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Sergio Ragonese, Giandomenico Nardone, Salvatore Gancitano,
Alberto De Santi, Domenico Ottonello & Patrizia Jereb

SEA WATER TEMPERATURE RECORDS GATHERED DURING EXPERIMENTAL BOTTOM TRAWL SURVEYS IN THE STRAIT OF SICILY (MEDITERRANEAN SEA)

SUMMARY

Depth and sea water temperature values recorded by a Minilog system during several bottom trawl surveys carried out in the Strait of Sicily (Central Mediterranean Sea) in spring (MEDITS) and late summer (GRUND), were analyzed by using an *ad hoc* developed software (MiSeAT). Depth and temperature profiles were analyzed for each haul. Three sea water temperature (T °C) values were considered: the upper and lower water layers temperature, and the difference between them. Mean values by depth stratum and the corresponding standard deviations were estimated for the three parameters, then compared between the two seasons. Haul parameters recorded during the more heterogeneous GRUND surveys (due to the vertical waters stratification occurring in summer), were fed to a GIS system in order to produce thematic spatial maps by survey and variable. Data recorded support an ongoing warming up of the water masses in the Strait of Sicily (13.5°C representing the asymptotic temperature between 200 and 800m), and confirm the existence of the basic three layers structure (Atlantic, Levantine and Transitional waters) reported for the area by classic literature. In spite of the limitations related to the use of Minilog (i.e., short coverage in space and time, incidental loss of devices, lower precision and accuracy of data if compared to those recorded by other devices), present results strongly support the validity of the Minilog-system-obtained temperature values.

RIASSUNTO

Analisi dei dati di temperatura dell'acqua di mare raccolti durante le campagne di ricerca a strascico nello Stretto di Sicilia. I dati relativi alla profondità ed alle temperature dell'acqua raccolti con Minilog durante una serie di campagne di pesca sperimentale condotte nel Canale di Sicilia (Mediterraneo Centrale) in primavera (MEDITS) ed in autunno (GRUND) sono stati analizzati utilizzando un software elaborato *ad hoc* (MiSeAT). Per ogni cala sono stati analizzati i profili di profondità e temperatura. Sono stati considerati tre valori di temperatura dell'acqua (T°C): la temperatura degli strati superficiale e profondo e la differenza fra questi due valori. Per ciascun parametro e per strato batimetrico sono stati stimati i valori medi e la relativa deviazione standard, confrontando poi i valori risultanti, per stagione. I dati di cala raccolti nel corso delle campagne GRUND (più eterogenee a causa della stratificazione verticale delle acque che si determina nel periodo estivo) sono stati elaborati tramite GIS al fine di produrre mappe tematiche spaziali per campagna di pesca e per variabile considerata. I dati raccolti sostengono l'ipotesi che nel Canale di Sicilia sia in atto un riscaldamento delle acque (con 13.5°C che rappresenta il valore asintotico della temperatura fra i 200 e gli 800 m) ed hanno confermato l'esistenza di una struttura base del corpo idrico in tre strati (acque atlantiche, levantine e strato di transizione), come riportato dalla letteratura. Nonostante i limiti insiti nell'uso del Minilog (i.e., copertura ridotta di spazio e tempo, perdita accidentale dello strumento, precisione ed accuratezza dei dati inferiori a quelle ottenibili con altre strumentazioni oceanografiche), i risultati ottenuti confermano la validità dell'uso dei dati così raccolti per integrare i modelli sviluppati dall'oceanografia applicata.

INTRODUCTION

Sea water temperature is one of the most relevant parameter in oceanological and biological investigations and a basic element for any hydrodynamic and ecosystem model. In the last decades remote sensing provided plenty of information about the Sea Surface water Temperatures (SST) by using satellite-derived thermal infra-red images, especially in those areas where the cloud coverage is relatively low.

On the other side, getting information on the thermo profiles of the water column and on the bottom waters temperature remains a very expensive, difficult and limitedly performed activity. More so in those areas that represent transitional zones between adjacent basins, thus characterized by high complex bottoms topography and strong mesoscale signals.

Such is the case of the Strait of Sicily (Central Mediterranean Sea; Fig. 1) a large area connecting the eastern and western sides of the Mediterranean basins and characterized by a basic three-layers horizontal hydrological stratification: the upper fresh Atlantic waters (AW), the intermediate salty Levantine waters (LIW) and the deeper waters (DW) strata.

