Data Center and the shore station; the cable, node and junction boxes ; and the instrumentation packages. The work under WP2 will consist in the following tasks: i) Define the full technical specifications for preparing the legal tender; ii) Publication of legal tender; iii) Selection of the different industrial providers and contractualization; iv) Obtain Administrative Clearance from Turkish Authorities; v) Coordination with AFAD (WP3) to establish the Observatory Data center and Data Management System; vi) Assembly of junction boxes and instrument packages; vii) Deploy cable and node; vii) Connect instrument packages and Junction Boxes.

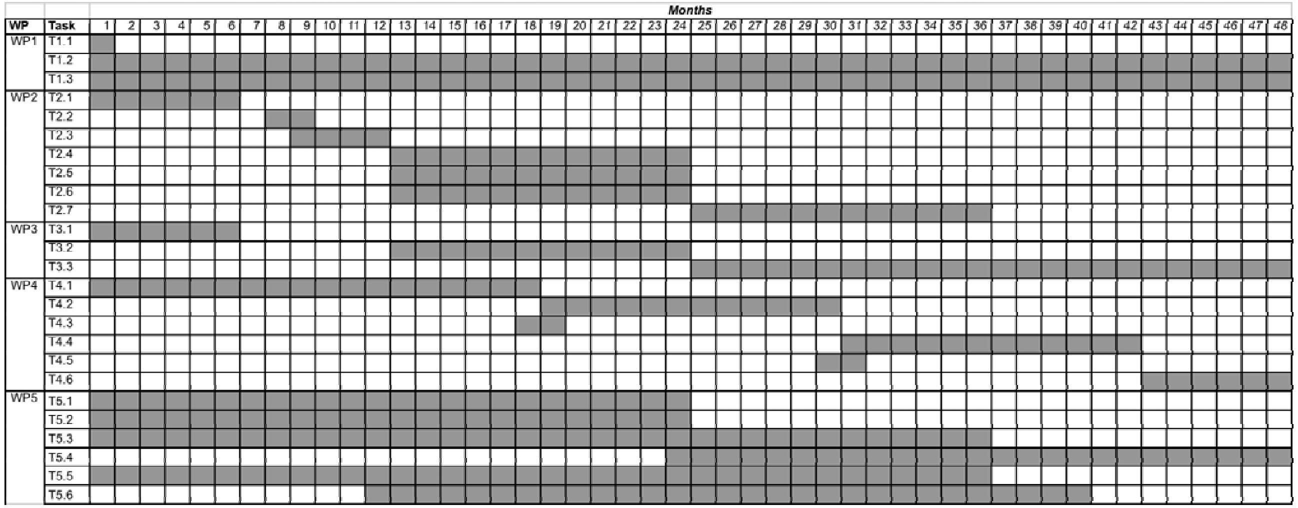
WP3: Real-time earthquake observatory data management and archiving (AFAD). This WP concerns the management and archiving system for the real-time seismicity and other multidisciplinary data. As the Turkish governmental authority on disaster and emergency management, AFAD will acquire the real time multidisciplinary data as well as the seafloor multidisciplinary data from the autonomous stations, process and archive them, along with data sets from the land stations in the region. Both seafloor and land seismic data will be integrated to understand earthquake behaviour in a time. The work package will start at month 6 of the project for preparing earthquake system design and testing. The WP includes the following tasks: i) Establishment of multi-disciplinary data management and archiving system, ii) data collection, quality control, archiving, evaluation, iii) Integrate and provide all seismic data to project participants, and iv) inform relevant organizations.

WP4: Collect additional time series (geophysical and geochemical) using autonomous

instrumentation (coordinator: CNR/ISMAR). Because the installation of MDSO will take time (~36 to 40 Mo), it is necessary to collect data from the very beginning of the project. At each site (P1, P2 and P3), we will deploy autonomous equipments, including SN-4 (the autonomous, multi-parameter observatory developed by INGV), additional seismometers, piezometers, and acoustic bubble detectors in order to start the work with data interpretation as soon as possible. The work within WP4 will consist each year in deploying and recovering autonomous instruments at sites P1, P2 and P3. Data of year 1 will be processed and validated during year 2 and so on.

WP5: Develop physical models and tools for data processing and analysis to improve predictability of earthquake (Coordinator: CNRS). This WP will start at month 1 of the project using available data (collected during the Marmara-DM project). After month 12, the work will be continued using the data collected within WP4. The WP includes the following tasks: i) Build an automated procedure for real-time earthquake locations and tremor identification; iii) Build an automated procedure for real-time visualization of all parameters; iv) Establish procedure for real time identification of anomalous gas activity and correlation with anomalous seismic activity.

The timing of the different WPs and their components is described in the GANTT Chart here after.


Months
WP
Task
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
WP1
T1.1
T1.2
T1.3
WP2
T2.1
T2.2
T2.3
T2.4
T2.5
T2.6
T2.7
WP3
T3.1
T3.2
T3.3
WP4
T4.1
T4.2
T4.3
T4.4
T4.5
T4.6
WP5
T5.1
T5.2
T5.3
T5.4
T5.5
T5.6

The work description broken down into work packages is indicated in the following pages:

Work package No	Work package title	Type of activity	Lead participant No	Lead participant short name	Person-months	Start month	End month
WP1	Project Management	MGT	1	IFREMER	34	1	48
WP2	Multidisciplinary Seafloor Observatory (MDSO)	RDT	5	ITU	353	1	48
WP3	Real time earthquake observatory data management and archiving system	RDT	4	AFAD	106	1	48
WP4	Collect long term time series from autonomous seafloor instruments	RDT	3	CNR/ISMAR	91	1	48
WP5	Models/tools/methods for improving earthquake predictability	RDT	2	CNRS	143	1	48
				TOTAL	727		

The list of milestrones of the Marquake proposal is indicated hereafter :

Milestone number	Milestone name	Work package(s) involved	Expected date [1]	Means of verification
M1.1	Kick off meeting	WP1	1	Public event
M1.2	1st 18-months meeting	WP1	18	Public event
M1.3	2nd 18 months meeting	WP1	36	Public event
M1.4	Closure meeting	WP1	48	Public event
M2.1	Publication of tender for MDSO	WP2	6	Public tender
M2.2	Selection of industrial offers	WP2	12	Contract with industrial providers
M2.3	Publication of administrative authorizations (clearances, work permits, etc)	WP2	24	Administrative documentation
M2.4	Shore station commissioning and testing	WP2	24	Report
M2.5	Start of marine operations	WP2	24	Report
M2.6	MDSO commissioning	WP2	36	Report
M3.1	Selection process for ODC and DMAS	WP3	12	report
M3.2	ODC and DMAS commissioning and testing	WP3	36	report
M3.3	Production of integrated data sets from MDSO	WP3	48	report
M4.1	Deployment (year 1) of autonomous instruments at sites P1 to P3	WP4	6	Cruise report
M4.2	Servicing (year 2) of autonomous instruments at sites P1 to P3	WP4	18	Cruise report
M4.3	Servicing (year 3) of autonomous instruments at sites P1 to P3	WP4	30	Cruise report
M5.1	Commissioning of software for ultra-precise real-time location	WP5	12	Report
M5.2	Commissioning of software for tremor identification	WP5	30	Report
M5.3	Commissioning of software for multi-parameter visualization	WP5	30	Report
M5.4	Commissioning of software for correlating anomalous gas activity and seismicity	WP5	36	Report

[1] **Measured in months from the project start date (month 1).**

Work package description of the Marquake Proposal :

Work package number	WP1	**Start date or starting event:**			1	
Work package title	Project management					
Activity Type[2]	MGT					
Participant number	**1**	2	3	4	5	6	
Participant short name	**Ifremer**	Cnrs	CNR/ISMAR	AFAD	ITU	DEU	Total
Person-months per participant:	34						34

Objectives

The objectives of this WP are: i) to provide an effective management and working programme for the project during the contractual period and a consistent, high quality of the work to be performed and of the reports to be produced; ii) manage relations with the EU/FP7 administration; iii) propose a management structure for the Marquake Observatory for the follow-up after the end of the contractual period so as to prepare the transfer from EU to Turkish institutions.

