CONSIGLIO NAZIONALE DELLE RICERCHE
ISTITUTO PER LA GEOLOGIA MARINA

SWATH BATHYMETRY AND GEOPHYSICAL SURVEY OF THE TYRRHENIAN SEA

REPORT ON BATHYMETRIC, MAGNETIC AND GRAVIMETRIC INVESTIGATIONS DURING CRUISES TIR96 AND TIR99

**G.Bortoluzzi, G.Carrara, P.Fabretti,
F.Gamberi, M.Marani, D.Penitenti, G.Stanghellini, M.Tonani, N.Zitellini,
C.Bonazzi, S.Lippolis, M.Musacchio (IGM)
A.Daviddi, G.Diroma, A.Ferrarini, A.Leotta (IIM)
D.Gilod, B.Nikaronenkov (MSU)
V.Efimov, S.Erofeev (GIN)**

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Abstract - A summary of the ship-board results of two swath bathymetry and geophysical surveys in the Tyrrhenian and Ionian seas is presented. The research cruises were done within the framework of the National Research Council and ”Dip.Servizi Tecnici Naz. - Pres.Consiglio” funded project “Lithosphere Formation in mid-oceanic ridges and back- arc basins : Geological Studies in the Equatorial Atlantic and Tyrrhenian Sea”. Apart from the detailed makeup of the Tyrrhenian seamounts and surrounding margins, with important implications that concern the rifting and opening of the Tyrrhenian Sea, the surveys have substantially increased our understanding of the basin-wide sedimentary dynamics through the combined use of the bathymetric and sonar data. The same combination, in addition to the magnetic data has also allowed the recognition of several new areas of recent submarine volcanic activity.

Sommario - Vengono presentati le metodologie e l’insieme dei risultati ottenuti durante due campagne di batimetria e geofisica nel Tirreno e nello Ionio, finanziate dal CNR e dal Dipartimento dei Servizi Tecnici Nazionali - Presidenza del consiglio. Al di la’ del dettagliato rilievo morfologico dei monti e dei margini Tirrenici, con importanti implicazioni sulla comprensione dei processi tettonici, si e’ ottenuto anche un sostanziale aumento della comprensione dei processi sedimentari a scala di bacino con l’uso combinato di dati batimetrici e sonar. Assieme ai dati di magnetometria si potra’ ottenere anche una maggiore definizione delle aree di magmatismo e vulcanesimo recente.

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ACRONYMS

ACRONYM	DESCRIPTION	URL-email
CNR	Consiglio Nazionale Delle Ricerche	www.cnr.it
IGM	Istituto per la Geologia Marina CNR	www.igm.bo.cnr.it
GIN	Geological Inst. Acad. Sc. Russia	Moscow, Russia
MSU	Moscow State University	www.msu.ru
PNRA	Progetto Nazionale Ricerche Antartide	www.pnra.it
ENEA	Ente Nazionale Energie Alternative	www.enea.it
IFREMER	Inst. Francais Eploitation Mer	www.ifremer.fr
DSTN	Dip. Servizi Tecnici Naz. - Pres.Cons.	www.dstn.it
GNV	Gruppo Nazionale Vulcanologia	
IIM	Istituto Idrografico della Marina	Passo Osservatorio, Genova
CGGE	Central Geol. Geophys. Expedition	Gelendzhik, Russia
UNESCO	United Nations Scient. and cultural org.	www.unesco.org
IOC	Intergov.Oceanogr.Comm. of UNESCO	www.ioc.org
IHO	Int. Hydrographic Organization	www.iho.org
BODC	British Oceanographic Data Center	www.nbi.ac.uk/bodc
IIV	Int. Inst. Vulcanology	www.iiv.ct.cnr.it
JOG	Joint Operation Group	
SACLANT	SACLANT Undersea Research Centre	www.saclantc.nato.int
IFA	Istituto Fisica Atmosfera CNR	www.ifa.rm.cnr.it
ING	Istituto Nazionale Geofisica	www.ingrm.it
OGS	Osservatorio Geofisico Sperimentale	www.ogs.it
IOF	Istituto Oceanografia Fisica CNR	www.iof.sp.cnr.it
ITS	Istituto Talassografico Trieste CNR	www.its.ts.it
GAS	Geological Application and Services	gas@asianet.it
SOPROMAR		
SEG	Society of Exploration Geophysicists	www.seg.org
GNU,GPL	GNU is not Unix,General Public License	www.gnu.org
GEBCO	General Bathymetric Chart of the Ocean	www.nbi.ac.uk/bodc/gebco.html
IBCM	Int. Bathym. Chart of the Mediterranean	www.nbi.ac.uk/bodc/gebco.html
MEDATLAS	Mediterranean Atlas	www.ifremer.fr/sismer/program/medatlas/gb/gb_medat.htm
WODB98	World Ocean Database 1998 edition	
NEPTUNE,MERLIN,IRAP	Kongsberg-Simrad	www.kongsberg-simrad.com/Products
CARAIBES	Traiment Cartographique Batimetrie	www.ifremer.fr/dnis_esi/cartographie/caraibes/index.html
GMT	Generic Mapping Tool	imina.soest.hawaii.edu/gmt
MySQL	Data Base Management System	www.tcx.se
GLOBE	Global 1km Land Project	www.ngdc.noaa.gov/seg/topo/globe.shtml
PostScript,PDF		www.adobe.com

Table 1: Acronyms of Organizations, Manufacturers, Products

PREFACE

This document reports the activity during two cruises in the Tyrrhenian Sea, that were planned to achieve the full bathymetric coverage of the basin, along with other important geophysical information. The Project, coordinated by E.Bonatti, was funded by CNR and other Scientific and Governmental Italian Agencies. To obtain this goal, the Institute of Marine Geology used most of its organizational, technical and scientific skill, in the use of modern swath bathymetry systems.

Since 1991 IGM started to work with multibeams. Several cruises were run with the russian ship A.N. Strakhov of GIN in the Equatorial and South Atlantic ([1],[2]). The bathymetric data were acquired with a medium resolution instrument (HOLLMING 626). During November 1995 a cruise around the Aeolian Islands with the ship J.Charchot provided very good quality data by SIMRAD's EM12 and EM1000 [5]). At the end of 1995 R/V Gelendzhik of CGGE (Russia) installed a high resolution multibeam (SIMRAD EM12-120S) and was chartered to IGM for a 6 months period during 1996, for works in the Atlantic Ocean (at the Bouvet Triple Junction and at the Romanche Fracture Zone, [3],[6],[4]), and in the Tyrrhenian Sea (first cruise, september and october 1996, TIR96). The operation was possible because of joint PNRA/ENEA fundings, that facilitated the contract and provided 4 months of work at sea in the Atlantic Ocean with minimum transits.

In 1998 R/V A.N.Strakhov installed a SIMRAD EM12-120S, owned by ELETTRA, a TELECOM ITALIA company, who signed a contract with ship owners and IGM, that had the opportunity to use the vessel for two months per year. During February and March 1999 we had the second cruise in the Tyrrhenian Sea (TIR99).

Whilst the Thyrrenhian project was in the pipeline, IGM started a very good cooperative relationship with the Hydrographic Institute of the Navy (IIM), that pushed into the project the multibeam and single-beam data acquired by their ships in the Aeolian and Sicilian Areas, along with very important data for datum shifts. The integration of these datasets was somehow challenging, because of the different gridding system and datum. More than the simple exchange of data and personnel, IIM offered also professionalism in hydrography and cartography, and the possibility of important future cooperation.

The project is still underway for the final processing of the data, expecially magnetics, gravimetry and seismics.

AUTHORSHIP

Giovanni Bortoluzzi wrote and finalized the main body of this report, in addition to being involved in the general organization and execution of the project.

D.Penitenti and G.Carrara took in charge the swath bathymetry data acquisition and processing. They wrote chapter 4.1, in addition to producing and finalizing the DTMs and cartographic production of both the 1996 and 1999 data. P.Fabretti helped with the processing of the second leg of TIR96. D.Penitenti was also responsible of the positioning data.

N.Zitellini was chief scientist for the first leg of TIR96, whereas M.Marani lead the second leg of TIR96 and the whole TIR99 cruise. They wrote the Geological Settings (part 1.1).

M.Tonani wrote the chapters regarding the Oceanographic Settings (1.2) and the analysis of the XBT-XCTD data of TIR99 (3.4.2).

HOW TO READ THIS REPORT

Part 1 gives the introductory and background information and settings, along with some technological and scientific issues that were involved in the organizational and execution tasks. The marine operations and results of the two cruises TIR96 and TIR99, are presented and discussed in Parts 2 and 3, respectively. The problems of data processing are addressed by Part 4 , whereas Part 5 gives some concluding remarks and targets the on-going data processing and usage. Some data processing procedures that were used in the production of this Report alongwith further technical details and data are presented in Appendix.

ACNOWLEDGMENTS

Many people contributed to the success of the project, and we apologize for any oversight. The project was funded by CNR and by the DSTN and GNV. We are indebted to the IGM, CNR and DSTN management staffs for the continuous efforts in tackling and solving the financial and technical problems. We wish to thanks Capt. Y.Sikora, the officers crew and Navigation Team of R/V Gelendzhik, and Capt. L.Sazonov, the officers and crew of R/V A.N.Strakhov for their professionalism and efforts in assuring the success of the two cruises.

Dr. Selshopp of SACLANT provided us with extremely useful XCTD probes and Dr. Santoleri of IFA made available XBT probes. We are indebted and warmly aknowledge them. Dr. Del Negro and Dr. R.Napoli of IIV-CNR of Catania and Dr. De Santis of ING of Rome kindly provided the Magnetic Observatory data. We are indebted and warmly aknowledge them. Prof. Marson of the University of Trieste and OGS, and Dr.Carbone of IIV helped us with the calibration of the gravimeters, with data and instrumentation. Prof. Nadia Pinardi helped with suggestions and discussions, together with Dr. G.P.Gasparini of IOF and Dr. Sparnocchia of ITS. We thank also ENEA-PNRA for the availability of instrumentation, and Dr. Tricart and IFREMER for the availability of some Swath Data in the Sardinia Channel. We thank ELETTRA for the availability of ship Strakhov and GAS for intrumentation during cruise TIR99. Mr. F. Occhiena and Mr. Bacchiega of GAS supervised Strakhov's Navigation and Multibeam equipment during the first and second leg of TIR99, respectively. Dr. Viezzoli of SO.PRO.MAR. helped for the equipment handling in Civitavecchia.

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Part 1

INTRODUCTION

THE PROJECT

In 1995, the Italian National Research Council (CNR) approved extra-budgetary funding (Progetto Strategico) for a project proposal entitled “Lithosphere Formation in mid-oceanic ridges and back-arc basins : Geological Studies in the Equatorial Atlantic and Tyrrhenian Sea” submitted by the Institute of Marine Geology (IGM) of Bologna. The project, coordinated by E.Bonatti, concerned detailed morfo-bathymetric and geophysical (magnetic, seismic and gravimetric) surveys of two end-member marine areas, the Equatorial Atlantic and the Tyrrhenian Sea, with the principal aim of determining their development in a geodynamic context. The project has been underway since May 1996, starting with a cruise in the Equatorial Atlantic (Romanche Fracture Zone) and foreseeing two campaigns in the Tyrrhenian Sea. This report targets the two research campaigns in the Tyrrhenian Sea (TIR96 and TIR99) that took place in 1996 and 1999, and presents an overview of the equipment used during survey operations and a preliminary insight to the results obtained.

The first expedition used the 104 m R/V Gelendzhik owned by CGGE of the Russian Federation, that was chartered to IGM by a direct contract. The second expedition used the 71 m R/V A.N.Strakhov of GIN, that was chartered to IGM upon a collaborative contract between GIN and ELETTRA (ships owners and Multibeam owners, respectively). Additional agreements for both the surveys were made with MSU for the gravimeters, and with GIN for single-channel reflection seismic. Survey planning and acquisition was supervised by IGM. IIM and GIN teams helped during data acquisition. Collaborative technical assistance to the marine gravimeters and seismic streamer were undertaken by personnel from MSU and GIN.

1.1 GEOLOGICAL SETTING

The Tyrrhenian Sea is surrounded to the east and south by the seismically active Apennine-Maghrebid fold and thrust belt, and to the west by the passive margin of the Sardinia-Corsica block. It is the most recent oceanic basin in the Mediterranean. Fig 1 presents the Tyrrhenian Basin within the regional bathymetric and topographic context, whereas Fig. 2 zooms into the area.

The results of ODP Leg 107 [14] showed that initial formation of the basin began in upper Tortonian due to crustal thinning of the plate comprising Corsica, Sardinia and Calabria. The E-ESE directed rifting process continued until upper Pliocene along the western margin. Basinwards, the western Tyrrhenian is characterised by thermal subsidence of the thinned crust and the emplacement, during the lower Pliocene, of oceanic crust in Vavilov basin. Subsequent crustal thinning continues to the east with emplacement of oceanic crust beginning at aprox. 2 My in the Marsili Basin, bordered by the active volcanism associated with the Eolian Island Arc. Characteristic features of the basins are the large volcanic edifices of Marsili , Vavilov and Magnaghi emplaced above the basaltic crust (Fig. 2).

The most widely accepted mechanism to explain the migration in space and time of rifting and oceanic crust emplacement links the eastwards migration of crustal thinning and oceanic accretion to the passive roll-back of the subducting Ionian plate beneath Calabria ([15], [16]). Thinning of the Tyrrhenian lithosphere is explained either by eastwards migrating rifting ([17], [18], [19]) or by east-dipping ([20], [14]) or west-dipping [21] crustal detachment shear zones.

The young age of the Tyrrhenian Sea implies that tectonic and associated volcanic processes exert a strong control on the its sedimentary dynamics and make-up. The western margin represents a typical passive continental margin while the eastern and southern margins are associated with high seismicity, active volcanism and elevated rates of uplift of land areas. In these latter areas, an important contribution to material entering the basin is given by the deposits deriving from both onshore and marine volcanic activity. The deeper parts of the basin are areas of terrigenous and volcanoclastic turbititic accumulation.

Numerous submarine canyons dissect the continental slopes, representing major sediment transport pathways from the margins and slope basins to the deeper parts of the basin. Important additional sediment transfer mechanisms are represented generally by gravitational failures of margins or parts of volcanic edifices triggered by seismic or volcanic activity.

The cruises that are reported here intend to add another dimension to the data collected so far in the Tyrrhenian Sea by investigating in detail the surficial morphology of the basin for the first time. Given the young age of the basin, we have found that much can be deduced about the geodynamic evolution, volcanic activity and sedimentary dynamics of this land-locked sea through time.

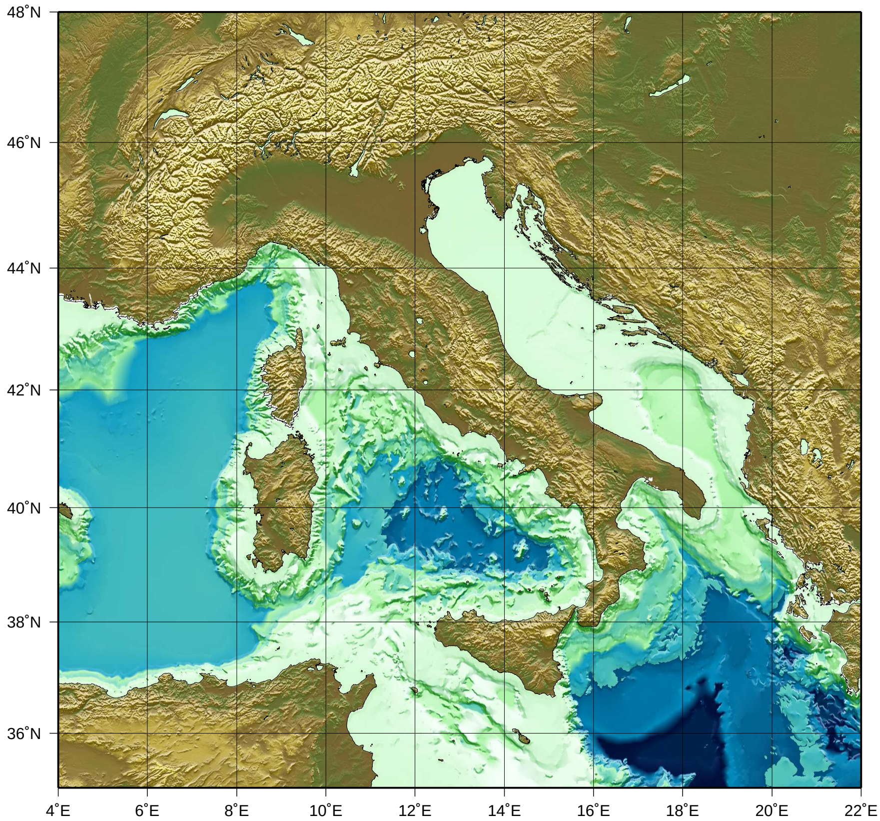


Figure 1: The Italian Topography. 30 arcseconds DTM gridded and displayed by GMT [7]. Original data from GLOBE (topography, [8]) and IBCM (bathymetry, [9] and [10]). Projection Direct Mercator on 40N.

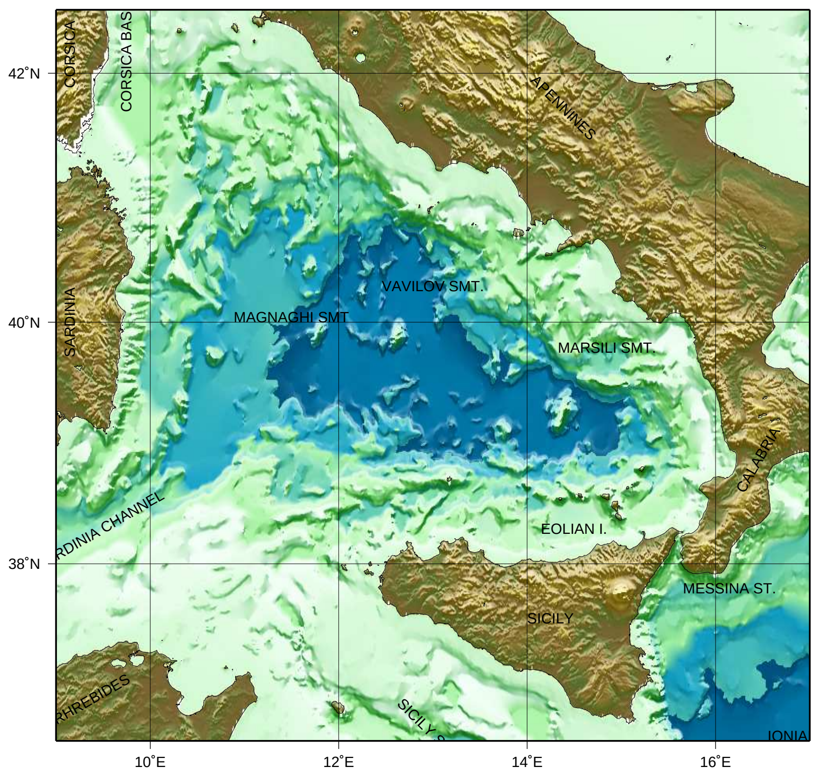


Figure 2: The Tyrrhenian Sea. Data and Projection as in Fig 1

1.2 OCEANOGRAPHIC SETTING

The Tyrrhenian Sea exchanges water with the rest of the Mediterranean Sea through the Sardinia Channel, the Sicily Strait and the Corsica Channel (Fig. 2), that represent morphologic constraints for the circulation of the intermediate and deep waters. The surface water (0-200m) entering the Tyrrhenian Sea through the Sardinia Channel is the Modified Atlantic Water (MAW) from the Algerian Current (AC) ([23], [24]). The MAW is characterized by low salinity (on average less than 38 PSU), and flows cyclonically along the italian coast.

Through the Sicily Strait and deeper than 200 m down to about 700m, the basin receives the Levantine Intermediate Water (LIW), which is marked by a subsurface temperature maximum and by a higher salinity (on average 38.8 PSU), and mixes with the surface MAW and deeper water masses [25].

From about 700 m to the bottom the Tyrrhenian Deep Water (TDW) is present, being the result of the modification of the West Mediterranean Deep Water (WMDW) that crosses the Sardinia Channel ([26], [27]).

The circulation pattern in the Tyrrhenian Sea is normally characterized by two cyclonic gyres in the south and in the northern basins, and by the presence of cyclonic and anticyclonic eddies in the central basin. MAW can reach the Ligurian sea through the Corsica channel.

During summer a strong thermocline occurs (Fig. 3).

Fig. 3 and 4 show CTD data retrieved from MEDATLAS [11] that are representative of different summer and winter water masses (see further discussion on chapter 3.4.2 for the data collected during TIR99).

