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MARM10_02: MARINE GEOLOGICAL STUDY OF THE NORTH ANATOLIAN FAULT BENEATH THE SEA OF MARMARA

EC ESONET MARMARA DEMO MISSION, R/V URANIA CRUISE REPORT (2010-09-29 – 2010-10-18)

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1. tectonics 2. active faults 3. paleoseismology 4. seismology 5. Sea of Marmara

Abstract - A marine geological cruise, MARM10_02, was carried out 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 was the 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 of the North Anatolian Fault and the deployment of seafloor observatories. We collected multibeam bathymetry, side-scan sonar imagery, chirp sub-bottom and ADCP data, together with carefully positioned core samples. A submarine station of 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.

Sommario - Vengono presentati le metodologie e l'insieme dei risultati ottenuti durante la campagna MARM2010_02 di rilievi geofisici, geologici e oceanografici nel Mar di Marmara. E' stata utilizzata la nave da ricerca *R/V Urania* del CNR. Sono stati raccolti dati di multibeam, Chirp SBP, ADCP. E' stato recuperato l'osservatorio INGV SN4 al termine del secondo periodo di 6 mesi di acquisizione. Durante i transiti e' stato campionato il fondo mare e sono stati raccolti campioni d'acqua nello Ionio Occidentale. Sono stati anche recuperati in basso Tirreno due degli OBS INGV posizionati a Febbraio 2010 nella campagna R/V Urania PANSTR10.

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ACRONYM	DESCRIPTION	URL-email
ESONET	European Seas Observatory NETwork	www.esonet-noe.org/about_esonet
ESONET-NOE	ESONET Network of Excellence	www.esonet-noe.org
CNR	Consiglio Nazionale Delle Ricerche	www.cnr.it
ISMAR	Istituto di Scienze Marine	www.bo.ismar.cnr.it
ISTI	Ist.Scienza e Informazione	www.isti.cnr.it
IFREMER	Institute Franc.Exploit. Mer	www.ifremer.fr
INGV	Istituto naz. geofisica e Vulcanologia	www.ingv.it
ITU	Istanbul Technical University	www.itu.edu.tr
EMCOL	Eastern Mediterranean Center for Oceanography and Limnology	www.mines.itu.edu.tr/emcol/
MTA	Maden Tetkik ve Arama Genel Mudurlugu	www.mta.gov.tr
COMU	Çanakkale Onsekiz Mart Universitesi	www.comu.edu.tr
CEREGE	Centre Europ. Res. Enseign. Geosc. Environ.	www.cerege.fr
PARIS-S	Universite Paris Sud 11	www.u-psud.fr
UNIBO	University of Bologna	https://www.unibo.it
UNIVPM	Polytechnic University Marche	http://www.univpm.it
SHODB	Seyir, Hidrografi ve Osinografi Dairesi Baskanligi	www.shodb.gov.tr
KOERI	Kandilli Obs.Earthquake Res.Institute	www.koeri.boun.edu.tr
SEG	Soc. of Exploration Geophysicists	www.seg.org
XTF	Extended Triton Format	www.tritonelics.com
UNESCO	United Nations Scient. and cultural org.	www.unesco.org
IOC	Intergov. Oceanogr. Comm. of UNESCO	ioc.unesco.org
IHO	Int. Hydrographic Organization	www.iho.org
GPS-DGPS-RTK	Global Positioning System	samadhi.jpl.nasa.gov
DTM	Digital Terrain Model	en.wikipedia.org
SRTM	Shuttle Radar Topogr.Mission	www2.jpl.nasa.gov/srtm
OBS	Ocean Bottom Seismometer	woodshole.er.usgs.gov/operations/obs
MBES	MULTIBEAM ECHOSOUNDER SYSTEM	
SBP	Sub Bottom Profiling	
PSU	Practical Salinity Scale	ioc.unesco.org
XBT	Expendable BathyTermograph	www.sippican.com
UTM	Universal Transverse Mercator	
UTC	Universal Time Coordinated	
WGS84	World Geodetic System 1984	
NMEA	National Marine Electronics Association	www.nmea.org
SO.PRO.MAR.	Societa' Promozione lavori Marittimi	Fiumicino (Italy)
TECNOMARE	ENI Tecnomare	www.tecnomare.it
SBE	Sea Bird Electronics	www.seabird.com
BENTHOS	Teledyne Benthos	www.benthos.com
SIS	Sea Floor Inf. System	www.kongsberg.com
KONGSBERG	Kongsberg Maritime	www.kongsberg.com
SERCEL	Sercel	www.sercel.com
COMM-TECH	Communication Technology	www.comm-tec.com
NEPTUNE	Simrad MBES Software	www.kongsberg-simrad.com
MB-SYSTEM	MB-SYSTEM	www.ldgo.columbia.edu/MB-System
GMT	Generic Mapping Tool	gmt.soest.hawaii.edu/gmt

Table 1: Acronyms of Organizations, Manufacturers and Products

HOW TO READ THIS REPORT

Section 1 gives the introductory and background information, including some technological and scientific issues of the organization and execution of tasks, whereas section 2 summarizes the cruise operations. Section 3 provides the technical aspects that were involved in the data acquisition and processing. Sections 5 and following discuss the initial results, the on-going data processing and usage, and give concluding remarks. Some data processing procedures that were used in the production of this report along with additional technical details and data are presented in the Appendix.

ACKNOWLEDGMENTS

Many people contributed to the success of the research cruise (MARM10_02 *R/V Urania*). We are particularly indebted to the Captain Vincenzo Lubrano Lavadera, the officers and crew members of *R/V Urania* for their professionalism and efforts in assuring the success of the cruise. Turkish SHOD is warmly acknowledged for support and encouragement. The project was co-funded by Italian CNR and EU's ESONET.

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1. INTRODUCTION AND BACKGROUNDS

After the 1999 disastrous Kocaeli earthquake the international community is attempting to produce reliable maps of active faults distribution in the Sea of Marmara. As a follow-up of this effort, within a framework of increasing knowledge of the North Anatolian Fault (NAF) system, a number of scientists is starting to realize that the Sea of Marmara constitute an unique opportunity to study seismogenic behavior of an active fault for several reasons, including the relatively high strain rates observed, and the presence of clear stratigraphic markers at the time scale of several thousand years. Another important point for studying the NAF system below the Sea of Marmara is that here the active fault segments lay close to a highly populated region and will be probably the site of large earthquakes in the next decades.

We believe that an integrated approach involving the acquisition and analysis of geophysical (multibeam, side-scan sonar, chirp), geological (cores) and seismological data, would represent an innovative strategy in the emerging field of submarine earthquake geology to assess the seismic hazard in the Marmara region. On the other hand, results from recent marine geological cruises that analysed the almost systematic association of cold seeps (emission of gas and fluids from the seafloor) and active faults in the Marmara Sea highlighted the importance of gathering long term time series to study correlation between fluid vents and seismicity. For this reason, the project includes a geological/geophysical survey in key areas of the Sea of Marmara as well as the deployment of a submarine observatory to monitor the behavior of the fault over a 1 year period.

Diverse earthquake scenarios can be envisioned that would fill the strain gap in the Sea of Marmara between the 1912 and 1999 ruptures, to the western and eastern bounds, respectively. The implications of each scenario for the hazard facing Istanbul (population: 12 million) and elsewhere around Marmara vary widely, and their likelihood needs to be evaluated. These evaluations can only be as reliable as the seismologic, geophysical and geological parameters on which they are based.

Major issues that can be addressed with reliable information on structure and rupture history are:

1 is the Marmara Sea gap going to be filled by a single large rupture or by a sequence of smaller ruptures?

2 is the plate motion through Marmara partitioned between distinct structures accommodating the trans-current and extensional components of motion?

3 do faults with complementary roles in such partitioned systems rupture in repeatable sequences?

4 how much close to rupture are seismogenic faults in the Marmara Sea as a result of the Coulomb stress effect of the 1999 sequence and what is the tsunamigenic potential of these structures?

5 are fluid and gas emissions observed during previous studies related to seismicity and could they be possibly used as earthquake precursors to mitigate hazards?

The survey carried out during MARM10_02 combined multibeam, side-scan sonar maps and chirp sub-bottom profiles with carefully positioned core samples to resolve the shallow geometry and kinematics of portions of the fault system in the north eastern Marmara Sea.

Our purpose was to resolve fault geometry and kinematics and to date their most recent ruptures at the same scale as typical paleoseismological studies on land. We were guided by previous and ongoing projects studying larger scale and deeper characteristics of the fault array in the Marmara. Our strategy was to juxtapose morphology and structures along the inferred rupture of the 1999 İzmitearthquake with other faults that may have ruptured in previous historic earthquakes near Istanbul, such as the very large and destructive earthquakes centered in the eastern Marmara sea in 1509 and 1766. Particularly important was to identify features characteristic of submarine ruptures of transcurrent faults which may be subtle in reflection profiles.

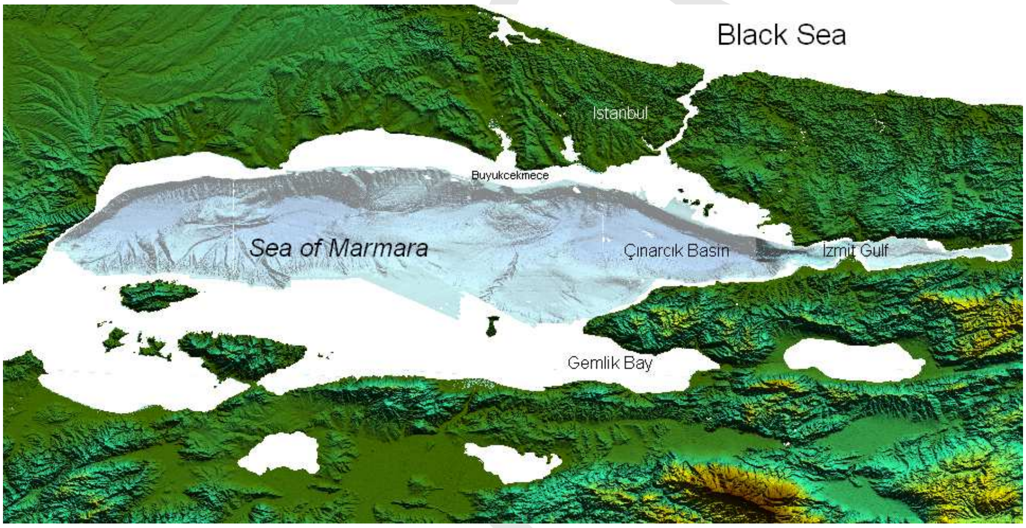

Figure 1: Sea of Marmara region setting. Bathymetry from Ifremer Atlas (Le Pichon and et al., 2005), DTM from SRTM data (Shuttle Radar Topogr. Mission NASA/ASI)

The main part of the cruise was devoted to the recovery of submarine observatory (SN-4, OBS and piezometers) after a 1 year deployment along the NAF track in the İzmitGulf (Fig.1 and 2). An extensive seabed sampling and mapping was performed. The fluid escape and interactions were studied by pore water analysis, heat flow measurements and microbiological subsampling.