Description of work (possibly broken down into tasks), and role of participants

This WP will deal with the EU administrative aspects as well as the financial management of the grant. The specific work includes: (1) ensure timely deliverables of the project and project budget, (2) coordinate the activities of the consortium towards the achievement of the MarQuake objectives, (3) secure the quality of the work performed and delivered documents, (4) manage relations with EU (GEO, EMSO) and with Turkish authorities in close collaboration with coordinators of WP2 and WP3, (5) prepare the future of the Marquake observatory structure beyond the end of the project. The management process will be implemented by the *Project Coordinator* and *Management Committee* (MC), and receive advice from the *Advisory Committee*, in which the Turkish authorities (AFAD) will be represented (see section 2.1). All participants will be involved in WP1, but Partner 1 will be the only one to have specific man month allocation for this WP. Tasks include:

Task 1.1 Project Initiation

The effective initiation of the project will involve the kick-off meeting and setting out a plan for the project including the detailed assignment of roles, responsibilities and resources, the project timetable and descriptions of each deliverable to be produced. GEO, EMSO, EC and AFAD representatives will be invited to take part in the meeting. The task of the meeting also involves setting up the Consortium Agreement, and discussion with the GEO, EMSO and DEMP representatives on the interoperability arrangements for project data and information including processing, storing and disseminating the data, metadata, and products.

Task 1.2 Operational project management

Once the project has been initiated it will be managed on a daily basis in line with standard project management methodology. A project web-site will be set-up for placing documents, data, and deliverables for sharing between partners. The management committee will meet every six months to assess the work and deliverables (see section 2.1) and also involve continuous communication with the EC Project Officers.

Task 1.3 Project Reporting

The project coordinator and the Management Committee will be responsible for producing the formal project reports, 6-monthly project activity reports of WP leaders, the yearly progress reports and the final project report. The coordinator will also be in charge of controlling the appropriate depletion of project resources.

Deliverables (brief description and month of delivery)

D.1.1 Kick off meeting and assignment of tasks and duties (D) M1
D.1.2 Periodic activity, management and financial reports (R) M18
D.1.3 Periodic activity, management and financial reports (R) M36
D.1.4 Final activity, management and financial reports (R) M48
D.1.5 Proposal for the management of the Marquake Observatory after the end of the contractual period.

Work package number	WP2	**Start date or starting event:**			1		
Work package title	Implementation of Multidisciplinary Seafloor Observatory at site P1						
Activity Type[3]	MGT						
Participant number	1	2	3	4	**5**	6	
Participant short name	Ifremer	Cnrs	CNR/ISMAR	AFAD	**ITU**	DEU	Total
Person-months per participant:	34	40	8	18	223	30	353

Objectives. The objective of WP2 is to implement a multidisciplinary seafloor observatory at Site P1 along the Istanbul-Siliviri segment of the North Anatolian Fault. This WP includes all phases of the implementation: i) Preparation and publication legal tender; ii) Selection of industrial providers and contractualization; iv) Obtain Administrative Clearance from Turkish Authorities; v) Build the shore station; vi) Assembly of junction boxes and instrument packages; vii) Deploy cable and node and connect to instrument packages and junction boxes.

Description of work (possibly broken down into tasks) and role of participants

T2.1 Define the full technical specifications for preparing the legal tender;
T2.2 Publication of legal tender;
T2.3 Selection of the different industrial providers and contractualization;
T2.4 Obtain Administrative Clearance from Turkish Authorities;
T2.5 Build the shore station in coordination with WP3
T2.6 Assembly of junction boxes and instrument packages;
T2.7 Deploy cable, node and instrument packages and Junction Boxes.

Deliverables (brief description and month of delivery)

D2.1 Full Specifications report of MDSO (M6)
D2.2 Legal tender (document) (M12)
D2.3 Administrative Clearance from Turkish Authorities (M24)
D2.4 Shore Station (M24)
D2.5 Junction boxes and instrument packages (M24)
D2.6 Fully connected marine system, e.g. cable, node, instruments and junction boxes (M36)

Work package number	WP3	**Start date or starting event:**			1		
Work package title	Real time earthquake observatory data management and archiving						
Activity Type[4]	RTD						
Participant number	1	2	3	**4**	5	6	
Participant short name	Ifremer	Cnrs	CNR/IS MAR	**AFAD**	Itu	DEU	Total
Person-months per participant:	10	0	5	78	13	0	106

Objectives: The objective of WP3 is to establish real-time earthquake observatory data management and archiving system in Istanbul and at AFAD Earthquake Department, acquire, archive and process all multidisciplinary, and integrate all seismic data

Description of work (possibly broken down into tasks), and role of participants

T.3.1 Establish technical specifications for observatory data center (ODC), shore station and DMAS, Data Management and Archiving system (in partnership with WP2)
T.3.2 Contribute to the selection process of industrial providers (in partnership with WP2)
T.3.3 ODC and DMAS commissioning and testing

This WP will be coordinated by AFAD. The work will start at the very beginning of the project to establish the technical specifications for the tender to be published within WP2.

Deliverables (brief description and month of delivery)

D.3.1 Report on technical specifications for ODC and DMAS (document for legal tender) (M6)

D.3.2 Observatory Data Center and Data management and archiving system (M24)

D.3.3. Integrated data sets from MDSO (36)

Work package number	WP4	**Start date or starting event:**		1		
Work package title	Collect additional time series (geophysical and geochemical) using autonomous instrumentation					
Activity Type[5]	DEM					
Participant number	1	2	**3**	4	5	6	
Participant short name	Ifremer	Cnrs	**CNR/ISMAR**	AFAD	ITU	DEU	Total
Person-months per participant:	30	0	18	0	13	30	91

Objectives

Description of work (possibly broken down into tasks), and role of participants

Year 1:

T4.1 Prepare and operate first Deployment of autonomous instruments at sites P1, P2 and P3 (M1)
T4.2 Process and validate data from 1st autonomous deployment (M18)

Year 2:
T4.3 Second deployment of autonomous instruments at sites P1, P2 and P3 (M18)
T4.4 Process and validate data from 2nd autonomous deployment (M30)

Year 3:
T4.5 Third Deployment of autonomous instruments at sites P1, P2 and P3 (M30)
T4.4 Process and validate data from 3rd autonomous deployment (M42)

WP4 will be essentially conducted by the WP coordinator, CNR/ISMAR (Partner 4), and by Ifremer (Partner 1). CNR/ISMAR will be assisted by the group of marine geophysics of INGV (Rom) for the preparation, deployment and recovery of the SN4 stations. Ifremer (Partner 1) will prepare and deploy the additional sensor packages (piezometers, bubble dectector, OBSs). ITU (Partner 5) will contribute to WP4 by providing ITU's research vessel, R/V Yunuz and by facilitating administrative paper work (for customs, clearances, work permits, etc).

Deliverables (brief description and month of delivery)

D.4.1 Report on first deployment (year 1) of autonomous instruments at sites P1, P2 and P3 (M19)

D.4.2 Report on second deployment (year 2) of auton. instruments at sites P1, P2 and P3 (M31)

D.4.3 Report on third deployment (year 3) of auton. instruments at sites P1, P2 and P3 (M43)

Work package number	WP5	**Start date or starting event:**			1		
Work package title	Develop physical models and tools for data processing and analysis to improve predictability of earthquake						
Activity Type[6]	RTD						
Participant number	1	**2**	3	4	5	6	
Participant short name	Ifremer	**Cnrs**	CNR/Ismar	AFAD	ITU	DEU	Total
Person-months per participant:	24	72	20	16	11	0	143

Objectives. The ultimate objective of WP5 is to develop physical models and tools for data processing and analysis to improve predictability of earthquake. This objective requires developing specific software : i)for ultra-accurate real-time earthquake locations and tremor identification; ii) for real-time simultaneous visualization of all parameters; iii) real time identification of anomalous gas activity; iv) real time detection of anomalous activity in gas emission and seismicity. Theoretical work will also be conducted to develop physical models to correlate gas emissions and seismic activity and improve earthquake predictability.

Description of work (possibly broken down into tasks), and role of participants

T5.1 Implement an automated procedure for real-time earthquake locations (M1)
T5.2 Build an automated procedure for identifying tremors (M1)
T5.3 Build software for geodetic data processing and interpretation (M30)
T5.4 Identification of anomalous gas emission activity and correlation with seismicity and other parameters (M1)
T5.5 Develop physical models to correlate anomalies in gas and in seismic activity and to improve predictability of earthquakes (M48).