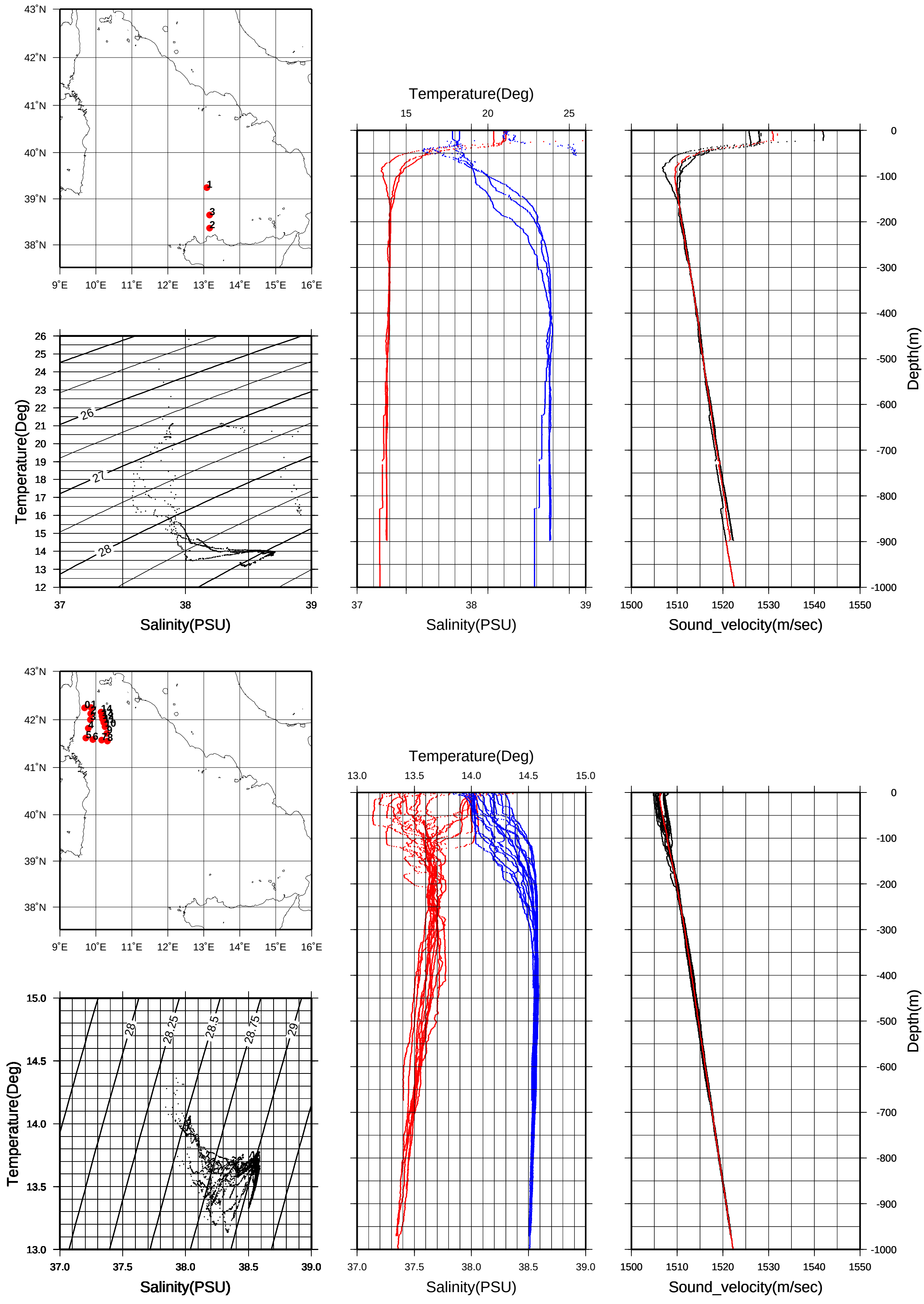


Figure 3: Summer (september,october)(above) and Winter (february,march)(below) STD data from MEDATLAS

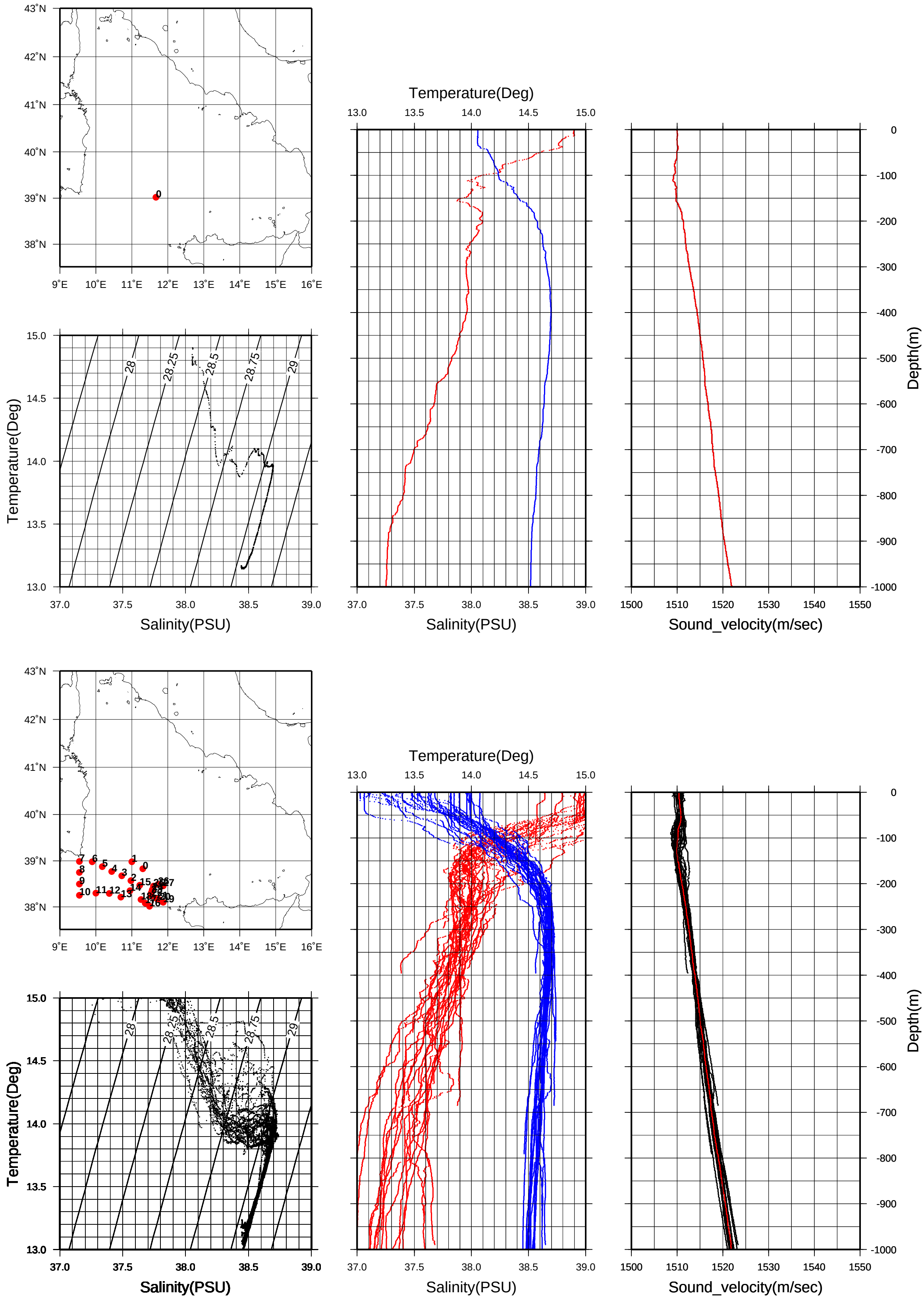


Figure 4: Winter (february,march) data from MEDATLAS.

1.3 METHODOLOGICAL ISSUES

The execution of modern geophysical surveying at sea calls for at least three components to guarantee the achievement of good results from a scientific project:

1. a good ship and crew
2. a good and coordinated scientific party
3. reliable and accurate technical and scientific equipment

These items must be complemented by the adherence to widely ackowledged normative rules and standards and by some degree of flexibility and of imagination (to face problems or change plans in response to the results achieved).

Hereafter we will briefly present some of the techniques and standards in geophysical surveying, with the aim to make more readable the more technical part that follows.

BATHYMETRIC AND GEOPHYSICAL SURVEYING

Modern bathymetric surveying dictates the use of Multibeam Systems, with varying models and configurations according to the goal of the project (from ultra high resolution in coastal areas down to full ocean depth). Among several manufacturers, Kongsberg-Simrad products are the state-of-the-art of such systems. The swath coverage can reach as much as 7 times the water depth, 3.5 times the water depth being normal. Analysis of backscatter information from the sonar data also provides reflectivity data from the sea bottom. During the multibeam data acquisition for bathymetric mapping, which normally provides the pattern of navigation lines, it is possible, and, sometimes, highly recommended, to collect other important data, such as SBP (if no interference occur with the Multibeam Sonar), magnetics, gravimetry, single-channel seismic. This contributes to the creation of extremely important, useful and co-ordinated data sets.

POSITIONING AND NAVIGATION

The positioning systems for long term sea going operations should be based on accurate (0-5 m) and reliable (24x7) instrumentations. The modern differential GPS by satellite links used by the offshore industry are well within there recommendations. The navigation and ancillary data should be acquired and recorded in digital form, suitable to be easily reprocessed and standardized within well known time and geographic datum frameworks. This is of paramount importance when dealing with extra accurate bathymetric surveying, such as in nearshore areas with strong tidal excursions (in these cases the use of RTK DGPS techniques is recommended).

SWATH BATHYMETRY

The modern multibeam systems, coupled with integrated navigation for ship's guidance, offer the necessary flexibility for both planning and execution of the survey. Kongsberg Simrad's MERLIN and IFREMER's CARAIBES are examples of such systems. The speed of surveying should be kept as close as possible to the range that gives the best and regular coverage athwartship and alongship. This figure is normally 6 to 8 Kn. However this contrasts with ship time availability and normally a compromise is necessary between area coverage and regularity and the fulfillment of the time schedule. The Calibration of a multibeam system is critical and should be performed with great care. The operation is done by collecting data capable to correct any roll, pitch, time biases of the equipment. Suitable areas are flat plains with negligible slope, and steep slopes. On these areas lines are to be repeated and crossed according to the technical specifications and recommendations of the Multibeam System Manufacturer. Moreover, the availability of an accurate position system is required. The knowledge of the Sound velocity in the investigated water column is another critical parameter to be investigated, mainly in areas with consistent seasonal variabilities. This could be done by some strategic measurements of CTD data (or sound velocity), complemented by more frequent XBT profiles, and by a good knowledge of the regional and local oceanography. This latter can be depicted at a rather good scale by using oceanographic data bases like MEDATLAS [11] and WODB [12].

Finally, two dilemmas:

(a) Full Coverage by (gently) following the bathymetric contours or by more rigid straight line patterns?

(b) surveying up slope or along slope?

that can make planning a very complicated task, or have sensible effects on the other geophysical data to be acquired, especially gravimetric or seismic data.

MAGNETIC, GRAVITY AND SEISMIC

Magnetics should be performed with the standard procedures that minimize the ship's noise, (i.e. towing the sensor 2-3 times the ship's length). When dealing with single sensor acquisition, the availability of the closest Ground observatory data is necessary for day-night corrections and for rejecting spikes. Furthermore, the data have to be reduced to IGRF anomalies ([13]) or to local anomalies, based upon available Ground Observatories time series). According to sensor's characteristics it may be necessary to check for the magnetic deviation, with lines running at different angles above a common point (preferably in areas with very low gradient and overnight).

Gravimetric surveying dictates the instrumental calibration and drift control by referencing to Control Points as close as possible to the ship. Yet, the data have to be reduced to local anomalies. To check for instrumental drift it is recommended to run crossing lines.

Seismic data can be collected at high speed by using low-noise array configurations. This is a difficult task, however quite important and interesting. The data, whenever possible, should be digitized and recorded in standard formats, such as SEG-D or SEG-Y.

DATA PROCESSING

MULTIBEAM

Swath bathymetry data processing is a difficult and complicated task, that requires a rather good knowledge of specialized Software Products (like for example Kongsberg-Simrad's NEPTUNE, which handles the Simrad's Multibeam Product Family, or more general packages like IFREMER's CARAIBES or MB-SYSTEM ([29], that handle different manufacturer's Multibeam data.

Among the main tasks to be performed, the filtering of the swath data is the most important and time-consuming. This is true especially in presence of noisy data, caused by instrumental or environmental (waves) problems.

NEPTUNE must be complemented by other packages such as IRAP to produce the DTMs. In contrast, CARAIBES and MB-SYSTEM include the DTM generation procedures.

The DTMs should be produced in standard cartographic projections, such as the UTM or Direct Mercator, with grid spacings possibly multiples of each other, to allow easier cut-and-paste operations on the grids. The newly produced DTMs may be merged with existing vector or DTM data. In this situation the highest care has to be taken in the change of datum or cartographic projections.

The final map production should be done at standard scales whenever possible.

DATA BASE ORGANIZATION

The data should be put in tabular forms with key fields. This will help the input into relational DBMS. This is the case, for example, of the navigation (magnetic, gravity) and of the oceanographic data, and of all the information that make-up the seismic database. In contrast, the gridded data are not easily handled by a relational DBMS. At least the DTM topographic and cartographic information should be input to the DBMS, with the reference to any specific grid. Such an organization is well suited for a more productive usage of the data in the normal cartographic production or into a GIS environment. The availability of powerful DBMS engines at the PC level enhance the possibilities of an on-board data center. At IGM we have selected the `MySQL` DBMS by TCX [32] for production and are experiencing `POSTGRES` [33]. These are Open Source products with GPL license for the `Unix`-like environment, and, in some cases, for other platforms.

Part 2

CRUISE TIR96

2.1 SCIENTIFIC PARTY AND INSTITUTIONS

NAME	AFFILIATION	TITLE	tel & email
Nevio Zitellini	IGM-CNR	chief-expedition	+39-051-6398889 nevio@igm.bo.cnr.it
Michael Marani	IGM-CNR	chief-expedition	+39-051-6398887 michael.marani@igm.bo.cnr.it
Giovanni Bortoluzzi	IGM-CNR		gb@igm.bo.cnr.it
Gabriela Carrara	IGM-CNR		gabriela.carrara@igm.bo.cnr.it
Paola Fabretti	IGM-CNR		paola.fabretti@igm.bo.cnr.it
Daniela Penitenti	IGM-CNR		daniela@igm.bo.cnr.it
Giuseppe Stanghellini	IGM-CNR		gstanghe@igm.bo.cnr.it
Claudia Bonazzi	IGM-CNR		
Andrea Ferrarini	IIM		
Vladimir Efimov	GIN		
Serghei Erofeev	GIN		
Dolores Gilod	MSU		
Boris Nikaronenkov	NIPI		
Christian Sue	UGREN		
Joseph Barraud	UGREN		
IGM-CNR	Istituto Geologia Marina CNR	Via Gobetti 101, Bologna	
GIN	Geology Institute, Academy of Sciences	Moscow	
MSU	Geology Faculty, Moscow State University	Moscow	
UGREN	Geol.Fac. Univ. Grenoble	France	
IIM	Istituto Idrografico della Marina	Genova	
NIPI	NIPIokeangeofisika	Gelendzhik	

Table 2: TIR96: Scientific Party

2.2 CRUISE SUMMARY

SHIP: R/V GELENDZHIK
START: 1996-09-10 PORT: NAPOLI
END: 1996-10-29 PORT: NAPOLI
SEA/OCEAN:

1. Tyrrhenian Sea

LIMITS: NORTH: 40.5 SOUTH: 38 WEST: 10.5 EAST: 17
OBJECTIF:
SWATH BATHYMETRY AND GEOPHYSICAL SURVEY OF THE CENTRAL AND SOUTHEASTERN Tyrrhenian SEA
IONIAN SEA
COORDINATING BODY: IGM CNR BOLOGNA (ITALY)
CHIEF SCIENTIST(S):

1. Dr. Nevio Zitellini IGM-CNR
2. Dr. Michael Marani IGM-CNR

PARTICIPATING BODIES:

1. ISTITUTO IDROGRAFICO DELLA MARINA, ITALY
2. GEOLOGICAL INSTITUTE ACADEMY OF SCIENCES, RUSSIA
3. GEOLOGICAL FACULTY, MOSCOW STATE UNIVERSITY, RUSSIA

DISCIPLINES:

1. SEA FLOOR MAPPING
2. GEOPHYSICS
3. OCEANOGRAPHY

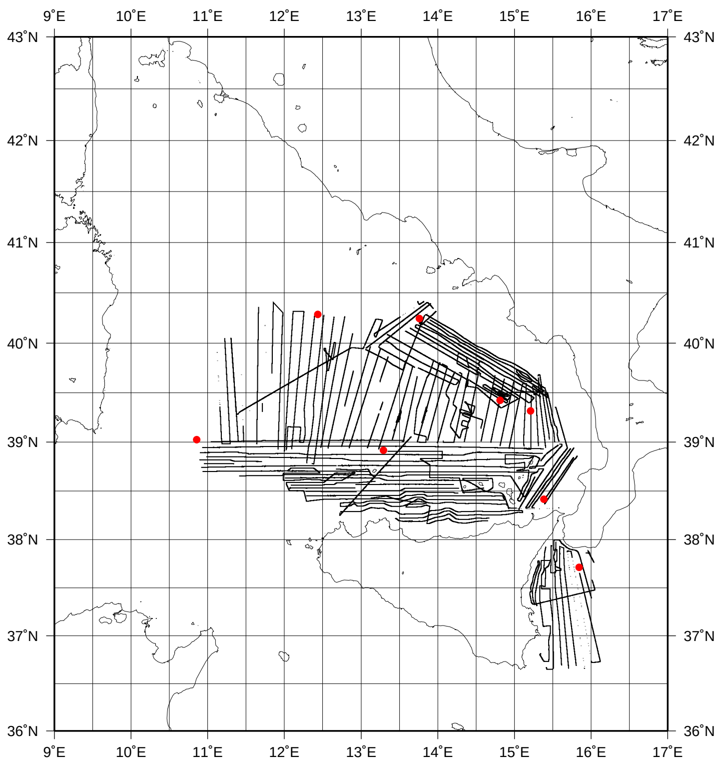
DATA TYPES:

1.

WORK DONE:

1. EM12 MULTIBEAM RUNS
2. MAGNETOMETRY
3. GRAVIMETRY
4. SINGLE CHANNEL SEISMIC
5. 5 SOUND VELOCITY PROBES

LOCATION MAP(S):



2.3 MARINE OPERATIONS

The cruise began September 10th and ended October 30th after 49 effective days of sea operations. A two-day port stop in Napoli partitioned the campaign into two legs. The vessel utilised was the 104 metre R/V Gelendzhik owned by Central Marine Geological and Geophysical Expedition (CGGE) of the Russian Federation. Survey planning and acquisition was undertaken by personnel from the Marine Geology Institute of Bologna while collaborative technical assistance to the marine gravimeters and seismic streamer were undertaken by personnel from Moscow State University and the Geology Institute of the Russian Academy of Sciences. Additionally, as part of a collaboration agreement with France, two French students were also on board.

The survey targeted the south-central portions of the Tyrrhenian basin and the northwestern Ionian Sea slope/rise along the eastern coast of Sicily (Fig. 2). Full swath bathymetric and geophysical coverage was obtained along the slope areas (in general to minimum depths of 600/800 metres) bordering northern and eastern Sicily, northern Calabria and the Campanian margin bounded northwards by the Sorrento Peninsula. In the Tyrrhenian bathyal plain, the survey covered an area bounded northwards by latitude 40 15'N and westwards by the R. Selli Line, roughly along 11 30' E. The portion of the northern Ionian Sea investigated, was south of the Messina Strait up to a latitude of 36 40'N and eastwards to longitude 16 10'E. An estimated 20,500 km were covered by the ship comprising a surface area of aproximately 72,000 km2.

2.4 MATERIALS AND METHODS

2.4.1 POSITIONING AND NAVIGATION

The survey was planned and executed at an average speed of 10 knots. Positioning was accomplished through differential GPS RACAL-Skyfix with corrections from the station based in Rome. The DGPS data were routed to the multibeam console and to the ship's logging and steering complex through Trimble HYDRO PC and Trimble 4000DL GPS sensors. The HYDRO navigation data were stored as binary files with a sampling rate of 10 seconds, to be converted ASCII offline. The multibeam navigation data were stored by the Simrad software MERMAID on the ships's logging workstation with a sampling rate of 1 second. The HYDRO navigation data were used for the integration with the russian magnetic and gravimetric data, thus obtaining for this dataset, the same sampling rate of 10 seconds. The seismic and italian magnetic data were recorded on a separate PC-based workstation, with a sampling rate at constant spacing of 50 metres. This latter workstation was served by a Trimble 4000 GPS. The data were then merged with the high-quality DGPS data and with the Multibeam and HYDRO data by correlating with the GMT date and time for all acquisition sytems.

The Navigation System had the following major settings:

1. Time zone GMT
2. Datum WGS84
3. Output position POS1
4. Projection UTM, zone 33 (for steering and navigation)

Tab. 3 and Fig. 5 show the offsets of principal instruments. It is worth to note that on Multibeam files the POS 1 position is recorded, as well as on the other instrumental binary and ASCII files. That is, the final coordinates for every instrument have to be recalculated accordingly.

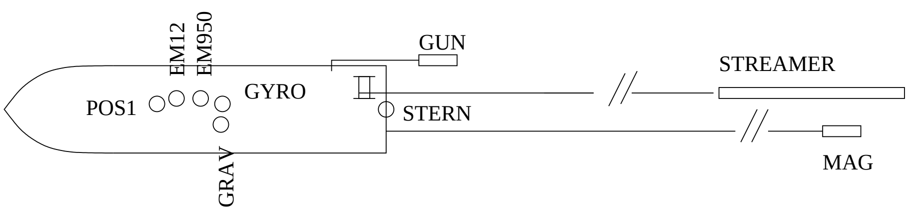


Figure 5: TIR96: offsets from primary navigation sensor (POS1)

COORDINATES				
POINT	ALONG	ACROSS	DISTANCE	BEARING
POS1	0.0	0.0	0.0	0.0
STERN	-43.0	-1.1	43.0	181.47
EM12	-3.08	0.70	3.16	167.20
GYRO	-3.0	0.0	?	?
GRAV	-3.0	0.0	?	?
MAG	-228.0	-5.0	?	?
GUN PORT	-48	-7.0	?	?
ACTIVE STREAMER	-148.0	5	?	?

Table 3: TIR96: Offsets from primary navigation sensor (POS1)

2.4.2 SWATH BATHYMETRY

A Simrad multibeam model EM12/120S was used. This system provides a swath coverage of approximately 3.5 times the water depth. The system was set with constant spacing on the sea-bottom of the available 81 beams, so that the pixel size varied according to the water depth. The multibeam system furnished both detailed bathymetric soundings and 13 kHz sea-floor reflectivity (sonar) data. In general, the quality of the data we obtained can be considered good. The survey was planned and executed to obtain the full coverage of the seabottom with overlapping areas ranging around 20 % of the swaths. Data were stored in real time by the the Simrad MERMAID software on the ship's logging workstation.

CALIBRATION

Two data sets for calibration of the instrument were also surveyed at the start of both legs, in an area around the Sirene Smt..

OCEANOGRAPHIC SETTING AND SOUND VELOCITY ANALYSIS

Several sound velocity measurements were taken ranging from 0 to 2000 metres water depth.

2.4.3 GEOPHYSICS

MAGNETICS

We used two systems. For the first part of the first leg a GEM model GSM 19D 'Overhauser effect' magnetometer was used. After this, a russian 'Proton precession' magnetometer was used.

Thank to ING of Rome we have been provided the data of the Observatory of L'Aquila for the entire cruise period. The data are presented in Fig. 6.

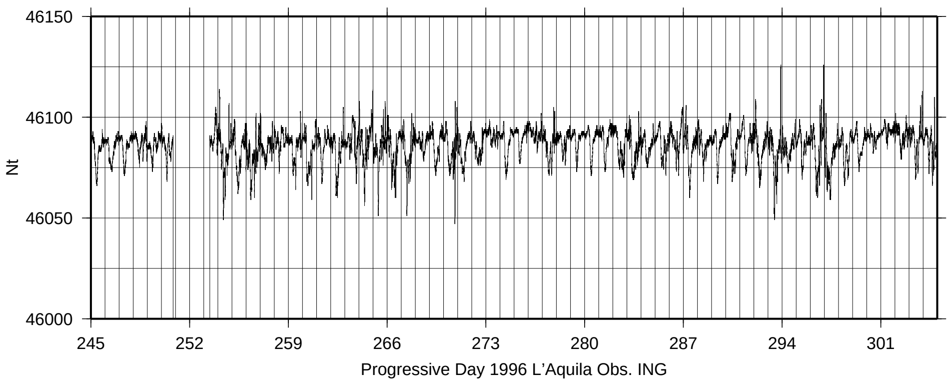


Figure 6: TIR99: magnetic observatories data (L'Aquila). Courtesy of ING of Rome (Dr. DeSantis)

Fig. 7 shows an example of unfiltered magnetic data corrected for IGRF95 and for Ground Observatory data.

