A Mediterranean and Black Sea oceanographic database and network

THE MEDAR GROUP

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(Received April 8, 2003; accepted October 29, 2004)

ABSTRACT The basic characteristics of a large multi-parameter ocean database for the Mediterranean and the Black Sea are described. The database has been developed through close cooperation between National Oceanographic Data Centres (NODCs) of IOC/UNESCO and specialized marine research institutes, within the framework of the MEDAR/MEDATLAS Concerted Action, supported by the European Union (EU). The data used in developing the database have been collected by about 150 scientific laboratories from 33 countries and consist of vertical profiles of in-situ temperature, salinity and bio-chemical parameters. In all, the database includes 285 879 qualified hydrographic stations of mechanical bathythermographs (MBT), expendable bathythermographs (XBT), CTDs and bottle casts. As regards the studied regions, these data increase (almost double) the volume of the ocean data made available to the user community greatly, when compared to earlier initiatives. They are published on a set of four Cd-roms, which include other products such as a Cruise Inventory, a Climatological Atlas of gridded numerical fields with vertical sections, maps (static and animated to illustrate the annual cycle), as well as, a selection and visualisation software. Although there are still some gaps before a complete data service can be provided, this important concerted action has contributed in developing data management standards and methods, in drawing attention to the necessity of acquiring professional data archiving systems and, finally, in increasing data and information circulation on the Mediterranean and the Black Sea.

1. Introduction

The Mediterranean Sea and the Black Sea have been investigated for more than a century and large amounts of data have been generated. During the last few decades, a growing number of new multi-parameter sensors have produced many more data providing a better spatial-temporal coverage. These marine data and related meta-data constitute an essential basis for many studies and applications (e.g., science, engineering, defence, economical zone management, policy making, etc.), and particularly for monitoring the state of the ocean, its seasonal cycle and variability and for estimating possible climate changes. All these studies require data that are compatible and comparable, no matter where, when or by whom they were collected. The recent development of ocean modelling and prediction has made these requirements urgent. However, in many cases, these data have remained dispersed in various systems within the scientific community and, frequently, were even in danger of being completely lost. Moreover, methodologies in data collection, the units and the formats used by the different laboratories were not standardized. Therefore, it was necessary to develop an ocean database system to facilitate access to data and information that were standardized and checked for quality.

In order to meet these requirements, the MEDAR/MEDATLAS-II (Mediterranean Data Archaeology and Rescue of temperature, salinity and bio-chemical parameters) Project was designed and implemented, from 1998 to 2001, with the financial support of the European Union. The main objective of the project, was to rescue, safeguard and make available to the user community, in an integrated data product, ocean observations made in the Mediterranean Sea and Black Sea, through close co-operation of the bordering countries. The Project was implemented by a consortium of 20 partners, mainly data centres and international organisations. During the life of the project, the consortium was enlarged and finally included (Fig. 1): nineteen National Oceanographic Data Centres (NODCs) or Designated National Agencies (DNAs), which operate within the Intergovernmental Oceanographic Commission Working Committee on International Oceanographic Data Exchange (IOC/IODE), two World Data Centres (WDC-A in Silver Spring, USA and WDC-B in Obninsk, Russian Federation), two institutions specialized in numerical modelling studies and two international organisations: the IOC/UNESCO and the International Council for the Exploration of the Sea (ICES). In order to achieve the objectives, cooperation links were established with other well known international projects, such as the IOC/UNESCO GODAR (Global Ocean Data Archaeology and Rescue) Project and the EU/ MFSPP (Mediterranean Forecasting System Pilot Project) Project, as well as, with several other IOC/IODE NODCs and marine institutes having some activities in the Mediterranean Sea and Black Sea regions.

The MEDAR/MEDATLAS Project followed a previous pilot project carried out in the Mediterranean Sea from1994 to 1996; as a result of which, a database of temperature, and salinity profiles for the region was published with observed data, analysed data and maps (MEDATLAS Group, 1997) and a preliminary protocol for data formatting and checking for quality (on Cd-roms). Data rescue within the MEDAR/MEDATLAS Project focused on an extended, but still

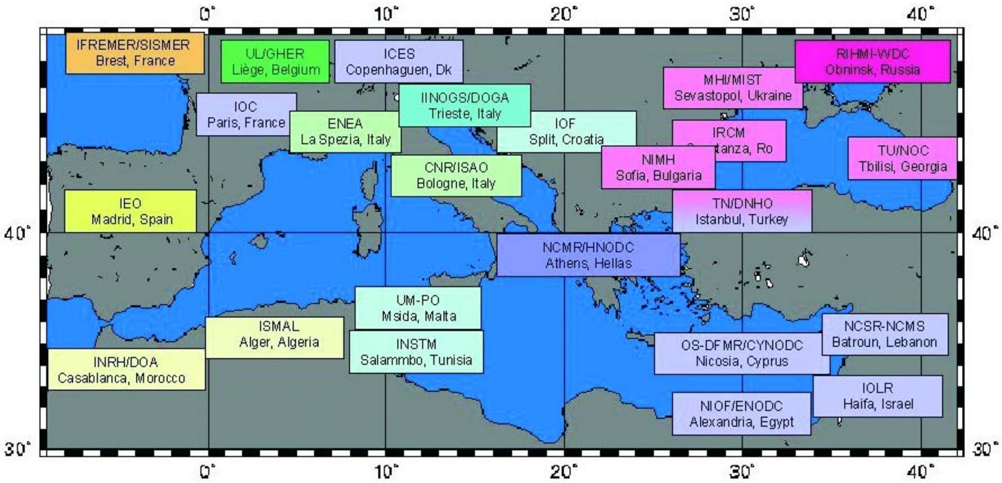


Fig. 1 - MEDAR/MEDATLAS Network. The different colours are associated with the regional and thematic work-packages underlined representing the coordinating centres.

selected list of basic parameters: temperature, salinity, oxygen, phosphate, nitrate, nitrite, ammonium, silicate, pH, alkalinity, chlorophyll, hydrogen sulphide (Black Sea), total phosphorus and total nitrogen. These parameters were considered essential for the study of climate changes, to initialise and calibrate coupled hydrodynamic-ecological numerical models. Moreover, preliminary information on the geographical distribution of the selected bio-chemical parameters was available from the World Ocean Atlas (Levitus *et al*., 1998) to implement preliminary quality control procedures.