MARM10_02 was carried out in the frame of MARMESONET project, a demo mission (DM) of the EC funded ESONET Network of Excellence (European Seafloor Observatory Network) that aims at demonstrating the relevance of Seafloor Observatories for monitoring geohazards in the Marmara Region. MARMESONET DM is complementary to KOERI's project MBSO (Marmara Sea Bottom Observatory project), which aims at implementing 5 cabled OBS in the Sea of Marmara, as part of the turkish national network for earthquake and tsunami hazards monitoring. The MBSO project has an operational and research finality, while the MARMARA DM is research-oriented. The former aims at being integrated into the national Turkish seismic network. The latter aims at testing the hypothesis that the physical and geochemical properties of the fluids change within the fault throughout an earthquake cycle and that these changes can be recorded at the seafloor. If true, this hypothesis would open new perspectives to determine whether water and gas circulation in subseafloor environments can generate detectable signals related to the stress-building process before large earthquakes, an issue of direct, social importance.

The collection of data series by bottom observatories was the main objective of the cruise. This implied a site survey prior deployment that included geophysical and geochemical observations carried out directly on board of Urania.

Specific tasks carried out during MARM10_02 cruise were :

1 recover the submarine observatory SN4 (Par.3.2), along the NAF track in the İzmitGulf

2 collect multibeam data from the Marmara shelves in depths ranging from 50 to 1000 m together with high-resolution 2D seismic lines

3 collect cores (gravity and water/sediment cores) at several sites in the Sea of Marmara

Main partners were : ITU(EMCOL) from Turkey, ISMAR and INGV from Italy and IFREMER and PARIS-SUD from France. At the international level, the project also benefits from the participation of scientists from the Scripps Institution of Oceanography (San Diego, California).

Relevant previous or future research cruises

The present project is based on many previous research cruises carried out using R/V Odin Finder and R/V Urania and also on cruises of R/V Le Soroit and R/V L'Atalante within the framework of an Italy,France,USA and Turkey collaborative programme. The key areas have been identified through the interpretation of the previously collected geophysical and geological data along the NAF strands and cruise work was designed in order to map active structures and features likely useful to understand fault kinematics. For details about some of these cruises see:

- Odin Finder 2000, projects.bo.cnr.it/CRUISE_REPORTS/2005/MARM05_REP
- Urania 2001, projects.bo.cnr.it/CRUISE_REPORTS/2001/MARM2001_REP
- Urania 2005, projects.bo.cnr.it/CRUISE_REPORTS/2005/MARM05_REP
- Urania 2009, projects.bo.cnr.it/CRUISE_REPORTS/2009/MARM09_REP

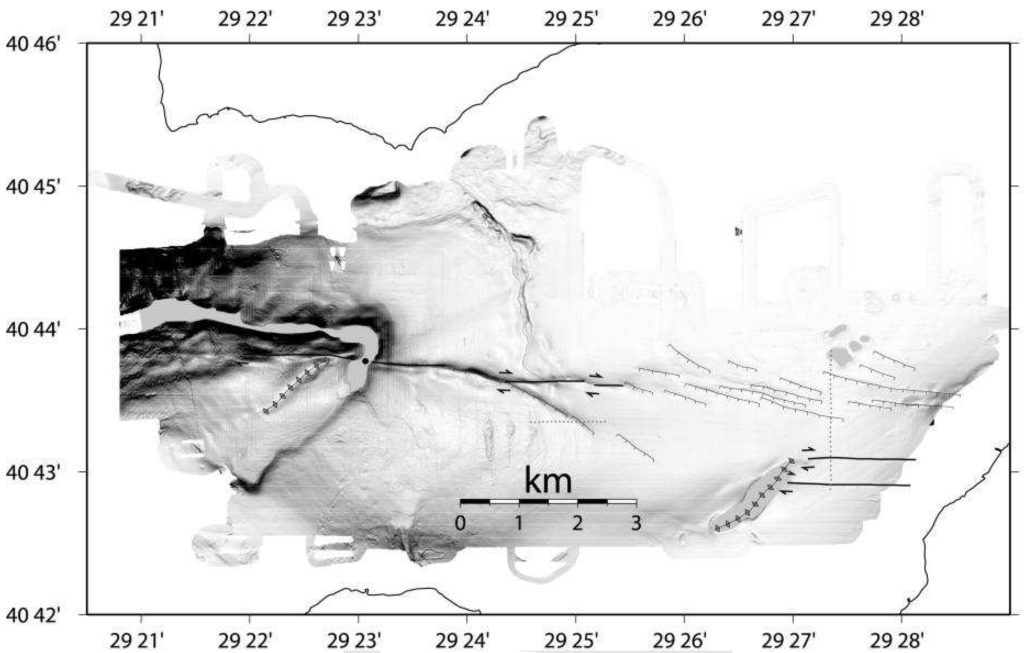

Figure 2: Morpho-tectonic map of the Darica basin close to the SN4 deployment site.

The references in bibliography cover broad aspects of the scientific problems and issues relating to the NAF in the Sea of Marmara, among the many others, tectonics, seismology, geochemical and sedimentary processes (Şengör, 1979; Barka, 1992; Çağatay et al., 1998; Hubert-Ferrari et al., 2002; Şengör et al., 2004, 1985; Armijo et al., 1999; McClusky et al., 2002; Armijo et al., 2002; Le Pichon et al., 2001, 2003; Aksu et al., 2000; Imren et al., 2001; Gokasan et al., 2001; Kuşcu et al., 2009; Alpar and Yaltirak, 2002; Demirbag et al., 2003; Barka and Kadinsky-Cade, 1988; Barka, 1992; Stein et al., 1997; Okay et al., 2000; Parke et al., 2002; Flerit et al., 2003; Polonia et al., 2004; Meade et al., 2002; Ambraseys and Finkel, 1991; Provost et al., 2003; Shindler, 1997; Okay et al., 2004; Polonia et al., 2002).

Moreover, in recent years a lot of effort was also devoted to the study of cold seeps, gas and fluid emissions. Geli et al. (2008) presents the results of geophysical investigations and of submersible dives during cruises MARMARA (R/V Le Suroit, September 2000) and MARNAUT (R/V L'Atalante, May-June 2007), pointing to clearcut evidence of gas and fluid emissions and active tectonics in the Dea of Marmara, particularly in the ÇinarcikBasin. Çağatay et al. (2009) discusses the late Pleistocene-Holocene stratigraphy of the northern shelf of the Sea of Marmara extending back to isotope stage 6. This study reports the discovery of two new sapropel units deposited during isotope stage 5 highstand and discusses water exchange between the Black Sea and Mediterranean through the Sea of Marmara during various isotopic stages, based on seismic stratigraphic and core analyses.

2. CRUISE SUMMARY

SHIP: *R/V Urania* Flag: Italy [IT] Call Sign: IQSU IMO: 9013220, MMSI: 247498000
START: 2010-09-29 PORT: Napoli
END: 2010-10-18 PORT: Napoli
SEA/OCEAN: Sea of Marmara, Mediterranean Sea
LIMITS: NORTH 39:50.0 SOUTH: 41:00.0 WEST: 25:30.0 EAST: 30:00
OBJECTIVE: Active Faults and historical earthquakes in the Marmara Sea
COORDINATING BODIES: ISMAR-Bologna BOLOGNA (ITALY)
CHIEF OF EXPEDITION: Luca Gasperini (ISMAR-CNR)
CONTACT: Luca.Gasperini@ismar.cnr.it
DISCIPLINES: MARINE GEOLOGY, MARINE GEOPHYSICS, PHYSICAL OCEANOGRAPHY, CHEMICAL OCEANOGRAPHY,BOTTOM OBSERVATORIES
WORK DONE: SN4 RECOVERY, 30 KM^2 MULTIBEAM, 1000 KM SBP
14 GRAVITY CORES, 35 SW CORES, 17 CTD CASTS, 4 ROV DIVES,

LOCALIZATION:

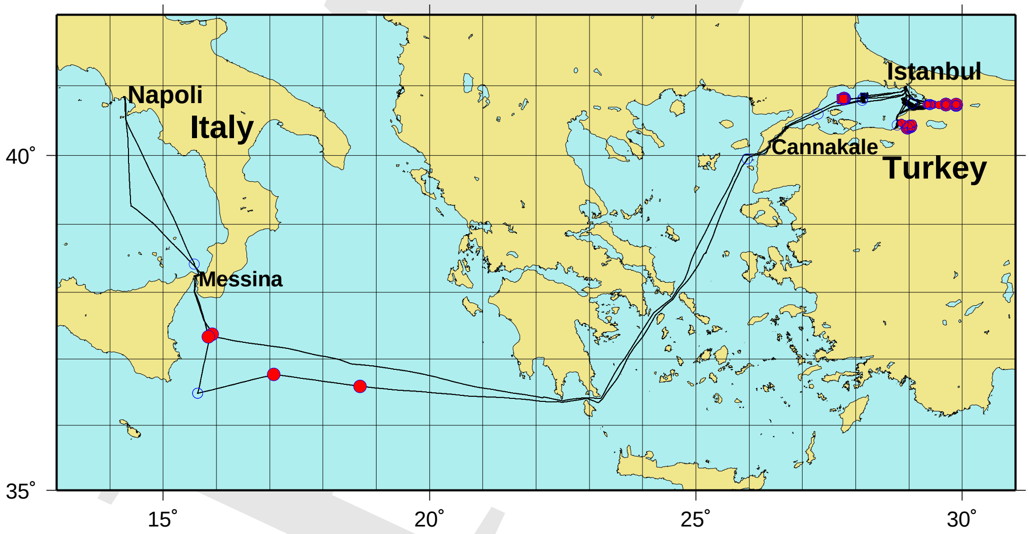

Figure 3: General ship tracks during Cruise MARM10_02, including transits from and to Napoli.