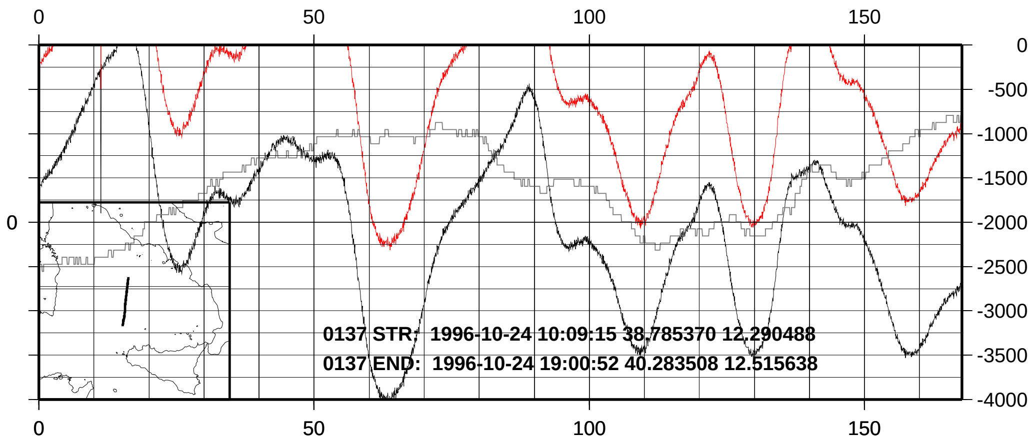


Figure 7: TIR99: example of unfiltered magnetic data (GEM GSM 19D).

GRAVIMETRY

Four quartz-stabilised russian NEFTEKIP, model GMN-K sea gravimeters were used in a noise-reduction configuration. The gravimeters had an accuracy of 1/2 mGal under accelerations of 100 Gal and the data was recorded digitally on a PC-based platform. Crossing lines were planned in order to obtain statistical parameters for optimum data reduction. In addition to this, two ground based measurments were taken in the port of Naples to serve as drift compensation and calibration points.

SEISMIC AND SUBBOTTOM PROFILING

The seismic source was a Sodera-SSI Gi-Gun in Harmonic configuration 45+45 cubic inches except for 4 lines run at 60+60 c.i. Shot spacing was at a constant distance of 50 metres through the control of IGM's integrated navigation and gun control system [31]. The depth of the source ranged from 5 to 6 metres and pressure was set at 130-150 bars. The signature was constantly checked and tuned in order to obtain the optimum peak-to-bubble ratio. Due to the high speed of the survey, we used a GIN (V.Efimov) designed single-channel streamer, that provided an excellent signal/noise ratio. The depth of the streamer ranged from 5 to 7 metres. Data were reproduced, after amplification and filtering, in real time on two EPC 4800 recorders running at different timescales. The unfiltered data were routed to a digital acquisition system that produced SEG-D 3480 tapes at a sampling rate of 1 millisecond using a Geometrics Strataview Seismometer and Lookout Geophysical workstation.

2.4.4 COMPUTING FACILITIES AND ON BOARD DATA PROCESSING

On the on ship's Ethernet coaxial backbone we established a network of computers for swath bathymetry and general purpose data processing, as shown by Fig. 8. Among them, PC's running Linux and Windows OS, and two SUN ULTRA 1 workstations running Solaris 2.5 and 2.7 OS. The SUN WS were devoted to multibeam data processing, whilst the LINUX WS were used for NFS disk and printer spooling services. The ship's HP Mod. 750 A0 color ink-jet plotter was used for charting.

During the 60 days cruise, we can report just a few stops of some machines, that recovered smoothly after the reboot or file system check.

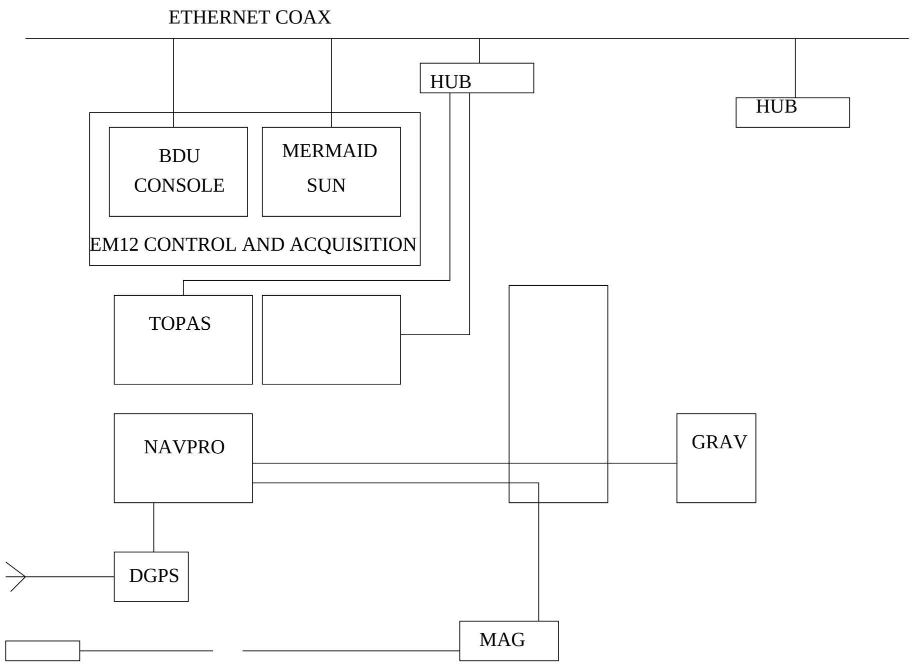


Figure 8: TIR96: computing center and data flow paths

Editing of the data was performed with the NEPTUNE package, and gridded and countoured with the IRAP software. Several maps at scales ranging from 1:50000 to 1:500000 were reproduced on board utilizing GMT, IGM's Plotmap software (Ligi and Bortoluzzi, 1989) and AUTOCAD.

2.5 RESULTS

Fig.9 shows the pattern of lines acquired during the multibeam runs. Fig.10 presents shaded relief maps of the multibeam data, gridded at 250 m (Tyrrhenian Sea) and 100 m intervals (Ionian Sea).

The multibeam data were edited and processed on-board, at the scales of 1:100000, 1:250000, 1:500000. The data quality ranged from good to acceptable.

Magnetic recordings showed a good continuity and quality of data, requiring just a minimal pass for filtering prior of the IGRF-95 anomaly calculation.

Continuous Seismic profiling was done for almost the totality of the cruise, giving the chance to define the thickness of the sediments above the acoustic basament and the structural makeup of the area.

Gravimetry data were collected during the whole cruise, and processing is ongoing to calculate free air and Bouguer anomalies.

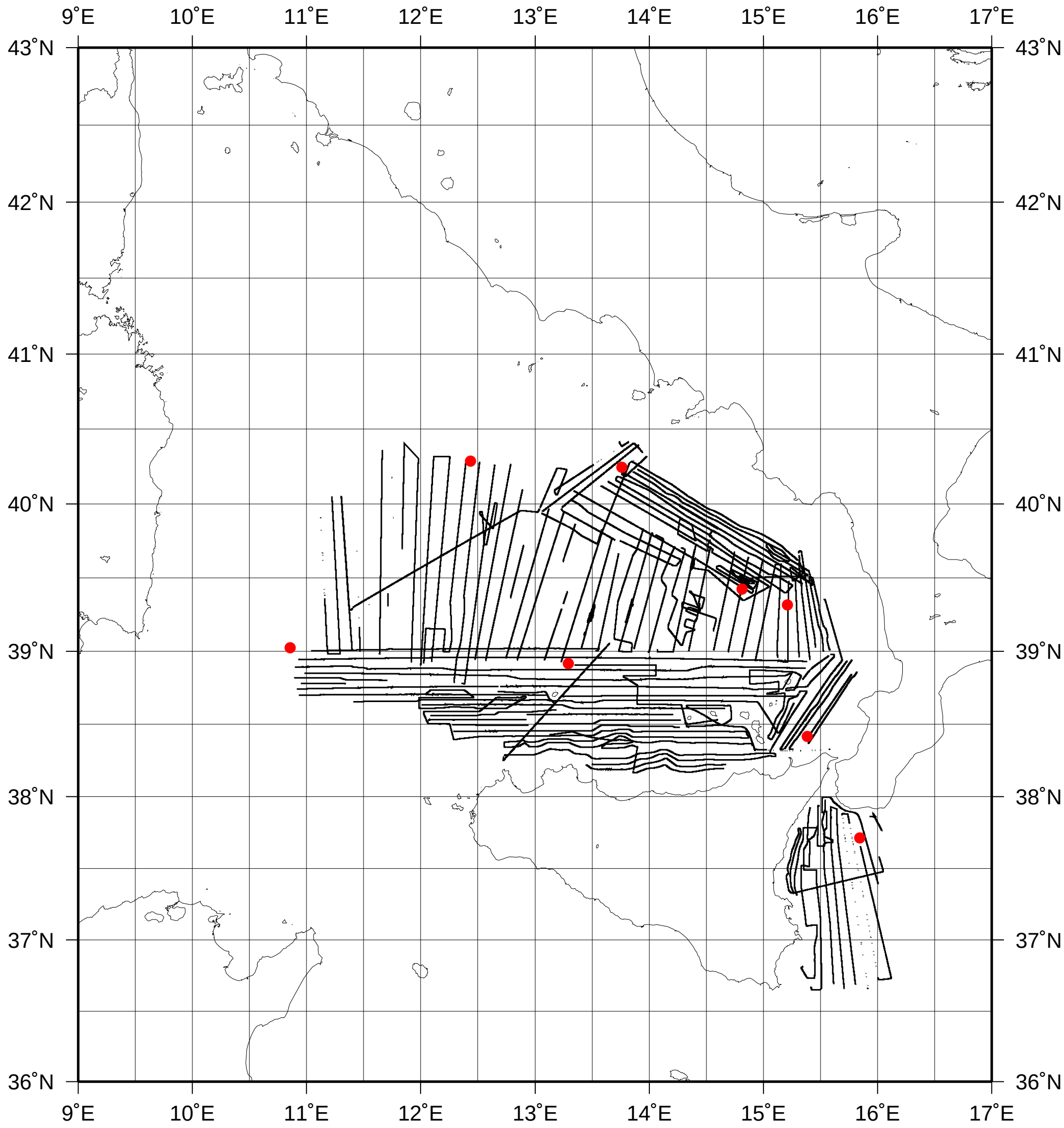
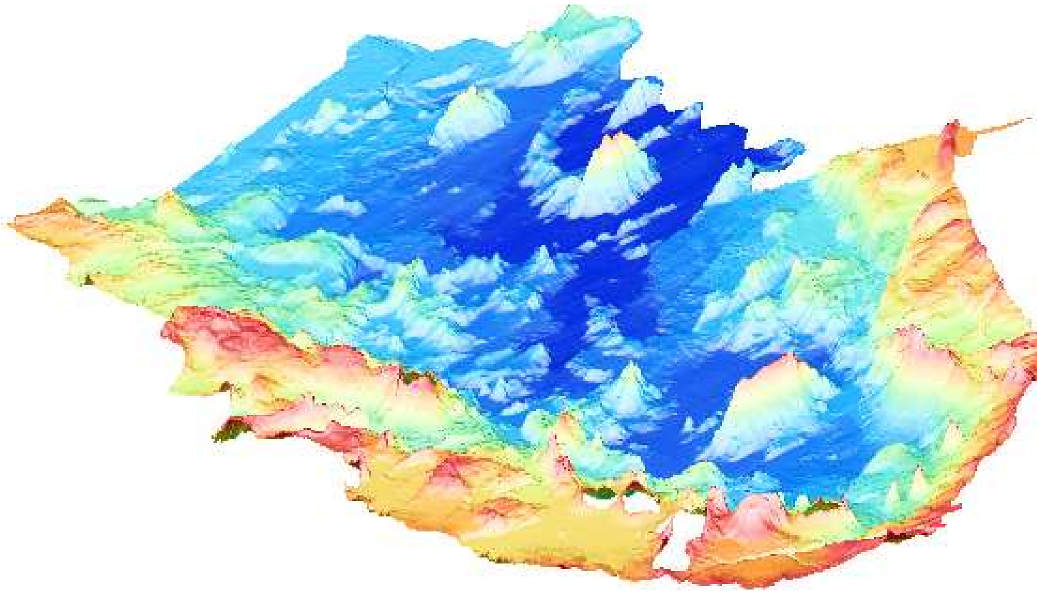


Figure 9: Navigation lines acquired during cruise TIR96



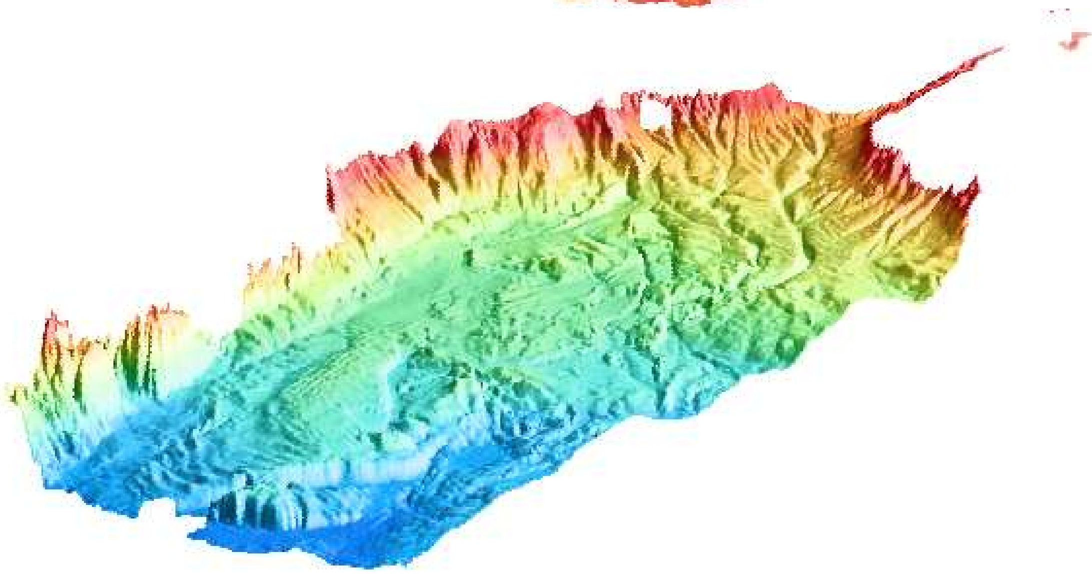


Figure 10: Multibeam data acquired during cruise TIR96. Top: shaded relief with azimuth from 45/315. Projection UTM, Zone 33, southern margin Tyrrhenian Sea. Below: shaded relief with azimuth from 135. Projection Direct Mercator on 40N, north western margin Ionian Sea.

Part 3

CRUISE TIR99

3.1 SCIENTIFIC PARTY AND INSTITUTIONS

NAME	AFFILIATION	TITLE	tel & email
Michael Marani	IGM-CNR	chief-expedition	+39-051-6398887 michael.marani@igm.bo.cnr.it
Giovanni Bortoluzzi	IGM-CNR		gb@igm.bo.cnr.it
Gabriela Carrara	UNI-PR		gabriela.carrara@igm.bo.cnr.it
Fabiano Gamberi	IGM-CNR		fabiano.gamberi@igm.bo.cnr.it
Stefano Lippolis	IGM-CNR		
Massimo Musacchio	UNI-BO		massimo.musacchio@igm.bo.cnr.it
Daniela Penitenti	IGM-CNR		daniela@igm.bo.cnr.it
Marina Tonani	IGM-CNR		m.tonani@isao.bo.cnr.it
Alessandro Daviddi	IIM		
Giovanni Diroma	IIM		
Antonio Leotta	IIM		
Galina Agapova	GIN		
A. Chilikov	GIN		
Vladimir Efimov	GIN		
Alexander Peyve	GIN		
Natalyia Turko	GIN		
Dolores Gilod	MSU		
A.Razumovski	MSU		
Roman Zaltsman	MSU		
Gil Brochard	UGREN		
Giovanni Dealteriis	GEOMARE		
Matteo Bacchiega	GAS		
Fabrizio Occhiena	GAS		
IGM-CNR	Istituto Geologia Marina CNR	Via Gobetti 101, Bologna	
UNI-BO	University of Bologna	Bologna	
UNI-PR	University of Parma	Parma	
GIN	Geology Institute, Academy of Sciences	Moscow	
MSU	Geology Faculty, Moscow State University	Moscow	
UGREN	Universite’ Grenoble	France	
GEOMARE	Geomare Sud CNR	Napoli	
IIM	Istituto Idrografico della Marina	Genova	
GAS	Geol.Assist.Services	Bologna	

Table 4: TIR99: Scientific Party

3.2 CRUISE SUMMARY

SHIP: R/V STRAKHOV
START: 1999-02-04 PORT: CATANIA
END: 1999-04-01 PORT: CATANIA
SEA/OCEAN:

1. Thyrrenhian Sea

LIMITS: NORTH: 42.5 SOUTH: 38 WEST: 9.5 EAST: 16
OBJECTIVES:
SWATH BATHYMETRY AND GEOPHYSICAL SURVEY OF THE WESTERN AND NORTHERN TYRRHENIAN SEA
COORDINATING BODY: IGM CNR BOLOGNA (ITALY)
CHIEF SCIENTIST(S):

1. Dr. Michael Marani IGM-CNR

PARTICIPATING BODIES:

1. ISTITUTO IDROGRAFICO DELLA MARINA, ITALY
2. GEOLOGICAL INSTITUTE ACADEMY OF SCIENCES, RUSSIA
3. GEOLOGICAL FACULTY, MOSCOW STATE UNIVERSITY

DISCIPLINES:

1. SEA FLOOR MAPPING
2. GEOPHYSICS
3. OCEANOGRAPHY

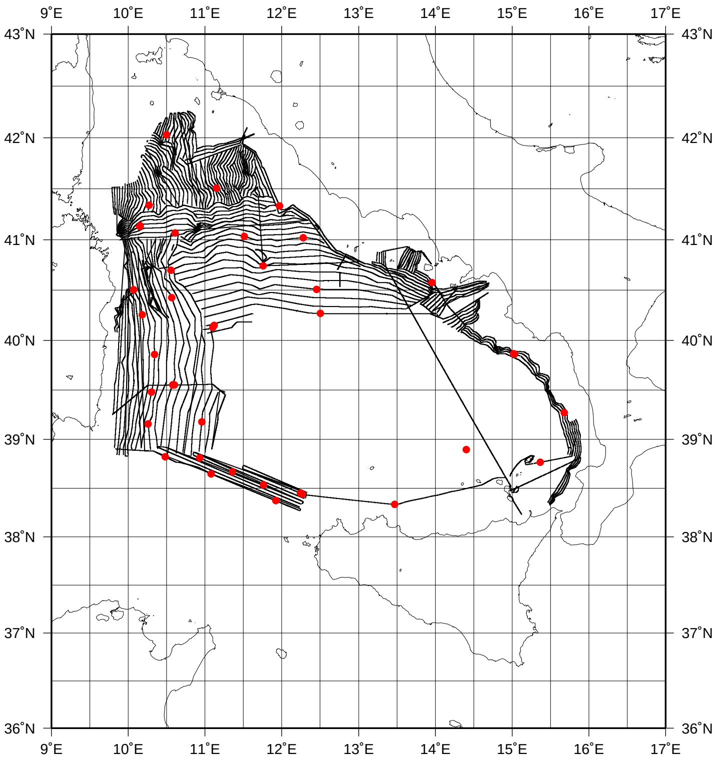
DATA TYPES:

1.

WORK DONE:

1. EM12 MULTIBEAM RUNS
2. MAGNETOMETRY
3. GRAVIMETRY
4. SINGLE CHANNEL SEISMIC
5. 5 XCTD 36 XBT
6. METEO

LOCATION MAP(S):



3.3 MARINE OPERATIONS

Cruise TIR 1999 was designed to accomplish the task of the full coverage swath bathymetry mapping of the Tyrrhenian Basin (Fig.2), from the isobaths of 800-1000 m, after the first cruise in september-october 1996 (chapter 2) that mapped the Central and Southeastern portions. The collection of other geophysical data along the multibeam tracks, such as magnetics, gravity and single channel reflection seismic was planned as well.

Figure 11: R/V Strakhov

R/V Strakhov of GIN was used. The cruise left Catania 4-feb-1999. Calibration of the two multibeams were performed 5-feb-1999 north of the Eolie Islands. During the first leg in february we worked primarily in the Sardinia Channel up to the Northern tip of Sardinia. Some lines were also run from Sardinia to Italy north of 40N.

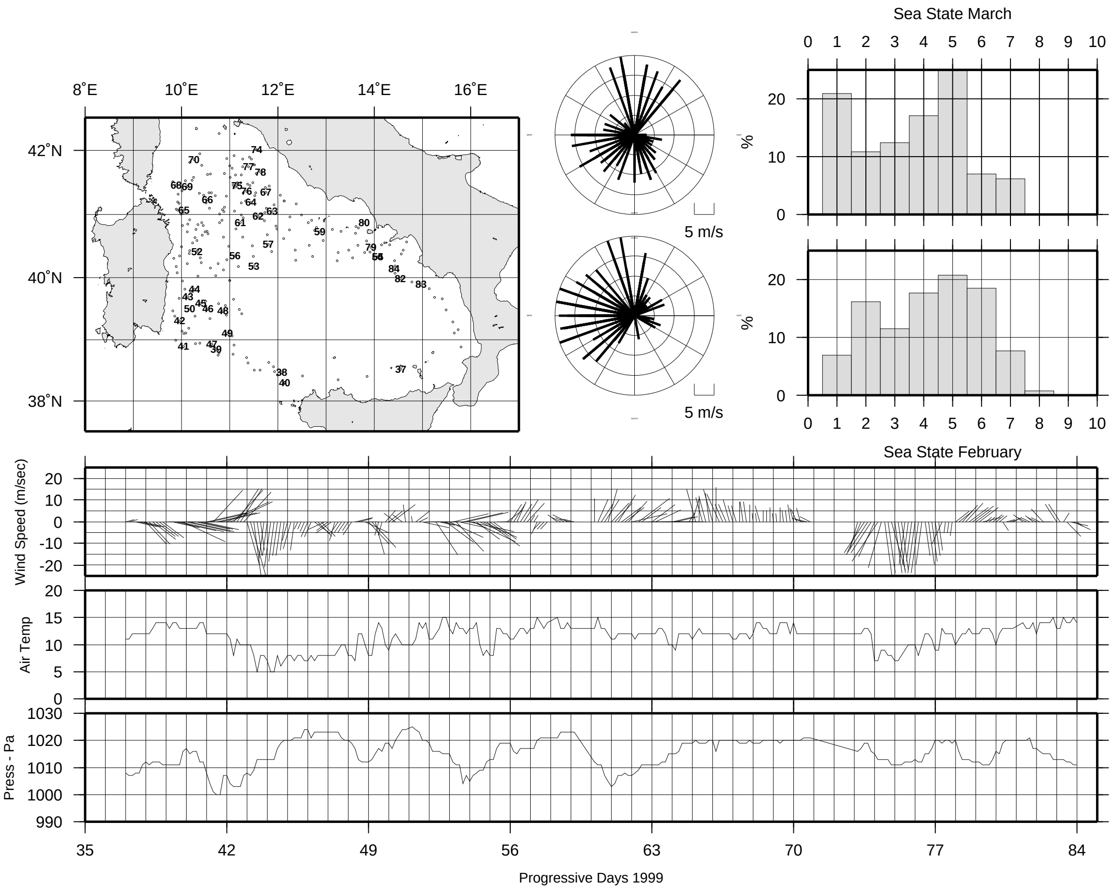


Figure 12: TIR99: summary metereological data.