2. Data Compilation and MEDAR/MEDATLAS 2002 - Observed Database

Ocean data and associated metadata were requested, through the partners NODC/DNAs of the project, from the various scientific laboratories, hydrographic services and other potential data holding agencies, in each bordering country. In addition, other countries that took part in marine research or data-collection activities in the region, were also contacted through their NODC's. The data requests were based on the preliminary development of a cruise inventory, supervised by the Russian NODC/World Data Centre. A total of 150 scientific laboratories and hydrographic services from 33 countries replied to these requests. Due to the great diversity of the technical means and methodologies used in data collection and the variety of local data handling procedures, the data obtained represented a host of formats and organizations. In a few cases, they were not even digitized. In addition to the above, the wide dissemination of certain data sets between various data centres has lead to the creation of a substantial amount of duplicate data sets, which had to be eliminated.

The resulting contents of the final integrated Mediterranean and Black Sea database, after elimination of duplicate profiles is given in Tables 1 and 2, according to the type of observation and according to the parameter, respectively. These observations are of prime importance because

Table 1 - MEDAR/MEDATLAS 2002 data type distribution.

TYPE OF OBSERVATION	NUMBER OF PROFILES
CTD	35679
Bottle Cast	88323
MBT and XBT	161848
Thermistor Chain	29

Table 2 - MEDAR/MEDATLAS 2002 parameters distribution.

CODE(S)	PARAMETER	NUMBER OF PROFILES	CODE(S)	PARAMETER	NUMBER OF PROFILES
TEMP	SEA TEMPERATURE	284371	PHOS	PHOSPHATE	20761
PSAL, SSAL	PRACTICAL SALINITY	118009	ALKY	ALKALINITY	2548
DOX1	DISSOLVED OXYGEN	44928	PHPH	PH	14512
NTRA	NITRATE (NO3-N)	10572	CPHL	CHLOROPHYLL-A TOTAL	4672
NTRI	NITRITE (NO2-N)	10508	HSUL	HYDROGEN SULPHIDE (H2S)	1843
AMON	AMMONIUM	5239	NTOT	TOTAL NITROGEN	153
SLCA	SILICATE	15920	TPHS	TOTAL PHOSPHORUS	2381

they cover more than one century, from 1889 to 2000. Compared to the previous release (MEDATLAS Group, 1997), the volume of available data is twofold. The main input concerns CTD and bottle stations (Figs. 2 and 3) and relatively recent data. The spatial distribution of the data has been considerably improved, even if, in the middle of the deep basins and on the Libyan shelf there are still some areas with very few data. Taking into account the mechanical bathythermograph (MBT) and expendable bathythermograph (XBT) profiles, the spatial coverage (not shown) for temperature data, is pretty dense. Salinity and dissolved oxygen distributions are still rather good, but there are empty areas in the southern parts of the Mediterranean. For the nutrients, the coverage decreases dramatically from phosphate onwards (20761 profiles, which is only a quarter of the available bottle stations, even though it is considered by biologists to be a control parameter of the biota), down to total nitrogen (only 153 profiles available). H_2S is only observed in the Black Sea, and is linked to the lack of oxygen in the subsurface layers, except for a tiny area in the deep Mediterranean water inflow near the Bosphorus Strait.

All these data were checked for quality to prepare a coherent integrated database, and this work required the development of standards and collaboration with scientific experts.

3. Data standardization and quality control methodologies

A common protocol for formatting and quality controlling the ocean data, based on internationally agreed-upon standards, was developed and implemented by the MEDAR/MEDATLAS partners (MEDAR Group, 2001). The general guidelines published by the International Council for the Exploration of the Sea (ICES, 2000) have been followed, and the specific methodology developed for the management of temperature profiles in the Global Temperature Salinity Profile Project (GTSPP) of the IOC/UNESCO (UNESCO) has been extended to process multi- parameter data sets. The broad range check values have been adjusted according to geographical sub-regions and vertical layers. The common tables and regional

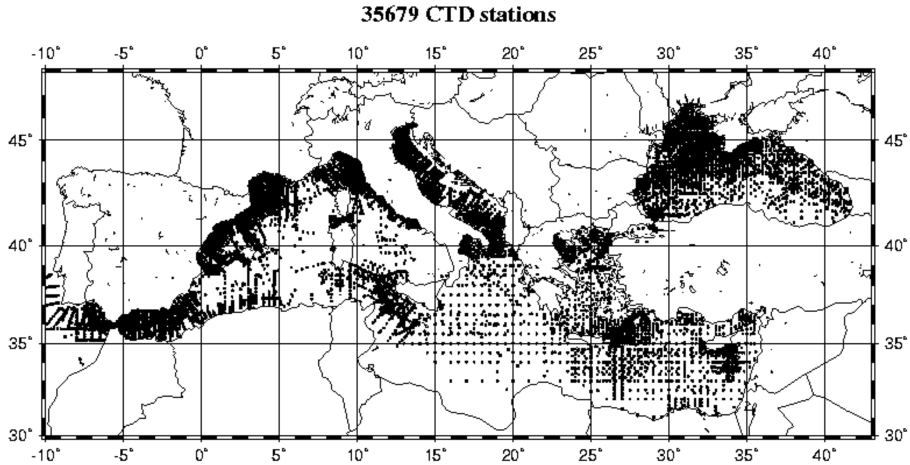


Fig. 2 - Distribution of the CTD stations.