This WP will be coordinated by CNRS. The work will start at the very beginning of the project, using available data from SN-4 (INGV) and from Ifremer. After 12 months, CNR/ISMAR will provide the dataset collected during WP4. Pierre Henry (CNRS/CEREGE Aix Marseille) will supervise the work on the identification of anomalies in gas activity and on correlations with seismic activity. Jérôme Amman and Anne Deschamps (CNRS, Brest) will process the geodetic data and integrate the geodetic dataset into the global data set (T5.3 and T5.5). Real-time phase association, event declaration and earthquake location will rely on the integration of automated phase detection and picking algorithms (e.g. Filter Picker; Lomax et al., 2010) into real time earthquake location software (e.g.RTLoc; Satriano et al., 2007), within the 3D velocity structure of the Sea of Marmara crust (Bayrakci, 2010). Procedures for identifying tremors will rely on ongoing work performed at CEREGE (by Anne Bécel and Pierre Henry) on Marmesonet data and on existing algorithms for real-time parameter determination and warning (e.g. Lomax and Michelini, 2010; http://alomax.free.fr/projects/de-warning/warning.html)

Deliverables (brief description and month of delivery)

D5.1 Automated procedure for real-time earthquake locations (M24)
D5.2 Automated procedure for identifying tremors (M36)
D5.3 Automated software for geodetic data processing and interpretation (M48)
D5.4 Procedure for real-time identification of anomalous gas emission activity (M36)
D5.5 Paper on physical models coupling gas emission with stress and strain variations (M48)

The Summary of staff effort for the Marquake proposal is summarized in the table below :

Participant no./short name	WP1	WP2	WP3	WP4	WP5	Total person months
Ifremer (1)	**34**	34	10	30	24	132
CNRS (2)	0	40	0	0	**72**	112
CNR/ISMAR (3)	0	8	5	**18**	20	51
AFAD (4)	0	18	**78**	0	**16**	112
ITU (5)	0	**223**	13	13	11	260
DEU (6)	0	30	0	30	0	60
TOTAL	34	353	106	91	143	727

Risks and contigency plan. The most significant risk incurred by the project is related to the trawling of the cable linking the different junction boxes to the central node. The design of the project is such that if this ever happens, only one junction box will be damaged, without affecting the other components of the observatory. To avoid this risk, it is of critical importance that the area has all clearances before the deployment starts.

The main difficulties that the project will have to face are mainly related to the potential delays that could affect the implementation of the cabled seabottom observatory. These are, most particularly:

- Delays on the delivery of permits and clearance certificates prior to the laying-out of the cable: the Sea of Marmara is an area of intense maritime traffic from the Mediterranean to the Black Sea. Because Site 2 is close to the Ambarlı Harbour anchoring area, the seafloor observatory must be protected from any maritime (cable dragging on the seafloor, trawling, etc). Clearance certificates by the Turkish authorities will be needed for all the area (along the cable route and near the observatory site). We will start the administrative process from the very start of the project (Month 0). ITU’s (Partner 5) has long years of experience organizing and coordinating marine operations and scientific cruises. This experience will be very beneficial in obtaining clearances for the deployment of the observatories. Regarding this, ITU shall obtain clearances from the Undersecretary of Maritime Affairs and establish strong coordination with the Department of Navigation Hydrography and Ocenaography of the Navy (SHOD), Turkish Coast Guard Command, Directorate General of Coastal Safety, MTA (Mineral Research and Exploration General Directorate of Turkey).

- Delays on the delivery of the industrial equipments (cables, junction boxes, nodes). A public tender will be launched, and we expect to receive different industrial offers. Although on-the-shelf equipment already exists entirely or partially (in Canada, for instance, cf. Neptune project), innovative proposals will be received. The reliability and ability of the industrial providers to meet delays will be considered as top criteria in the selection process.

- Delays due to technical problems during the laying-out of the cable. These delays are unavoidable and inherent to any complex, technical project.

For the contigency plan, we have integrated all foreseeable, potential delays in the work plan schedule, by multiplying by two the duration of the most critical phases, e.g.: administrative clearance, manufacturing and installation of the equipment and the cable. We reasonably expect that after 40 months (the duration of the project), the full system will be installed and to be working on a routine basis.

Management structure and procedures

The objective of the Marquake Project is to initiate the creation of a marine facility for earthquake monitoring in the Sea of Marmara integrated in the plans of the Disaster and Emergency Management System of Turkey. This system is managed and coordinated by the Prime Ministry of Turkey Disaster and Emergency Management Presidency (AFAD, Partner 4). AFAD, in adition to operating the national seismological station network of Turkey. The data from the cabled seafloor observatory (and the autonomous observatories) will be received and archived at the Data Managment and Archiving Centre of the project at ITU in Istanbul, as well as the archiving and processing at the National Seismological Network of AFAD. In case of the detection of the anomalous signals, AFAD will have the responsibility of making the necessary announcement and warning, using the *Earthquake Advisory Committee* chaired by AFAD.

The MARQUAKE Project is a medium size project and a cooperation of 6 partner institutions, all of which have a very good experience with EU projects, and most of which have already worked successfully together in a variety of other EU projects of the 5th and 6th FP (e.g. ASSEM, ORION, NEAREST, ESONET, EMSO, HYPOX). Hence, the procedures are generally well understood by partners, work package leaders and the coordination team. IFREMER will ensure the coordination with well established methods from the many EU funded projects this institute has managed in the past.

The MARQUAKE management structure is set up in a way to ensure a smooth execution of the project in a timely way and according to the terms of the contract. This includes ensuring that:

- All the project's activities are properly coordinated with appropriate levels of legal, contractual, ethical, financial and administrative management of the consortium
- Proper operational project management is provided throughout the project
- The project completes its work to the expected timescales, resources and quality levels
- Appropriate reporting to the European Commission is undertaken.

The main decision-making components of the management structure are: a) Management Committee composed of the Coordinator (IFREMER) and WP leaders, and b) Advisory Committee composed of outside members.

<u>Management Committee (MC)</u>

The MC will be composed of the Coordinator and WP leaders and will be in charge of the operational aspects of the MARQUAKE project. This will include the relationships with the European Commission, related EC projects such as EMSO-PP and ESONET Viso. It will be in close relation with scientists of other disciplines also interested in the Marquake infrastructure for the establishment of a permanent EMSO site. There are already some scientists (e.g., Jean-François Rolin, Namik Cagatay) from the steering committee of EMSO PP who are also the MC member of MARQUAKE projects.The MC will meet bi-annually and will continuously monitor the progress of the activities of the project. Prime Ministry of the

Republic of Turkey Disaster and Emergency Management Presidency (AFAD) as the national organization responsible for earthquake and other disasters and as a partner of the project is represented in the MC.

The MC will organize the operational aspects of the project phases, distributing the work among the participants to each WP, monitoring the timing of the expected results and taking appropriate measures in case of deviation from the originally-planned work.

The WP Leaders will be responsible for the work planned in each WP including the timely dispatch of the deliverables, according to the MARQUAKE workplan.

The Project Coordinator (PC), (Louis Géli, IFREMER) has a broad experience in the management of international scientific projects, including as a coordinator of the ESONET Marmara-DM project. He is the Scientific Committee member of ESONET NoE. He will chair the MC and be responsible for the general coordination and organisation of the project activities. He will be assisted by Jean-François Rolin, who has a long experience in the management of European Projects (ESONET, EMSO). The specific tasks of the Coordinator will be:

- Coordination at consortium level of the management and support activities of the project, ensuring cooperation among partners, anticipating and managing potential conflicts.
- Coordination of financial aspects.
- Definition and implementation of the management framework (structure and procedures) to be adopted throughout the project.
- Coordinating the project reporting and management of project variations from the initial schedule and outputs.
- Establish appropriate guidelines for each of the participants.
- Overseeing the quality management of the project task coordination and managing interdependencies.
- Coordinate links with GEO, EMSO/ESONET, and other seafloor observatory networks such as DONET, VENUS, NEPTUNE Canada, OOI, MARS as well as third countries and the industry (including SMEs).
- Coordinate links between the EU and the Turkish Authorities.

The coordinator will handle all the relationships with the EC and will work in close coordination with the deputy, in close consultation with the other members of the Steering Committee

The project coordinator will be supported for administration matters by its institution, Ifremer. A vice-coordinator at Ifremer will be appointed for the day-to-day management of the project and communication with the AC and MC as well as with all partners. The Vice coordinator will also replace the coordinator in times of absence.