Weather conditions were very bad for more than half of the leg. We were forced to a 12 H stand-by to Favignana and 24 H to Capri and Ischia.

The leg ended with a port call to Civitavecchia on 1-mar-1999. During the two day stop a partial takeover of the scientific crew occured. The second leg started 3-mar-1999 and covered the Northern part of the basin. The last week was instead devoted to collect data in the South-eastern margin and in the Eolie Islands (mainly Stromboli and Panarea), to try to fill some gaps from the cruise of 1996.

The weather conditions during the leg were bad, especially the first and third week. No stand-by meteo occured. The cruise ended in Catania 1-apr-1999. Fig. 12 summarizes the metereological conditions, which are also presented in Appendix 6.3. It is worth to note that more that 50% of the cruise had sea state higher than 4-5. The prevailing winds and seas were from the WSW to NNE sectors.

Hereafter, a description of the equipment and of their usage is given, along with details of the general setting, performances and results (Chapter 3.4). Chapter 3.4.2 presents the Oceanographic setting and the problems encountered in the sound velocity data acquisition and processing. Chapter 4.1 describes the swath bathymetry data processing.

3.4 MATERIALS AND METHODS

A description of the equipment, of the data acquisition and of the processing techniques used can be found hereafter.

3.4.1 POSITIONING AND NAVIGATION

The ship's NAVPRO 5.4 Navigation Software by Communication Technology of Cesena was used (URL: http://www.comm-tec.com). The primary positioning sensor was the RACAL DGPS SKYFIX SPOT BEAM with a 12 channel Trimble receiver. The system was used for ship's guidance on the planned lines and targets, and for data logging of various sensors, among them the ANSHUTZ gyrocompass Mod. Standard 20 and the GEM magnetometer. In addition, it routed positioning data to the Seismic and Gravimetric Laboratory, for additional data logging. The system performed quite well. The availability of Differential GPS signals by the RACAL receiver was good, thus allowing metric accuracy for almost the totality of the acquisition time. Very few position spikes were detected and removed easily by the post-processing sequence of the swath bathymetry and magnetics data.

The Navigation System had the following major settings:

1. Time zone GMT+1
2. Datum WGS84
3. Projection Direct Mercator on 40 N (for ship's guidance)
4. Output position POS1

The Navigation System Time (NAVPRO) had a variable delay against GMT+1 as taken by the GPS receiver. Table 11 in Appendix 6.4 reports the delays. On almost the totality of the cruise the DGPS corrections were provided by the RACAL Station of Rome (code 800). In a very few occasions we turned to the Station of Ankara (code 830) due to problems in Rome. Tab. 5 and Fig. 13 shows the offsets of principal instruments. It is worth to note that on Multibeam files the POS 1 position is recorded, as well as on the NAVPRO binary and ASCII files. That is, the final coordinates for every instrument have to be recalculated accordingly.

COORDINATES				
POINT	ALONG	ACROSS	DISTANCE	BEARING
POS1	0.0	0.0	0.0	0.0
STERN	-43.0	-1.1	43.0	181.47
EM12	-3.08	0.70	3.16	167.20
EM950	-8.05	0.70	8.08	175.03
MRU	-1.70	0.15	1.71	174.96
GYRO	-3.0	0.0	?	?
GRAV	-3.0	0.0	?	?
MAG	-228.0	-5.0	?	?
GUN PORT	-48	-7.0	?	?
GUN STBD	-48	7.0	?	?
ACTIVE STREAMER	-148.0	5	?	?

Table 5: TIR99: Offsets from primary navigation sensor (POS1)

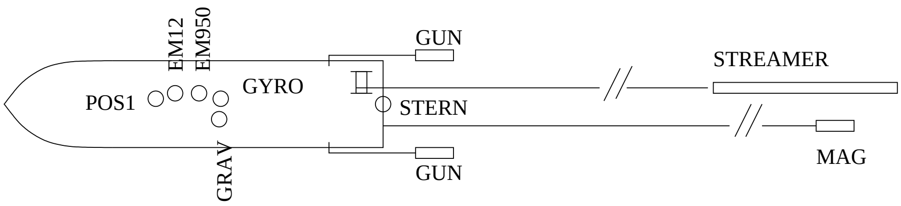


Figure 13: TIR99: offsets from primary navigation sensor (POS1)

3.4.2 SWATH BATHYMETRY

A Kongsberg-Simrad (KS) EM12-120S hull-mounted multibeam was used as primary source during the campaign. The system was interfaced to the ANSHUTZ gyrocompass, to the TSS Mod. DMS05 MRU and to the RACAL DGPS receiver. The KS EM-950 was also available. The EM12 was calibrated after departure from Catania in an area north of the Eolie Islands. Roll calibration was performed in a flat area at roughly 3000 m depth, whereas pitch and time calibration were performed on a steep slope just north of the Island of Salina (Tab. 6). Further information on calibration can be found in 3.4.2. Additional checks were made during the survey when lines were repeated in opposite or at 90 degrees direction.

Some small areas were investigated with the available hull-mounted KS EM-950, that were calibrated jointly with EM12 in a shallow area north of Panarea Island.

Data logging and survey control were done by the KS MERMAID and MERLIN software. The acquired data were pushed on the net for processing and backups upon completion of every line.

The survey was planned and performed at the economical speed of 10.5 Kn. This was normally attained and even overcome, except when the routes contrasted the wind and seas, bringing the speed to 7-8 Kn. The quality of data ranged from very good to acceptable, according to the weather conditions. Some lines were affected by noise during very bad weather conditions. Some deep lines showed noise and spikes on the outer beams.

CALIBRATION

Multibeam calibration (roll and pitch) was performed in an area North of The Eolie Islands. Fig.14 show the operations within NEPTUNE.

Tab. 6 shows the resulting calibration data for the EM12.

EM12				
AREA	DATE	ROLL	PITCH	TIME
EOLIE	03-feb-1999	-0.65	0.0	-
EOLIE	30-mar-1999	-0.65	0.0	-

Table 6: TIR99: EM12 Calibration data

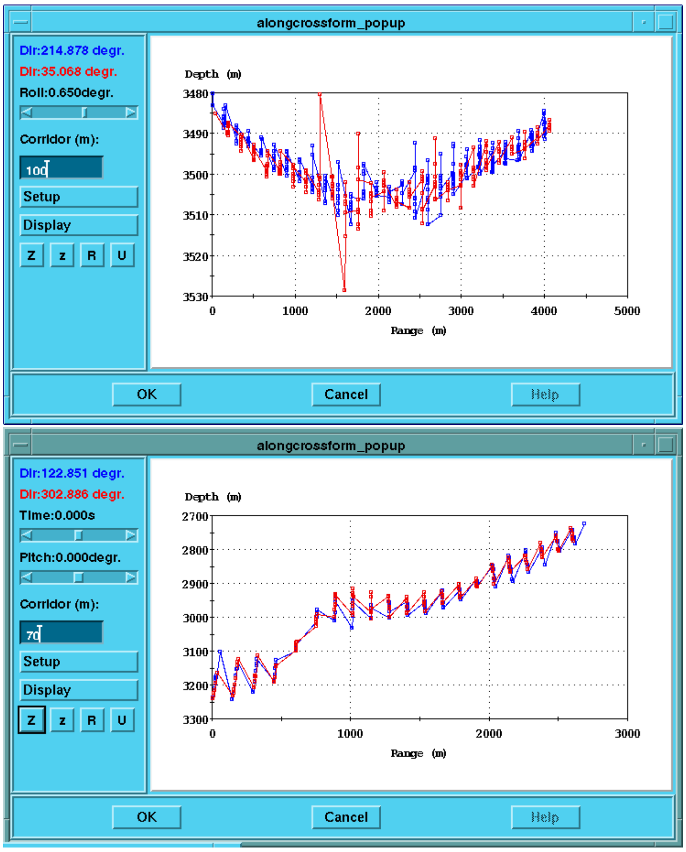


Figure 14: TIR99: calibration setup: roll (above) and pitch (below). (lines 0008_19990205_082110 0009_19990205_092327) (roll) and (lines 0010_19990205_104859 and 0011_19990205_115530) (pitch)

SOUND VELOCITY ANALYSIS

During the Multibeam mapping several Sippican XBT and XCTD probes were launched, with a higher frequency in areas of greater variability of the water column properties, i.e. the Sardinia Channel and the Northern Basin.

Fig. 15 shows the position of the sampling stations. Further information, including time,date and position information (Tab. 12) can be found in Appendix 6.5.

In the investigated area we can report the following features and subdivide the region into homogeneous areas:

AREA A NW of the Sicilian coast the upper layer of the water column (0-100m) is occupied by the incoming MAW, marked by a lower salinity (less than 37.8 PSU). Down to about 700m the incoming LIW is characterized by temperature and salinity maxima (T=14.4C at 100m, S=38.7 PSU at 600m).

AREA B N-E of the Sicily coast and along the Calabria coast the salinity of the upper layer increases (37.9-38 PSU) due to the mixing of the incoming MAW with the water of the basin. Nearshore the depth of the temperature maximum deepens down to 200m. The surface temperature in the whole area was found to be higher (T=14.5C) than in area A.

AREA C In the middle of the basin the values of the subsurface temperature and salinity maxima were found at a deeper depth than in B (300m and 500m respectively) and the temperature values ranged from 14.1C at the Sardinia side to 14.3 C at the Campanian coast.

AREA D North of 41 the data showed a great variability of the surface temperature values (from 13.2 to 14C) and of the vertical temperature profiles, that presented several oscillations. All of these features are typical of a zone of intense mixing.

AREA E South of 40 down to 39 the temperature profiles were found similar to those of area C, except for the depth of temperature maximum at 200m instead of 300m.

AREA F In the Sardinia Channel toward the Sardinian coast, the MAW was found from the surface to the depth of 100m, with salinity higher than 38.1 PSU and temperature range between 13.6C and 13.8C. Down to 700 m the modified LIW was characterized by a temperature maximum (T=14.1C) at 100m and by a salinity maximum (S=38.7 PSU) at 300m.

The XBT and XCTD data are presented in Fig. 16, 17, 18.

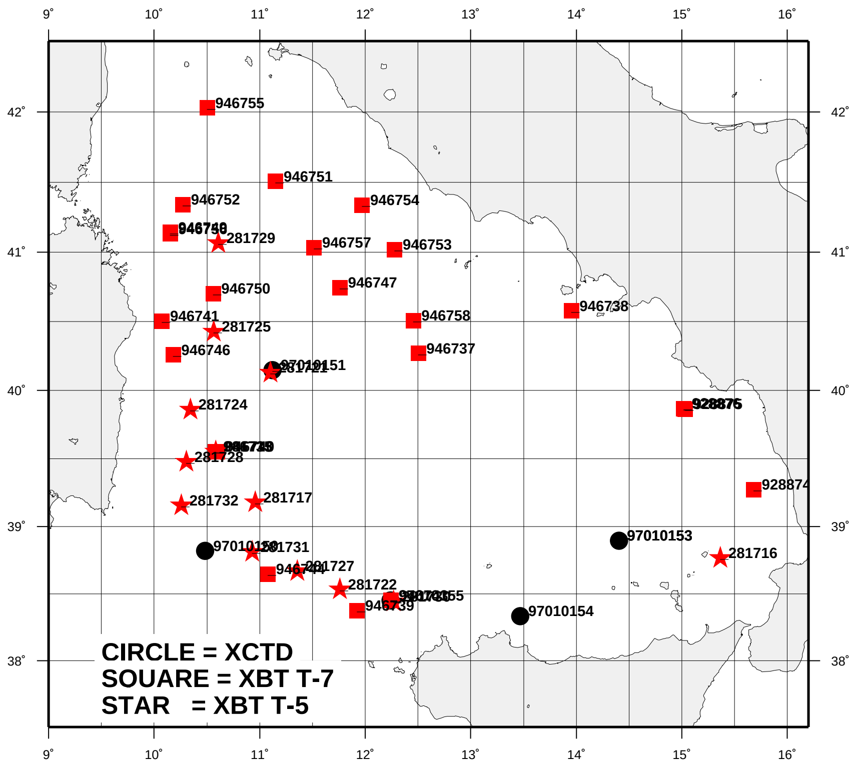


Figure 15: TIR99: location of XBT and XCTD probes.

DATA ORGANIZATION AND SOUND VELOCITY PROFILES

A rather crude, yet effective, relational database was created to handle the newly collected data of the cuise, along with the available historical data, from the MEDATLAS database [11].

Once collected, the XBT (or XCTD) data were just edited for the headers and for very bad and suspicious data and immediately put into the database. The depth readings were corrected according to the UNESCO recommendations [34]. A few procedures were then prepared for the browsing and plotting of the data, along with the procedures for the creation of the velocity profiles for the depth processing. These last accounted primarily for the data in the upper layer down to 700-800 m. After this depth the profiles were integrated with the best available data found in the historical databases or within the ISDGM profiles. The analysis led to the subdivision of the surveyed area into some major areas with the same hydrologic properties, and the relevant transition zone between them.

At this point, the data were used to provide the best sound velocity profile for any grouping of lines that crossed the geographical blocks of approximately 20x30 primes (or more) in latitude and longitude, respectively, that divided the survey area for processing. This sound velocity profile was then used for the depth processing phase in NEPTUNE (as it will for CARAIBES). Some software routines were built for the handling of data and for the automated production of the sound velocity profiles, according to the formats required by the KS EM12 BDU and software (AML and NEPTUNE).

PROBLEMS AND RECOMMENDATIONS

We had several difficulties in launching the XBT's. First, in the Sardinia Channel and SE of Sardinia, the weather conditions were very bad and, moreover, the launching station was situated at mid ship, toward the bow, thus increasing the probablity that the wire went onboard when launching downwind. We at last positioned the launching station at stern. Nonetheless, the ship towed seismic arrays and streamers, and a magnetometer. Several probes were thus lost.

Due to the fact that surveying with multibeam, seismic, magnetics and gravity poses some sharp limitations to the steering of the ship, the only clear strategies when crossing areas with higly varying water mass properties can be:

1. launch probes every three-four hours on EVERY multibeam run;
2. launch probes at strategic points, depicted by seasonal analysis on historical databases, verify the present conditions and intensify the sampling on the troublesome areas, in order to create a database useful for the evaluation of the appropriate sound velocity profiles for every specific area.

Clearly, strategy (1) requires a much larger economic investment and a tighter sampling, in terms of success of every launch and ship's guidance and control. In contrast, strategy (2) may have the disadvantage of a possible undersampling of some specific areas. For both (1) and (2), however, it is highly recommended that at some points the full hydrologic properties of the water masses are investigated, by CTD or XCTD profiles. In addition, it should be stated that the analysis of the seasonal oceanographic conditions of the investigated areas has to be performed for the proper planning and execution of the survey. Whether available, additional tools like Satellite Surface temperature data may be helpful during the survey.