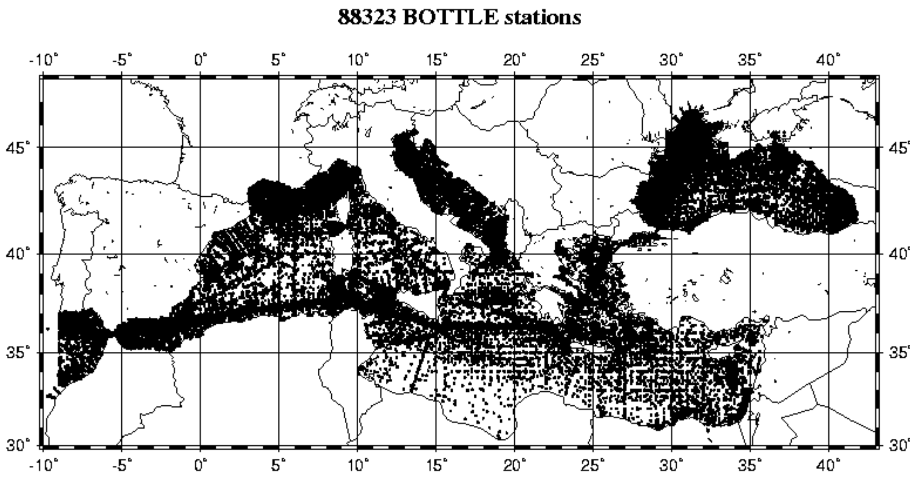


Fig. 3 - Distribution of the bottle stations.

statistics used to perform the quality control were made available on internet and published also with the protocol that was included in the final data product (MEDAR Group, 2002).

The first part of the protocol presents the common auto-descriptive MEDATLAS format. It includes archiving a minimum amount of mandatory information about space and time co-ordinates, the ship or platform, the source laboratory and the parameter names and units. These mandatory meta-data and the numerical data are standardized to allow automatic checking. Any additional relevant information is included as optional textual fields.

The second part of the protocol explains the methodology used to perform the quality checks. According to the agreed methodology, automatic and visual checks are made for duplicates, location and date (Step I, Fig. 4) and data points (Step II, Fig. 5). As a result of these checks, the data are not modified, but a simple numerical quality flag has been added to each numerical value. In both steps, the automatic checks end by plotting the data on a screen, with colours associated to each quality flag. Afterwards, these flags are validated manually by the operator.

Step I of the quality check includes checking for duplicate profiles, computing the ship's velocity between two consecutive stations, comparing the observed bottom depth with the available gridded bottom bathymetry, visually checking the ship's track and comparing the stations, positions with the shoreline and isobaths.

Step II of the quality control includes the common checks for all numerical values of the

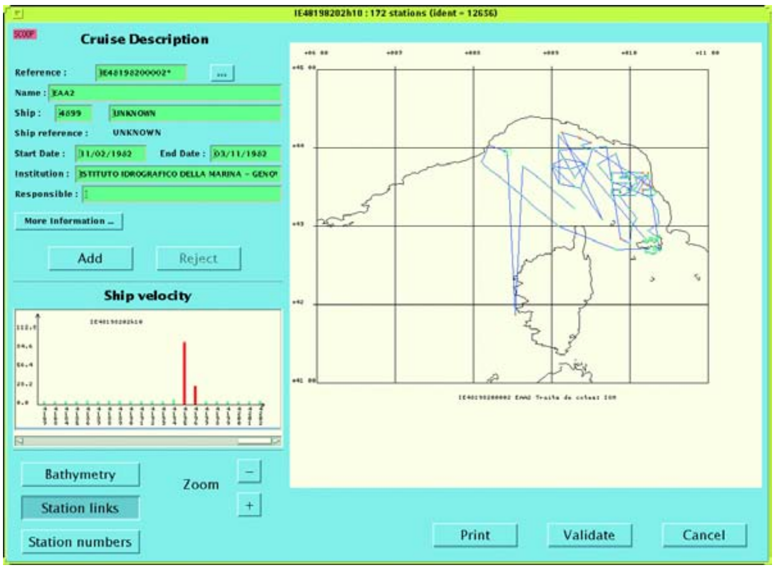


Fig. 4 - Check of the location, date and duplicates.

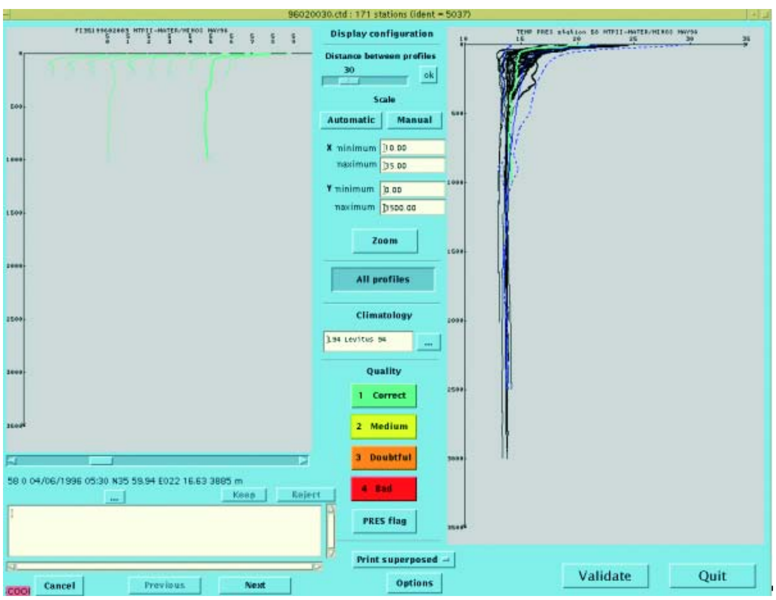
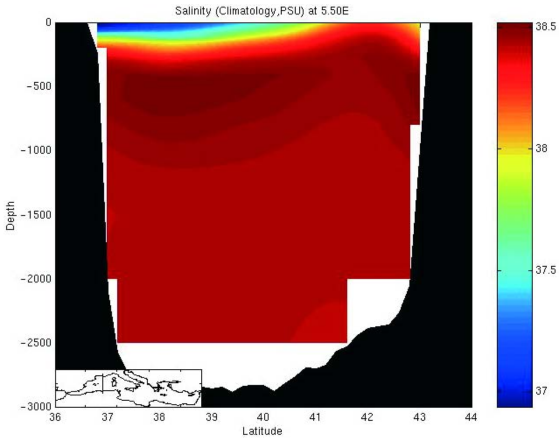
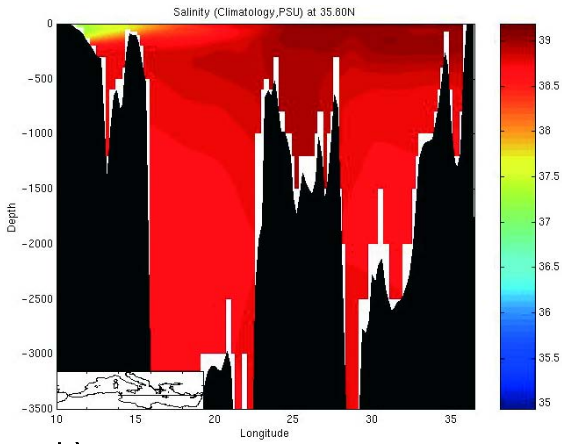