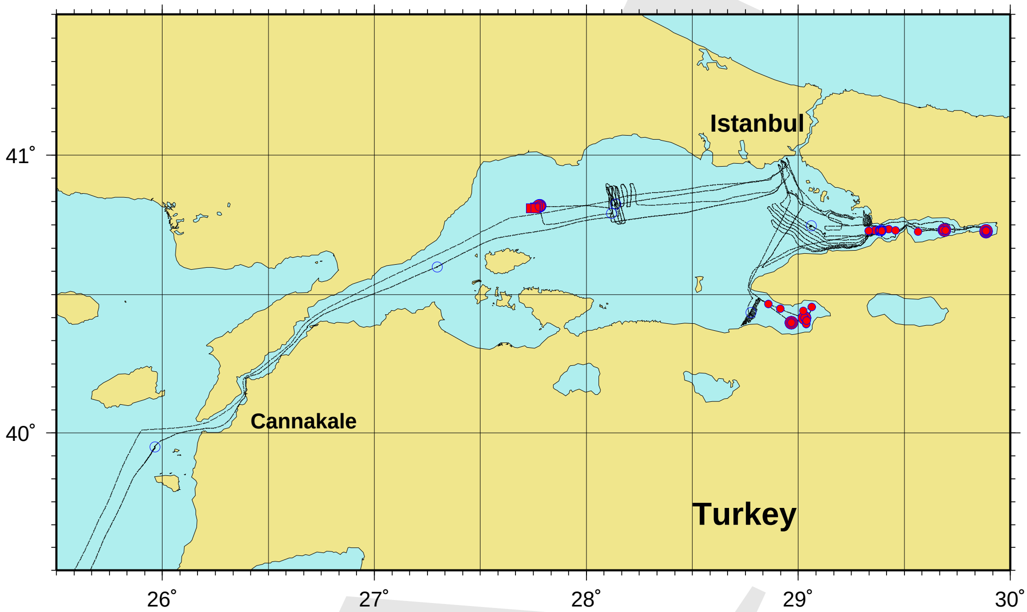

Figure 4: Ship tracks during Cruise MARM10_02 in the Marmara Sea.

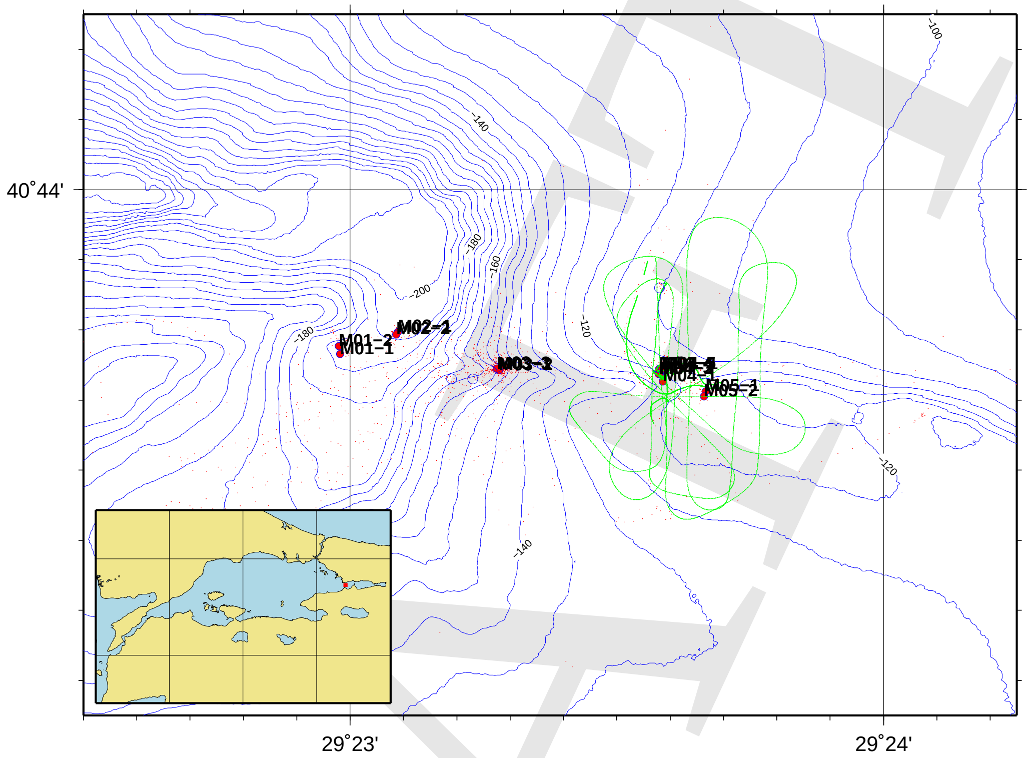

Figure 5: Ship tracks during cruise MARM10_02, İzmit Area. Red and blue circles and squares are coring locations. Red hollow circles are CTD and water sampling locations. Green lines are the ADCP navigation data.

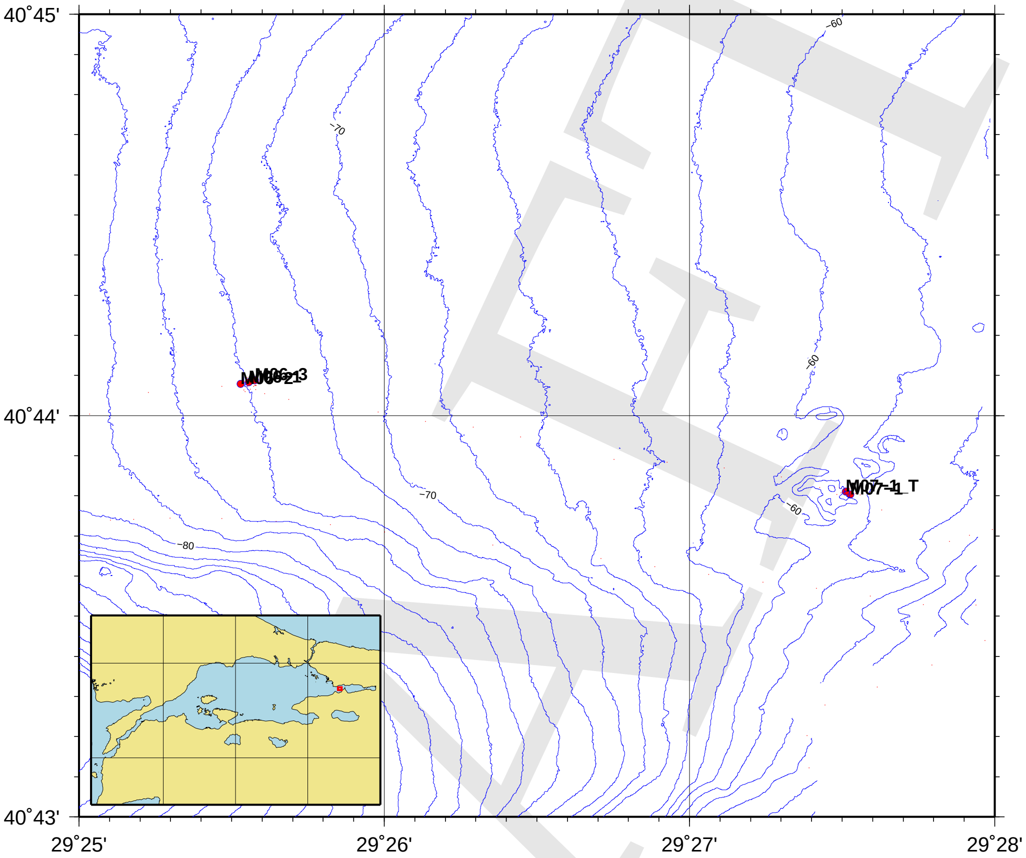

Figure 6: Ship tracks during cruise MARM10_02, İzmit Area. Red and blue circles and squares are coring locations. Red hollow circles are CTD and water sampling locations. Green lines are the ADCP navigation data.

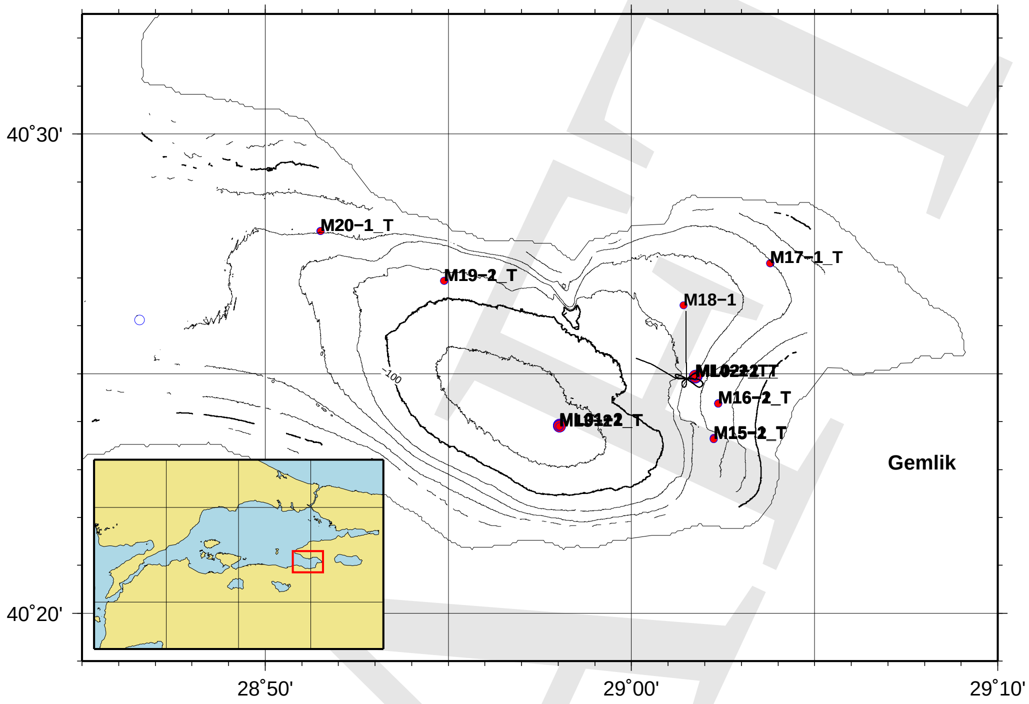

Figure 7: Ship tracks during cruise MARM10_02, Gemlik Area. Red and blue circles and squares are coring locations. Red hollow circles are CTD and water sampling locations. Green lines are the ADCP navigation data.