<u>Advisory Committee (AC)</u>
The AC will be composed by external members, chosen by the MC among scientists and technologists from Europe in the area of real time seismology, earthquake hazards, deep sea instrumentation, sea technology. The AC will also include representatives of the Turkish authorities in charge of civil protection, under proposition of AFAD. At least one member from the GEO will be included in the AC. The AC will include some scientists (e.g., Jean-François Rolin, Namik Cagatay) from the steering committee of EMSO Preparatory Phase. The Japanese experience will be represented by Dr. Kaneda from JAMSTEC. The tasks of AC will be:

- overseeing the project development and advising continuously on the progress
- inform DEMP on the advancement of the work and, in return, receive observations of DEMP
- providing expert support on specific technical and scientific matters
- advising on effective collaboration with GEO and networking with other projects, providing hints on possible integration and sharing of solutions.
- advising more specifically on the relation to the EMSO Research Infrastructure in order to establish and enhance the position of the Marmara Sea as a mature EMSO site to be supported by EU member states and Turkey.

Project Management Tools

A web-based, secured platform will be set-up to support the project information flow, ensuring good communication among the different decision-making components of the management structure. It will be accessible as a web portal including:

- external pages that will display news, outreach products, all public intermediate results and deliverables
- in the internal pages, accessible with a password, collaborative tools allowing all participants to share data, materials and knowledge in a very efficient way, as well as allowing all to follow the project activities. This tool will therefore be an important component of effective project management and coordination.

A reporting tool suited for the FP7 rules and already tested on previous projects will be managed by the coordinator and used by all partners to produce intermediate and final financial and management reports.

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 MARMARA-DM PROJECT

Deliverable 6.1: Support agreement contract with Turkish authorities

Due date of deliverable: November 2010
Actual submission date: January 2011

Start date of project: **April 1st, 2007** Duration: **30 months**

Organisation name of lead contractor for this deliverable:
Lead authors for this deliverable: Namik Çagatay, Istanbul Technical University

Revision [final version]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	PU
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)	

CONTENTS

EXECUTIVE SUMMARY

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.

1. INTRODUCTION

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. 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. This report provides details of the latter group of activities leading to the preparation of a project proposal, *MARDEP: Marmara Seafloor Observatory Infrastructure for Earthquake and Environmental Research and Modeling*".

2. MAIN REPORT

Much effort was spent to obtain funding for the establishment of seafloor observatories in the Sea of Marmara. The major effort to fulfill this deliverable was the preparation of a project proposal with an 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 (see Annex 1). However, the submittal was postponed, because all high level officials including state ministers in charge of funding organizations were all busy with the referendum for the constitutional changes that was held on 12 September 2010 and we wanted to submit the proposal at the most opportune time.

We decided to submit the *MARDEP Project* proposal for funding to the Prime Ministry of Turkey State Planning Department's (DPT) 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.

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 (D6.1: Support agreement contract with Turkish authorities) and preparation of the *MARDEP project* can be listed as follows:

1) A meeting of all stakeholders was held at Istanbul Technical University (ITU) 29 May 2009. EMSO (European Multidisciplinary Seafloor Observatory) ve ESONET NoE (European Seas Observatorty Network of Excellence) Projects and the ESONET Marmara-DM project results were presented. A conccensus was reached on the preparation of a project proposal for the establishment of “the multidiciplinary seafloor observatories in the Sea of Marmara” for submitting to the Turkish governement authorities was reached (Annex 6).

2) Namik Çagatay, Louis Geli, Pierre Henry and Yves Auffret worked on the MARDEP proposal in February 2010.

3) Namik Çagatay and Naci Görür were invited by the Deputy Prime Minister Mr. Cemil Çiçek to present the Marmara observatory project in Ankara on 17 February 2010, and met with the officals of Prime Ministry’s Disaster and Emergency Management Presidency.

4) Namik Çagatay and Naci Görür met with the officals of Prime Ministry Disaster and Emergency Management Presidency in their Istanbul regional office on 12 March 2010, and worked on the MARDEP project proposal.

5) Namik Çagatay, Louis Geli and Naci Görür met with the technical personnel of Prime Ministry’s Disaster and Emergency Management Presidency on April on 5-6 April, and worked on the MARDEP project proposal.

6) Namik Çagatay had a meeting with the academic personnel of the Institute of Marine Sciences and Technology of Dokuz Eylül University in Izmir on 28 April 2010. The meeting involved a presentation by Namik Çagatay and discussion of the MARDEP project proposal.

7) Price quotations for sensors were obtained Yves Aufrett during April – May 2010 for preparation of the MARDEP budget.

8) Several teleconference meetings were held with Neptune Canada and OcanWorks International during April and May 2010 regarding the MARDEP proposal.

9) A meeting was held with the Ocean Works International and Aykor A.Ş. on MARDEP project proposal on the mornings of 21 April and 2 June 2010. They presented a talk on marine observatories and on Neptune Canada.

10) The MARDEP project proposal was distributed to the Turkish partners on 28 April 2008 and a meeting of the partners on Wednesday, 2nd June 2010 was called. The meeting was attended by 19 representatives from 11 different organizations (Annex 7). It was also attended by the ITU Vice Rector for Research, Prof. Mehmet Karaca and representatives of Ocean Works International and its Turkish representative company Aykor. After an introductory talk by Namik Çagatay about the MARDEP project proposal, representatives of the different

organizations presented their views on the proposal. Consensus was reached on the following points:

i) ITU administration reconfirms that the MARDEP project is a high priority project that will receive necessary logistics support from the ITU administration.

ii) Kandilli Earth Observatory and Eartquake Research Institute (KOERI) of Bosphorus University will merge the MARDEP/WP3: "Seismological Research and WP4: Earthquake and Tsunami Risks and Early Warning Research".

iii) Institute of Marine Sciences (IMS) at METU (Emin Özsoy and colleagues) will develop WP2: "Oceanographic and Environmental Changes" and submit a new version in two weeks time.

iv) The Istanbul Municipality accepts to be a user of the MARDEP project (Annex 2).

v) The proposal will be finalized for submission to the TUBITAK-KAMAG or Prime Ministry State Planning Organization (DPT), to the next project call in 2011.

10. Namik Çagatay and Sena Akçer visited on 1 November 2010 the Prime Ministry State Planning Organization (DPT), the main funding organization in Turkey for science infrastructures, and briefed the experts about the MARDEP proposal and EMSO ERIC (Annex 8). Geological Survey of Turkey (MTA) officials were also present at the meeting. ITU received information about the next infrastructure project proposal call, which was stated to be sometime between April and June 2011.

11. The Sea of Marmara Node group (ITU, AFAD, IFREMER, CEREGE, ISMAR, DEU-IMST) applied on 16 November 2009 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.

3. CONCLUSION

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.

ANNEXES

List of Annexes

1. The Mardep project proposal (under a separate file)
2. Istanbul Metropolitan Municipality (IBB) letter
3. MTA (Nineral research and Exploration General Direct. Turkish Geological Survey) letter
4. French EMSO support letter
5. Italian- EMSO contribution letter
6. Minutes of Turkish Marine Institutions meeting 1: Consensus meeting
7. Minutes of Turkish Marine Institutions meeting 2 : Mardep meeting
8. Funding agency (DPT) meeting on EMSO and Mardep project proposal, participant list

Annex 1: Mardep project proposal (included as a separate file)

Annex 2: Letter of Istanbul Metropolitan Municipality stating to be a user of *Mardep project*

T.C.
İSTANBUL BÜYÜKŞEHİR BELEDİYE BAŞKANLIĞI
Deprem Risk Yönetimi ve Kentsel İyileştirme Daire Başkanlığı
Deprem ve Zemin İnc… me Müdürlüğü

Sayı : M.34.0.İBB.0.32.70.310.01/ 85800 - 1372 16/06/2010
Konu : Marmara Denizi Denizaltı Gözlemleriyle
Deprem ve Çevre Sorunlarının Araştırılması ve Modellenmesi işi

İSTANBUL TEKNİK ÜNİVERSİTESİ
MADEN FAKÜLTESİ
DOĞU AKDENİZ OŞİNOGRAFİ VE LİMNOLOJİ MERKEZİ
Ayazağa Kampüsü, Maden Fakültesi, Emcol, 34469 Maslak / Sarıyer / İstanbul

İLGİ: 26.04.2010 tarih ve IBB No: 87419 sayılı yazınız

İlgi yazınız ile "Marmara Denizi Denizaltı Gözlemleriyle Deprem ve Çevre Sorunlarının Araştırılması ve Modellenmesi" projesi kapsamında 3 adet denizaltı istasyonlarının kurulacağı ve başta doğal afetler olmak üzere tüm oşinografik ve iklim değişiklikleriyle ilgili kritik konularda araştırma yapılacağı, bunun için gerekli altyapının oluşturulacağı ve böylece uzun süreli, sürekli ve gerçek zamanlı denizaltı ölçüm ve gözlemlerinin yapılacağı bildirilmektedir. Ayrıca projenin; fay etkinliği, heyelan hareketliliği, tsunami, deniz kirliliği, çevre güvenliği, fiziksel, kimyasal ve biyolojik oşinografi, çevresel ve iklim değişimi gibi konuların araştırılmasına katkılarda bulunacağı belirtilmektedir.