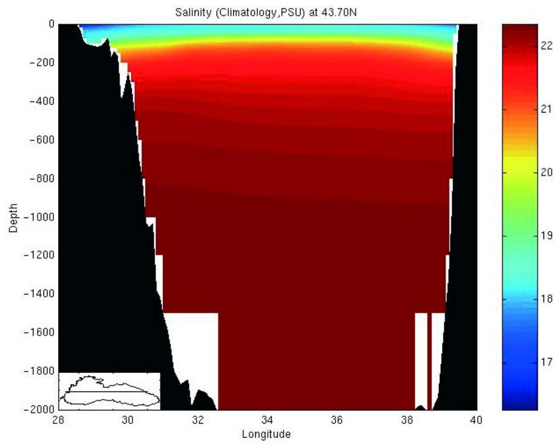
Fig. 5 - Check of the data points.



a)



b)



c)

Fig. 6 - Annual mean vertical distribution of (a) salinity along 5.50 E - Western Basin; (b) salinity along 35.8 N - Eastern Basin and Aegean Sea; (c) salinity along 43.7 N - Black Sea.

measured parameters and other specific checks. For all parameters, data below the bottom depth, constant vertical profiles and data outside regional broad range values were considered as “false”. Spikes were considered as “doubtful” data. Data that show discrepancies from the mean climatological values of 3 to 5 times (depending on the station depth) the standard deviations were considered to be “probably correct but outside the narrow statistical ranges”. The computed MEDATLAS 1997 climatologies were used to perform the checks of temperature and salinity data and the Levitus climatologies (Levitus *et al*., 1998) for the nutrients data. In addition, specific checks were made when known relationships existed between parameters: vertical stability if the temperature and salinity were measured, Redfield ratio between the nutrients. However, this last check has not yet been implemented systematically, as the procedure was not worked out during the project itself. The final visual checks took into consideration the internal coherency of an experiment (superposition of profiles of the same cruise) and the coherency with other data sets (superposition of profile of another dataset collected in the same area at the same season).

These quality checks were implemented in four Regional Data Qualification Centres, in Obninsk for the Black Sea, Athens for the Eastern Basin, Trieste for the Central Basins and Madrid for the Western Basin, respectively. Close cooperation with the scientific national and regional experts was necessary, and specialists were frequently contacted in the event of doubtful data. Another crucial issue was the technical development, as these quality controls were made by using two compatible and inter-calibrated expert softwares, either for UNIX (Bardet and Fichaut, 2000) or for WINDOWS (Garcia *et al.*, 2001).

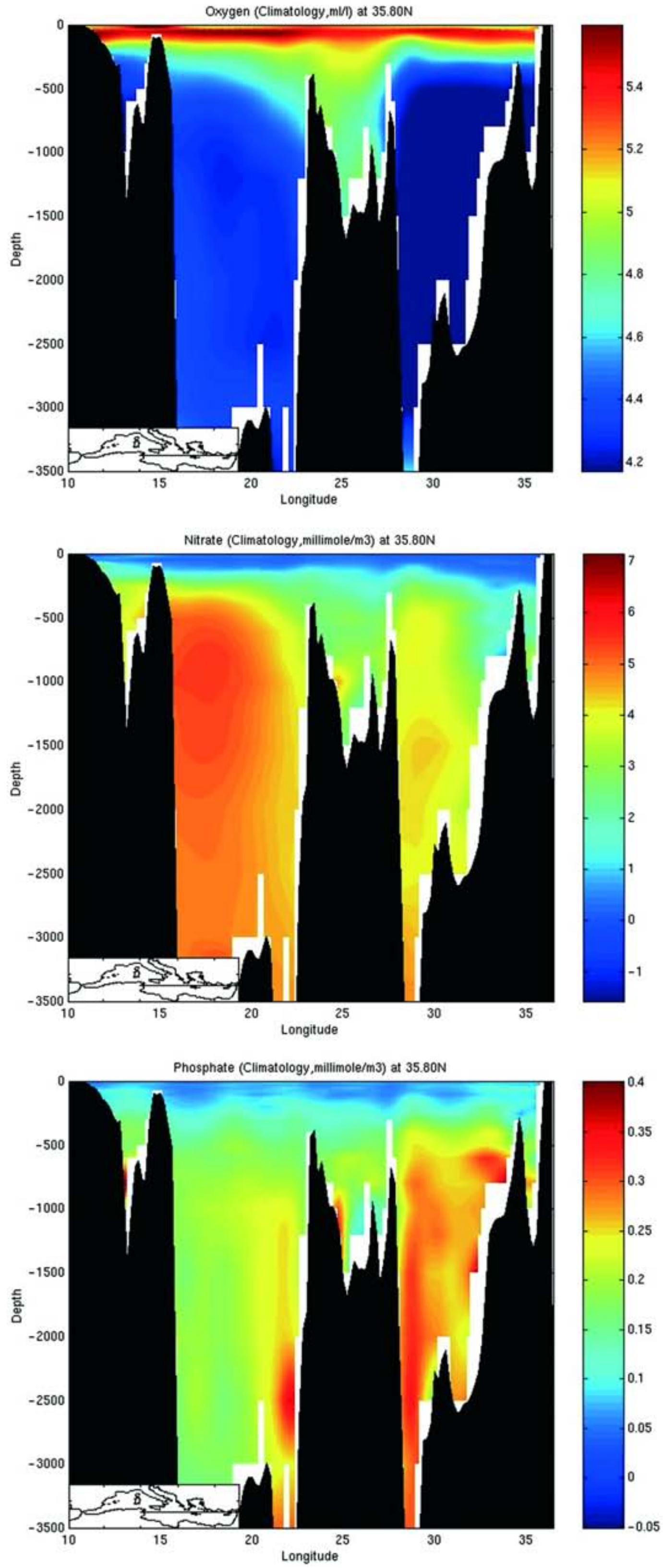
At the end of the regional quality check phase, the data sets were assembled at the Assembling Centre in Brest. There a final check was performed regarding format and remaining duplicates (always a critical problem in the historical data sets), and some further random checks. Any outstanding problems were solved in collaboration with the regional centres. The results show that the highest numbers of outliers are found in the dissolved oxygen (20% of outlier data points), in chlorophyll-a and total nitrogen (7% of outliers). For the other parameters, less than 5% of outliers were detected. Outliers are defined here as data with severe anomalies that would create problems and doubtful results in further computations or work on the data.