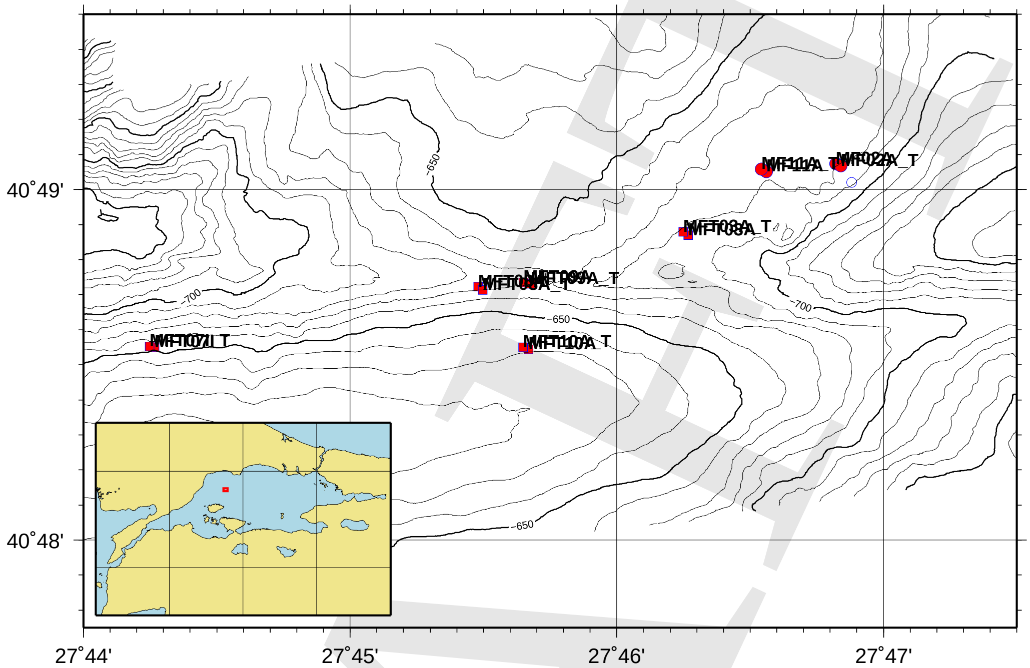

Figure 8: Ship tracks during cruise MARM10_02, Western High Area. Red and blue circles and squares are coring locations. Red hollow circles are CTD and water sampling locations.

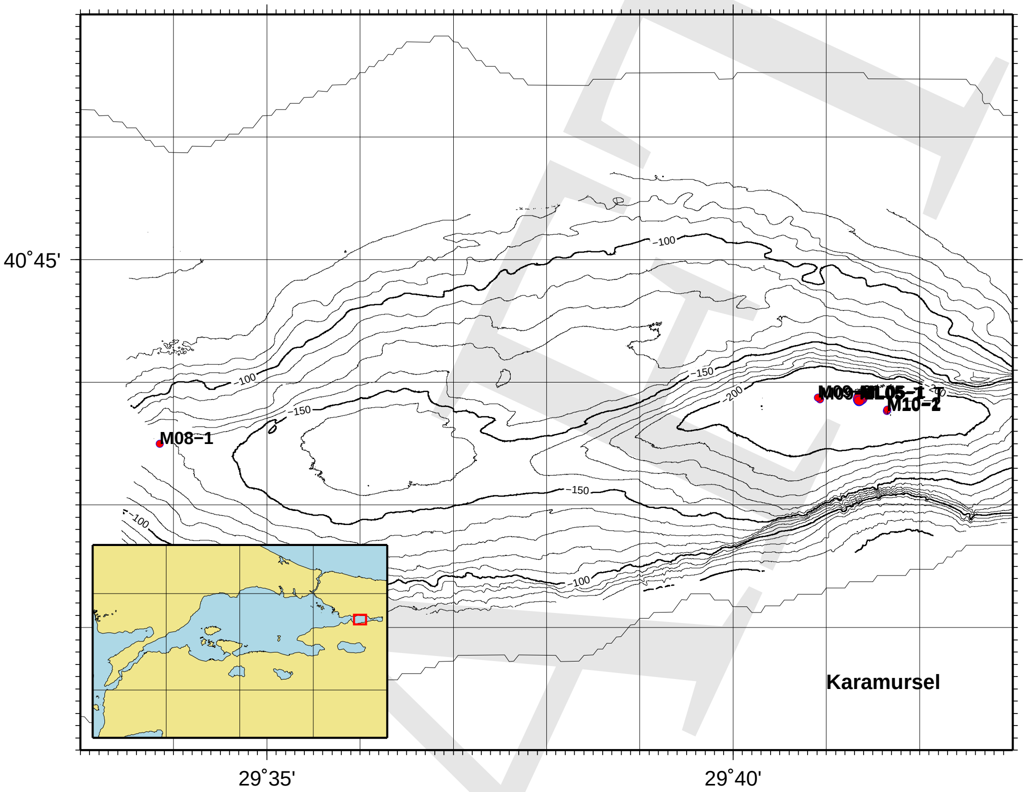

Figure 9: Ship tracks during cruise MARM10_02, Karamürsel Area. Red and blue circles and squares are coring locations. Red hollow circles are CTD and water sampling locations.

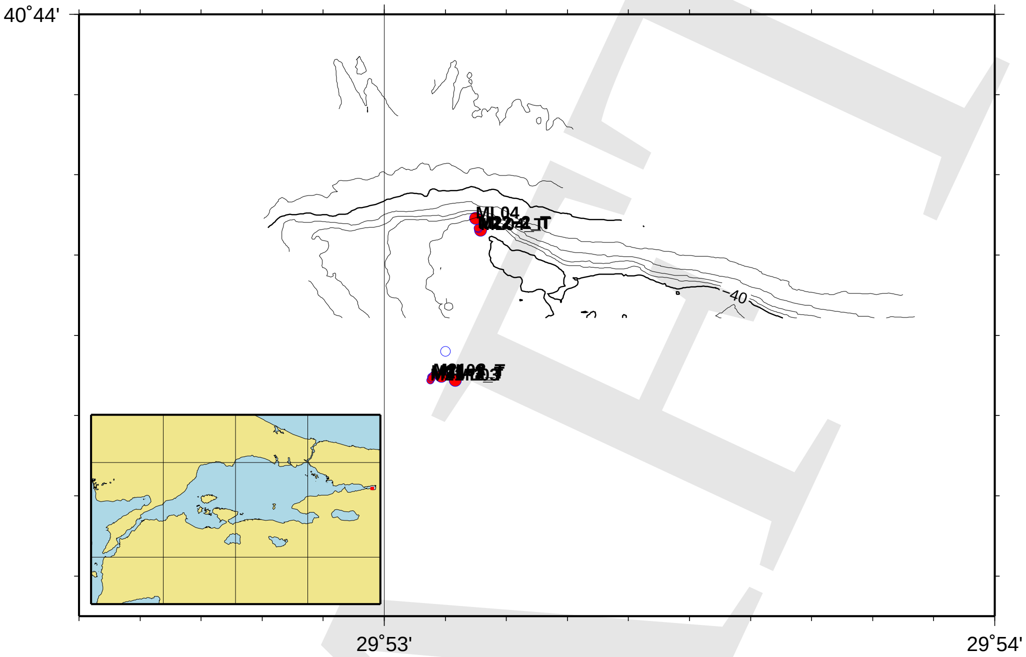

Figure 10: Ship tracks during cruise MARM10_02, Gölcük Area. Red and blue circles and squares are coring locations. Red hollow circles are CTD and water sampling locations.

SCIENTIFIC AND TECHNICAL PARTIES

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Zeynep Erden	ITU-EMCOL		
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Table 2: Scientific and technical parties

3. MATERIALS AND METHODS

The research cruise was carried out with the 61 meter *R/V Urania* (Fig.11), owned and operated by SO.PRO.MAR. and on long-term lease to CNR. The ship is normally used for geological, geophysical and oceanographical work in the Mediterranean Sea and adjoining waters, including but not limited to, the Atlantic Ocean, the Red Sea, and the Black Sea.

R/V Urania is equipped with DGPS and SEAPATH positioning system (satellite link by FUGRO), single-beam and multibeam bathymetry and integrated geophysical and oceanographical data acquisition systems, including ADCP, CHIRP SBP and other Sonar Equipment, other than water and sediment sampling. Additional equipment can be accommodated on the keel or towed.

Figure 11: *R/V Urania*.