Given the very irregular bottoms structure, it is very difficult to get representative sea water temperature profiles by methods alternative to the unsuitable remote sensing (cfr. SARDÀ *et al.*, 2004). This information, however, is crucial to improve the knowledge on the hydrological frame: temperature profiles taken in a limited area of the Strait of Sicily in 1994 allowed the identification of at least seven water masses (ROBINSON *et al.*, 1996).

In addition to the various methodology used to achieve such important data (tripods, CTD, XTB, etc.), an alternative was eventually considered in the very last years: the experimental bottom trawl surveys carried on in the

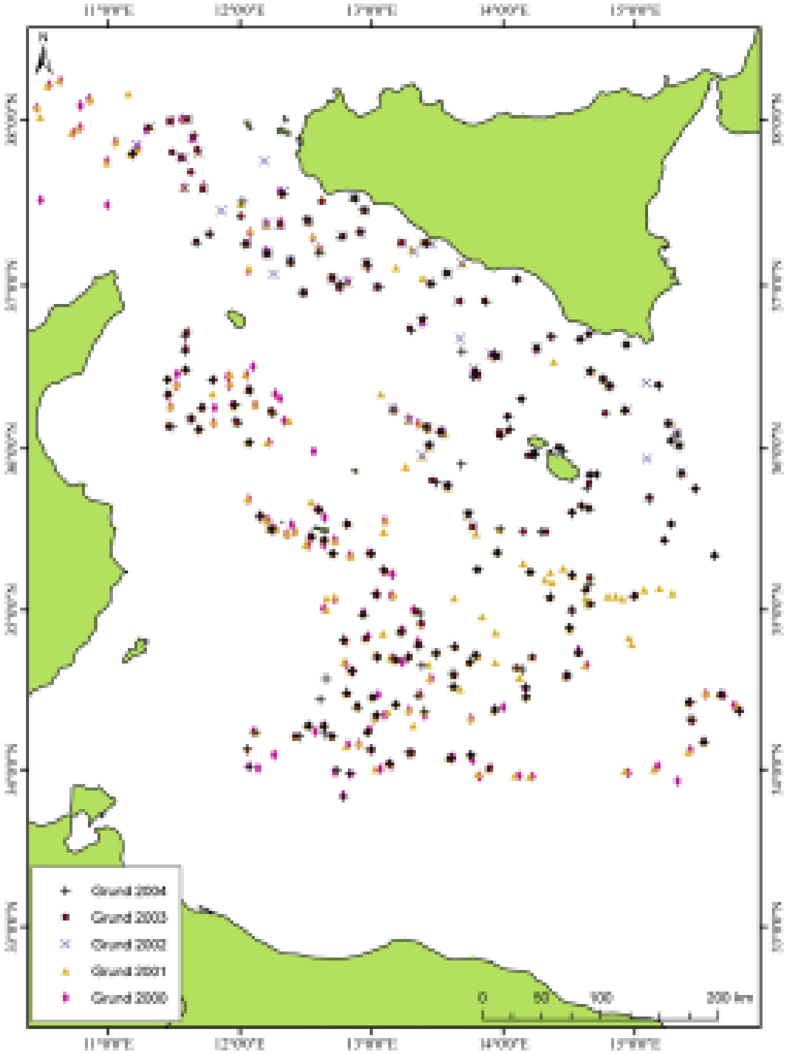

Fig. 1 — The study area (Strait of Sicily; Central Mediterranean Sea); haul location by sampling year is evidenced.

Mediterranean Sea within National (GRUND; RELINI, 2000) and International (MEDITS; BERTRAND *et al.*, 2002a) research programs.

Both programs protocols include bathy-thermo sea-water-profiles recording, by applying a Minilog device onto the head rope of the bottom gear. This procedure was conceived for a twofold purpose: 1) to help monitoring the gear performance (cfr. BERTRAND *et al.*, 2002b) and 2) to get a real time measure of sea-water temperature, especially close to the bottom (i.e. where the catching itself occurs), in order to figure out possible T °C-catch-level relationships. A further purpose (still to be evaluated to the Authors knowledge) could be to employ temperature data gathered during experimental bottom trawl survey as additional information for the calibration of oceanological models

Aim of the present work was to use temperature records collected by Minilog to produce thematic spatial maps and corresponding data bases ready for oceanological investigations. A selected number of trawl surveys carried on in the Strait of Sicily between 1999 and 2004, was taken as the case study.