In spite of all the efforts made to develop standardized methodology, to design sophisticated dedicated software and to operate the data checking itself, there are still some limitations in the methodology in the areas with poor data coverage, in the coastal waters and in the standardization of the earliest historical data. When the data are sparse, the climatological statistics are questionable, and consequently the “climatology check” (narrow range check) detects outliers that are not always anomalies. In this case, careful manual checks and feedback from climatological computations compared to observations and vice-versa were made. Another difficulty is the qualification of observations in coastal waters, especially for the nutrients. In these cases, it was sometimes difficult to know whether an outlier was due to a real erroneous observation or to a unit problem, and not always possible to return to the source scientists. For the earliest historical data, the general accuracy is generally lower than the more recent data. Moreover, it is not always possible to know if the reported vertical coordinate was “depth” (in meter) or “pressure” (in dbar). Salinity is either, in part, per thousands (i.e. according to the 1969 scale proportional to the Knudsen scale) or following the “Practical Salinity Scale (PSS 78)” (Lewis and Perkin, 1981). However, differences between the two scales are less than 0.01 in the oceanic range (32-40). The “nitrate” parameter represents, generally, “nitrate+nitirite”. However for these data, the differences between the adopted standards were smaller than the overall accuracy of the historical data, and to avoid adding more noise and to follow the international rules, it was decided not to modify the archived values.

Finally, the work on standardization produced a useful protocol, which not only enabled the integration of such heterogeneous data sets, but was also used in other projects. It is worthy of noticed that the MEDATLAS format is now widely used by the Mediterranean and Black Sea community and beyond. The common protocol also facilitated the allocation of national responsibilities regarding data handling and the transfer of expertise to less developed data centres. Therefore, this protocol should be developed further when enough new data will be released and the statistics revised accordingly.

4. Objective analysis of the data

In addition to the observed data, the database also includes gridded analysed data because raw in-situ data sets may be difficult to interpret and higher-level data products are required to offer



a)

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Fig. 7 - Average vertical distribution of nutrients in the Eastern Basin at 35.80°N: a) dissolved oxygen, b) nitrate, c) phosphate.

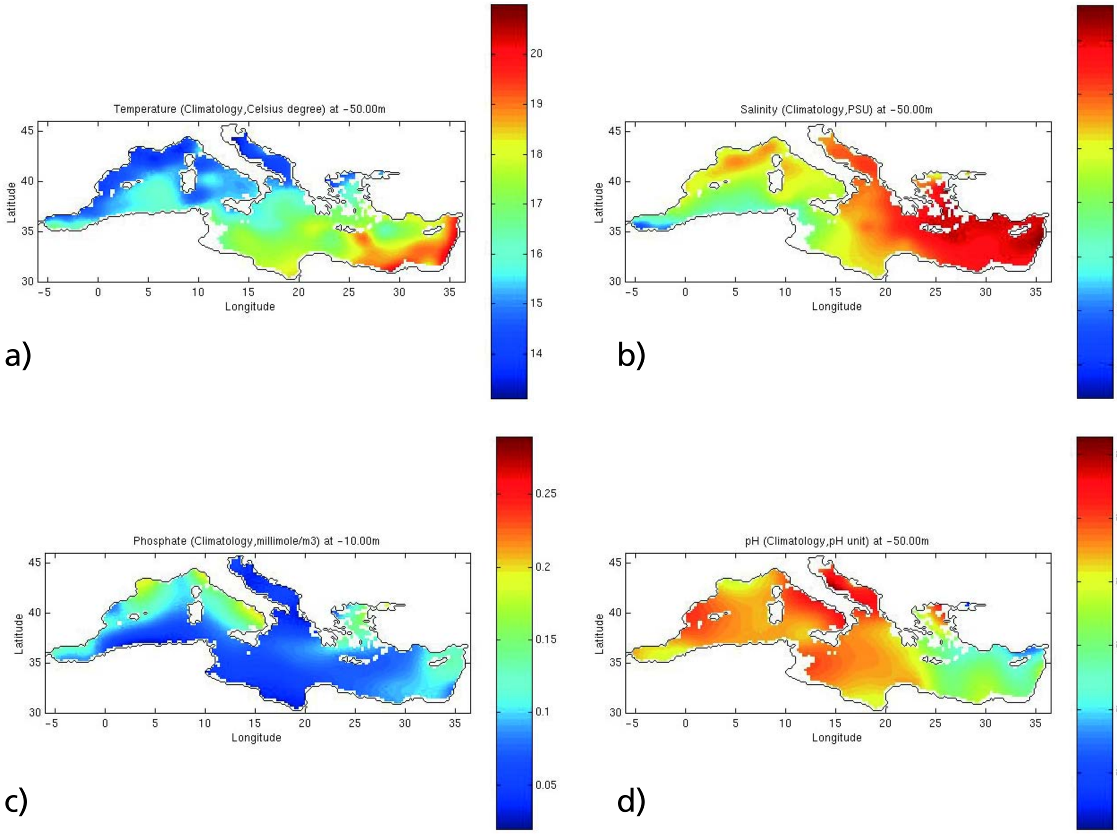

Fig. 8 - Mean annual distributions of: a) temperature, b) salinity, c) phosphate, and d) pH at 50 dbar in the Mediterranean Sea.

a more comprehensive and synthetic view of the Mediterranean and Black Sea physical and biochemical systems. In particular, the gridded climatological fields provide initial or boundary conditions to numerical models. To compute the gridded data, the dubious data points have been first filtered out from the observed profiles. Afterwards, the profiles were interpolated at 25 vertical standard levels by using the Reiniger and Ross (1968) method and transferred to the Analysis Centre in Liège (Fig. 1) to perform objective analysis at each standard level.