3.1. NAVIGATION AND DATA ACQUISITION

The vessel was set-up for data acquisition and navigation with PDS-2000 software by RESON, interfacing by a multiserial and Ethernet link several instruments, among them the DGPS (Fugro), the Atlas-Krupp Deso-25 single-beam echosunder, the MAHRS MRU and the meteorological station. The position and depth data were also distributed to the CTD data acquisition console. A Kongsberg processor running the SIS software, collected the multibeam data, including a SEAPATH MRU, compass, and DGPS. The MBES was the 70kHz, 400 1x2°, 150°aperture EM-710 (2000 m range) model by Kongsberg, with sonar head positioned on the ship's keel using a V-shaped steel frame. A Sound Velocity probe at the keel 1m above the Sonar Head is interfaced directly to the MBES processor, thus providing the necessary real-time data for the beam-forming. CTD casts were used for input of the sound velocity profile to the system. An Anderaa Meteorological Station was also made available, at a rate of one measurement every 5 minutes.

POSITION	ACROSS	ALONG	HEIGHT
REFERENCE POINT	0.00	0.00	0.00
DGPS	1.64	14.30	14.18
MBEAM	0.00	14.36	-4.96
MAHRS	0.00	0.0	-3.40
ECHO SOUNDER 33	5.50	-1.85	-3.80
CHIRP	-1.0	11.80	-4.00
A-FRAME	6.5	-6.70	0.0
STERN	0.00	-30.60	0.00

Table 3: Instrumental Offsets of PDS2000 on Ship Urania (PDS2000). The GPS antenna (primary positioning system) is located on point DGPS.

POSITION	ACROSS	ALONG	HEIGHT
REFERENCE POINT	0.00	0.00	0.00
SEAPATH_GPS	-4.039	0.163	-18.211
MRU	-0.341	-1.342	-1.596
MBEAM_TX	0.0936	10.2964	5.0623
MBEAM_RX	-0.0031	11.0144	5.0600
SEALEVEL	0	0	-0.0875

Table 4: Instrumental Offsets on Ship Urania (EM710). The DGPS antenna (primary positioning system) is located on point SEAPATH_GPS.

CTD DATA

CTD casts were taken throughout the surveyed areas, for sound velocity analysis, and were used for real-time MBES acquisition and post-processing.

The position of the CTD stations are reported in Table 5 and can be viewed in Fig.3 and Fig.4, respectively.

LON	LAT	DATE_TIME	STATION
01535.15	3825.11	2010-09-30T08:02:38	CTD_01
01539.01	3628.99	2010-10-01T01:33:55	CTD_02
01538.97	3628.98	2010-10-01T04:27:50	CTD_03
02557.88	3956.93	2010-10-04T06:41:07	CTD_06
02717.75	4035.94	2010-10-04T15:51:45	CTD_07
02903.70	4044.80	2010-10-05T14:50:27	CTD_08
02923.19	4043.73	2010-10-06T06:16:10	CTD_09
02923.36	4043.75	2010-10-06T18:36:08	CTD_10
02808.32	4049.43	2010-10-09T20:11:43	CTD_11
02746.88	4049.02	2010-10-10T05:54:53	CTD_12
02807.11	4047.44	2010-10-10T17:00:55	CTD_13
02858.01	4023.92	2010-10-11T09:38:16	CTD_14
02846.57	4026.12	2010-10-11T19:35:49	CTD_15
02923.23	4043.73	2010-10-12T05:27:51	CTD_16
02953.10	4043.58	2010-10-12T08:52:07	CTD_17
02941.35	4043.85	2010-10-12T14:08:04	CTD_18
02923.58	4043.86	2010-10-12T21:03:59	CTD_19

Table 5: CTD positions, Time is UTC

CHIRP SBP

SBP data was acquired by the 16 transducers, hull mounted BENTHOS (DATASONICS) Mod.CAP-6600 CHIRP-II profiler, with operating frequencies ranging between 2 and 7 kHz. The pulse length was mantained at 20 ms while the trigger rates varied from 0.25 to 1 seconds according to water depth. Digital data acquired by the Communication Technology SWANPRO software were recorded in the XTF format on local disks and transferred on the network upon request. Backups were loaded on HD and DVD. The navigation data was made available to the system as lat/long by NMEA sentences of the DGPS receiver at a rate of aproximately 1 Hz or by the PDS200's NMEA at 1Hz. The XTF data were then converted to SEG-Y by the Triton-Elics's Xtf2Seg software. This latter data were then input to the ISMAR's SEISPRO software (Gasperini and Stanghellini, 2009) for data processing and display. Since the SEG-Y converted positions were found to be truncated, the accurate position data were recovered from the XTF headers by routines developed at ISMAR, and re-input to SEISPRO. The operation was also useful to check data integrity, other than for producing the navigation map and database.

3.2. SN4 BOTTOM OBSERVATORY

The INGV and TECNOMARE SN-4 observatory was developed in the framework of ORION (Ocean Research by Integrated Observatory Networks) EC project and deployed as node of ASSEM (Array of Sensors for long-term SEabed Monitoring of geohazards) EC project during a joint experiment in the Corinth Gulf (Greece, 400 m w.d.) in 2004 (Favali and Beranzoli, 2009), proving compatibility of GEOSTAR-class observatories with other networks.

All sensors installed on the observatory are managed by dedicated low-power electronics, able to perform the following tasks: (a) management and acquisition from all scientific packages and status sensors; (b) event detection; (c) preparation and continuous update of hourly data messages; (d) management of bidirectional communications via hydro-acoustic telemetry link (including transmission of seismic wave forms); (e) actuation of commands received (e.g., data request, system reconfiguration, restart) and (f) complete data back-up on internal memory. The SN-4 electronics can manage a wide set of data streams with quite different sampling rates tagging each datum according to a unique reference time set by a central high-precision clock.

During its first mission in Corinth Gulf SN-4 was equipped with a 3-C broad-band seismometer, an hydrophone and a methane sensor, with one year autonomous operation with 12-V, 960-Ah lithium battery pack. To reduce disturbance of the frame and electronics, special devices were designed and implemented for installing the seismometer, which is lodged in a dedicated vessel integrated in a separate structure connected to the SN4 by a special mechanical release. To guarantee a good coupling with the sea bottom, the structure is disconnected just after the touch-down and kept linked to the frame by a slack rope. This method of seismometer installation proved to record higher quality data during all the GEOSTAR-class observatory missions. For the Marmara mission the configuration of the SN4 was modified, aiming at better quantifying the temporal relations between fluid expulsion, fluid chemistry and seismic activity along the NAF. The new payload and relevant sampling rates are summarised in Tab.6. The station will be deployed using ship's winch and an acoustic release like in ASSEM mission, but the recovery procedure was redesigned, i.e. station will be recovered by a rope released by an acoustic command, letting the operations be performed by ship-of-opportunity. To achieve this result, the total weight in water was reduced to 0.15kN ($\approx$ 150 kg)from the 500kg in air by installing 8 benthospheres on the frame and adopting new lighter vessels for batteries and Electronics. This new fitting will make recovery and redeployment eeasier at the end of scheduled 6 months of activity . For future applications, SN-4 can be re-configured to operate as cabled observatory for permanent long-term real-time monitoring of the Marmara Sea to study relationship between fluids and seismicity.

INGV SN-4 is a multidisciplinary observatory, designed and built in cooperation with Tecnomare. It can support on-demand payloads and it is based on technical solutions developed for INGV Geostar-class observatories (¿4000 days of operation, 13 missions, up to 3320 m water depth). Its original seismometer management procedure, allows SN-4 to be re-configured to operate as cabled observatory (using a simple and cheap electrical umbilical cable, with cost in the order of few E/m).

The configuration for the ESONET Marmara Mission (Fig.12) was as follows:

- Communication with ship of opportunity by Sercel High Speed Acoustic Modem for data transfer and system's control
- Deployment via winch and acoustic release and recovery via pop-up system (recall buoy canister) actuated by acoustic release
- Autonomy about 6 months; Power: 12V,1920 Ah primary lithium pack;data storage 30GB HD
- Dimensions: 2000 x 2000 x 2000 mm; Weight: 6.5 kN in air, 1.5 kN in water

SENSOR	MODEL	SAMPLING RATE
Seismometer	Guralp CMG-40T	100Hz
Current meter	Nobsvka MAVS-3	5 Hz
CTD	SBE-16 Plus	1 sample/10min
Turbidimeter	Wet Labs Echo-BBRTD	1 sample/10min
CH_4 #1	Franatech METS	1Hz
Oxygen	Aanderaa Oxygen Optode 3830	1Hz

Table 6: INGV's SN-4 payload.

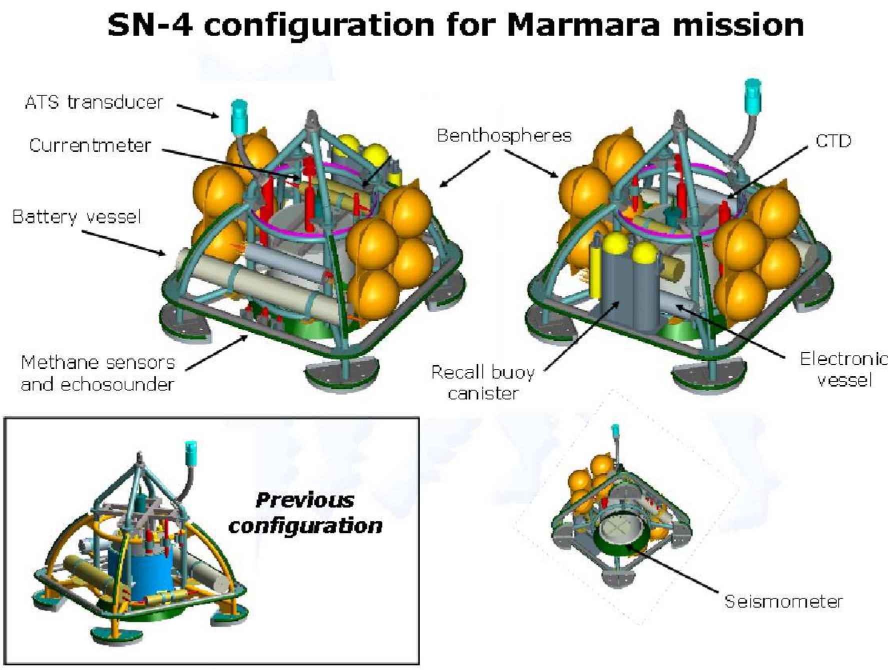

Figure 12: SN4 sketches.