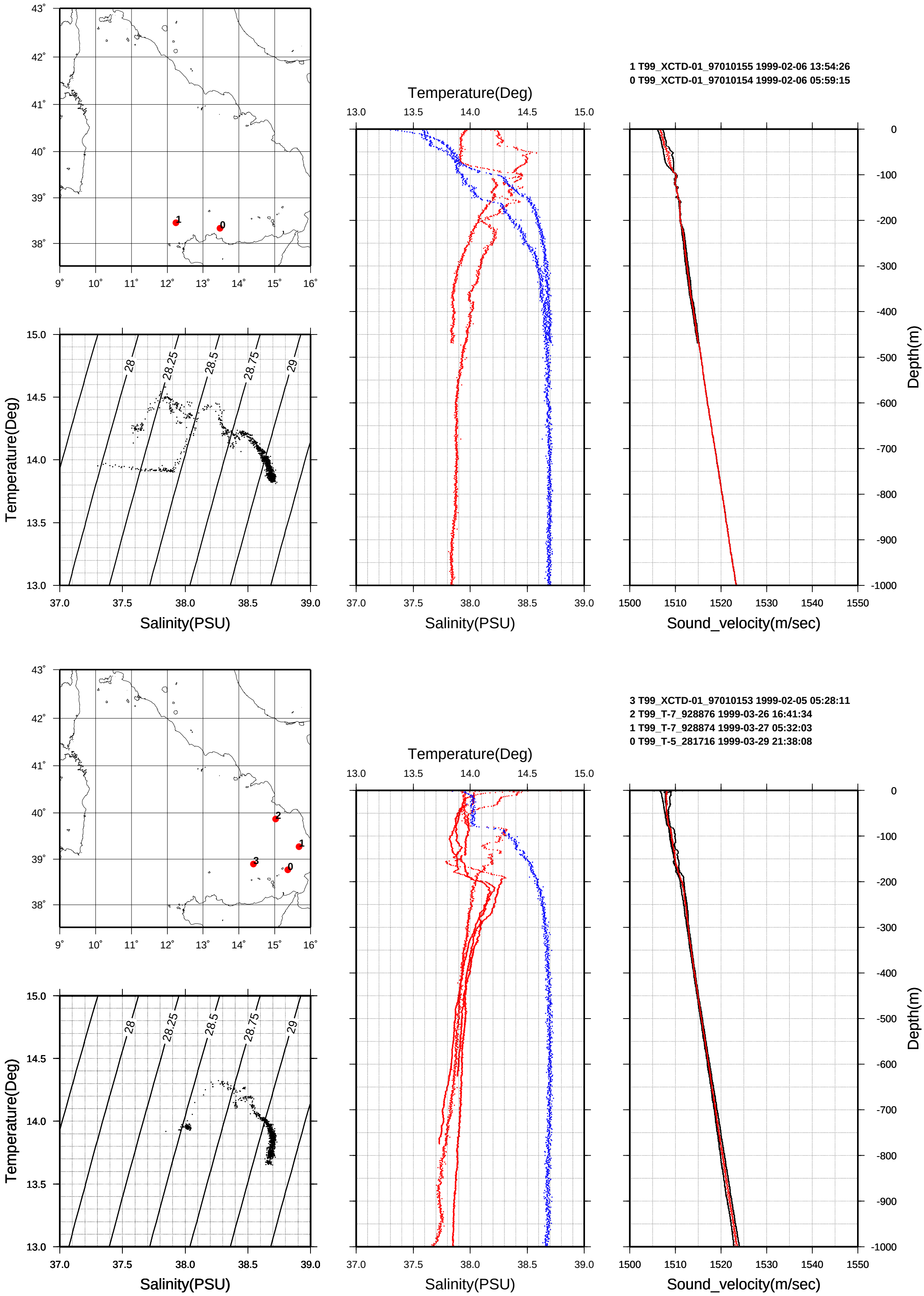


Figure 16: TIR99: AREA A (above) and AREA B (below) XBT-XCTD data

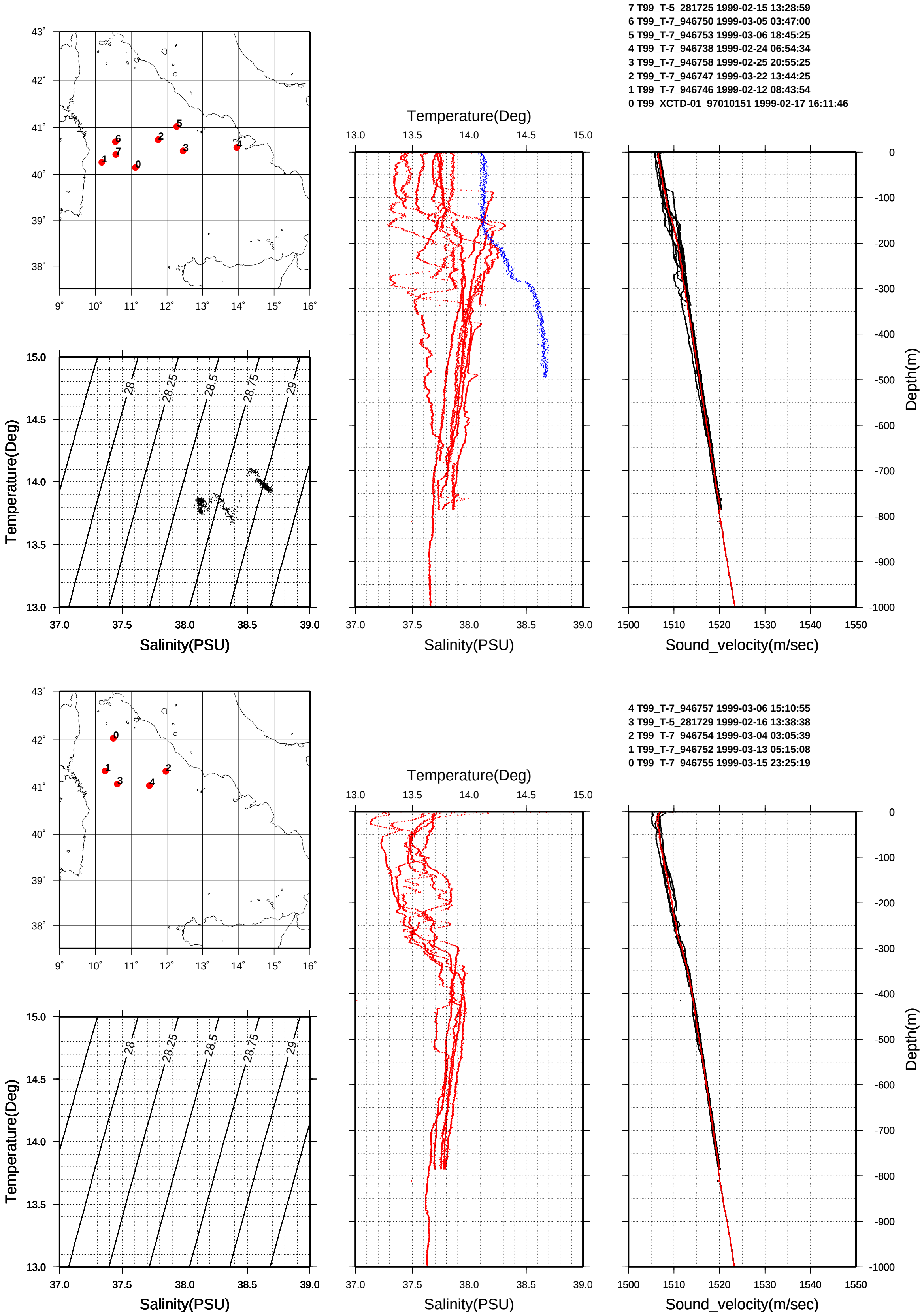


Figure 17: TIR99: AREA C (above) and AREA D (below) XBT-XCTD data

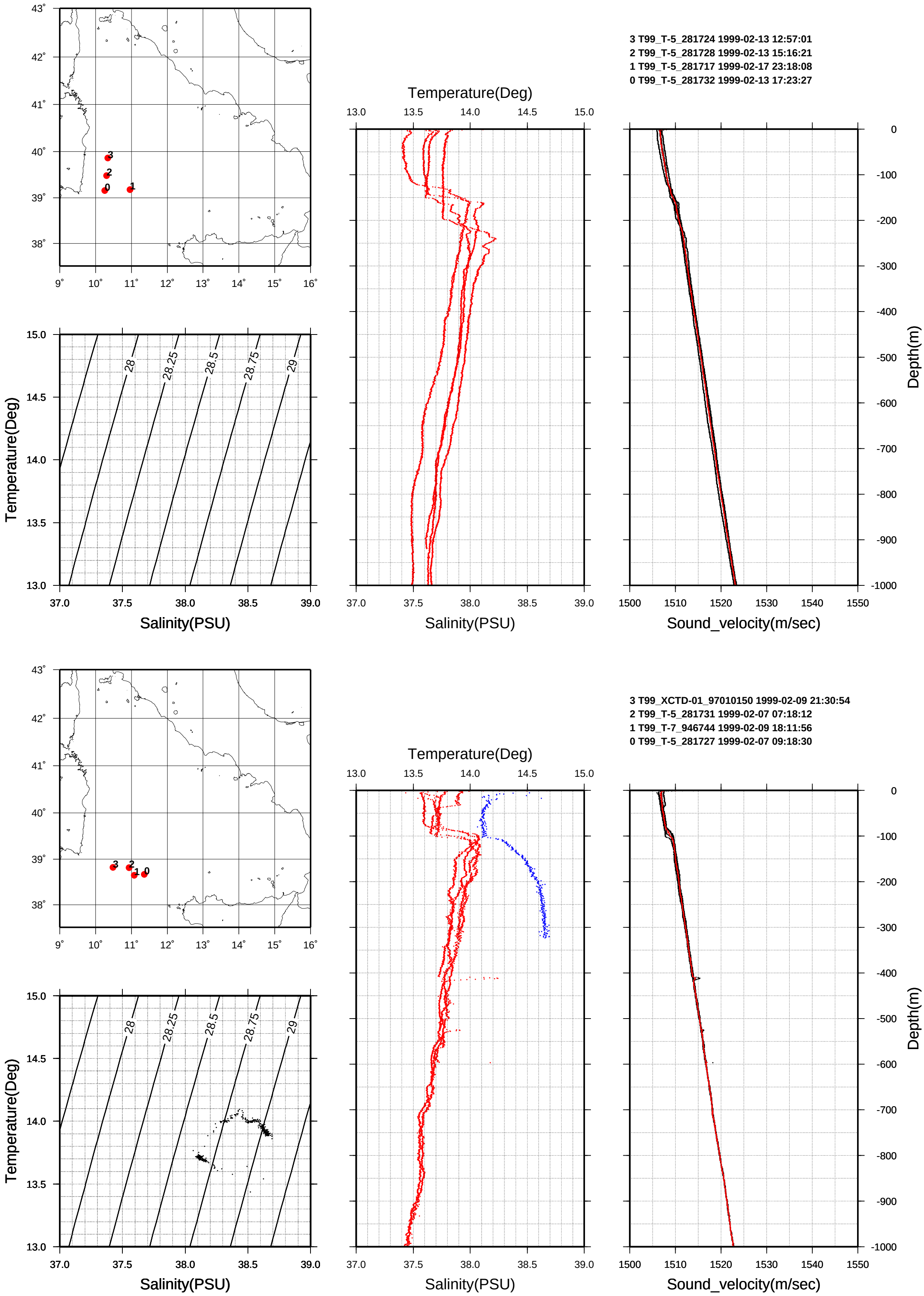


Figure 18: TIR99: AREA E (above) and AREA F (below) XBT-XCTD data

3.4.3 GEOPHYSICS

MAGNETICS

GEM Mod. GSM-19MD Overhauser Effect Magnetometer was used (the instrument was kindly provided by PNRA). The sensor was towed at a constant offset of 185 m from ship's stern. Data were recorded at the rate of about 0.1 Hz by the NAVPRO navigation system. During the cruise we received by e-mail the data from the Observatory operated by the IIV-CNR of Catania (courtesy of Dr. Del Negro and Dr. Napoli) in the proximity of the M.Etna (located at 37 50.9N, 14 44.5E, 1340m), that were used for preliminary clean-up to eliminate possible abnormal magnetic activity and to prepare the algorithms for the final processing.

The instrument performed well for the totality of the cruise, when it was towed at the speed of 10-10.5 Kn constantly, except when the ship was in contrasting seas. We were forced to change the bronze shackle and nut at the nose of the fish after 45 days cruise. Some 12 H data were lost at the end of the cruise for problems at the connectors on the fish.

The magnetic data of the 1999 survey were collected by the NAVPRO navigation computer, along with date, time (+1GMT), DGPS antenna latitude and longitude, gyrocompass, bathymetry (central beam of EM12). A procedure was set to make a first display of the data, by means of:

1. positioning of the sensor according to the offset and gyro;
2. computing of the IGRF-95 anomaly
3. display of magnetics and bathymetry along the line;

This served primarily for data inspection. An example can be seen in Fig. 19.

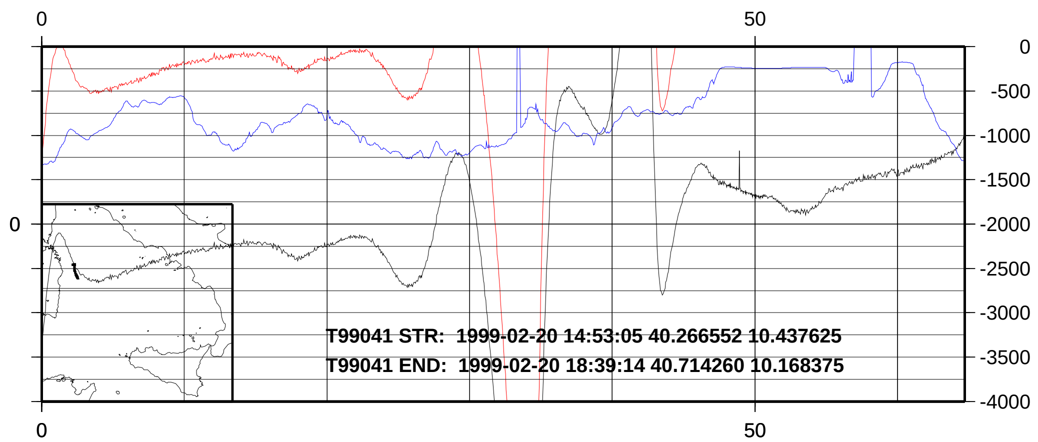


Figure 19: TIR99: example of unfiltered magnetic data (GEM GSM 19D).

Thank to Istituto Nazionale di Geofisica and to Istituto Internazionale di Vulcanologia we have been provided the data of the Observatories of L'Aquila and od Catania for the entire cruise period. The data of the two observatories are presented in Fig. 20.

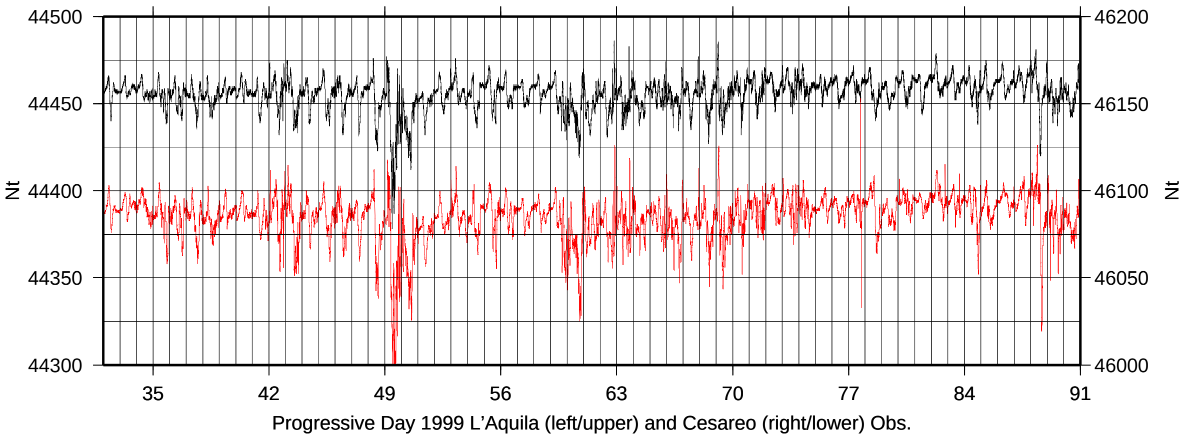


Figure 20: TIR99: magnetic observatories data (Aquila and Catania). Courtesy of ING of Rome (Dr. DeSantis)and IIV of Catania (Dr. DelNegro and Dr. Napoli)

GRAVIMETRY

A set of two running and one spare quartz controlled gravimeters by NEFTEKIP (Mod. GMN-132) were used during the second leg. The measuring principle consisted of the measure of the angles of a horizontal pendulum, which depend on the local mass differences. The reaction of the system to the movements of the pendulum, tending to bring it back to the horizontal position were recorded as a potential drop on a logging PC. During the port call in Civitavecchia (2nd leg) the system was calibrated against the reference point in the harbour. Final calibration was done upon the arrival in Catania at the end of the cruise. Appendix 6.2 reports the monographs.

SEISMIC AND SUBBOTTOM PROFILING

On almost the totality of the survey lines high-speed reflection seismics was performed. The deployment and recovery was always done at full speed, thus maintaining the planned multibeam acquisition rate. Tab. 5 and Fig. 13 shows the instrumental offsets.

SINGLE CHANNEL REFLECTION SEISMIC

GINS's developped streamer and guns were used. The data were taken at a shot interval of 8 seconds, with analog display at 4 seconds on ship's RAYTHEON line recorder. The seismic source was made up by two guns towed at the port and starboard sides of the stern. Guns' capacity ranged from 0.5 to 1 L each.

A new high resolution gun and a new streamer were developed, built and tested onboard. The used air-guns were built around an original design patented by GIN (V.Efimov). The materials are stainless steel, titanium, poliurethane. The new, high resolution gun was entirely built in titanium.

Two streamers were used. The first, employed an array of 50 ceramic elements (25 mt active) in diesel oil, whilst the second employed an array of 30 ceramic elements (15 m active) in a vacuum poliurethane jacket, contained in a larger poliurethane jacket filled by seawater during deployment. This latter configuration helped to increase substantially the signal/noise ratio. The tow leader consisted of an armoured steel cable, plus a stretch section. Total length to active was aprox. 150 m from stern.

Some lines were run with the two guns synchronized. The air pressure ranged from 70 to 100 Bar, as provided by ship's seismic compressors. The guns were towed at 4-5 m (2-3 m for the high resolution one), whereas the streamer was towed at 11 m.

Figure 21 show an example of the data acquired.

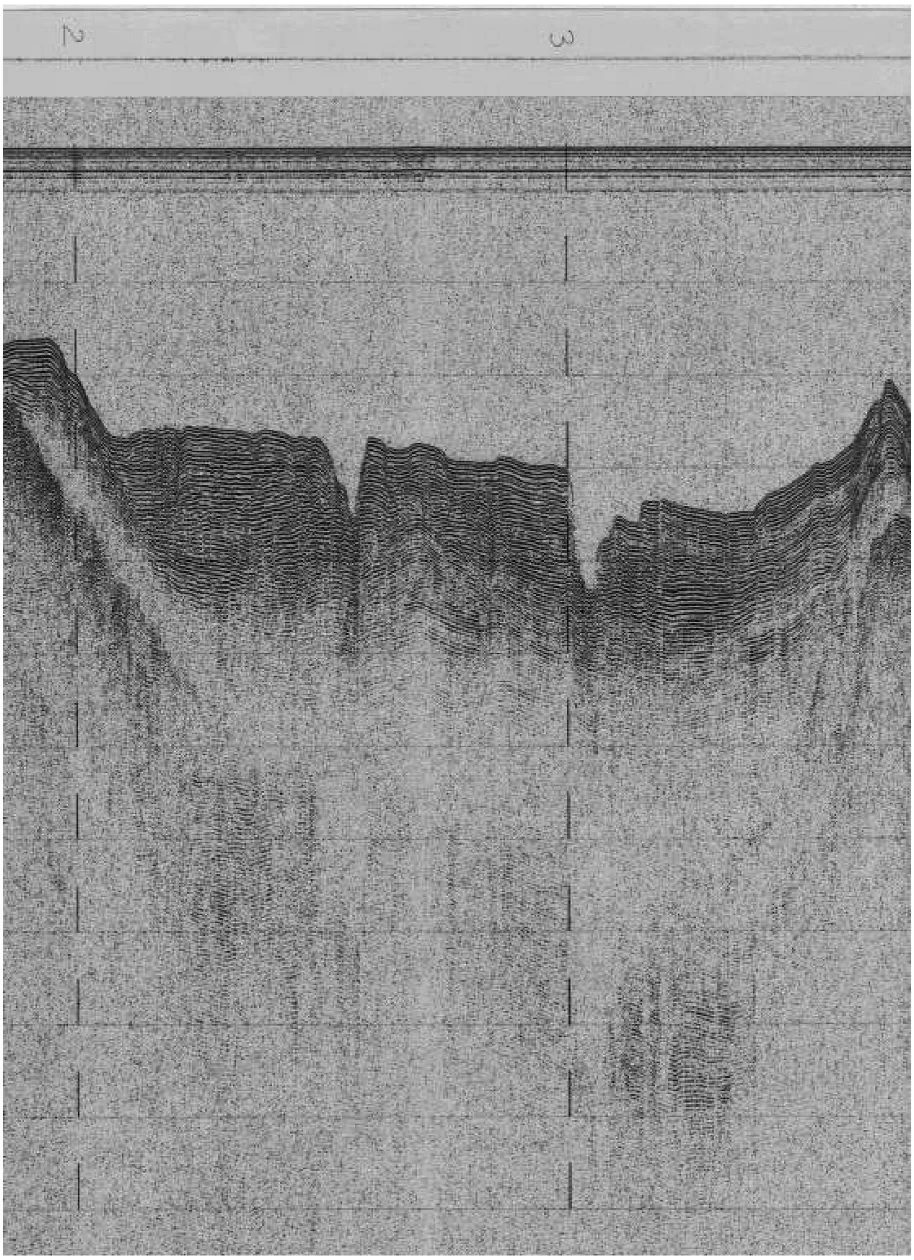


Figure 21: TIR99: example of single channel seismic

SUB BOTTOM PROFILING

The Kongsberg-Simrad TOPAS system was tested on two lines. Due to the strong interference between the EM12 and the TOPAS transducers we rejected to make continuous mapping. Instead, the system worked well with the EM-950.

3.4.4 COMPUTING FACILITIES AND ON BOARD DATA PROCESSING

On the on ship's existing Ethernet coaxial backbone we established a network of computers for swath bathymetry and general purpose data processing, as shown by Fig. 22. Among them, PC's running Linux and Windows OS, and two SUN ULTRA 1 workstations running Solaris 2.5 and 2.7 OS. The SUN WS were devoted to multibeam data processing, whilst the LINUX WS were used for NFS disk and printer spooling services. In addition to this, ELETTRA's Sparc Station 20 workstation, running Solaris 2.5 OS was also used. One HP Mod. 750 A0 color ink-jet plotter was used for charting.

During the 60 days cruise, we can report just a few stops of some machines, that recovered smoothly after the reboot or file system check.

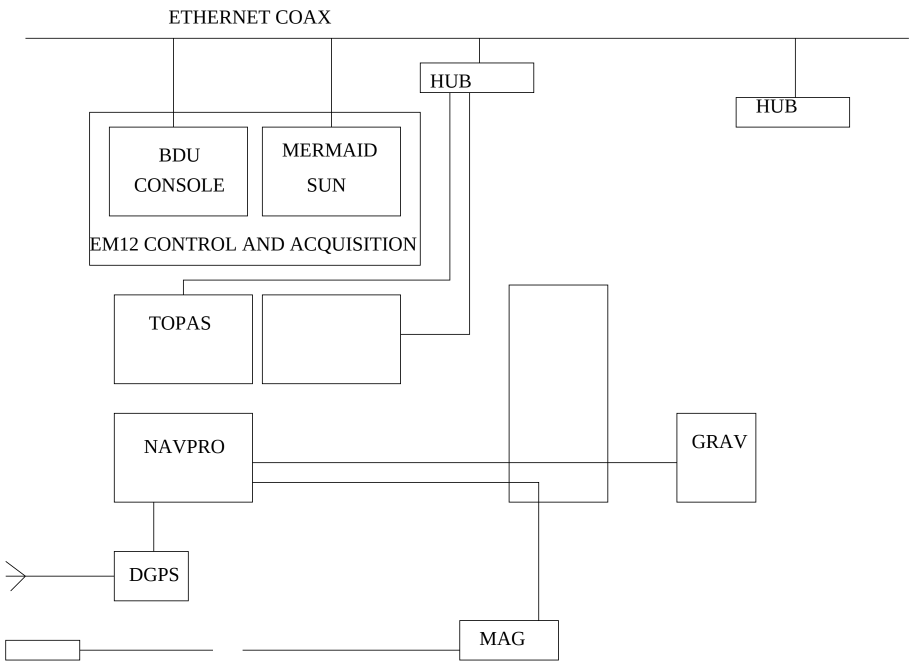


Figure 22: TIR99: computing center and data flow paths

3.5 RESULTS

During the 1999 cruise a total of 16000 km of multibeam and magnetics lines were collected (see Fig.23.

The multibeam data were edited and processed on-board, at the scales of 1:100000, 1:250000, 1:500000. The data quality ranged from very good to acceptable, mainly depending upon the weather conditions and investigated depths. The data acquired were merged with the data collected during the 1996 cruise. Fig.24 shows the result.

Magnetic recordings showed a good continuity and quality of data, requiring just a minimal pass for filtering prior to the IGRF-95 anomaly calculation.

Continuous Seismic profiling was done for almost the totality of the cruise, giving the chance to define the thickness of the sediments above the acoustic basament and the structural makeup of the area.

Gravimetry data were collected only during the second leg, and processing is ongoing to calculate free air and Bouguer anomalies.

Several XBT and some XCTD launches were done. The data will be useful for the better reprocessing of the Multibeam data and will provide good oceanographic information at the basin level. During the 60 days cruise TIR99 a good quality morpho-bathymetric and geophysical data set was collected in the Tyrrhenian Sea, up to minimum depths of about 500 m in almost all margins. The integration with the same data collected during cruise TIR96 was performed on board.

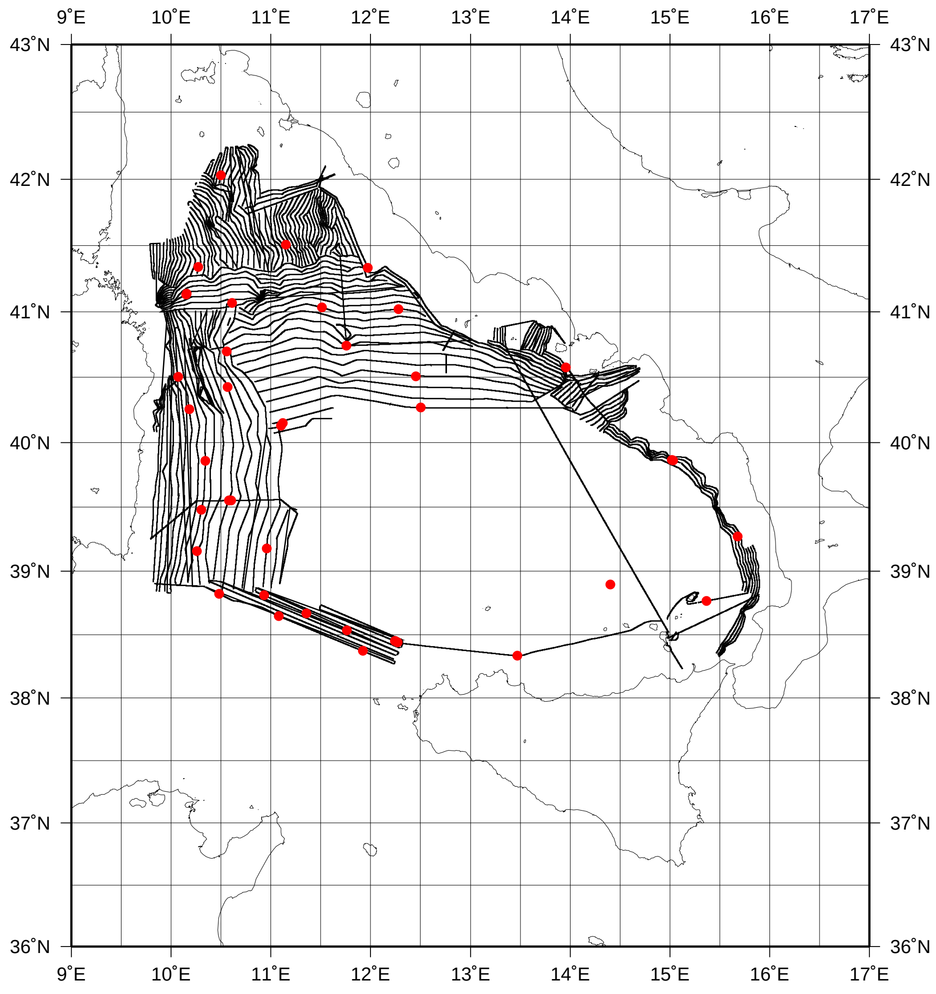


Figure 23: Navigation lines during cruise TIR99

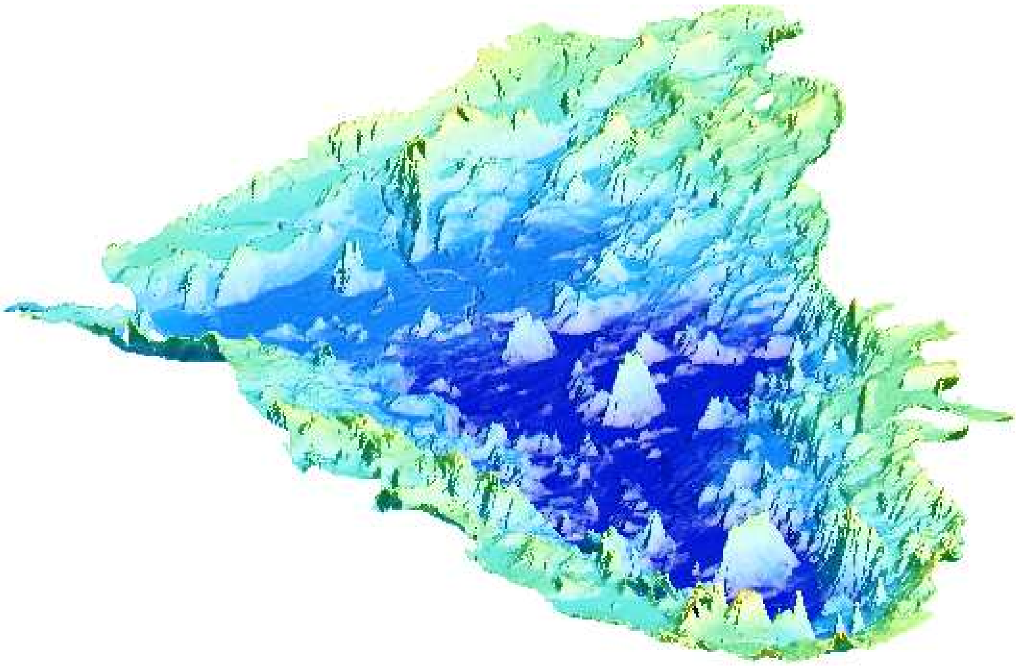


Figure 24: Shaded relief (azimuth from 135) with the Multibeam data of cruises 1996 and 1999

Part 4

DATA PROCESSING

4.1 SWATH BATHYMETRY DATA PROCESSING AND ORGANIZATION

The multibeam lines of the two surveys were planned to achieve the full coverage, with an average overlap of 15-20%. During the acquisition in 1999 the lines collected in the 1996 survey were input on the MERLIN logging workstation in order to have the proper guidelines for the routes.