The gridded fields were computed using the Variational Inverse Model (Brasseur, 1991). This model has been shown to be statistically equivalent (Rixen *et al.*, 2001) to the objective analysis scheme (Carter and Robinson, 1987), but with better efficiency. The basic idea of a variational analysis is to determine a continuous field approximating the data and exhibiting small spatial variations. In other words, the gridded analysed field is defined as the smoothest field that respects consistency with the observed values regarding the domain of interest. It is also referred to as a spline interpolation method. Expressed in mathematical terms, the analysis is obtained as the minimum of a variational principle in a two-dimensional, horizontal space. The initial characteristic space length of the finite elements is 1 degree for the Mediterranean, 0.8 degree for the Black Sea and 0.5 degree for a local analysis. This mesh is then divided by 3 and the final

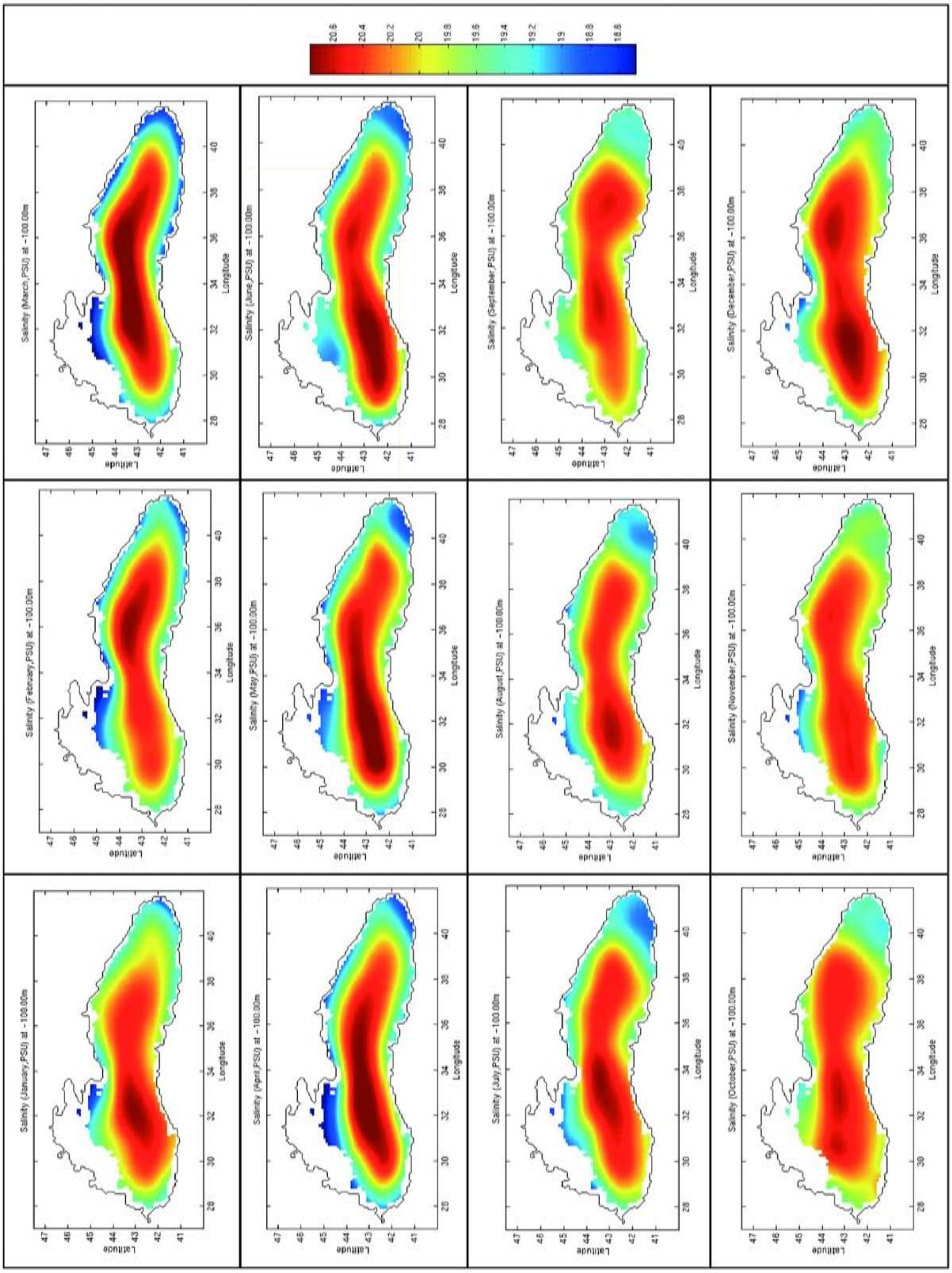

Fig. 9 - Mean monthly salinity distribution at 100 dbar in the Black Sea. The scale of variation is 18.5 to 20.8.

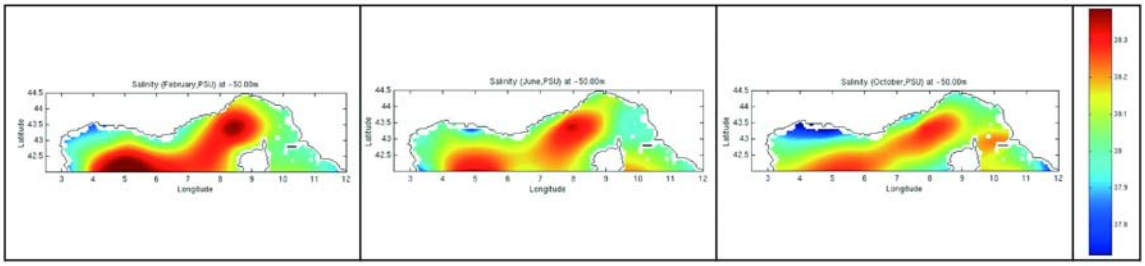

Fig. 10 - February, June and October salinity distribution at 50 dbar in the Gulf of Lions. The scale of variation is 37.7 to 38.4.

grid resolution is 0.2 degrees for the Mediterranean, 0.1 degree for the Black sea and 0.04 to 0.08 degrees for the local sub-region and for some specific areas with higher space resolution.