3.3. *SEABED SAMPLING*

The sea bottom samples were collected with 1.2 Ton gravity corer, with 6m pipes, (Fig.**??**) and with a Sediment/water corer using 1,2m m liners, Cores recovered by the 1.2T corer were split on 1m long pieces.

The sample locations are shown in Fig.5,6, 7, 10, 9, 8 and are reported on Tab.7

3.4. *SAMPLE COLLECTION FOR MICROBIOLOGY*

The PARIS-Sud group collected two types of samples, seawater and sediment, in two main locations, the Ionian Sea and the Sea of Marmara.

Seawater samples were mainly obtained through CTD casting. 240 liters of seawater per CTD were collected for a total of 5 CTD castings (see Table **??**). Samples were taken at different depths, with the largest volumes collected at deep-sea waters (3000 to 3500 m in the Ionian Sea) or at the proximity of the observatory SN4 (154 m depth) in Marmara. Seawater was subsequently filtered through different pore-size filters (200, 20, 5 and 0.22 μm in diameter) to analyze various components of the microbial communities, from protists to prokaryotes and picoeukaryotes. Different fixation protocols were subsequently applied (see table). In addition, surface seawater samples (5l) were taken from the vessel in order to have a transect along the Italian Ionian Sea and the Sea of Marmara. Cells were concentrated for subsequent flow cytometry analyses.

Sediment samples (ca. 50 ml) were taken from the upper and lower part of cores taken from the Ionian Sea and the Marmara Sea (see attached table). Different sediment fractions were either frozen in liquid nitrogen or fixed using different protocols for subsequent analyses.

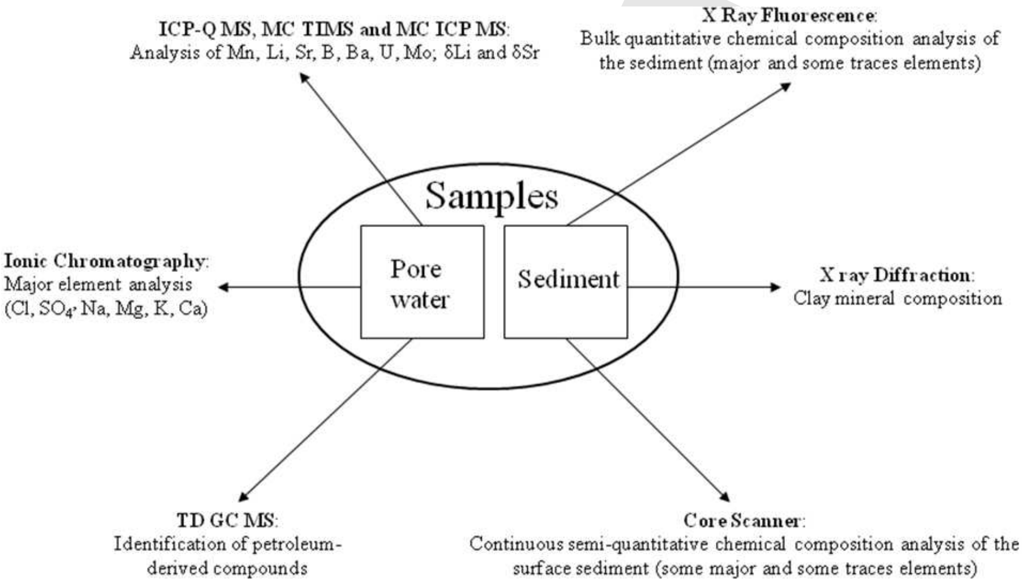

Figure 13: The RHYZON methodology for pore water extraction.

4. FLUID CIRCULATION STUDIES

In order to improve knowledge about the fluid-circulation within the Sea of Marmara, the IFREMER group have carried out pore-water extraction and thermal measurements in some selected fluid-active sites. Main focus was the Western High as gas hydrates have been recovered there, and there is ongoing study on their dynamics. A total of 7 cores have been collected on the Western High: 3 on the Northern part of the fault; 3 on the Southern part of the fault and 2 within the fault zone. Upon recovery, the pore waters have been collected for each core and for 4 selected cores, the measurement of the alkalinity has been performed on board. Thermal measurements have also been done on 5 sites (Cores 9A; 8A; 3A; 7I and 10A (Figure 1 & Table 1). Furthermore, we have extracted the pore-water from cores collected on the Izmit (ML04 & ML05) and Gemlik gulfs (ML-01_2) where no seeps activity has been characterized.

4.1. PORE WATER ANALYSIS

The geochemical analyses of both the pore water and the sediment aim at improving the understanding of fluid migration in chosen location in the Sea of Marmara. Fig.13 shows the methodology. A particular interest was given to the Western High as gas hydrates have been recovered there during the R/V L'Atalante 2007 Marnaut Cruise. The work proposed here in as continuation of the pore water analysis done by M.K.Tryon from samples recovered during the already mentioned Marnaut Cruise (Tryon et al., 2010).

- **Bottom sea water sampling**. From the CTD casts, the sea waters near the seafloor have been sampled in 5 stations in order to compare with the pore-water profiles. Plastic bottles were rinsed several times with water of the Rosette Bottle, filled and stocked in deep freezer at -20°C. Three of them were filtered.

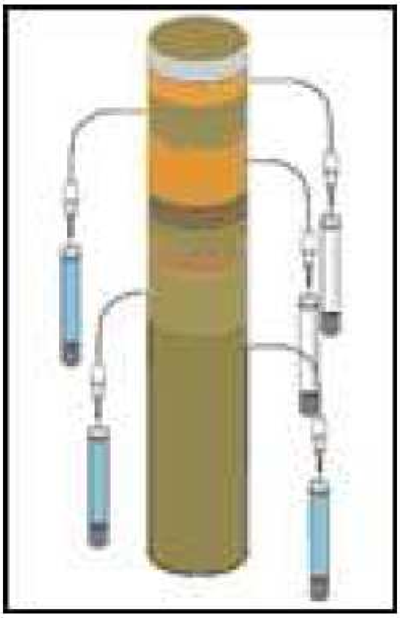

Figure 14: .Pore-water sampling from a core section using Rhizon technology

- **Pore-water sampling**. After recovery, the gravity cores were immediately cut into segments of 1m length. The whole round sediment sections were capped and transported to the shipboard laboratory for pore water extraction. The pore waters have been sampled for chemical analysis using the Rhizon soil moisture samplers. This is an innovative water extraction technology. The sampler consists of a hydrophilic, porous polymer tube of 2.5mm in diameter. The tube is permanently connected to the soil surface from one end, and to a connector for attaching a vacuum tube of 10mL from the other end where the samples are collected. The pore waters pass trough a filter 0.1 μm diameter, therefore no further filtration is required. The samplings were performed with a resolution of about 30cm in depth. In few hours following the sampling, the pore waters were analysed to determine their alkalinity by titration, using the 716 DMS Titrino and 728 Stirrer by Metrohm. This measurement has not been carried on the core recovered on the Western High. A number of 10 cores ware sampled for a total of 108 analysis on subsamples.

4.2. HEAT-FLOW MEASUREMENTS

Thermal conductivities have been measured on-board on the cores in order to determine the thermal conductivity of the sediments. The method of the hot- needle has been applied, which consists on the triggering an electric current in a needle. This current releases a certain amount of heat in one impulsion. A temperature sensor inside the needle measures the decrease with time of the temperature straight after the heating; then we can deduce, by the evolution of temperature with time, the thermal conductivity of the sediment.

4.1. MISCELLANEOUS

The WGS84 datum, the UTM35N projection and UTC were chosen for navigation and display, and for data acquisition. The time zone was set to the UTC for the instrumental data acquisition. The positioning maps and bathymetric images were produced with GMT (Wessel and Smith, 1995) and Globalmapper. The multibeam data were pre processed on board by the GMT software and ISMAR's routines and scripts, using the SIS production DTMS, after conversion to the ASCII format.

ISMAR'S Bathymetric data were complemented by the IFREMER's DTM of Sea of Marmara (Le Pichon and et al., 2005). On-land SRTM topography data was used for mapping, structural analysis, after conversion to NETCDF GMT grid files.

The computing center employed INTEL based PC running the GNU-Linux in addition to portable computer for data acquisition and personal processing. The Linux machines were used as data repositories using the SAMBA software, providing alse network services like WWW, DHCP and NAT.

5. DESCRIPTION OF DEPLOYMENTS AND OF DATA COLLECTED

Initial results are presented, in order to address the importance of the preliminary findings and processing sequence of the data acquired.

5.1. SN-4 OBSERVATORY RECOVERY

SN4 was recovered in March 2010 during Cruise MARM10_01 by R/V Yunus, and was redeployed after servicing (see CRUISE REPORT MARM10_01 http://www,ismar.cnr,it) ..

The recovery of the INGV's SN-4 at the entrance of the Gulf of İzmittook place evening of 2010-10-03. After several attempts of unsuccessful releases, a multibeam survey located it about 100m SE of March 2010's deployment, A ROV dive confirmed the possible target as the SN4, that was found to be tilted and turned over the bottom, with release mechanism buried in sediment. The last ROV dive was able to drive a hook into the frame and the SN4 was recovered by ship's winch (Fig.15). A quick analysis of the data revealed that the system was moved end of september, a few weeks before our arrival.

Figure 15: SN-4 overturned on bottom being uplifted by hook.

5.2. SEABED SAMPLING

Tables 7 and **??** show the positioning data and description of samples.