Fig. 25 shows the lines that were collected during the two surveys.

The logging procedure was designed in order to minimize the risks of data loss and to have an easier handling of the files during the post-processing phase. For these reasons, we decided to close and open new raw multibeam files every two hours on straight routes and at every turn larger than 10 degrees.

Once the file was closed, it was pushed on the network by NFS or FTP as soon as possible and logged by another UNIX workstation. The raw data file integrity was then checked by importing it on the Neptune package and, finally, backed up on CD-ROMs, DATs and Magneto-optical cartridges. A double check with the files on the MERLIN workstation allowed the deletion to make space for the incoming multibeam data. For additional safety the data were also backed up on line on a DAT during the acquisition by the MERMAID tape logging facility.

DEPTH PROCESSING

The swath-data processing underwent the following guidelines:

1. division of the surveyed area into main geographical sectors (projects), e.g. the Sardinia Channel, the Sardinia Margin, The Central Thyrrhenian, the Northern Thyrrhenian and the SouthEast Margin, including the data acquired during the 1996 survey;
2. creation of blocks (NEPTUNE) within the above geographical sectors, with an average number of points of 500000;
3. line positioning processing (smoothing with cutoff frequency 0.07 and filter length 20), with NEPTUNE's POSPROC Module;
4. depth processing with the appropriate sound velocity profiles (generated upon the XBT and statistical data) and additional local processing if necessary, with NEPTUNE's DEPTHCORR Module;
5. block processing with Statistical or hand filtering, with NEPTUNE's BINSTAT Module (cell size ranging from 100 to 200 m, according to the crosstrack resolution of the data, noise 3%, local rules to get rid of macroscopic depth errors); a lot of effort was applied in order to keep as much of valid data as possible. This was not always sufficient to eliminate some of the errors that were present on the ovelapping swaths on deepest areas.
6. export of the block data in NEPTUNE binary xyz format (geographical);

CARTOGRAPHY AND DTM

The choice of the cartographic outputs underwent the following guidelines (see Fig. 26):

1. division of the whole surveyed area in 1 x 2 Degrees Latitude and Longitude sheets at the scale 1:250000 according to the Join Operation Group (JOG) cuts, to be produced with the UTM and Mercator projections. Accordingly, the names of the maps follow the JOG numbering (e.g. NJ32_6).
2. division of each JOG sheet in 4 working maps at the scale of 1:100000 (Direct Mercator on 40N), extending 2 km WSEN of the geographical limits. The names of the map follow the JOG numbering and quadrant (e.g. NJ32_6SW, NJ32_6SE, NJ32_6NE, NJ32_6NW). In some cases the limits were extended, with an E added to the map name.

The gridding and DTM production (IRAP) underwent the following guidelines:

1. preparation of all previuos data (including grids and single beam) for the input to IRAP and datum transformation to WGS84 if necessary.
2. reading and storing of the xyz NEPTUNE files in the SIMRAD STB format (Direct Mercator on 40N), and straight conversion to UTM 32 or 33 of the STB file if necessary (procedure stb2stb).
3. production of the DTM 100x100 m for each of the above 1:100000 working maps (Direct Mercator on 40N) (search radius 1000m, number of quadrant 4, number of point per quadrant 8);
4. production of the DTM 250x250 m 1:250000 (Direct Mercator on 40N) by regridding the 4 1:100000 DTMs (search radius 1250 m, number of quadrant 4, number of point per quadrant 8).
5. straightforward production of GMT netcdf grids from the IRAP grids (procedure gri2grd)
6. production of larger DTM's of the whole area
7. production of higher resolution maps at scales ranging from 1:25000 to 1:100000 on most interesting areas.
8. compilation and backups of the digital data

The processing flow was automated by some procedures that created the command files to be executed in batch by IRAP, on the basis of each particular JOG map and of the data files that were found to be present on the area.

The STB datafile names were created with the NEPTUNE block numbering, plus:

nn_CRid.ellprj.stb

nn = block
CRid = cruise and Area ID
ell = W for WGS84, E per ED50
prj = m40 for Mercator 40, u33 UTM zone 33

The naming of the processed grids is Name_of_the_project.GRI

DATA DIRECTORY ORGANIZATION

At the end of the preliminary cleaning phase, the data were reorganized in directories and the XYZ files were renamed in such a way that they can be identified by CRUISE and NEPTUNE project, as follows:

nn_CRid.ell.xyz

where nn = block name, CRid = cruise and area id, obtaining:
T96_1 TIR96 first leg
T96_2 TIR96 second leg
T99_1 TIR99 AREA2
T99_2 TIR99 AREA3
T99_3 TIR99 AREA3 north
T99_4 TIR99 AREA4 north
T99_5 TIR99 AREA4 south
T99_6 TIR99 eolie
T99_7 TIR99 napoli

and where ell = W for WGS84, E per ED50.

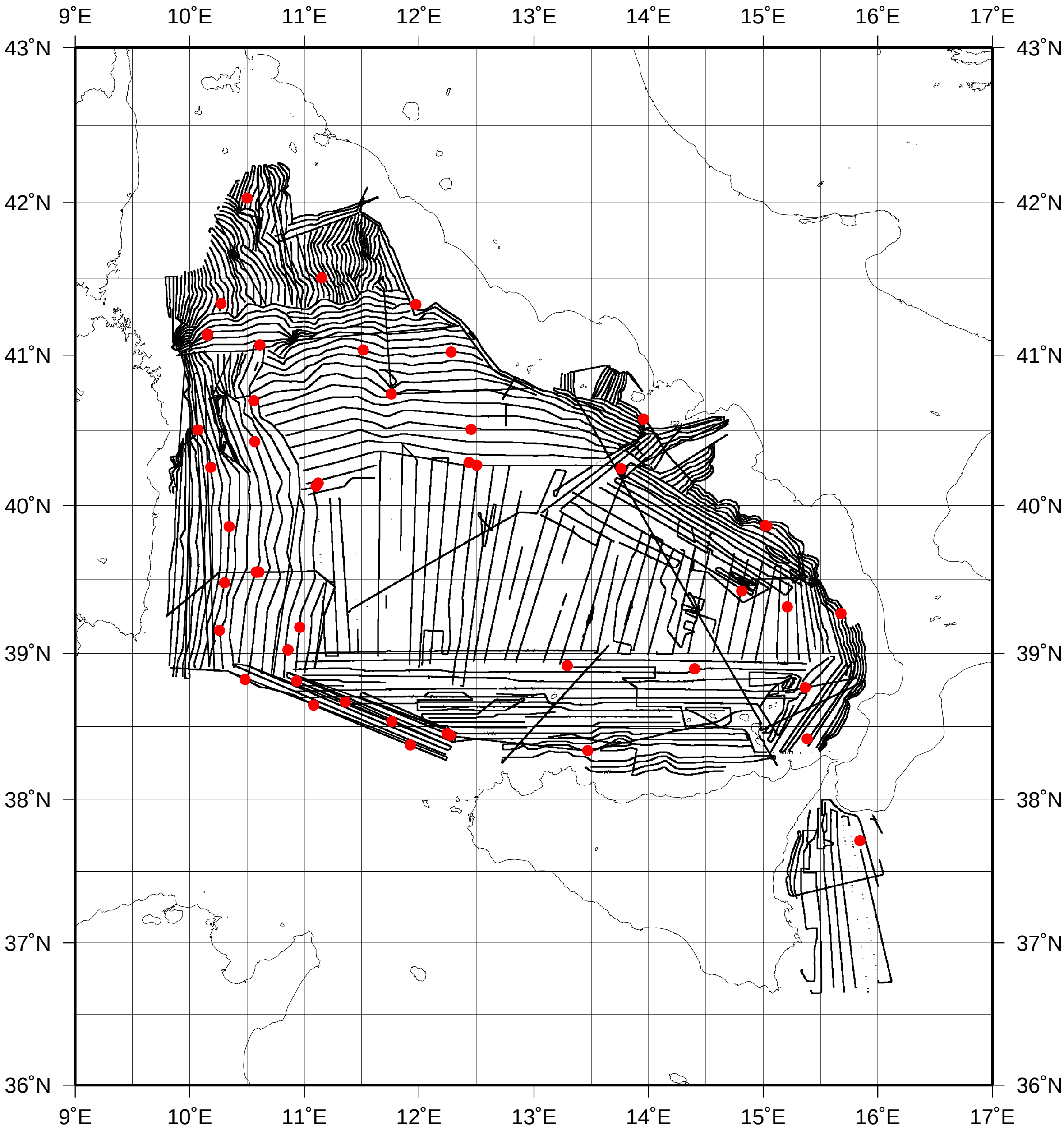


Figure 25: Multibeam Navigation lines (1996=blue,1999=red)

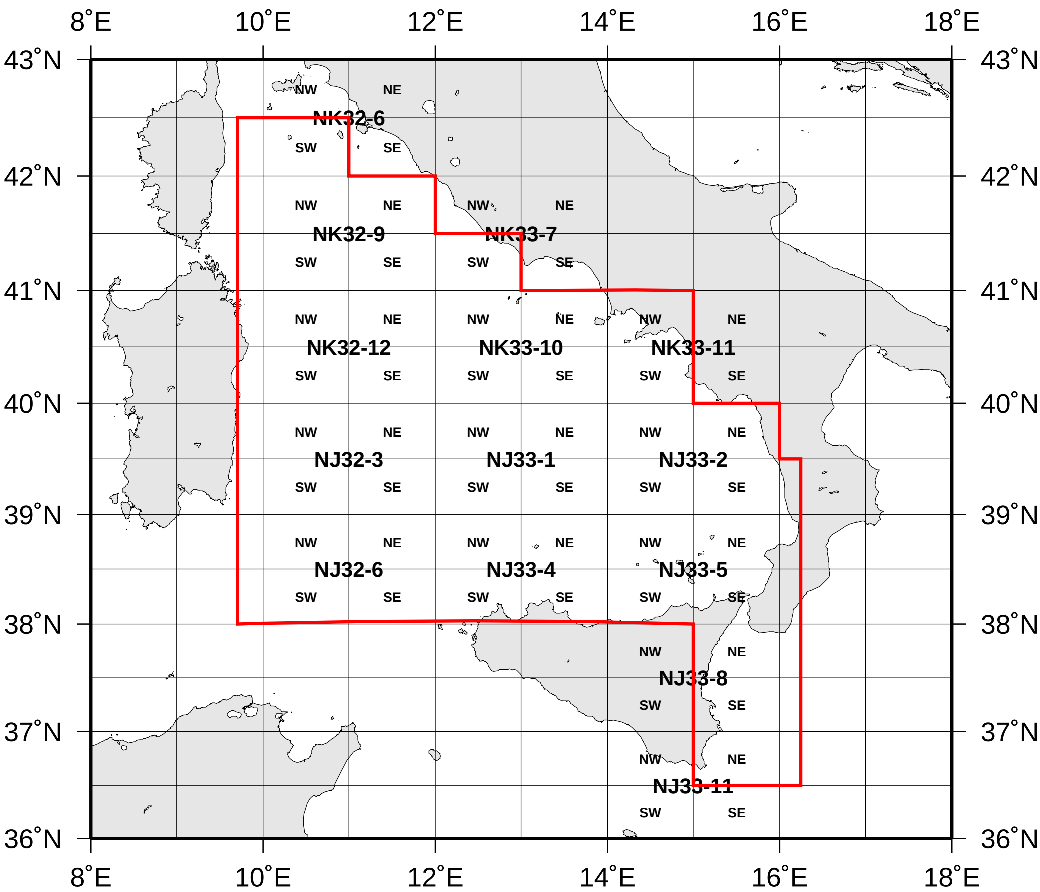


Figure 26: Cartographic coverage

Part 5

CONCLUSIONS

During some 100 days of work at sea we have run aproximately 36000 Km of multibeam and geophysics lines in the Tyrrhenian and Ionian Sea, thus obtaining almost the full bathymetric coverage of the Thyrrhenian Sea from an average depth of 500 m down to the bathyal plain. The data were processed and DTMs were produced with a resolution of 100 m and even better in some areas. From these DTMs, maps at scales ranging from 1:50000 to 1:1000000 can easily be produced, by using the single grids or joining them to make larger ones, at the same resolution or lower.

Figures 27 and **??** present 3-d shaded reliefs maps at different scales and resolutions.

At this stage of data processing, the swath bathymetry data may be used at 1:100000 and smaller scales. Spots at larger scales may also be possible. We still have some work to perform on some noisy data in the deeper flat portions of the basin. In addition, much work have to be done on the integration of bathymetry and reflectivity data.

Magnetic and gravity data were recorded along the multibeam navigation lines, with a spatial resolution which varied with the line spacings. We expect to be able to produce grids at the resolution of 500 m and even better. Unfortunately, we were not able to collect gravity data during the first leg of cruise TIR99. The processing of the data is ongoing.

Seismic data were also collected along the multibeam lines, giving the possibility to better define the sedimentary cover and structures.

The data collected can be considered of good quality, and have a large potential for further processing and integration with existing or future data.

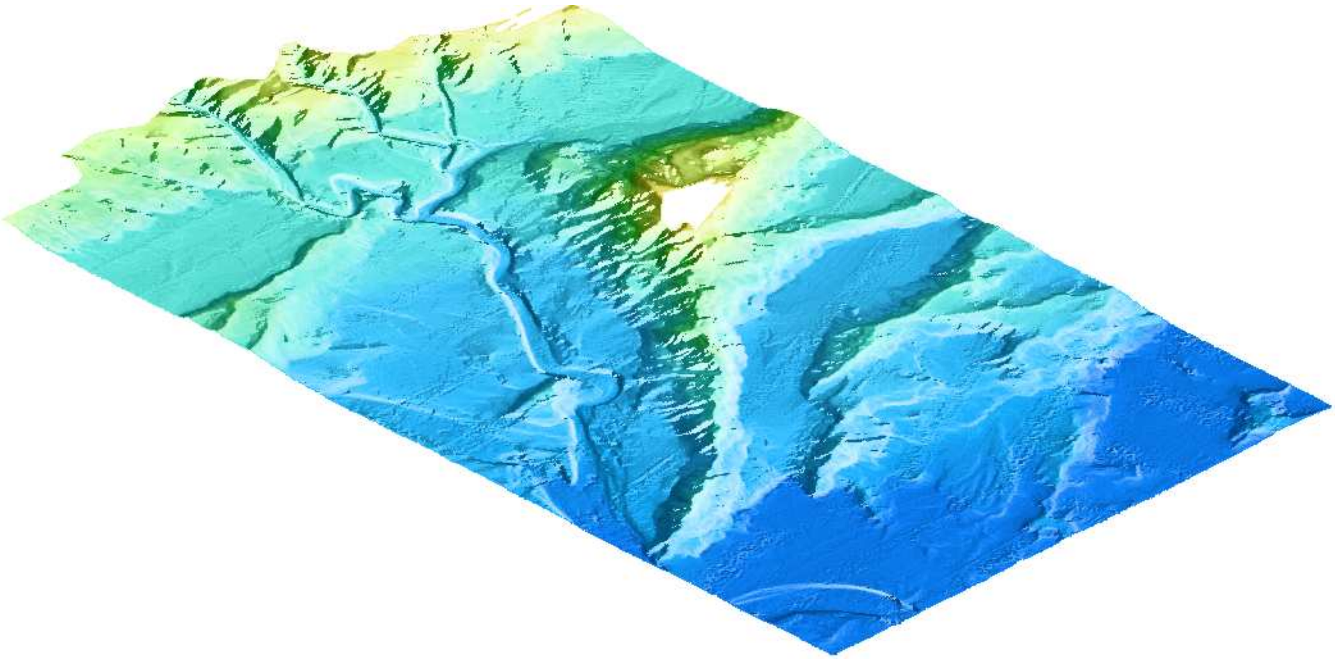


Figure 27: Shaded relief from sheet NK32_12SWE, view from 135. DTM 100m, Projection Direct Mercator on 40N.

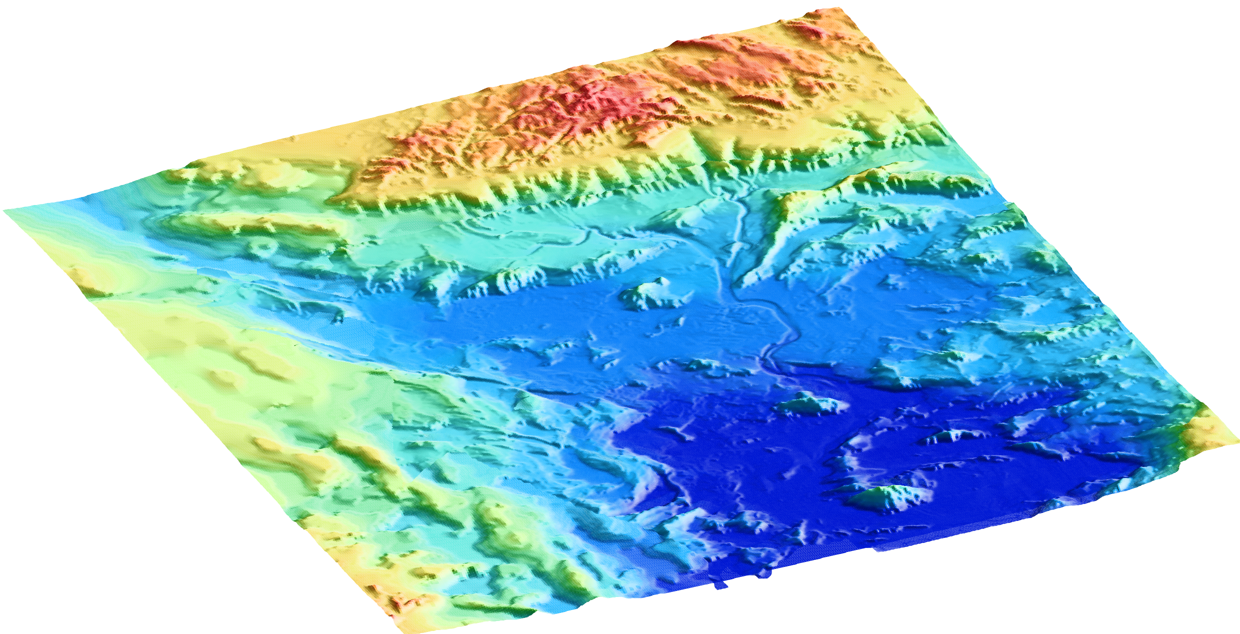


Figure 28: Topography and low resolution bathymetry, same as 1. High resolution bathymetry from TIR96 and TIR99 cruises, view from 115/30, Projection Direct Mercator on 40N.

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Part 6

APPENDIXES

6.1 DATA PROCESSING COOKBOOK

During the on-going data acquisition at sea and during the production of the Report several data processing procedures were developped and used.

Table 7 presents the software that was used.

SW	CLASS	WHAT	URL
gcc, f77, awk	Compilers, Scripting	C,Fortran	www.gnu.org
GMT	Mapping, Processing	Generic Mapping Tool	imina.soest.hawaii.edu/gmt
PERL	Compilers, Scripting		www.perl.com
MySQL	SQL DBMS		www.tcx.se
IGM-LIB	Topographic Processing		
ghostscript	PostScript Interpreter		
tex, latex	Math and Technical Typesetting		www.tug.org
latex2html	Latex to HTML Translator		
latex2rtf	Latex to RTF Translator		
igrf	Mag reference fields		

Table 7: Software used in data processing

We will present and discuss hereafter some of the procedures.

6.1.1 GMT DTM PRODUCTION

6.1.2 DTM RENDERING

6.1.3 NAVIGATION DATA

6.1.4 MAGNETIC DATA

6.1.5 STD DATA

6.2 GRAVIMETER CALIBRATION AND OPERATIONS - TIR99

Upon departure in Catania (2-feb-1999), we established an absolute reference point at ship's docking (Molo sporgente Centrale), thanks to the cooperation of IIV (Dr. Carbone) (Fig. 29. A SCINTREX portable gravimeter Mod. CG-M was used from absolute point at the Palazzo delle Scienze to the ship point. The coordinates of ship POS1 during the measurements are reported on Fig. 29: the WGS84 coordinates are the centroid of 20 min. acquisition from NAVPRO, whereas the M.Mario coordinates were converted by DATUM (Ligi and Bortoluzzi, 1988). The GMT coastline (probably ED50) and the Molo Centrale Coordinates (from map N. 272 of Istituto Idrografico Della Marina, M.Mario) are reported as well.

Upon departure in Civitavecchia (4-mar-1999) the gravimeter was calibrated against the absolute point in the harbour (courtesy of Dr. Cesi, Servizio Geologico Nazionale), which was found to be at a distance less that 600 m.