Marmara Bölgesi Kuzey Anadolu Fayı'nın varlığı nedeniyle deprem tehlikesi altındadır. Bu gerçek doğrultusunda yapılan araştırmalar, olası bir depremin oluşturabileceği can kaybı ve ekonomik kayıplar nedeniyle, Afetlere ilişkin çalışmaların önemini arttırmakta ayrıca alınması gereken önlemlerin aciliyetini ortaya koymaktadır. Kurulması planlanan istasyonlardan gelecek uzun süreli ölçüm sonuçlarının depremin ve diğer tehlikelerin, ön habercisi olabilecek parametre ve yöntemlerinin geliştirilmesine katkıda bulunabilecek olması çok önemlidir. Kurumumuz bu tür bilimsel projelerin içinde bulunmayı önemsemektedir. Projeye kullanıcı olarak ve herhangi bir maddi sorumluluk üstlenmeden katılmamız tarafımızca uygun görülmüştür.

Gereğinin yapılmasını rica ederim.

İrfan UZUN
Başkan a.
Genel Sekreter Yardımcısı

İstanbul Büyükşehir Belediye Başkanlığı
Atatürk Bulvarı No:162 (Ek Hizmet Binası)
34134 Fatih / İSTANBUL

Ayrıntılı bilgi için irtibat: B.E.KONUKCU Deprem ve Zemin İnceleme Md.
betul.konukcu@ibb.gov.tr
Tel: 0212 455 23 62 Faks:0212 455 26 16
e-posta:depremzemin@ibb.gov.tr Elektronik Ağ: www.ibb.gov.tr

Annex 3 : MTA support letter for the Mardep project

T.C.
ENERJİ VE TABİİ KAYNAKLAR BAKANLIĞI
MADEN TETKİK VE ARAMA GENEL MÜDÜRLÜĞÜ

GENERAL DIRECTORATE OF MINERAL RESEARCH AND EXPLORATION

Sayı : B.15.1.MTA.25.00.00.604.99- 41 07/02/2011
Konu : Proje İşleri

İSTANBUL TEKNİK ÜNİVERSİTESİ
DOĞU AKDENİZ OŞİNOGRAFİ VE LİMNOLOJİ ARAŞTIRMALARI MERKEZİ (EMCOL)

İlgi: 3 Şubat 2011 tarihli ve EMCOL: 2011-002 sayılı yazınız.

İlgi yazınızla; Avrupa Birliği 6. Çerçeve Programı *ESONET NoE: Eurpoean Seas Observatory Network of Excellence* ve 7. Çerçeve Programı, *EMSO: "European Multidisciplinary Seafloor Observatory (Avrupa Çok Disiplinli Deniztabanı Gözlemevi)"* Bilim Altyapısı projeleri kapasamında gözlem alanı olarak seçilen Marmara Denizi'nde doğal afet (deprem, sualtı heyelanı, tsunami), oşinografi, çevresel ve iklim değişimi gibi çok disiplinli konularda sürekli gözlemler yapacak ulusal bir bilim araştırma altyapısı oluşturmak üzere önerilmesi planlanan MARDEP projesinde Kurumumuzun etkin bir şekilde katılımının arzu edildiğinden bahisle söz konusu projede yer alarak gözlem istasyonlarının oluşturulması ve işletilmesinde Genel Müdürlüğümüzün desteğinin belirtildiği bir destek mektubunun tarafınıza verilmesi talep edilmektedir.

Genel Müdürlüğümüzce ilkesel olarak yapılan değerlendirme sonucunda; yukarıda belirtilen amaçlar doğrultusunda Marmara Denizi tabanında tesis edilmesi planlanan gözlem istasyonları vasıtasıyla Ülkemiz açısından hayati öneme haiz bir veri tabanının oluşturulmasının yararlı olacağı mütalaa edilmekle birlikte, Kurumumuzca söz konusu projenin öneri taslağının teknik ve mali açıdan detaylı olarak incelenmesiyle ve üç yıl sonra hizmete girmesi planlanan tam donanımlı araştırma gemisinin imkanlarıyla değerlendirilebileceği hususunu bilgilerinize rica ederim.

Mehmet ÜZER
Genel Müdür

İletişim : MTA Genel Müdürlüğü
Üniversiteler Mah. Dumlupınar Bulvarı No : 139
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e-posta : mta@mta.gov.tr

Faks : (0-312) 287 91 88

Form No. D-08/01
Ayrıntılı bilgi için irtibat :

Annex 4 : French-EMSO support letter

EMSO-Fr

May 3rd 2010

Dear sir,

As representative of the EMSO.FR group, we can testify that the multidisciplinary observatory of Marmara Sea as described in the EMSO/ESONET projects is included in the request for funding to the French government.

The process of support by the French government of the EMSO infrastructure as part as the French ESFRI roadmap started in 2009.
The request for funding of Capital expenditures as well as Operating expenditures is based on a report in French issued by the EMSO.FR group. This group involves IFREMER and CNRS.

The support of the Marmara sea observatory under definition by the Istanbul Technical University and other Turkish partners is one of the basis of the EMSO.FR document:

« The French participation to EMSO concerns at first three of the eleven EMSO nodes(Figure 1):

1- Marmara Sea, in collaboration mainly with Turkish and Italian colleagues.
2- MoMAR site in the Azores
3- Ligurian Sea "

Figure 1

Ifremer/RDT/ESONET/10069

EMSO-Fr

« A precise project of installation of a cabled infrastructure exists for the Marmara node»
« The multidisciplinary observatory project carried by French teams in collaboration with Istanbul Technical University and Italian teams should benefit from this infrastructure.»

The requests for funding towards French Ministry of Research is based on the above mentioned document.
We hope this information will be helpful for the funding requests to the Turkish funding agencies.

Best regards.

Mathilde Cannat — for EMSO.FR group

Roland Person — Esonet NoE coordinator

Ifremer/RDT/ESONET/10069

Annex 5 : Italian-EMSO contribution letter

Italian contribution to the Marmara Sea Turkish project

Work already done

INGV and ISMAR-CNR are very interested to continue their activities of multiparametric monitoring of the North-Anatolian Fault (NAF) in Marmara Sea in search for earthquake precursors. This project started on October 2009 with the deployment of SN-4 observatory in its "autonomous" configuration, and is the final action after almost 10 years of marine geological studies in the region that followed the 1999 disastrous earthquake of Izmit.

Geological maps compiled after 3 oceanographic expedition in the Gulf of Izmit, carried out with the Italian ship R/V Urania, suggested a particularly favourable location to monitor the seismogenic behaviour of the NAF, where it is formed by a single E-W oriented strike-slip segment, and where gas emission in correspondence of the fault have been observed. This is also the place where the surface rupture of the 1999 Izmit event terminated, and where the next rupture affecting the Cinarcik segment towards Istanbul will probably nucleate (Figure 1).