Table 7: Bottom sample positions. Latitude, Longitude true position, Time UTC

LON LAT	EAST NORTH	DATE TIME	CORE	LEN	DEPTH
dd.xxx	UTM 35	UTC		cm	m
15.920829 37.371277	0 0	2010-09-30 16:28:30	IONMAR01_BT		
17.077440 36.766446	0 0	2010-10-01 13:24:04	IONMAR03_BT_TRUE		
18.694505 36.590906	0 0	2010-10-01 22:52:41	IONMAR04_BT		
29.383014 40.729429	701241 4511453	2010-10-07 07:27:03	M01-1_	45	-186.8
29.382977 40.729611	701238 4511473	2010-10-07 07:43:20	M01-2_	45	-187.8
29.384824 40.729951	701392 4511515	2010-10-07 08:15:27	M02-1_	50	-190.0
29.384775 40.729892	701388 4511509	2010-10-07 08:30:06	M02-2_	55	-189.5
29.387927 40.729071	701657 4511425	2010-10-07 08:50:09	M03-1_	43	-150.8
29.387985 40.729043	701662 4511422	2010-10-07 09:07:12	M03-2_	31	-150.0
29.387917 40.729084	701656 4511426	2010-10-07 10:30:00	M03-3_	40	-151.1
29.393100 40.728774	702095 4511404	2010-10-07 12:19:47	M04-1_	35	-120.7
29.393142 40.729061	702098 4511436	2010-10-07 12:37:37	M04-1_	35	-122.4
29.393010 40.728946	702087 4511423	2010-10-07 12:48:18	M04-2_	40	-122.1
29.392973 40.728953	702084 4511423	2010-10-07 13:10:00	M04-3_	40	-122.4
29.392992 40.729073	702085 4511437	2010-10-07 13:46:31	M04-4_	-1	-123.3
29.393077 40.729076	702092 4511437	2010-10-07 14:05:36	M04-5_	-1	-122.8
29.394446 40.728532	702209 4511380	2010-10-07 14:26:15	M05-1_	68	-116.2
29.394398 40.728418	702206 4511367	2010-10-07 14:35:26	M05-2_	70	-116.3
29.425940 40.734713	704850 4512139	2010-10-07 15:00:09	M06-1_	72	-74.2
29.425497 40.734645	704813 4512131	2010-10-07 15:09:12	M06-2_	75	-74.4
29.426268 40.734804	704878 4512150	2010-10-07 15:18:26	M06-3_	75	-73.9
29.458769 40.730053	707637 4511699	2010-10-07 15:41:20	M07-1_	25	-58.9
29.458533 40.730177	707617 4511712	2010-10-07 15:54:58	M07-1__TRUE	25	-58.8
29.564169 40.724983	716555 4511391	2010-10-07 17:08:22	M08-1_	55	-136.4
29.682235 40.731031	726507 4512360	2010-10-07 18:11:13	M09-1_	93	-208.5
29.681855 40.731277	726474 4512387	2010-10-07 18:25:09	M09-2_	95	-208.4
29.694155 40.729429	727519 4512214	2010-10-07 18:46:00	M10-1_	104	-209.2
29.694194 40.729636	727522 4512237	2010-10-07 19:04:05	M10-2_	103	-209.2
29.360351 40.730162	699325 4511483	2010-10-08 06:02:00	M12-1__TRUE	-1	-192.4
29.360318 40.730226	699322 4511490	2010-10-08 06:15:00	M12-2__TRUE	-1	-193.0
29.331238 40.728881	696870 4511275	2010-10-08 06:46:00	M11-1__TRUE	91	-288.5
29.331298 40.728925	696875 4511280	2010-10-08 06:58:00	M11-2__TRUE	83	-289.4
29.331296 40.728862	696875 4511273	2010-10-08 07:20:00	M11-3__TRUE	83	-287.7
29.331298 40.728925	696875 4511280	2010-10-08 07:40:00	M11-4__TRUE	-1	-289.4
27.780366 40.817896	565811 4518835	2010-10-10 05:34:41	MF02A_	420	-681.7
27.780677 40.817799	565837 4518824	2010-10-10 05:35:03	MF02A__TRUE	420	-683.9
27.760828 40.812241	564168 4518193	2010-10-10 07:51:53	MFT09A_	300	-660.3
27.761310 40.812192	564209 4518188	2010-10-10 08:05:04	MFT09A__TRUE	300	-659.9
27.757998 40.812057	563930 4518170	2010-10-10 09:10:03	MFT08A_	321	-658.5
27.758279 40.811888	563954 4518152	2010-10-10 09:10:13	MFT08A__TRUE	321	-655.2
27.771131 40.814496	565035 4518451	2010-10-10 10:35:56	MFT03A_	345	-688.3
27.770812 40.814655	565008 4518468	2010-10-10 10:36:11	MFT03A__TRUE	345	-686.2

Table 7: Bottom sample positions. Latitude, Longitude true position, Time UTC

LON LAT	EAST NORTH	DATE TIME	CORE	LEN	DEPTH
dd.xxx	UTM 35	UTC		cm	m
27.737787 40.809158	562228 4517834	2010-10-10 11:46:46	MFT07I_	357	-641.7
27.737464 40.809212	562201 4517840	2010-10-10 11:47:03	MFT07I__TRUE	357	-642.5
27.761135 40.809067	564197 4517841	2010-10-10 12:56:12	MFT10A_	390	-627.0
27.760812 40.809165	564170 4517851	2010-10-10 12:56:23	MFT10A__TRUE	390	-627.8
27.776022 40.817516	565445 4518790	2010-10-10 14:26:19	MF11A_	350	-680.8
27.775714 40.817632	565418 4518802	2010-10-10 14:26:26	MF11A__TRUE	350	-679.8
28.967182 40.398409	666943 4473836	2010-10-11 09:54:56	M13-1_	86	-113.0
28.967157 40.398370	666941 4473832	2010-10-11 10:04:31	M13-2_	83	-113.0
28.967179 40.398771	666942 4473876	2010-10-11 10:18:27	ML01-1_	339	-112.9
28.967247 40.398504	666949 4473847	2010-10-11 10:18:47	ML01-1__TRUE	339	-113.0
28.967204 40.398774	666944 4473877	2010-10-11 10:59:03	ML01-2_	270	-112.9
28.967243 40.398496	666948 4473846	2010-10-11 10:59:28	ML01-2__TRUE	270	-113.0
29.029374 40.415851	672177 4475892	2010-10-11 11:42:57	ML02-1_	325	-72.7
29.029023 40.415810	672148 4475886	2010-10-11 11:43:28	ML02-1__TRUE	325	-73.0
29.029011 40.415565	672147 4475859	2010-10-11 12:14:19	ML02-2_	343	-72.7
29.029045 40.415834	672149 4475889	2010-10-11 12:14:41	ML02-2__TRUE	343	-72.9
29.029069 40.415844	672151 4475890	2010-10-11 12:25:40	M14-1__TRUE_	103	-72.9
29.029111 40.415715	672155 4475876	2010-10-11 12:25:45	M14-1_	103	-72.8
29.029128 40.415798	672156 4475885	2010-10-11 12:35:21	M14-2_	110	-72.9
29.029045 40.415846	672149 4475890	2010-10-11 12:35:44	M14-2__TRUE	110	-72.9
29.037500 40.394275	672922 4473512	2010-10-11 13:08:14	M15-1_	85	-74.3
29.037404 40.394296	672914 4473514	2010-10-11 13:08:36	M15-1__TRUE	85	-74.4
29.037493 40.393998	672922 4473482	2010-10-11 13:19:34	M15-2_	85	-74.2
29.037503 40.393938	672923 4473475	2010-10-11 13:19:50	M15-2__TRUE	85	-74.2
29.039466 40.406327	673058 4474854	2010-10-11 13:49:19	M16-1_	90	-65.4
29.039421 40.406382	673054 4474860	2010-10-11 13:49:32	M16-1__TRUE	90	-65.5
29.039415 40.406343	673054 4474856	2010-10-11 14:06:28	M16-2_	97	-65.5
29.039476 40.406319	673059 4474853	2010-10-11 14:06:51	M16-2__TRUE	97	-65.4
29.063159 40.455156	674942 4480321	2010-10-11 14:47:37	M17-1_	80	-70.9
29.063100 40.455158	674937 4480321	2010-10-11 14:48:10	M17-1__TRUE	80	-70.9
29.023677 40.440470	671631 4478614	2010-10-11 15:18:17	M18-1_	78	-87.7
28.914808 40.449011	662377 4479356	2010-10-11 17:07:36	M19-1__TRUE	101	-96.8
28.914689 40.449009	662367 4479355	2010-10-11 17:17:31	M19-2__TRUE	98	-96.7
28.858508 40.466289	657562 4481172	2010-10-11 17:46:05	M20-1_	90	-70.2
28.858584 40.466290	657568 4481172	2010-10-11 17:46:30	M20-1__TRUE	90	-70.1
29.884615 40.725798	743630 4512400	2010-10-12 09:02:09	M21-1_	-1	-1
29.884589 40.725736	743628 4512393	2010-10-12 09:02:27	M21-1__TRUE	-1	-1
29.884669 40.725838	743634 4512405	2010-10-12 09:11:21	M21-2_	-1	-1
29.884631 40.725773	743631 4512397	2010-10-12 09:11:39	M21-2__TRUE	-1	-1
29.885269 40.725733	743685 4512395	2010-10-12 09:23:46	ML03_	-1	-1
29.884896 40.725817	743653 4512403	2010-10-12 09:24:04	ML03__TRUE	-1	-1
29.885832 40.729101	743709 4512692	2010-10-12 10:00:44	ML04_	290	-39.7

Table 7: Bottom sample positions. Latitude, Longitude true position, Time UTC

LON LAT	EAST NORTH	DATE TIME	CORE	LEN	DEPTH
dd.xxx	UTM 35	UTC		cm	m
29.885959 40.728851	743721 4512664	2010-10-12 10:00:59	ML04__TRUE	290	-39.8
29.885908 40.728878	743717 4512667	2010-10-12 10:14:00	M22-1__TRUE	113	-39.8
29.885880 40.728896	743714 4512669	2010-10-12 10:20:08	M22-2__TRUE	113	-39.8
29.689346 40.731286	727107 4512407	2010-10-12 13:56:18	ML05_	290	-209.0
29.689229 40.731046	727098 4512380	2010-10-12 13:56:48	ML05__TRUE	290	-208.9
29.689527 40.731206	727122 4512399	2010-10-12 14:35:10	ML05-1_	293	-208.7
29.689219 40.731085	727097 4512385	2010-10-12 14:35:33	ML05-1__TRUE	293	-208.9
15.845737 37.332305	0 0	2010-10-16 17:59:19	IONMAR02_BT_TRUE		

5.3. CHIRP SBP

A quick processing with SEISPRHO (Gasperini and Stanghellini, 2009) was made on board for navigation and geological target selection, other that structural and stratigraphical analysys. Example of the recorded and processed data are shown in Fig.16, **??**, **??** and **??**.