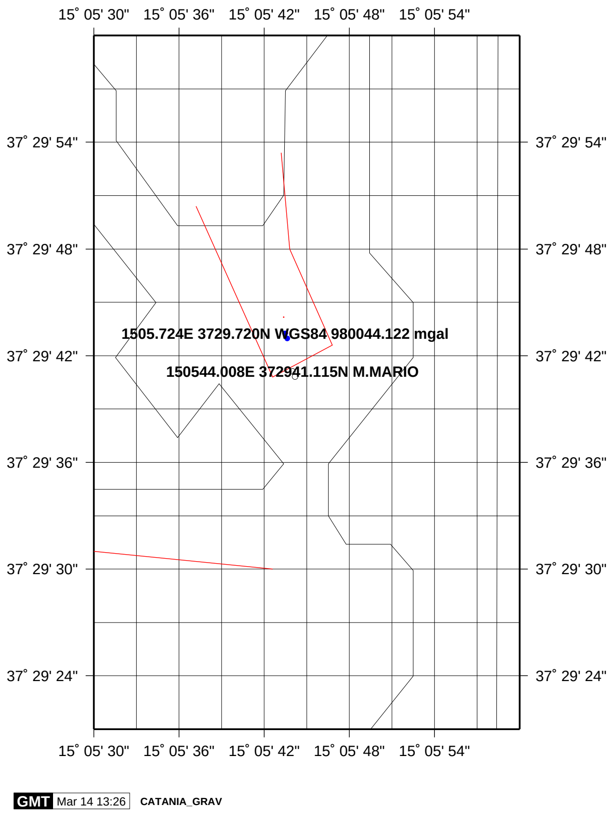

Figure 29: Ship location at Catania 3-mar-1999

After a 4 hour of thermal and electronic stabilization, the value of the on board gravimeter was read for a period of time of 6 hours. The values were then averaged and the result was set as the instrumental zero.

During the cruise the dynamic characteristics of the system was measured two times. The procedure consisted of changing the pressure on the springs of the pendulum and reporting the response at the logging PC. In addition to this, the temperature inside the sensor and the horizontal stability of the gyroscopic platform were checked every hour. These latter were found to be well within the instrumental characteristics. At the end of the cruise in Catania, the above procedure was repeated and the resulting reading was set as the total drift of the instrument. The ship was docked at a distance of about 300 m from the absolute point that was established at the departure.

GRAVIMETER CAL. COORDINATES							
POINT POS1	Date	Ship Lat	Ship Lon	Abs Lat	Abs Lon	DIST	BRG
CATANIA	3-feb-1999	3729.7209	1505.7244	?	?	10	300
CIVITAVECCHIA	4-Mar-1999	?	?	?	?	?	?

Table 8: Gravimeter Calibration POS1

DATA ORGANIZATION AND PROCESSING

The data were logged on a PC. The record consisted of PC SYSTEM TIME (corrected by data from NAVPRO navigation system), gravimetric band (turns of the main spring, 0 to 16), mV. The field data were tranformed from mV to mgal with the following formula:

$$\mathrm{G} = \mathrm{CV} \tag{1}$$

where G is the gravimetric anomaly (mGal), V is the voltage drop reading, and C is a numerical constant wich is related to the gravimetric band (Table 9). These coefficients were calculated during the zero drift calibration in Civitavecchia 3-apr-1999. This tranformation will be recalculated basing on a new theoretical, non-linear approach.

BAND	COEFFICIENT
0-5	2.3434
5-6	1.900974
6-7	1.394063
7-8	0.901813
8-9	0.38655
9-10	0.12485
10-11	0.6484
11-12	1.142673
12-14	1.676638
14-16	2.1815

Table 9: Coefficients for the conversion of Voltage readings to mGal

G was then corrected (a) for ship's speed and for response time of the system (typically 300 seconds) using a moving average filter at 300 seconds. A (b) classical Eotvos correction was then applied according to Dehlinger (1978)(p.150). A better correction will be evaluated and applied during final processing of the data, due to the high frequency of turning of ships' heading; (c) Normal Gravity field correction (1970 formula of International Geodesy Association, Dehlinger, 1978)) was finally applied, and the Free Air anomaly data were obtained. No drift correction was applied yet.

$$\gamma_{\mathrm{FreeAir}} = \mathrm{G}_{\mathrm{Filt}} - \gamma_{\mathrm{Normal}} - \gamma_{\mathrm{Eotvos}} \tag{2}$$

A crossing line was performed in order to check the drift of the sensors and to make an estimate of the errors. This analysis will be used for the final processing of the Free Air Gravity anomaly.

By using a 1km grid of the surveyed area the Bouguer Gravity Anomaly will then be computed at a constant density of 2.67 gr/cm3.

6.3 METEROLOGICAL CONDITIONS DURING CRUISE TIR99

METEREOLOGICAL DATA TIR99

DATE	TIME	PROG_DAY	LAT	LON	W_D	W_S	S_D	S_S	VIS	PRESS	A_T	W_T
5-Feb-1999	00:00:00	36.00000	-	-	-	-	-	-	-	-	-	-
5-Feb-1999	04:00:00	36.16667	-	-	350	5	350	2	8	1024	10	12
5-Feb-1999	08:00:00	36.33333	-	-	280	6	280	3	8	1020	10	13
5-Feb-1999	12:00:00	36.50000	-	-	270	7	270	3	8	1020	12	13
5-Feb-1999	16:00:00	36.66667	-	-	270	7	270	3	8	1016	12	13
5-Feb-1999	20:00:00	36.83333	-	-	270	2	270	1	7	1013	11	12
6-Feb-1999	00:00:00	37.00000	14.54994	38.52322	260	4	260	3	7	1008	11	12
6-Feb-1999	04:00:00	37.16667	13.84758	38.39908	260	4	260	4	7	1007	11	12
6-Feb-1999	08:00:00	37.33333	13.24810	38.35116	270	6	270	4	7	1007	12	12
6-Feb-1999	12:00:00	37.50000	12.50705	38.41445	280	10	280	4	6	1008	12	12
6-Feb-1999	16:00:00	37.66667	11.91097	38.55770	280	10	280	4	8	1008	12	12
6-Feb-1999	20:00:00	37.83333	11.80603	38.63115	280	10	280	4	7	1011	12	12

METEREOLOGICAL DATA TIR99

DATE	TIME	PROG_DAY	LAT	LON	W_D	W_S	S_D	S_S	VIS	PRESS	A_T	W_T
7-Feb-1999	00:00:00	38.00000	12.08110	38.46449	310	12	310	5	7	1012	12	13
7-Feb-1999	04:00:00	38.16667	11.34907	38.70597	310	12	310	5	8	1011	12	12
7-Feb-1999	08:00:00	38.33333	11.06636	38.76419	300	12	300	5	8	1012	13	13
7-Feb-1999	12:00:00	38.50000	11.92834	38.47842	300	10	300	5	8	1012	14	13
7-Feb-1999	16:00:00	38.66667	11.98764	38.42289	300	10	300	5	8	1012	14	13
7-Feb-1999	20:00:00	38.83333	11.37671	38.62430	300	11	300	5	8	1011	14	14
8-Feb-1999	00:00:00	39.00000	10.72148	38.84173	270	12	270	5	6	1011	14	14
8-Feb-1999	04:00:00	39.16667	10.77697	38.78609	270	12	270	5	8	1011	13	13
8-Feb-1999	08:00:00	39.33333	11.62901	38.50360	280	12	280	5	8	1011	14	14
8-Feb-1999	12:00:00	39.50000	12.14140	38.30027	280	18	280	7	7	1011	14	14
8-Feb-1999	16:00:00	39.66667	12.14140	38.30027	280	20	280	7	7	1011	13	13
8-Feb-1999	20:00:00	39.83333	12.14140	38.30027	290	20	290	7	7	1016	13	13
9-Feb-1999	00:00:00	40.00000	12.14140	38.30027	280	20	280	8	7	1017	13	13
9-Feb-1999	04:00:00	40.16667	12.14140	38.30027	280	20	280	6	7	1015	13	13
9-Feb-1999	08:00:00	40.33333	12.14140	38.30027	270	17	270	7	8	1016	13	13
9-Feb-1999	12:00:00	40.50000	12.14140	38.30027	280	15	280	6	7	1016	13	13
9-Feb-1999	16:00:00	40.66667	11.50680	38.50647	280	15	280	6	7	1012	14	14
9-Feb-1999	20:00:00	40.83333	10.76315	38.74618	280	16	280	6	7	1012	14	14
10-Feb-1999	00:00:00	41.00000	10.03569	38.89094	260	18	260	7	7	1008	12	13
10-Feb-1999	04:00:00	41.16667	9.85869	39.37859	260	18	260	7	7	1004	12	13
10-Feb-1999	08:00:00	41.33333	9.91450	40.07630	230	17	220	6	7	1001	12	14
10-Feb-1999	12:00:00	41.50000	9.96250	40.34562	260	18	260	6	6	1000	12	13
10-Feb-1999	16:00:00	41.66667	9.94522	39.66884	260	18	260	6	7	1000	12	13
10-Feb-1999	20:00:00	41.83333	9.87528	38.99137	270	19	270	7	7	1007	12	14
11-Feb-1999	00:00:00	42.00000	9.96267	39.29899	250	20	250	6	7	1007	12	13
11-Feb-1999	04:00:00	42.16667	10.01719	39.94190	250	20	250	6	8	1004	11	12
11-Feb-1999	08:00:00	42.33333	9.99714	40.48455	230	17	250	5	8	1003	8	12
11-Feb-1999	12:00:00	42.50000	10.06659	39.81620	220	15	220	3	8	1003	11	12
11-Feb-1999	16:00:00	42.66667	10.00570	39.13734	220	15	230	6	6	1003	10	12
11-Feb-1999	20:00:00	42.83333	10.04623	39.10261	230	16	230	6	6	1007	10	12
12-Feb-1999	00:00:00	43.00000	10.12663	39.68948	340	16	340	6	6	1008	10	12
12-Feb-1999	04:00:00	43.16667	10.12103	40.22043	340	20	340	6	6	1007	10	12
12-Feb-1999	08:00:00	43.33333	10.15519	40.38358	350	20	350	7	6	1009	8	12
12-Feb-1999	12:00:00	43.50000	10.19409	39.77440	350	12	350	5	6	1013	5	11
12-Feb-1999	16:00:00	43.66667	10.09377	39.11008	350	10	350	5	7	1013	8	11
12-Feb-1999	20:00:00	43.83333	10.14873	39.18840	010	14	010	5	7	1013	8	11
13-Feb-1999	00:00:00	44.00000	10.27294	39.81143	010	12	010	5	6	1013	7	11
13-Feb-1999	04:00:00	44.16667	10.17254	40.42929	010	16	010	6	8	1013	5	15
13-Feb-1999	08:00:00	44.33333	10.11743	40.72069	010	14	01	5	8	1013	5	15
13-Feb-1999	12:00:00	44.50000	10.34081	40.02372	010	12	010	5	7	1017	8	13
13-Feb-1999	16:00:00	44.66667	10.27961	39.38059	010	12	010	5	7	1019	6	13
13-Feb-1999	20:00:00	44.83333	10.28519	38.93258	010	10	010	4	6	1020	7	13
14-Feb-1999	00:00:00	45.00000	10.39652	39.58644	020	7	020	3	6	1020	8	13
14-Feb-1999	04:00:00	45.16667	10.41225	40.23639	020	10	020	4	6	1020	8	13
14-Feb-1999	08:00:00	45.33333	10.13498	40.84383	010	10	010	4	7	1021	7	13
14-Feb-1999	12:00:00	45.50000	10.38709	40.31230	030	3	030	1	8	1021	8	12
14-Feb-1999	16:00:00	45.66667	10.49837	39.62260	030	3	030	1	8	1021	8	12
14-Feb-1999	20:00:00	45.83333	10.37705	38.94316	030	4	030	2	8	1024	7	12
15-Feb-1999	00:00:00	46.00000	10.55383	39.49971	030	6	030	2	6	1024	7	11
15-Feb-1999	04:00:00	46.16667	10.59618	40.15410	030	6	030	2	8	1021	8	13
15-Feb-1999	08:00:00	46.33333	10.30233	40.76141	300	8	300	3	7	1023	7	14
15-Feb-1999	12:00:00	46.50000	10.42997	40.66991	310	8	310	2	6	1023	8	13
15-Feb-1999	16:00:00	46.66667	10.71300	40.02777	310	8	310	2	8	1023	8	12
15-Feb-1999	20:00:00	46.83333	10.59114	39.34357	070	8	070	3	7	1023	8	12
16-Feb-1999	00:00:00	47.00000	10.63362	38.92464	060	6	060	2	5	1023	8	13
16-Feb-1999	04:00:00	47.16667	10.77268	39.57802	060	8	060	3	6	1023	8	13
16-Feb-1999	08:00:00	47.33333	10.76100	40.22308	020	7	020	2	8	1023	8	12
16-Feb-1999	12:00:00	47.50000	10.44589	40.82676	040	5	040	1	8	1023	9	12
16-Feb-1999	16:00:00	47.66667	10.52727	40.73420	040	5	040	2	8	1021	10	12
16-Feb-1999	20:00:00	47.83333	10.86742	40.12168	040	5	040	2	8	1020	10	12
17-Feb-1999	00:00:00	48.00000	10.86109	39.46860	040	4	040	1	8	1020	8	12
17-Feb-1999	04:00:00	48.16667	10.74713	38.83755	040	6	040	5	8	1019	8	12
17-Feb-1999	08:00:00	48.33333	10.92907	39.39245	260	8	200	4	8	1017	7	12
17-Feb-1999	12:00:00	48.50000	10.99773	39.95459	260	6	260	4	7	1013	12	13
17-Feb-1999	16:00:00	48.66667	10.99773	39.95459	270	8	270	4	8	1012	12	13
17-Feb-1999	20:00:00	48.83333	11.07837	39.64815	290	11	290	5	7	1012	10	12
18-Feb-1999	00:00:00	49.00000	10.94769	39.09688	310	12	310	6	6	1012	8	12
18-Feb-1999	04:00:00	49.16667	11.04598	39.06281	310	14	310	6	8	1013	8	12
18-Feb-1999	08:00:00	49.33333	11.19711	39.49174	340	12	340	5	8	1015	12	12
18-Feb-1999	12:00:00	49.50000	11.09113	38.91283	020	5	020	2	8	1017	14	13
18-Feb-1999	16:00:00	49.66667	11.25156	39.42090	020	5	020	2	8	1016	13	13
18-Feb-1999	20:00:00	49.83333	10.90669	39.55385	230	6	230	3	7	1019	10	13
19-Feb-1999	00:00:00	50.00000	10.17271	39.49474	240	7	240	3	7	1019	9	13
19-Feb-1999	04:00:00	50.16667	9.82008	39.46620	240	12	240	3	8	1017	11	12
19-Feb-1999	08:00:00	50.33333	9.88812	40.17112	120	6	120	2	8	1020	12	12
19-Feb-1999	12:00:00	50.50000	9.87388	40.12977	-	-	-	-	8	1024	13	13
19-Feb-1999	16:00:00	50.66667	9.84134	40.30200	120	5	120	2	8	1024	10	13
19-Feb-1999	20:00:00	50.83333	10.02108	40.82196	170	6	170	2	7	1024	10	13
20-Feb-1999	00:00:00	51.00000	10.02572	40.52836	-	-	-	-	8	1025	10	13
20-Feb-1999	04:00:00	51.16667	9.98681	41.00400	170	2	170	1	8	1025	10	13
20-Feb-1999	08:00:00	51.33333	10.16572	40.91540	240	7	240	3	7	1024	11	13

METEREOLOGICAL DATA TIR99

DATE	TIME	PROG_DAY	LAT	LON	W_D	W_S	S_D	S_S	VIS	PRESS	A_T	W_T
20-Feb-1999	12:00:00	51.50000	10.31856	40.58907	250	4	250	2	6	1023	14	13
20-Feb-1999	16:00:00	51.66667	10.33546	40.43483	280	12	280	4	8	1020	13	13
20-Feb-1999	20:00:00	51.83333	10.22651	40.54533	270	10	270	5	7	1020	14	13
21-Feb-1999	00:00:00	52.00000	10.31557	40.41490	270	14	270	5	6	1019	11	13
21-Feb-1999	04:00:00	52.16667	10.27611	40.63137	270	14	270	4	6	1016	11	13
21-Feb-1999	08:00:00	52.33333	10.33971	40.84193	320	15	320	6	6	1016	12	13
21-Feb-1999	12:00:00	52.50000	10.41849	40.86811	280	7	280	3	8	1016	13	13
21-Feb-1999	16:00:00	52.66667	10.48803	40.72659	280	8	280	4	8	1015	15	15
21-Feb-1999	20:00:00	52.83333	10.93661	40.28063	300	14	300	4	7	1015	15	14
22-Feb-1999	00:00:00	53.00000	11.50391	40.18230	290	16	290	6	6	1015	13	13
22-Feb-1999	04:00:00	53.16667	11.18294	40.17753	260	16	280	6	8	1012	12	13
22-Feb-1999	08:00:00	53.33333	11.49440	40.33306	310	16	310	6	7	1011	14	14
22-Feb-1999	12:00:00	53.50000	12.36642	40.27168	280	12	280	6	6	1011	13	14
22-Feb-1999	16:00:00	53.66667	13.22744	40.26618	260	18	260	7	8	1004	13	13
22-Feb-1999	20:00:00	53.83333	14.07046	40.32844	260	19	260	7	7	1007	12	13
23-Feb-1999	00:00:00	54.00000	14.07046	40.32844	280	20	280	6	6	1005	13	13
23-Feb-1999	04:00:00	54.16667	14.07046	40.32844	290	20	280	6	8	1007	13	13
23-Feb-1999	08:00:00	54.33333	14.07046	40.32844	300	12	300	5	8	1008	14	14
23-Feb-1999	12:00:00	54.50000	14.07046	40.32844	290	10	290	5	3	1009	10	13
23-Feb-1999	16:00:00	54.66667	14.07046	40.32844	290	16	290	5	6	1009	8	13
23-Feb-1999	20:00:00	54.83333	14.07046	40.32844	300	17	300	6	5	1012	9	13
24-Feb-1999	00:00:00	55.00000	14.07046	40.32844	300	10	300	5	7	1013	8	13
24-Feb-1999	04:00:00	55.16667	14.07046	40.32844	300	12	300	5	8	1013	8	13
24-Feb-1999	08:00:00	55.33333	14.07046	40.32844	270	10	270	4	8	1017	13	14
24-Feb-1999	12:00:00	55.50000	13.55372	40.31531	270	4	270	3	6	1019	13	13
24-Feb-1999	16:00:00	55.66667	12.72046	40.33590	270	4	270	3	8	1019	12	13
24-Feb-1999	20:00:00	55.83333	11.86723	40.41519	240	8	240	4	8	1019	12	14
25-Feb-1999	00:00:00	56.00000	11.10735	40.34272	220	8	220	4	8	1019	11	13
25-Feb-1999	04:00:00	56.16667	11.46570	40.50195	220	8	220	4	8	1016	11	13
25-Feb-1999	08:00:00	56.33333	12.36458	40.43125	210	8	210	4	7	1015	12	14
25-Feb-1999	12:00:00	56.50000	13.24778	40.39720	220	8	220	4	5	1017	13	14
25-Feb-1999	16:00:00	56.66667	13.47092	40.43512	220	10	220	4	8	1017	13	14
25-Feb-1999	20:00:00	56.83333	12.65286	40.50864	230	10	230	4	6	1017	12	14
26-Feb-1999	00:00:00	57.00000	11.79606	40.53001	220	3	220	2	6	1017	13	14
26-Feb-1999	04:00:00	57.16667	10.98392	40.49585	220	3	220	2	8	1017	13	14
26-Feb-1999	08:00:00	57.33333	11.26852	40.64227	030	5	030	2	8	1020	15	14
26-Feb-1999	12:00:00	57.50000	12.11549	40.62123	050	4	050	1	8	1021	14	14
26-Feb-1999	16:00:00	57.66667	12.94448	40.58388	050	4	050	1	8	1021	13	14
26-Feb-1999	20:00:00	57.83333	13.79600	40.40017	050	4	050	2	8	1021	14	14
27-Feb-1999	00:00:00	58.00000	13.04185	40.64267	-	-	-	-	9	1021	12	13
27-Feb-1999	04:00:00	58.16667	12.69223	40.67992	-	-	-	-	9	1021	13	13
27-Feb-1999	08:00:00	58.33333	11.78083	40.67962	120	5	120	2	9	1021	15	14
27-Feb-1999	12:00:00	58.50000	10.87154	40.64078	110	4	110	2	7	1023	13	14
27-Feb-1999	16:00:00	58.66667	11.13223	40.77309	110	4	110	3	7	1023	13	14
27-Feb-1999	20:00:00	58.83333	11.98044	40.76810	110	7	110	3	7	1023	14	14
28-Feb-1999	00:00:00	59.00000	12.86857	40.72187	100	5	100	1	7	1023	13	14
28-Feb-1999	04:00:00	59.16667	13.66409	40.51068	100	5	100	1	8	1023	13	14
28-Feb-1999	08:00:00	59.33333	13.38081	40.64443	-	-	-	-	6	1024	14	14
28-Feb-1999	12:00:00	59.50000	12.55951	40.98975	-	-	-	-	7	1024	14	14
28-Feb-1999	16:00:00	59.66667	11.92166	41.34325	-	-	-	-	8	1024	14	14
28-Feb-1999	20:00:00	59.83333	11.43903	41.92286	-	-	-	-	8	1024	14	14
1-Mar-1999	00:00:00	60.00000	10.86768	41.81665	-	-	-	-	6	1024	12	14
4-Mar-1999	04:00:00	60.16667	12.05183	41.29985	180	8	180	5	8	1012	13	13
4-Mar-1999	08:00:00	60.33333	12.69575	40.90608	210	9	220	4	7	1011	15	14
4-Mar-1999	12:00:00	60.50000	12.75671	40.74582	220	8	220	4	6	1011	13	13
4-Mar-1999	16:00:00	60.66667	12.80225	40.79489	220	10	220	4	7	1007	13	13
4-Mar-1999	20:00:00	60.83333	11.95993	40.81892	200	12	200	5	6	1005	12	14
5-Mar-1999	00:00:00	61.00000	11.21848	40.86998	230	10	230	5	6	1003	11	13
5-Mar-1999	04:00:00	61.16667	10.54616	40.69624	230	10	230	5	8	1004	11	13
5-Mar-1999	08:00:00	61.33333	11.27750	40.94819	220	12	230	5	8	1007	12	14
5-Mar-1999	12:00:00	61.50000	11.72177	40.89742	240	10	240	5	8	1007	12	13
5-Mar-1999	16:00:00	61.66667	12.62596	40.86700	240	10	240	5	8	1008	12	13
5-Mar-1999	20:00:00	61.83333	12.24851	40.96058	230	11	230	5	7	1007	12	11
6-Mar-1999	00:00:00	62.00000	11.59180	40.96645	260	16	160	6	6	1007	12	13
6-Mar-1999	04:00:00	62.16667	11.23685	40.99361	270	16	270	6	8	1008	11	13
6-Mar-1999	08:00:00	62.33333	10.78524	40.86973	240	16	240	6	8	1009	12	14
6-Mar-1999	12:00:00	62.50000	10.83607	40.90311	240	10	240	4	7	1011	12	16
6-Mar-1999	16:00:00	62.66667	11.66652	40.99673	270	16	270	5	8	1011	12	16
6-Mar-1999	20:00:00	62.83333	12.49298	40.99158	270	16	270	5	7	1011	12	13
7-Mar-1999	00:00:00	63.00000	11.87839	41.04811	240	12	240	5	6	1011	12	13
7-Mar-1999	04:00:00	63.16667	11.10434	41.04882	250	12	250	4	8	1011	12	13
7-Mar-1999	08:00:00	63.33333	10.88056	41.04500	270	12	270	5	8	1011	13	13
7-Mar-1999	12:00:00	63.50000	11.76157	41.09767	270	12	270	5	8	1012	13	13
7-Mar-1999	16:00:00	63.66667	12.37686	41.16039	270	14	270	5	8	1012	12	14
7-Mar-1999	20:00:00	63.83333	11.91897	41.14815	270	15	270	6	8	1015	10	13
8-Mar-1999	00:00:00	64.00000	11.44143	41.18967	260	10	260	5	6	1015	10	13
8-Mar-1999	04:00:00	64.16667	10.78693	41.00418	260	10	260	4	8	1015	9	14
8-Mar-1999	08:00:00	64.33333	10.85406	41.07503	270	12	270	5	8	1016	12	14
8-Mar-1999	12:00:00	64.50000	10.02540	41.01174	270	8	270	3	8	1019	12	14
8-Mar-1999	16:00:00	64.66667	10.58234	41.09244	270	5	270	2	8	1019	12	14
8-Mar-1999	20:00:00	64.83333	10.89110	41.11470	220	4	220	1	8	1019	12	14