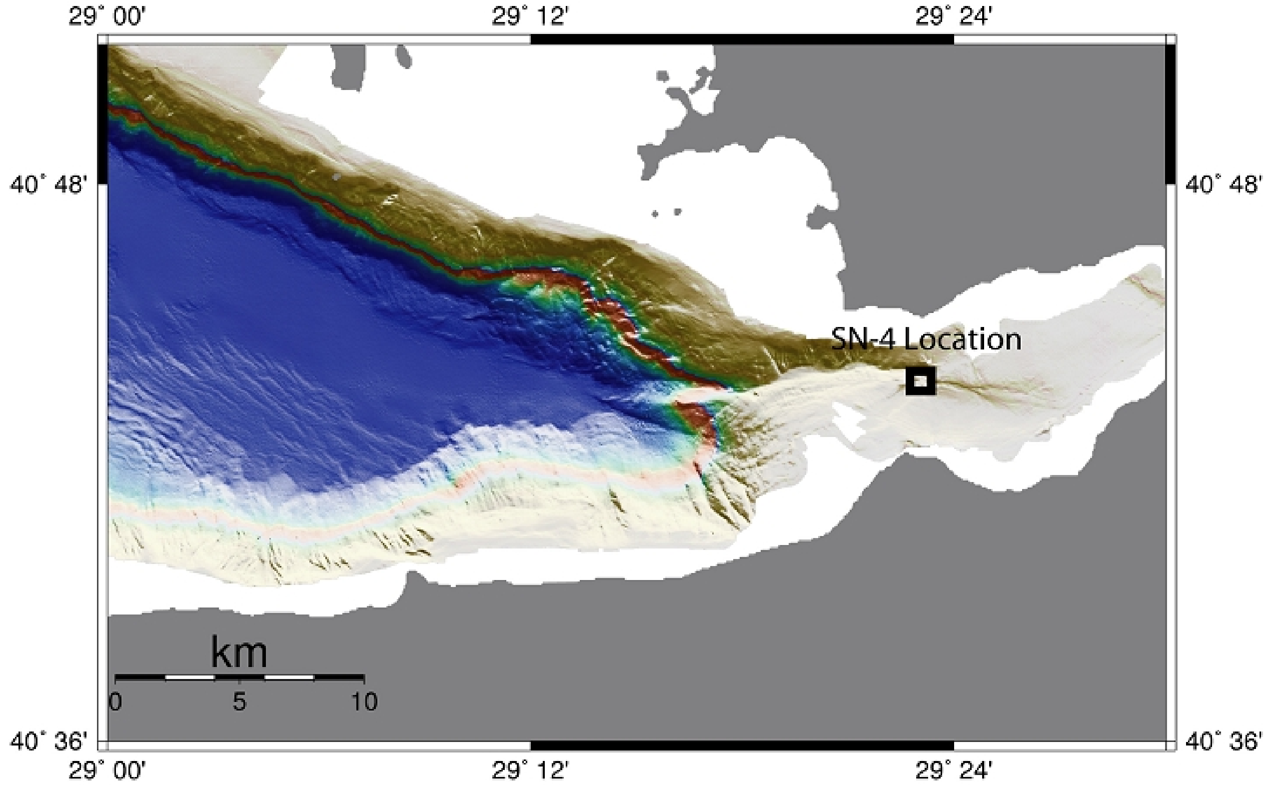

Figure 1 Location of SN-4 station at the entrance of the Izmit Gulf

The current project is expected to end next October 2010.

SN-4 is one of GEOSTAR-class seafloor observatories. Main task of multi-disciplinary seafloor observatories is the monitoring of geophysical and oceanographic processes; the simultaneous collection of different data can show links among natural processes allowing a better understanding of phenomena.

In the Gulf of Izmit, repeated surveys have shown that the intensity of methane emission from the seafloor increased after the August 17, 1999 earthquake. The hydrogeological system in submarine environment appears to be directly coupled to the tectonic system through the

interaction of fluid pressure and stress state. Coupling between deformation and fluid flow may lead to post-seismic fluid release, precursor events, and/or systematic variations in flow rates during inter-seismic phases.
The SN-4 mission is testing this hypothesis that, if verified, could open new perspectives to determine whether water and gas circulation in the sub-seafloor sediments can generate detectable signals related to the stress building process during the seismic cycle.
In order to have a better characterisation of the fault site, SN-4 hosts a lot of sensors: seismometer, current meter, methane sensors, oxygen sensor, instruments to measure conductivity, temperature, pressure and transmissivity. With all these sensors SN-4 is able to quantify the temporal relations between fluid expulsion, fluid chemistry and seismic activity.
Last March SN-4 was recovered to download all data and to replace batteries for further 6 months of mission. All data series from sensors were collected for the whole period of the experiment (October 2009-March 2010) and it is evident that data quality is very good and INGV and ISMAR are processing data for a quantitative analysis to study the relationship between seismic activity and fluid flow.

Italian contribution to the project

The Italian contribution to this project can be summarised in two activities:
(a) Upgrade of SN-4 to a “cabled” observatory
(b) set-up of a second GEOSTAR-class “cabled” observatory (SN-3)

(a) Maintenance the SN-4 experiment for years having a cabled system. Therefore SN-4 can be powered through that cable and have 2-way communications, collecting data in real-time at the shore station.

(b) Use of another GEOSTAR-class seafloor observatory. We have available two GEOSTAR-class seafloor observatories: SN-2 and SN-3, developed, tested and validated in previous projects. These observatories are exactly as SN-1 (the system cabled off Sicily). We propose to use SN-3.

Both activities have the strong advantages to collect quite soon valuable data to show to the Turkish Authorities, giving another further strong added value to the project because we can show results since the very beginning.

Accordingly, this document aims to define possible technical solutions for the cases (a) and (b), and the estimation of budget and timing.

(a) SN-4 “CABLED VERSION”

The simplest extension of SN-4 with a cabled version includes the addition of a new interface between the existing observatory and external cable (which leads power and communication lines).
The cable can be very simple (telemetry twisted pair copper, no fibre) and then economical. All SN4 features are kept, so in case a failure occurs in the cable or in the on-shore station, the observatory can continue to operate independently with its own batteries (6 months autonomy in the current configuration).
The new features are:
- Power supply from on-shore station (with automatic switch to internal batteries in case of failure of the power by supply cable)
- near real time control and data retrieving.

This system is not an actual “real time” observatory, as data retrieval should be delayed in time (for e.g. once a day or at request by operator)
SN-4 can be installed as in the actual case with a rope and an acoustic release and it can be recovered by a recall buoy canisters (like the current version of SN-4). A ROV is necessary for cable connection and disconnection. This solution has a lot of advantages:
a) easy to realise this version of SN-4

b) data formats already available

c) it guarantees operations even in case of loss of telemetry or power supply from shore

d) it is possible to change mission configuration if necessary

e) this architecture can be easily expanded to further system re-configuration.

- **Estimated budget and timing**

The total budget is estimated in 420 kE, including re-configuration of SN-4, shore station, cable, instruments and spares, travels, custom clearances and logistics (not including ship and ROV costs, for instance Urania costs 15 kE per day).
The time is estimated in 6-8 months from T0 to start the experiment at sea.

(b) SN-3 “CABLED” OBSERVATORY

We propose to use SN-3 to be deployed in the deep basin off Istanbul at the convenient place and depth. SN-3 will be prepared to be completely integrated and interfaced with the Ifremer cable design. SN-3 can be deployed and managed easily by Urania, we performed more than 25 successful deployments/recoveries down to 3350 m water depth. The use of Urania can reduce strongly the costs and its use can be scheduled from one year to another.
SN-3 observatory will use an existing mechanical frame already realised and used in previous EU projects by INGV. This observatory should be deployed as SN-4, by a rope with an acoustic release, and recovered by a rope with ROV assistance. SN-3 will be connected to shore by an electro-optical cable for power supply and real-time data transmission following the same configuration of SN-1 (off-shore Sicily). In this case a Junction Box is necessary to connect (by ROV) the umbilical of the station to the main cable. SN-3 has a bigger frame than SN-4, so it can host many instruments more than the ones on board of SN-4, it is possible to have also redundancy for some of them (such as methane sensors). As chemical sensors have limited life, it would be better to think to a modular observatory in with chemical sensors should be hosted into a “plug & play” module by using a ROV-mateable connector. This solution is to avoid the complete recovery of the observatory just to replace part of scientific payload.
Moreover, the use of an observatory developed in previous EC projects (like SN-3) can constitute another way to reduce costs and a strong European added value for using systems already developed in the past.

- **Estimated budget and timing**

The total budget is estimated in 548 kE, including design and realisation of the cable configuration of SN-3 (including ROV-mateable connector), shore station, instruments and spares, travels, custom clearances and logistics (not including ship and ROV costs, electro-optical cable and JB).
The time is estimated in 12-15 months from T0 to start the experiment at sea.