The computations were made on annual, seasonal and monthly means. Depending on data availability, further computations at the inter-annual to decadal scale were also made in some areas (Rixen *et al*., 2005). Due to the time distribution of the data, these mean fields seems to be more representative of the 1955-1995 period than for the whole century.

The gridded fields were mapped horizontally and vertically, illustrating the seasonal cycle through animated maps. One subset of this electronic atlas is presented in Figs. 6 to 10. The main features of the region appear very clearly and could be used to illustrate lectures and training. At the basin scale of the Mediterranean, the main water masses and gradient appear clearly, but the quasi-permanent meso-scale features are too smoothed.

The main permanent feature, well illustrated in the vertical section, is the three layers stratification and the relatively huge volume of intermediate (200-800 dbar) and deep water (800 dbar to the bottom), compared to the surface layers. The deep water is relatively homogeneous within each basin, with discontinuities from one basin to another. The annual mean salinity values at 2000 dbar are 38.42 in the Western Basin (Fig. 6a), 38.46 in the Tyrrhenian Sea (not shown), 38.67 south and east of the Levantine Basin (Fig. 6b), 39.00 in the Aegean Sea (Fig. 6c) and 22.35 in the Black Sea (Fig. 6d). The discrepancies from the mean values are less than 0.02 units. However, in the north of the Levantine Basin, near the Hellenic Straits, the deep water variability of the Levantine Basin is higher, with mean annual salinities reaching 38.73. The distributions of oxygen and of the chemical parameters reflect not only the water masses, but also the vertical ventilation and the biological processes; moreover, the biochemical observations exhibit larger variability than the physical one as it can be seen from the Levantine and Aegean Sea sections (Fig. 7). The correlation between the distributions of oxygen and nutrients is high in this section, in spite of the noise. This led the MEDAR scientists to work on the distribution of the Redfield ratio between the bio-chemical parameters (Manca *et al*., 2003), and the results are expected to improve both the quality checking methodology in the future and the related climatological fields.

The horizontal analyses show the maximum variability near 50 dbar in the Mediterranean (100 dbar in the Black Sea). Fig. 8, presents the annual mean distribution of four parameters (temperature, salinity, phosphate and pH) at this horizon in the whole Mediterranean Sea. The west-east gradients that go towards warmer, saltier, less rich in nutrients and less basic surface waters, appear clearly. The north-south gradient is also visible, particularly on salinity (Fig. 8b); it shows the path of the Algerian current that transports Atlantic water along the southern Mediterranean regions.

Some sub-basin scale features are also evident from the annual and seasonal mean climatologies computed over the whole basin, however the resolution is in general not sufficient to get an appropriate description of these features:

- the meanders of the Algerian current in the South-Western Basin and the related modified Atlantic current in the Levantine Basin are probably too smoothed;
- in the Eastern Basin, the Rhodes Gyre is visible in the temperature distribution, but not in the other parameter distributions, and the other gyres, as described by the POEM Group (1992) are not seen on the horizontal maps;
- the cyclonic gyre in the Gulf of Lions, i.e. the main source of deep water formation in the Western Basin, appears only as a broader region of highly saline water mass.

These sub-basin scale features are better detected with the higher resolution fields adopted for the Black Sea (Fig. 9) and the Gulf of Lions sub-region (Fig. 10). In both cases, a two-gyres system appears with a strong seasonal variability. On the mean seasonal cycle, the separated gyres are alternatively intensified and periods of merging in only one gyre are also found. Consequently, the seasonal component seems important, but it is not regular all along the year and it is likely that the variability includes other frequencies; some interannual components of this variability are in need additional studies.

5. The database on Cd-rom

Even if several modules of the database are available on line, Cd-roms publication provides a reference data set, and also facilitates the day-to-day work of scientists and engineers, who may or may not have access to a fast computer network. Therefore, the project results have been published on a set of four Cd-roms (MEDAR Group, 2002). They include the Cruise Inventory, the meta-data, the observed data, the gridded data, a subset of the vertical sections, horizontal maps and animated layouts. They also include the project documentation, the description of the MEDATLAS format and the common protocol for data checking.

Considering the huge amount of gridded data and the size of the electronic atlas, a selection of the analysed data and maps has been made, limiting the product to the data computed from the best space and time data coverage. Accordingly, the MEDATLAS 2002 database provides the following numerical gridded fields:

(i) annual, seasonal and monthly for temperature, salinity and dissolved oxygen;
(ii) annual and seasonal for silicate, phosphate and hydrogen sulphide (Black Sea only);
(iii) annual mean for nitrate, nitrite, pH, ammonium, alkalinity and chlorophyll.

In addition to data and meta-data, they also include software tools: the QCMEDAR quality checking software (Garcia *et al.*, 2001), Ocean Data View software (Schlitzer, 2001) and the SELMEDAR (Fichaut *et al.*, 2001, 2002), to select and visualize the observed data according to different criteria like parameter, geographical region, time period, month of the year, country, ship and quality flag. The technical development, necessary to prepare the publication of MEDATLAS 2002 on Cd-rom represents an important part of the project.

6. Conclusions

It is expected that the MEDATLAS 2002 database will provide a useful tool for a whole host of users, modellers and experimental scientists, teachers and engineers, as was the case regarding the 1997 release. Qualified integrated data sets of bio-chemical data collected over a long period of time are rather scarce, and this new data product is extremely valuable in this field. It provides the present best estimates of the mean fields and the seasonal cycles and a possibility of better estimating the local correlation lengths. Finally, it gives information on the data availability and where more observations are needed for studying the region.

Moreover, the MEDAR experience shows that an essential aspect of cooperative data management is the importance of software engineering. Scientific expertise in data is necessary, but not sufficient for adequate data management, and more and more technical skills are also needed. Development of expert software is necessary to assist data checking and various kinds of processing. This software should be portable on different platforms. Communication technology is another critical issue in terms of distributed data management.