MATERIALS AND METHODS

Depth (0.1 m) and sea water temperature (0.1 T °C) values recorded by a Minilog 8-bit TDR data Logger system (VEMCO, 2005), placed onto the head-rope of the trawl, during bottom trawl surveys carried out in the Strait of Sicily (Mediterranean Sea; Fig. 1) were used. Minilogs are provided after a standard calibration is carried out by the source companies; this takes into consideration information, suggestions and data provided by the technical staff of the MEDITS UU.OO. themselves. Minilogs could be calibrated directly by the users, but the procedure is very long, time consuming and eventually not worth it, due to the instrument losses during trawl surveys operations. To the aim of the present work, the correspondence between Minilog data and data recorded by a portable surface probe was occasionally tested and no peculiar discrepancies were recorded. The readings precision and accuracy depends on the model of the device; in the present study, the precision/±accuracy were 0.3/±0.5°C and 4/±20m for the temperature and depth respectively.

In particular, data gathered during six MEDITS (spring-summer; 1999-2004) and five GRUND (summer-autumn; 2000-2004) surveys were analyzed. Surveys time schedules and basic specifications are presented in Table 1.

Hauls were performed according to standardized protocols: haul duration (i.e. the effective contact of the gear with the bottom) varied, being set at 30 minutes for the shelf in the MEDITS Program, and 60 minutes otherwise, i.e. for the shelf in the GRUND Program and for the slope in both.

MEDITS and GRUND programs employ different gears (FIORENTINI *et al.*, 1999); the most important difference in relation to the present work targets, consists in the Vertical Net Opening (VNO), which is 2.5 and 1 m in the MEDITS and GRUND used gear respectively. The sweep lines length (i.e.,

Table 1
Season, survey number and code, year, and time range of the MEDITS and GRUND surveys carried out in the Strait of Sicily and used in the present study. Start and end refer to the beginning and end of the survey. Nominal time refers to the median day of given survey period.

Season	*Survey code*	*Year*	*Start*	*End*	*Nominal time*	*N° of hauls (1473)*
Spring	MEDSp99	1999	28-May	9-Jun	2-Jun	56
Spring	MEDSp00	2000	26-May	8-Jun	31-May	61
Autumn	GRUAu00	2000	05-Sep	11-Nov	8-Oct	245
Spring	MEDSp01	2001	19-May	1-Jun	26-May	65
Autumn	GRUAu01	2001	03-Sep	18-Nov	11-Oct	247
Summer	MEDSu02	2002	11-Jul	24-Aug	2-Aug	120
Autumn	GRUAu02	2002	24-Sep	07-Oct	30-Sep	69
Summer	MEDSu03	2003	13-Jul	13-Aug	28-Jul	120
Autumn	GRUAu03	2003	12-Sep	6-Nov	9-Oct	199
Summer	MEDSu04	2004	10-Jun	11-Jul	25-Jun	119
Autumn	GRUAu04	2004	9-Sep	38290	29-Sep	172

the length of the cable connecting the otter doors to the gear) also differs in the two gears: it is 100-150 m (according the bottom depth) and 232 m for the MEDITS and the "tartana" gear respectively.

Further details about the methodology followed in the two programs are available in RELINI (2000) and BERTRAND *et al.* (2002a).

Depth and temperature profiles were registered for each haul, from the setting to the retrieval of the gear, then downloaded to a desktop directly on board. Once back to the laboratory, the original data base (*.bin) was converted into the ASCII format and the resulting files fed to an *ad hoc* developed software (MiSeAT, free available from the Authors) to erase outliers, set the computations defaults and obtain the most reliable haul bathy-thermo profiles.

Beside the individual haul profile, three descriptive variables were considered: sea water temperature at the upper (USwT) and bottom (BSwT) water layers and their differential, i.e., the Absolute Haul Temperature Interval (AHTI), as an approximation of the degree of stratification. Mean values and the corresponding standard deviations of the three parameters by each haul and depth stratum (A: 10-50; B: 51-100; C: 101-200; D 201-500 and E: 501-800m) were estimated, as the required outputs by both protocols.

Haul parameters were then transferred under a GIS system in order to produce thematic spatial maps by applying a georefencing software WGeo 4.0 (WASI SOFTWARE GMBH, 2000). All sample sites were georeferenced with the same software. Two-dimensional zone maps were drawn using the GIS program ArcView™ 9.0 (ESRI-ENVIRONMENTAL SYSTEMS RESEARCH INSTI-

TUTE, Inc., 1999-2004); this software transforms discrete data into a continuous distribution model with a specific extension (Geostatistycal analyst). Different interpolators were tested and the exact interpolator (IDW Inverse Distance Weighting) was eventually chosen. The temperature (°C) registered in each sample site is the ecological parameter used to draw the maps, after interpolation. Surface and bottom maps were then overlapped to form two-dimensional maps, in order to evaluate the relationship between surface and bottom water temperature in each sample site. To allow future comparisons with other possible information gathered in the area, the absolute coordinates were used. The projected coordinate Mercator system was used for the spatial analysis and representation (Datum WGS-1984, Ellipsoid WGS-1984; a = 6378137 c = 6356752 f = 1/298.257).