Final remarks

All the sensors installed on board SN-3 and SN-4 are time referenced, this allows to compare the different data streams to search for correlation, and also the data collected by the two observatories installed in two completely different NAF segments. The first (SN-4) at the end of NAF segment already ruptured in recent years and the second (SN-3) in a portion of NAF not recently ruptured.
This can allow the comparison between the time variability of phenomena like occurrence of earthquakes and gas seepage looking at the cause/effect of these processes in 2 different context possibly opening a new window on “precursors”.
An investment of less of 1 ME will allow to have 2 multiparametric observation points to contribute to the hazard assessment of the Marmara Sea, particularly related to the megacity Istanbul.
Finally, put at disposal already realised systems in previous EC projects can demonstrate to the Turkish Authorities the European interest and contribution to the Turkey node of EMSO (European Multidisciplinary Seafloor Observatory) infrastructure.

Annex 6: Minutes of EMSO, ESONET Marmara Meeting at ITU, 29th May 2009

EMSO (European Multidisciplinary Seafloor Observatory) ve ESONET NoE (European Seas Observatorty Network of Excellence) Projeleri ve Marmara Denizi Ayağı çalışmaları Tanıtım Toplantısı Tutanağı

EMSO projesi tanıtım toplantısı İTÜ Maden Fakültesi Yönetim Kurulu Salonunda 29 Mayıs 2009 Cuma günü saat 10:30 da başlamıştır. Toplantıya isim listesi ekte verilen katılımcılar katılmıştır (Ek-1).

Toplantı, EMSO projesinin İTÜ Yürütücüsü Prof.Dr. Namık Çağatay'ın sunumu ile başlamıştır. Sunumda EMSO projesinin Avrupa Birliği'nin ESFRI (European Strategy Forum on Research Infrastructures) yol haritası listesinde yeralan bir bilim altyapı projesi olarak, hazırlık aşamasındaki amacının Avrupa Çok-disiplinli Deniztabanı Gözlem Ağının yönetimsel, hukuksal ve finansal altyapısını oluşturmak olduğunu belirtilmiştir. EMSO projesi 8 iş paketinden oluşmaktadır.

Bunlar sırası ile 1) EMSO Proje yönetimi, 2) Yönetim Çalışması, 3) Yasal Çalışma, 4) Finans çalışması, 5) İşletme planı, 6) Lojistik çalışması, 7) Strateji belirleme çalışması, ve 8) Teknik çalışma'dır. Bu projenin gözlem bölgeleri arasında Marmara Denizi, Karadeniz ve Akdeniz'nin bulunması nedeniyle Türkiye için önemi anlatılmış ve Marmara Denizi bölgesel ayağının oluşturulması için gerekli öneriler sunulmuştur.

Toplantının ikinci kısmında karşılıklı görüş alış-verişi sonucunda aşağıdaki kararlar alınmıştır:

1. EMSO Avrupa Bilim Altyapısı projesi; ülkemizin bir iç denizi olan Marmara Denizi'ni bölgesel bir gözlem alanı seçmiş olması nedeniyle önemlidir. Zira Marmara Denizi'nde deprem ve tsunami gibi doğal afetler, Ege Denizi ve Karadeniz arasındaki oşinografik su kütlesi hareketleri ile tanker kazaları ve bunlar sonucu oluşacak kirliliğin gerçek zamanlı, sürekli ve uzun süreli izlenmesi çok önemlidir.

2. EMSO'nun Marmara Denizi Bölgesel Altyapısının oluşturulması süreci, ulusal bir proje olarak ele alınmalıdır. Bu bağlamda Türkiye'deki ilgili bilimsel kurumlar bir konsorsiyum oluşturmalı ve altyapı çalışmaları ulusal bir politika çerçevesinde bilimsel kurum temsilcilerinin yeraldığı bir kurul tarafından yürütülmelidir.

3. Bu tür bir ulusal projenin birinci derecede kaynağı, bu proje için niyet mektubu vermiş Başbakanlık Devlet Planlama Teşkilatıdır (DPT). Bu nedenle 2010'da DPT'ye sunulmak üzere, amaçları, kapsamı ve sürdürülebilirliği iyi açıklanmış, İTÜ Rektörlüğü desteğinde bir altyapı proje önerisi hazırlanmalıdır.

4. Dünyadaki benzer örnekleri dikkate alınarak, Deniz Tabanı Gözlem İstasyonu verilerine ihtiyacı olan pertrol endüstrisi ve sigorta şirketleri ile işbirliği ve mali kaynak yaratma olanakları araştırılmalıdır.

5. Proje ilgi alanı bakımından İBB, Marmara Belediyeler Birliği, İstanbul Valiliği İstanbul Özel İdaresi, Afet İşleri Genel Müdürlüğü gibi kamu kurumlarını ilgilendirmektedir. Bu nedenle bu kurumlarla gerekli işbirliği yapılmalıdır.

6. Projenin yeni teknoloji geliştirme ve uygulama potansiyeli bulunmaktadır. Bu nedenle teknokentler ve KOBİ'lerle işbirliği olanakları araştırılmalıır.

7. Denizaltı gözlem istasyonlarının oluşturulmasında yasal mevzuat için D.K.K. SHOD, Sahil Güvenlik Komutanlığı, Kıyı Emniyeti ve Gemi Kurtarma Genel Müdürlüğü gibi kurumlara danışılacaktır.

Participant list

Ek 1:

EMSO Toplantısı Katılım Listesi
İTÜ, 29 Mayıs 2009

İsim	Kurum	Telefon	e-posta
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EMSO TOPLANTISI
İTÜ, 29 Mayıs 2009

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Annex 7: Minutes of EMSO Meeting at ITU, 2nd of June 2010

MARMARA DENİZİ DENİZALTI GÖZLEMLERİYLE DEPREM VE ÇEVRE SORUNLARININ ARAŞTIRILMASI VE MODELLENMESİ (MARDEP) PROJE ÖNERISI TOPLANTI TUTANAĞI

MARDEP projesi tanıtım ve bilgi alış-verişi toplantısı İTÜ Maden Fakültesi Yönetim Kurulu Salonunda aşağıdaki gündem ve ekte isim listesi verilen kurum temsilcileri ile 02 Haziran 2010 Çarşamba günü, saat 14:15-15:30 arasında yapılmıştır.

Toplantı gündemi:

1) Projenin Sunumu
2) Kurumların proje önerisi konusundaki görüşleri
3) Proje önerisinin desteklenmesi için sunulacağı kurumlar: (DPT veye TÜBİTAK)
4) Proje önerinin sunulma zamanlaması

TUTANAK

1) Toplantı, araştırmadan sorumlu İTÜ Rektör Yardımcısı Prof.Dr. Mehmet Karaca'nın açılış konuşması ile başlamış ve Prof.Dr. Namık Çağatay'ın MARDEP projesini tanıtan ve yaklaşık 30 dakika süren sunumu ile devam etmiştir. Sunumda AB Çerçeve projeleri ESONET ve EMSO kapsamında Marmara Denizi'nde yapılan gözlem ve araştırma sonuçlarından hareketle gözlem istasyonlarının gerekliliği ve MARDEP proje önerisinin ana hatları ve önerinin güncel durumu hakkında bilgi verilmiştir.
2) Toplantının ikinci kısmında karşılıklı proje önerisi ile ilgili görüş alış-verişi özetle aşağıdaki şekilde gerçekleşmiştir:

   A. ODTÜ Deniz Bilimleri Enstitüsü'nden Prof.Dr. Emin Özsoy, Marmara Denizi'nin oşinografisi ile ilgili ayrıntılı bilgiler vererek, projede yapılması gereken çalışmaları sunmuştur.

   B. B.Ü. Kandilli Rasathanesi Deprem Araştırma Enstitüsü temsilcileri Dr. Doğan Kalafat, Doç.Dr. Nurcan Özel ve Doç.Dr. Uğur Şanlı Türkiye genelinde ve özel olarak da Marmara Bölgesinde karada ve denizde sismolojik gözlemlerle ilgili gerçekleştirdikleri ve yapacakları çalışmaları sunarak, MARDEP projesinin özellikle 4. Iş paketini "*Deprem ve Tsunami Tehlikesi ve Riski: Erken Uyarı Araştırmaları*" üstleneceklerini açıklamıştır.