Besides the scientific and technical aspects of the project, sharing knowledge and know-how amoung participants is another essential result of MEDAR. It has contributed in enhancing the overall capacity of the data centres, in terms of oceanographic data management. This should prove useful in managing the greater volume of new data expected in future, from research cruises and from operational oceanography observation systems as well.

The results seem promising, but it is important to maintain continuity in data flow management, to fill the remaining gaps in the southern part of the Mediterranean and to meet the ever-growing demand for data and products. Several issues deserve attention in the future, in particular:

1) to ensure full on-line access to distributed data;
2) to continue developing data standards and quality checks methodology, especially for bio-chemicals;
3) to continue developing portable software tools to format and process the data according to the set standards;
4) to integrate data sets that have been collected during the most recent field projects, including a few other parameters such as surface data, current data, and carbon cycle data.

With this aim in view, the data centres, network is preparing a new concerted action, where priority will be given to the use of new communication technologies to provide on-line access to data and information. However, the best data management system cannot produce data in regions void of data, like in the middle of the basins and along the Southern Mediterranean coast. Therefore, it is hoped that more sea monitoring programmes will also be undertaken in the region in the years to come, assisted by a professional data management infrastructure, to take into account the standardization and management issues from the very beginning of the data collection to the long term archiving.

Acknowledgements. The MEDAR Group acknowledges institutes, scientists, technicians and crews of the vessels referenced in the MEDAR Inventory, who participated in the data collection in whatever way and made it available for public use, and also those whom we are not able to identify. We also thank S. Levitus, leader of the GODAR project and his colleagues of WDC-A very much for their support and good cooperation. We gratefully thank the EU for the financial support (contract MAS3-CT98-0174 & IC20-CT98-0103), and highly appreciated the support provided by the EU Project Officer, Dr Elisabeth Lipiatou, throughout the implementation of the Project.

REFERENCES

Bardet D. and Fichaut M.; 2000: *System of Control Oriented Oceanographic Parameters Scoop, V4.2, User Manual*. Rap Int. Ifremer/Tmsi/Idm/Sismer/02-072.

Brasseur P.; 1991: *A Variational Inverse Method for the reconstruction of general circulation fields in the Northern Bering Sea.* Journal of Geophysical Research, **96**, 4891-4907.

Carter E.F. and Robinson A.R.; 1987: *Analysis models for estimation of ocean fields*. J. Atmos. Oceanic Technol., **4**, 49-74.

Fichaut M., Garcia M-J., Maudire G., Rixen M., Vyazilov E. and MEDAR Group; 2002: *Added values to oceanographic multiparameters data sets, example of an European Concerted Action: MEDAR/MEDATLAS 2,* Symposium Ensuring Long-Term Preservation and Adding Value to scientific and technical data. Toulouse 5-7 November 2002, France.

Fichaut M., Maudire G., Larour M.; 2001: *SELMEDAR, Data selection from the MEDAR database*. Rap. Int. R.INT.TMSI/SISMER-ISIB/SIS/01-042, 28 pp.

Garcia M.J., Nikouline A., Alcantara P., Molinero J.; 2001: *QCMEDAR,. MEDATLAS Format & Quality Control (V1.1). Users guide*. Rap. Int. Instituto Espanol de Oceanografia IEODC.

ICES Working Group on Marine Data Management, 2000. *Data Type Guidelines.* http://www.ices.dk/ocean/

Levitus S., Boyer T.P., Conkright M.E., O'Brien T., Antonov J., Stephens C., Stathoplos L., Johnson D. and Gelfeld R.; 1998: *NOAA Atlas NESDIS 18, World Ocean Database 1998*, U.S. Gov. Printing Office, Wash., D.C., 346pp + set of Cd-roms.

Lewis E.L. and Perkin R.; 1981: *The practical salinity scale 19878; Conversion of existing data,* Deep Sea Res., **28**, 307-328.

Manca B., Burca M., Giorgetti A., Coatanoan C., Garcia M.-J. and Iona A.; 2003: *Physical and biochemical averaged vertical profiles in the Mediterranean regions: an important tool to trace the climatology of water masses and to validate incoming data from operational oceanography.* J. Mar. Syst., **48**, 83-116.

MEDAR Group (The); 2001: *Medar-Medatlas Protocol (Version 3) Part I: Exchange Format and Quality Checks for Observed Profiles*; Rap. Int. IFREMER/TMSI/IDM/SIS002-006, 50 pp.

MEDAR Group (The); 2002: MEDATLAS 2002, *Mediterranean and Black Sea database of temperature, salinity and bio-chemical parameters and climatological atlas* (4 Cd-roms), European Commission Marine Science and Technogy Programme, and internet server www.ifremer.fr/sismer/program/medar IFREMER/TMSI/IDM/SISMER (Ed.), Centre de Brest.

MEDATLAS Group (The); 1997: *A Mediterranean Hydrographic Atlas from a composite quality checked temperature and salinity data* (3 Cd-roms), IFREMER Ed.

POEM Group (The); 1992: *General circulation of the Eastern Mediterranean*, Earth-Sci. Rev., **32**, 285-309.

Reiniger R.F. and Ross C.K., 1968: *A method for interpolation with application to oceanographic data*. Deep-Sea Research, **15**, 185-193.

Rixen M., Beckers J.-M., Brankart J.-M. and Brasseur P.; 2001: *A numerically efficient data analysis method with error map generation*. Ocean Modelling, **2**, 45-60.

Rixen M., Beckers J.-M., Levitus S., Antonov J., Boyer T., Maillard C., Fichaut M., Balopoulos E., Iona S., Dooley H., Garcia M.-J., Manca B., Giorgetti A., Manzella G., Mikhailov N., Pinardi N. and Zavatatrelli M.; 2005: *The Western Mediterranean deep water: a proxy for climate change*. Geophys. Res. Lett., 32, L12608, doi: 10.1029/2005GL022702.

Schlitzer R.; 2001: *Ocean Data View* http://www.awi-bremerhaven.de/GEO/ODV.

UNESCO; 1993: *Manual of quality control procedures for validation of oceanographic data*. Prepared by CEC: DG-XII, MAST and IOC: IODE Manual and Guides 26, 436 pp.