The data quality ranged from good to very good, with penetration down to 40 m.

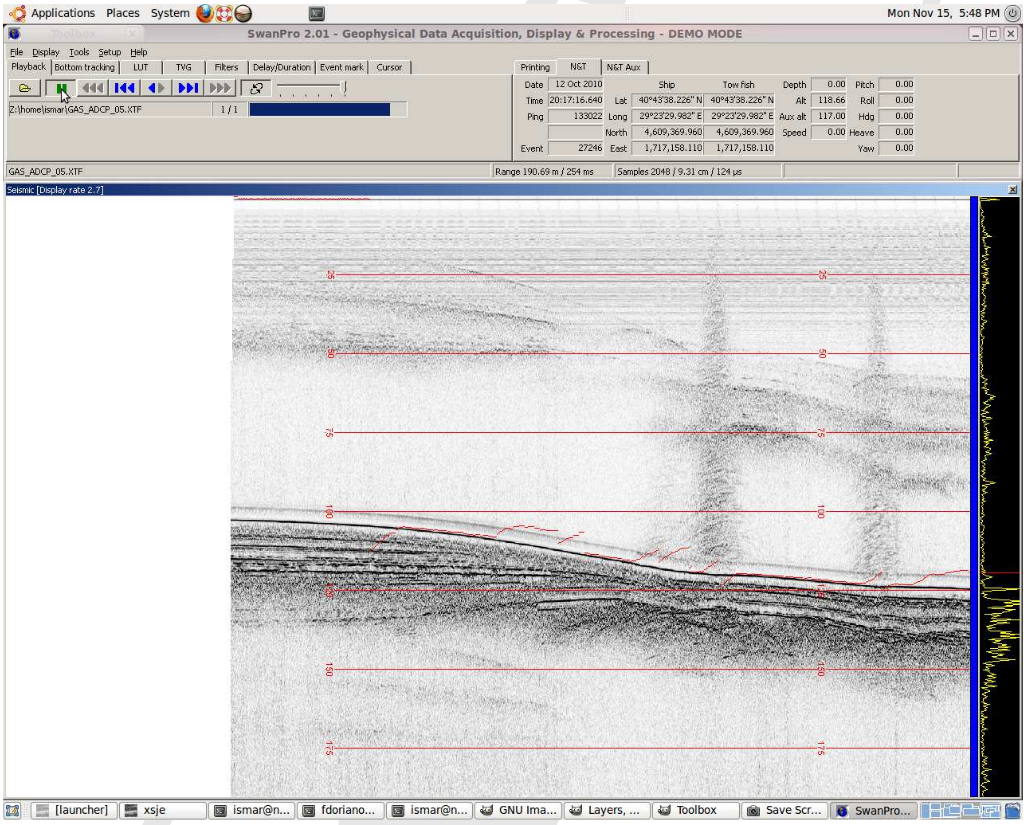

Figure 16: Example of raw data acquired with COMM-TEC Swanpro Software. The picture show gas flowing in the water column on a 'pockmark' along the NAF. The area was also investigated with ADCP (see Fig.6).

5.4. CTD AND SOUND VELOCITY DATA

Figure 17 shows the SV profiles, the TS diagram and location of the CTD casts, in Marmara and the Dardanelles.

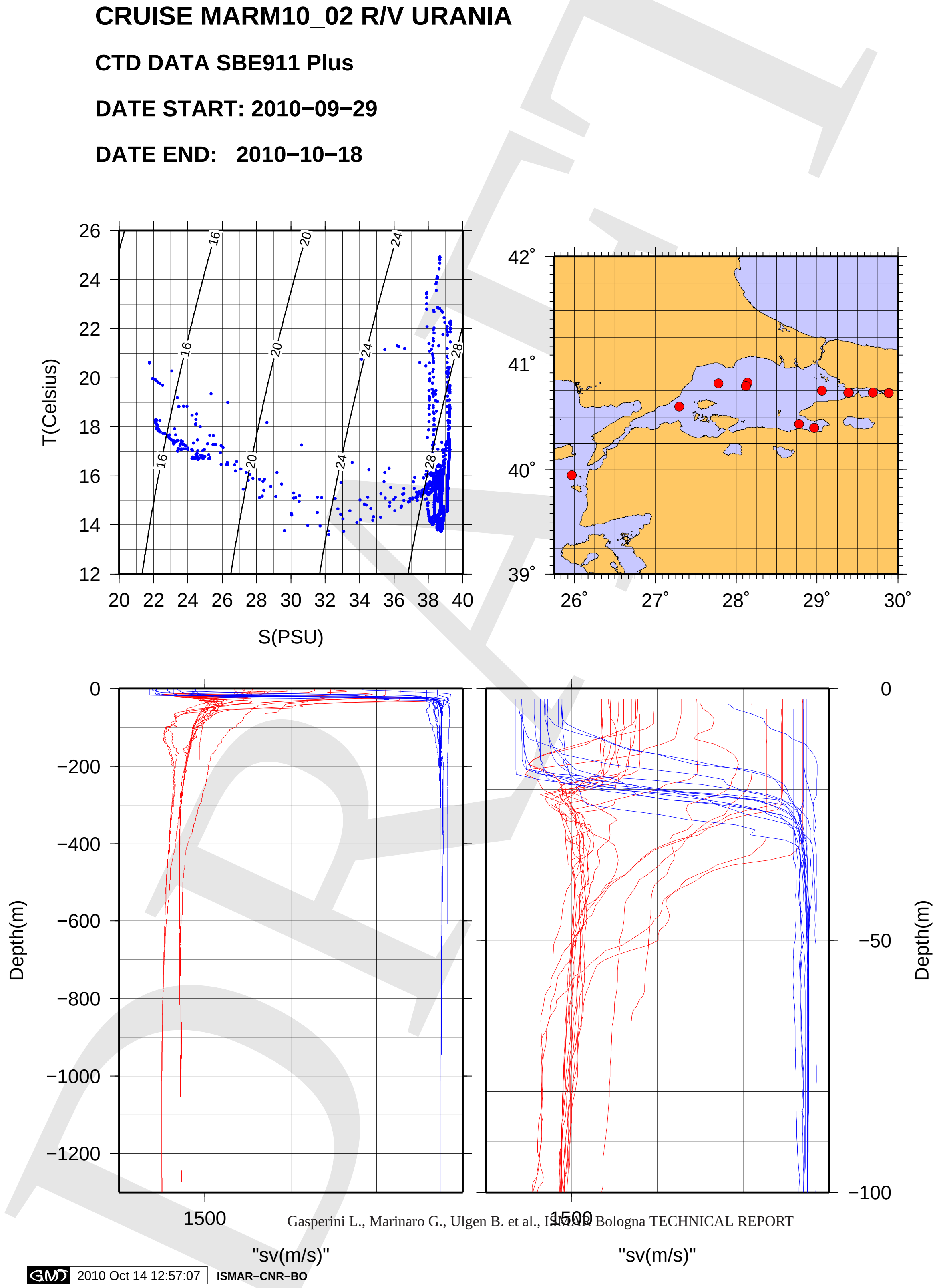

Figure 17: Cruise MARM10_02 CTD casts. Lower left: Sound Velocity(gray), T(red,12-26), S(blue, 20-40PSU). Lower right: TS diagram.

6. CONCLUDING REMARKS AND FUTURE WORKS

Main targets of MARMARA2009 cruise have been reached. A schematic list of first results is indicated.

- **Recovery of the SN4 observatory** Th SN4 Observatory was found to be overturned on bottom and to be moved twice by 40-50m SE of the deployment site of the MARM10_01 cruise with R/V Yunus, during the second half of september. The system have been located by the multibeam and by three ROV dives. The last ROV dive was able to drive a hook into the frame and the SN4 was recovered by ship's winch.
- **Sampling of the seabed** The seabed have been sampled by ISMAR gravity corers and turkish Water/sediment corers, that were also used for preserving the uppermost veneer and overlying waters. On one 6m pipe of the ISMAR corer 6 temperature sensors were installed at different lengths along the pipe, for heat flow and thermal conductivity measurements. The pore waters were collected within few hours from the recovery by the Rhizone method, employing syringes and 0.1 μm filter. The so collected pore waters have been store in deep-freezer and liquid N. The cores and water samples will be used for fluid migration analysis.
- **ROV survey** Apart from the dives on the SN4, we launched the ROV on the gulf of Gölcük close to the 1999 earthquake rupture visible at the seafloor just S of the NAF, and on some sites potentially interesting for gas and fluid emissions. Those emissions were somewhere detected as anomalous reflections of the sonars in the water column and subsequently investigated using the 300 KHz ADCP.
- **Geophysical data**

  First results highlighted the high-resolution of the MB and the Chirp system on board of Urania that fitted perfectly the requirement of accuracy in mapping the subtle trace of active faults in the Sea of Marmara.

Analysis of the data collected during the expedition is under process, and will continue during the forthcoming several months.

No problems were encountered regarding neither the people nor the environment during the cruise.

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7. APPENDIX

7.1. DIARY OF OPERATIONS

- 2010-09-29 Mobilization and embarkation of participants. Leave dock on 16:30 UTC, heading to Messina.
- 2010-09-30 Coring and Water sampling in the Ionian Sea.
- 2010-10-04 Arrive Cannakale at Dardanelles. Make bathymetry Western and Central Mrmara Sea close to earthquake epicenter.
- 2010-10-04 Anchored SW Istanbul. Embark Turkish and French Teams.
- 2010-10-13 Istanbul, disembark of Turkish and French participants. Sailing to Napoli, 14:00 UTC.
- 2010-10-17 Core IONMAR-02 E of Catania.
- 2010-10-17 Recover NE Stromboli and Marsili INGV' OBS deployed during PANSTR10 Cruise.
- 2010-10-18 Disembark people and de-mob on Napoli.