METEREOLOGICAL DATA TIR99

DATE	TIME	PROG_DAY	LAT	LON	W_D	W_S	S_D	S_S	VIS	PRESS	A_T	W_T
9-Mar-1999	00:00:00	65.00000	10.04768	41.06755	200	8	200	3	8	1019	11	13
9-Mar-1999	04:00:00	65.16667	10.51249	41.17840	160	12	160	5	5	1020	12	13
9-Mar-1999	08:00:00	65.33333	11.23985	41.17587	180	9	180	4	8	1019	13	14
9-Mar-1999	12:00:00	65.50000	12.13286	41.21135	160	9	160	4	6	1019	12	14
9-Mar-1999	16:00:00	65.66667	12.13286	41.21135	160	9	160	4	8	1019	12	14
9-Mar-1999	20:00:00	65.83333	11.33136	41.21000	170	10	170	5	6	1020	12	14
10-Mar-1999	00:00:00	66.00000	10.53647	41.23511	160	12	160	5	6	1020	12	13
10-Mar-1999	04:00:00	66.16667	9.91988	41.06842	180	12	180	4	8	1016	12	14
10-Mar-1999	08:00:00	66.33333	10.69602	41.29540	150	11	150	4	6	1020	12	13
10-Mar-1999	12:00:00	66.50000	11.52006	41.29525	150	7	150	4	6	1020	12	13
10-Mar-1999	16:00:00	66.66667	11.54481	41.34036	150	7	150	4	6	1020	12	13
10-Mar-1999	20:00:00	66.83333	10.93152	41.28456	160	8	160	4	7	1020	12	13
11-Mar-1999	00:00:00	67.00000	11.75450	41.34154	160	6	160	3	5	1020	11	13
11-Mar-1999	04:00:00	67.16667	11.28176	41.34043	160	6	160	3	8	1020	11	13
11-Mar-1999	08:00:00	67.33333	10.45948	41.29802	180	7	170	3	5	1019	12	14
11-Mar-1999	12:00:00	67.50000	9.89350	41.08021	170	7	170	3	5	1019	12	14
11-Mar-1999	16:00:00	67.66667	9.94625	41.17153	170	7	170	3	6	1019	12	14
11-Mar-1999	20:00:00	67.83333	9.81984	41.50892	180	6	180	4	8	1020	11	14
12-Mar-1999	00:00:00	68.00000	9.88830	41.46139	170	3	170	1	7	1019	12	14
12-Mar-1999	04:00:00	68.16667	9.91542	41.19438	170	3	170	1	8	1019	14	14
12-Mar-1999	08:00:00	68.33333	9.93076	41.31415	160	6	160	3	8	1019	14	14
12-Mar-1999	12:00:00	68.50000	10.01362	41.37057	180	4	180	1	6	1020	13	14
12-Mar-1999	16:00:00	68.66667	10.07620	41.52302	180	4	180	1	8	1020	13	14
12-Mar-1999	20:00:00	68.83333	10.11942	41.43726	180	5	180	2	8	1020	12	14
13-Mar-1999	00:00:00	69.00000	10.11942	41.43726	170	3	170	1	8	1020	12	14
13-Mar-1999	04:00:00	69.16667	10.21594	41.53660	170	3	170	1	8	1020	12	14
13-Mar-1999	08:00:00	69.33333	10.24773	41.57941	180	5	180	2	8	1019	14	14
13-Mar-1999	12:00:00	69.50000	10.37241	41.32993	170	4	170	1	8	1020	14	14
13-Mar-1999	16:00:00	69.66667	10.17312	41.81023	170	4	170	1	8	1020	14	14
13-Mar-1999	20:00:00	69.83333	10.57073	41.33999	170	6	170	2	7	1020	12	14
14-Mar-1999	00:00:00	70.00000	10.26173	41.85755	160	5	160	1	8	1020	14	14
14-Mar-1999	04:00:00	70.16667	10.61917	41.33464	150	5	150	1	8	1020	12	14
14-Mar-1999	08:00:00	70.33333	10.42018	41.76695	160	5	160	1	8	1020	12	14
14-Mar-1999	12:00:00	70.50000	10.54437	41.62655	100	4	100	1	5	1021	12	14
14-Mar-1999	16:00:00	70.66667	10.59863	41.63366	100	7	100	1	5	1021	12	14
14-Mar-1999	20:00:00	70.83333	10.37783	41.94644	110	5	110	2	6	1021	12	14
15-Mar-1999	00:00:00	71.00000	10.57371	41.70579	-	-	-	-	8	1020	12	14
15-Mar-1999	04:00:00	71.16667	10.44293	41.95175	-	-	-	-	6	1021	12	14
15-Mar-1999	08:00:00	71.33333	10.74864	41.51039	-	-	-	-	6	1023	13	14
15-Mar-1999	12:00:00	71.50000	10.61080	41.74100	-	-	-	-	4	1024	13	13
15-Mar-1999	16:00:00	71.66667	10.37928	42.10094	-	-	-	-	6	1024	13	13
15-Mar-1999	20:00:00	71.83333	10.37928	42.10094	-	-	-	-	6	1021	14	14
16-Mar-1999	00:00:00	72.00000	10.37928	42.10094	-	-	-	-	7	1023	14	14
16-Mar-1999	04:00:00	72.16667	10.60174	41.92355	-	-	-	-	8	1021	13	14
16-Mar-1999	08:00:00	72.33333	10.72906	42.05714	-	-	-	-	6	1021	14	14
16-Mar-1999	12:00:00	72.50000	10.87796	41.45342	-	-	-	-	4	1020	13	14
16-Mar-1999	16:00:00	72.66667	10.70597	41.78286	-	-	-	-	4	1024	14	14
16-Mar-1999	20:00:00	72.83333	10.77216	42.22258	-	-	-	-	4	1024	14	14
17-Mar-1999	00:00:00	73.00000	10.87526	41.56478	-	-	-	-	5	1016	11	13
17-Mar-1999	04:00:00	73.16667	10.88746	41.63821	020	10	020	3	8	1016	12	14
17-Mar-1999	08:00:00	73.33333	10.78078	42.25553	030	12	030	5	7	1017	12	14
17-Mar-1999	12:00:00	73.50000	10.94459	41.87230	040	14	040	6	7	1019	13	14
17-Mar-1999	16:00:00	73.66667	11.55864	42.00439	040	15	040	6	7	1019	13	14
17-Mar-1999	20:00:00	73.83333	11.55864	42.00439	040	14	040	5	7	1016	12	14
18-Mar-1999	00:00:00	74.00000	11.55864	42.00439	030	14	030	5	7	1015	7	12
18-Mar-1999	04:00:00	74.16667	11.09462	41.91609	040	18	040	6	6	1013	7	13
18-Mar-1999	08:00:00	74.33333	11.07176	41.45921	020	17	020	7	5	1013	9	14
18-Mar-1999	12:00:00	74.50000	11.11917	41.42825	350	20	350	7	5	1013	9	13
18-Mar-1999	16:00:00	74.66667	11.00949	41.57560	350	18	350	7	5	1013	8	13
18-Mar-1999	20:00:00	74.83333	11.00069	41.75522	340	18	340	7	5	1011	8	13
19-Mar-1999	00:00:00	75.00000	11.14987	41.45345	350	18	350	7	5	1011	7	13
19-Mar-1999	04:00:00	75.16667	11.15795	41.49404	350	18	350	7	5	1011	7	13
19-Mar-1999	08:00:00	75.33333	11.05325	41.72256	350	17	350	7	5	1011	8	13
19-Mar-1999	12:00:00	75.50000	11.12297	41.61262	010	15	010	6	5	1012	9	13
19-Mar-1999	16:00:00	75.66667	11.22985	41.49350	010	15	010	5	6	1012	10	13
19-Mar-1999	20:00:00	75.83333	11.27417	41.86249	010	14	010	5	7	1012	10	13
20-Mar-1999	00:00:00	76.00000	11.34857	41.35853	010	18	010	7	5	1013	10	13
20-Mar-1999	04:00:00	76.16667	11.23958	41.61910	010	18	010	5	6	1012	8	13
20-Mar-1999	08:00:00	76.33333	11.26615	41.74670	010	15	010	5	7	1012	10	13
20-Mar-1999	12:00:00	76.50000	11.36734	41.47024	350	12	350	6	7	1015	12	13
20-Mar-1999	16:00:00	76.66667	11.40866	41.89483	350	15	350	5	8	1015	12	13
20-Mar-1999	20:00:00	76.83333	11.41965	41.44919	350	14	350	5	7	1017	11	13
21-Mar-1999	00:00:00	77.00000	11.39125	41.74208	350	12	350	5	8	1020	9	13
21-Mar-1999	04:00:00	77.16667	11.45079	41.86409	350	10	350	3	8	1020	9	13
21-Mar-1999	08:00:00	77.33333	11.47689	41.49546	030	9	030	4	8	1019	13	13
21-Mar-1999	12:00:00	77.50000	11.55401	41.63969	010	4	010	1	7	1020	12	13
21-Mar-1999	16:00:00	77.66667	11.51048	41.77340	010	4	010	1	7	1020	12	13
21-Mar-1999	20:00:00	77.83333	11.51048	41.77340	010	5	010	2	8	1019	12	13
22-Mar-1999	00:00:00	78.00000	11.64188	41.66396	240	7	240	3	7	1020	10	13
22-Mar-1999	04:00:00	78.16667	11.82088	41.44579	240	7	240	3	8	1016	11	13
22-Mar-1999	08:00:00	78.33333	11.73787	41.42186	230	9	230	4	7	1013	12	13

METEREOLOGICAL DATA TIR99

DATE	TIME	PROG_DAY	LAT	LON	W_D	W_S	S_D	S_S	VIS	PRESS	A_T	W_T
22-Mar-1999	12:00:00	78.50000	11.72951	41.02611	230	10	230	5	6	1013	12	13
22-Mar-1999	16:00:00	78.66667	12.23571	40.75543	240	10	240	5	8	1013	13	13
22-Mar-1999	20:00:00	78.83333	13.12835	40.75906	240	11	240	5	7	1012	12	13
23-Mar-1999	00:00:00	79.00000	13.92685	40.47669	240	8	340	4	4	1012	12	13
23-Mar-1999	04:00:00	79.16667	13.30513	40.73154	240	10	240	5	6	1012	12	13
23-Mar-1999	08:00:00	79.33333	13.84275	40.57956	260	8	260	4	7	1011	13	13
23-Mar-1999	12:00:00	79.50000	13.60999	40.70429	240	3	240	2	7	1011	13	14
23-Mar-1999	16:00:00	79.66667	13.67490	40.78755	240	3	240	2	8	1011	13	14
23-Mar-1999	20:00:00	79.83333	13.61526	40.80564	240	5	240	3	8	1013	12	14
24-Mar-1999	00:00:00	80.00000	13.79048	40.87020	240	4	240	2	6	1016	10	14
24-Mar-1999	04:00:00	80.16667	14.15043	40.51626	240	4	260	2	8	1015	12	14
24-Mar-1999	08:00:00	80.33333	14.31671	40.51715	320	4	320	1	8	1019	13	14
24-Mar-1999	12:00:00	80.50000	14.66962	40.56305	260	4	260	1	8	1020	13	14
24-Mar-1999	16:00:00	80.66667	13.97748	40.30395	260	4	260	1	8	1020	13	14
24-Mar-1999	20:00:00	80.83333	13.91478	40.40124	250	4	250	1	8	1020	13	14
25-Mar-1999	00:00:00	81.00000	14.12254	40.33396	-	-	-	-	7	1020	12	14
25-Mar-1999	04:00:00	81.16667	14.60284	40.43179	-	-	-	-	8	1020	12	14
25-Mar-1999	08:00:00	81.33333	14.60284	40.43179	120	5	120	2	8	1020	14	14
25-Mar-1999	12:00:00	81.50000	14.42230	40.26910	110	4	110	1	6	1020	13	14
25-Mar-1999	16:00:00	81.66667	14.56484	40.37258	110	4	110	2	6	1021	13	14
25-Mar-1999	20:00:00	81.83333	14.42954	40.18098	120	4	120	1	7	1017	14	14
26-Mar-1999	00:00:00	82.00000	14.54106	39.98598	110	4	110	1	7	1017	12	14
26-Mar-1999	04:00:00	82.16667	15.25315	39.67902	110	4	110	2	8	1016	14	14
26-Mar-1999	08:00:00	82.33333	15.66454	39.10664	130	7	130	3	7	1015	14	14
26-Mar-1999	12:00:00	82.50000	15.63366	39.28980	090	3	090	1	6	1015	14	14
26-Mar-1999	16:00:00	82.66667	15.14250	39.81923	090	3	090	1	8	1015	14	14
26-Mar-1999	20:00:00	82.83333	14.43336	40.06991	090	3	090	1	8	1013	15	14
27-Mar-1999	00:00:00	83.00000	14.96863	39.89277	140	8	140	3	7	1013	13	14
27-Mar-1999	04:00:00	83.16667	15.48595	39.48077	140	8	140	3	7	1013	13	14
27-Mar-1999	08:00:00	83.33333	15.79683	38.88147	220	4	220	2	6	1013	15	14
27-Mar-1999	12:00:00	83.50000	15.74454	39.15903	310	8	310	4	7	1012	14	14
27-Mar-1999	16:00:00	83.66667	15.41289	39.65869	280	8	280	4	7	1012	14	14
27-Mar-1999	20:00:00	83.83333	14.78024	39.92861	290	8	290	4	8	1011	15	14
28-Mar-1999	00:00:00	84.00000	14.41058	40.13788	300	3	300	1	7	1011	14	14

Table 10: Essential metereological data

6.4 NAVIGATION SYSTEM TIME DELAYS DURING CRUISE TIR99

DATE	GMT+1	NAVSYS_TIME	DATE	GMT+1	NAVSYS_TIME
-	-	-	1999-03-01	00:00:00	-
-	-	-	1999-03-01	12:00:00	-
-	-	-	1999-03-02	00:00:00	-
-	-	-	1999-03-02	12:00:00	-
-	-	-	1999-03-03	00:00:00	-
-	-	-	1999-03-03	12:00:00	-
-	-	-	1999-03-04	00:00:00	00:01:30
-	-	-	1999-03-04	12:00:00	12:01:25
-	-	-	1999-03-05	00:00:00	00:01:20
-	-	-	1999-03-05	12:00:00	12:01:26
-	-	-	1999-03-06	00:00:00	00:01:33
-	-	-	1999-03-06	12:00:00	12:01:40
-	-	-	1999-03-07	00:00:00	00:01:47
-	-	-	1999-03-07	12:00:00	12:01:53
-	-	-	1999-03-08	00:00:00	00:02:00
-	-	-	1999-03-08	12:00:00	12:01:50
-	-	-	1999-03-09	00:00:00	00:01:34
-	-	-	1999-03-09	12:00:00	12:01:32
-	-	-	1999-03-10	00:00:00	00:01:44
-	-	-	1999-03-10	12:00:00	12:01:51
-	-	-	1999-03-11	00:00:00	00:01:57
1999-02-11	12:00:00	12:03:05	1999-03-11	12:00:00	12:01:20
1999-02-12	00:00:00	00:03:01	1999-03-12	00:00:00	00:01:24
1999-02-12	12:00:00	12:03:07	1999-03-12	12:00:00	12:01:30
1999-02-13	00:00:00	00:03:12	1999-03-13	00:00:00	00:01:35
1999-02-13	12:00:00	12:03:16	1999-03-13	12:00:00	12:01:42
1999-02-14	00:00:00	00:03:28	1999-03-14	00:00:00	00:01:48
1999-02-14	12:00:00	12:03:33	1999-03-14	12:00:00	12:01:53
1999-02-15	00:00:00	00:03:05	1999-03-15	00:00:00	00:02:00
1999-02-15	12:00:00	12:02:15	1999-03-15	12:00:00	12:02:07
1999-02-16	00:00:00	00:01:57	1999-03-16	00:00:00	00:02:13
1999-02-16	12:00:00	12:02:24	1999-03-16	12:00:00	12:02:06
1999-02-17	00:00:00	00:02:09	1999-03-17	00:00:00	00:01:35
1999-02-17	12:00:00	12:02:14	1999-03-17	12:00:00	12:01:27
1999-02-18	00:00:00	00:02:22	1999-03-18	00:00:00	00:01:28
1999-02-18	12:00:00	12:02:29	1999-03-18	12:00:00	12:01:28
1999-02-19	00:00:00	00:01:05	1999-03-19	00:00:00	00:01:30
1999-02-19	12:00:00	12:01:45	1999-03-19	12:00:00	12:01:29
1999-02-20	00:00:00	00:01:44	1999-03-20	00:00:00	00:01:27
1999-02-20	12:00:00	12:01:50	1999-03-20	12:00:00	12:01:32
1999-02-21	00:00:00	00:01:54	1999-03-21	00:00:00	00:01:38
1999-02-21	12:00:00	12:02:01	1999-03-21	12:00:00	12:01:40
1999-02-22	00:00:00	00:02:09	1999-03-22	00:00:00	00:01:14
1999-02-22	12:00:00	12:02:15	1999-03-22	12:00:00	12:01:25
1999-02-23	00:00:00	00:02:23	1999-03-23	00:00:00	00:01:33
1999-02-23	12:00:00	12:02:28	1999-03-23	12:00:00	12:01:39
1999-02-24	00:00:00	00:02:32	1999-03-24	00:00:00	00:01:18
1999-02-24	12:00:00	12:02:38	1999-03-24	12:00:00	12:01:24
1999-02-25	00:00:00	00:02:45	1999-03-25	00:00:00	00:01:30
1999-02-25	12:00:00	12:02:53	1999-03-25	12:00:00	12:01:20
1999-02-26	00:00:00	00:02:59	1999-03-26	00:00:00	00:01:26
1999-02-26	12:00:00	12:03:05	1999-03-26	12:00:00	12:01:32
1999-02-27	00:00:00	00:03:10	1999-03-27	00:00:00	00:01:38
1999-02-27	12:00:00	12:03:15	1999-03-27	12:00:00	12:01:44
1999-02-28	00:00:00	00:01:42	1999-03-28	00:00:00	00:01:50
1999-02-28	12:00:00	12:01:48	1999-03-28	12:00:00	12:01:19
1999-02-29	00:00:00	00:01:55	1999-03-29	00:00:00	00:01:26
-	-	-	1999-03-29	12:00:00	12:01:16
-	-	-	1999-03-30	00:00:00	00:01:21
-	-	-	1999-03-30	12:00:00	12:01:27
-	-	-	1999-03-31	00:00:00	00:01:17
-	-	-	1999-03-31	12:00:00	12:01:15

Table 11: Navigation System time delays

6.5 EXPENDABLE PROBES LAUNCHED DURING CRUISE TIR99

Table 12 shows the date/time and position information of the XBT and XCTD samplings.

XBT STATIONS				
STA_ID	DATE	TIME	LATITUDE	LONGITUDE
XCTD-01_97010153	1999-02-05	05:28:11	38.89362	14.40243
XCTD-01_97010154	1999-02-06	05:59:15	38.33381	13.47063
T-5_281730	1999-02-06	13:24:34	38.44173	12.27008
T-7_946743	1999-02-06	13:50:38	38.44936	12.24596
XCTD-01_97010155	1999-02-06	13:54:26	38.45079	12.24203
T-5_281731	1999-02-07	07:18:12	38.80989	10.93034
T-5_281727	1999-02-07	09:18:30	38.66757	11.35552
T-5_281722	1999-02-07	11:10:56	38.53324	11.76136
T-7_946739	1999-02-08	15:57:09	38.37500	11.92450
T-7_946744	1999-02-09	18:11:56	38.64692	11.08004
XCTD-01_97010150	1999-02-09	21:30:54	38.82042	10.48328
T-7_946746	1999-02-12	08:43:54	40.25621	10.18032
T-5_281724	1999-02-13	12:57:01	39.85900	10.34367
T-5_281728	1999-02-13	15:16:21	39.47717	10.30383
T-5_281732	1999-02-13	17:23:27	39.15433	10.25900
T-5_281725	1999-02-15	13:28:59	40.42543	10.56566
T-5_281729	1999-02-16	13:38:38	41.06567	10.60917
T-5_281721	1999-02-17	15:17:18	40.12833	11.10183
XCTD-01_97010151	1999-02-17	16:11:46	40.14793	11.12088
T-5_281717	1999-02-17	23:18:08	39.17667	10.95700
T-5_281713	1999-02-18	21:42:28	39.54983	10.58217
T-7_946735	1999-02-18	21:45:27	39.54967	10.57833
T-7_946740	1999-02-18	21:53:35	39.54933	10.60000
T-7_946741	1999-02-19	18:00:34	40.50383	10.07283
T-7_946737	1999-02-22	12:40:51	40.26733	12.50383
T-7_946738	1999-02-24	06:54:34	40.57655	13.95597
T-7_946758	1999-02-25	20:55:25	40.50733	12.45367
T-7_946754	1999-03-04	03:05:39	41.33510	11.97220
T-7_946750	1999-03-05	03:47:00	40.69918	10.55825
T-7_946757	1999-03-06	15:10:55	41.03267	11.51383
T-7_946753	1999-03-06	18:45:25	41.01933	12.27782
T-7_946749	1999-03-09	02:11:02	41.13950	10.15367
T-7_946756	1999-03-09	02:16:14	41.13195	10.15150
T-7_946752	1999-03-13	05:15:08	41.33926	10.27225
T-7_946755	1999-03-15	23:25:19	42.02800	10.50000
T-7_946751	1999-03-19	04:10:32	41.50650	11.15250
T-7_946747	1999-03-22	13:44:25	40.74367	11.75817
T-7_928875	1999-03-26	16:31:56	39.86083	15.03417
T-7_928876	1999-03-26	16:41:34	39.86450	15.02083
T-7_928874	1999-03-27	05:32:03	39.27000	15.67933
T-5_281716	1999-03-29	21:38:08	38.76550	15.36717

Table 12: XBT and XCTD stations