   C. SHOD temsilcisi Kd. Albay Dr.Erhan Gezgin, projenin bir koordinasyon kapsamında gerçekleştirilmesi gereken bir proje olduğunu belirterek, eleman yetersizliği nedeniyle projede aktif olarak SHOD'un yer alamayacağını bildirmiştir.

   D. MTA'dan Dr.Tuğrul Şükrü Yurtsever, projenin araştırma projesi niteliği üzerinde durarak projeyi MTA Gene Müdürlüğü olarak idestekleyeceklerini belirtmiştir.

E. İÜ Deniz Bilimleri ve İşletmeciliği Enstütüsü Temsilcisi Prof.Dr. Fatih Adatepe projenin yaralrı bir proje olduğunu ve projede katılımcı bir kurum olarak yer alacaklarını açıklamıştır

F. İBB Deprem ve Zemin İnceleme Müdürlüğü temsilcileri Betül Ergün Konukçu ve Ahmet Emre Basmacı, İBB'nin projeyi yararlı bulduğunu ve projenin kullanıcısı olacağını belirtmiştir.

TOPLANTIDA ALINAN KARARLAR

1) Projede 3. İş Paketi "*Sismoloji Araştırmaları ve* 4. İş paketinin *"Deprem ve Tsunami Tehlikesi ve Riski: Erken Uyarı Araştırmaları* " BÜ Kandillii Rasathanesi ve Deprem Araştırma Enstitüsü tarafından birleştirilerek iki hafta içerisinde geliştirilmesine,
2) ODTÜ Deniz Bilimleri Enstitüsü'nün projenin 2. İş Paketini "*Oşinografik ve Çevresel Etkiler"* geliştererek iki hafta içerisinde yazmasına,
3) Projenin sağlıklı bir şekilde bütçesinin hazırlanmasına, ve
4) Projenin KAMAG proje önerisi olarak hazırlanarak, desteklenmesi için 6 ay sonraki TÜBITAK'a KAMAG projeleri ilanına başvurulmasına karar verilmiştir.

EK-1: **MARDEP Toplantısı katılımcı listesi**

İTÜ, 02 Haziran. 2010

sim	**Kurum-Organizasyon**	**e-posta adresi**
Namık Çağatay	İTÜ EMCOL	cagatay@itu.edu.tr
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Ahmet Emre Basmacı	İBB Dep.Zem. İnc. Müd.	ahmet.basmaci@ibb.gov.tr
Betül Ergün Konukcu	İBB Dep.Zem. İnc. Müd.	betul.konukcu@ibb.gov.tr
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Cemallettin Şevli	Denizcilik Müsteşarlığı Bölge Müd.	0212 251 41 09
Ender Kurt	Denizcilik Müsteşarlığı Bölge Müd.	0 505 270 44 21

MARDEP TOPLANTISI KATILIMCI LİSTESİ 2 Haziran 2010

İsim - Name	Kurum - Organizasyon	e-mail address
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Metin Karadağ	Aykor A.Ş.	mkaradag@aykor.com
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Tuğrul Şükrü YURTSEVER	Maden Tetkik ve Arama G.M	tsyurtsever@mta.gov.tr
Erhan Gezgin Dr. Yük. Müh. Alb	Seyir, Hidrografi ve Oşinografi Dairesi Başkanlığı	egezgin@shodb.gov.tr
Emin Özsoy	ODTÜ DBE	ozsoy@ims.metu.edu.tr
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Nurcan M. Özel	Kandilli Ras.	ozeln@boun.edu.tr
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Ender Kurt	//	0.505.2704421
Namık Çağatay	İTÜ	cagatay@itu.edu.tr 212-285 6211

Annex 8 : Funding agency (DPT) meeting on EMSO and Mardep project proposal: participant list

TOPLANTI TUTANAĞI
DEVLET PLANLAMA TEŞKİLATI MÜSTEŞARLIĞI

Toplantı Konusu : EMSO Projesi
Toplantı Tarihi : 01.11.2010
Toplantı Başkanı : Süleyman Alata

Toplantıya Katılanlar (Participants):

NO	Adı Soyadı (Name)	Kurumu (Organization)	Unvanı (Title)	E-Posta (E-Mail)	Telefon (Pho.) #	İmza (Signature)
1	Hmmet Parmaksız	DPT	Uzman	hparmak@dpt.gov.tr		
2	Özgür Kadir Özer	"	"	kozer@dpt.gov.tr		
3	Aslı Zeynep CAN	MTA Deniz Araştırmaları	Jeofizik Yük. Müh.	zcan@mta.gov.tr		
4	Barbaros ŞİMŞEK	MTA " "	Jeoloji Y. Müh.	barbarossimsek@mta.gov.tr	2011538	
5	Seren Akçer Ön	İTÜ EMCOL	Araş. Gör.	akcer@itu.edu.tr	212 2856211	
6	Süleyman Alata	DPT	Daire Başk.	alata@dpt.gov.tr	2946109	
7	Namık Çağatay	İTU	Prof Dr Emcol	cagatay@itu.edu.tr	212-2856211	
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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**

Deliverable reference number and title

ESONET MARMARA-DM PROJECT

Deliverable 6.2 : MARMARA-DM Website

Start date of project: **April, 1st 2007** Duration: **30 months**

Organisation name of lead contractor for this deliverable: ITU
Lead authors for this deliverable: Umut Ülgen and Cengiz Cabci (ITU)

Revision [final version]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	PU
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)	

Contents : link to 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.

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**

Deliverable reference number and title

ESONET MARMARA-DM PROJECT

Deliverable 6.3 : MARMARA-DM Training course

Start date of project: **April, 1st 2007** Duration: **30 months**

Organisation name of lead contractor for this deliverable: ITU
Lead authors for this deliverable: Namik Çagatay (ITU)

Revision [final version]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	PU
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)	

ESONET NoE (European Seas Observatory Network of Excellence) training course on
"Seafloor Observation Techniques for Marine Geohazard Monitoring"

18-19 August 2009
Istanbul, Turkey

The aims of the training course are:
1) To train young engineers and scientists on seaflor observatory techniques (addressed by the main second part of the course), and
2) To raise interest in seafloor observatories among stakeholders, funding organizations and public at large (addressed by the first part of the course).

This activity is an important deliverable of the ESONET Marmara DM project under WP6.

Young engineers and scientists from marine institutes, other related governmental and private organizations are invited to participate. High level officals from funding organizations in Turkey (e.g., TUBITAK, State Planning Department, TPAO, MTA) are invited to attend the introductory lectures (Part I). The training workshop will follow 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 Izmit Earthquakes.

Tentative programme

Tuesday, 18 August 2009

Part I: Introductory Lectures

9:30: History of marine geological research and the need for seafloor observatories in the Sea of Marmara (Namık Çağatay, ITU-EMCOL)

10:15 Disaster risk reduction studies of Istanbul Metropolitan Municipality (Ahmet Emre Basmacı, IBB)

11:00 Coffee break

11:20 Seafloor observatories for geohazard and oceanographic studies (Louis Geli, Ifremer, France)

12:05 Relations between geofluids and marine geohazards (Pierre Henry, CNRS, France)

12:50 Lunch

Part 2: Technical Lectures

14:15 Borehole monitoring: Case studies (Earl Davies, Canada)

15:00 Borehole instrumentation (Heinrich Villinger, Marum, Bremen, Germany)

15:45 Coffee break

16:05 Fluid sampling and analyis (Mike Tryon, Scripps Oceanographic Institution, USA)

16:50 Observatory design (Yves Auffret, Ifremer, France)

17:35 Acoustic sensors (Francesco Chierici, Italy)

Wednesday, 19 August 2009

Part 2: Technical Lectures (continued)

9:30 Gas-bubble monitoring (Carla Scalarbin, Ifremer, France)

10:15 Chemical sensors (Jean Luc Charlou, France)

11:00 Coffee break

11:20 SN-4 and Geostar stations for seafloor observations (Paolo Favali, INGV, Italy)

12:05 Ocean Bottom Seismometers (Cansun Güralp, Güralp Instruments, U.K.)

12:50 Lunch

14:15 Precise earthquake determination based on multiplet technique (Jean-Luc Got, Ifremer)

15:00: KOERI cabled seafloor observatory stations in the Sea of Marmara (Cemil Gürbüz, Koeri, Turkey)

15:45 Coffee break

16:05 Tsunami observatories (Klaus Schleisiek, SEND Off-Shore Electronics GmbH)

16:50 Discussion and exercises