RESULTS

Minilog data were available for 1239 out of 1473 hauls, 439 belonging to the MEDITS and 800 to the GRUND surveys. MiSeAT performed very well with the GRUND data (100% used), whereas 56 MEDITS hauls (12.7%) were rejected for different reasons mainly a) the lack of synchronicity between Minilog activation and haul start; b) the high speed of the gear descending phase; c) the time variability of the contact and stabilization of the gear with and on the bottom and d) the step in the profile occurring when the haul ended, and the gear started to be recovered.

A synoptic overview of sea water temperature data and their gradient for the MEDITS and GRUND surveys is presented in Table 2 and 3, respectively. With the exception of stratum A, usually poorly represented (no usable haul profile in MEDSu03), at least five hauls for each stratum were suitable for the analysis.

Considering MEDITS data (Tab. 2), USwT values ranged between "colder" (19.3-20.0°C; MEDSp01) and "warmer" (27.0-28.1; MEDSu03) situations. Spring oriented surveys (May-centered; 19.3-23.1°C) resulted "cooler" and more homogeneous than summer oriented surveys (extending till August; 20.0-28.1°C). On the contrary, and as expected, the BSwT values varied much less, especially on the outer shelf and in the upper slope strata (101-800m; 13.8-14.8°C); also, the difference between the spring- (14.9-16.6°C) and summer- (15.1-16.3°C) oriented surveys was detectable only on the inner shelf (10-100m). When comparing the mean temperature values, the difference between the standard deviations computed for the USwT and the BSwT is evident (about 1 order of magnitude), as a result of the more homogeneous hydrological conditions at the bottom waters layers. As for the temperature

Table 2
MEDITS surveys sea water temperature overview obtained by MiSeAT. HN = Haul number. AHTI denotes the Absolute Haul Temperature Interval (USwT-BsWT). In brackets, the nominal survey time.

Depth Stratum		HN	Upper (USwT)		Bottom (BSwT)		AHTI	
Code	Depth (m)		mean (°C)	s.d.	mean (°C)	s.d.	mean (°C)	s.d.
MEDSp99 (02-Jun)								
A	10-50	3	20.96	0.36	15.35	0.34	5.61	0.69
B	51-100	8	21.18	1.33	15.03	0.43	6.15	1.04
C	101-200	11	21.46	1.49	14.42	0.18	7.04	1.44
D	201-500	15	21.59	1.60	14.02	0.07	7.57	1.62
E	501-800	19	22.97	0.96	13.84	0.06	9.14	1.00
MEDSp00 (31-May)								
A	10-50	2	22.03	1.80	15.46	0.71	6.57	1.10
B	51-100	9	21.83	1.28	14.93	0.52	6.91	1.19
C	101-200	12	23.13	1.10	14.48	0.19	8.65	1.10
D	201-500	15	21.88	1.29	14.03	0.09	7.85	1.32
E	501-800	17	21.95	1.31	13.88	0.06	8.06	1.31
MEDSp01 (26-May)								
A	10-50	4	19.32	0.38	16.58	0.28	2.74	0.59
B	51-100	12	19.84	1.11	15.43	0.49	4.41	1.52
C	101-200	12	19.53	0.69	14.78	0.16	4.75	0.81
D	201-500	17	19.97	1.12	14.16	0.19	5.80	1.03
E	501-800	17	19.63	0.53	13.84	0.07	5.79	0.52
MEDSu02 (02-Aug)								
A	10-50	5	21.57	1.23	16.28	0.59	5.29	1.61
B	51-100	17	24.11	2.13	16.28	1.02	7.83	1.78
C	101-200	23	24.55	1.49	14.85	0.32	9.71	1.36
D	201-500	38	25.61	1.43	14.20	0.22	11.41	1.44
E	501-800	37	26.05	1.50	13.95	0.08	12.10	1.53
MEDSu03 (28-Jul)								
A	10-50	0						
B	51-100	5	26.94	1.60	15.44	0.48	11.50	1.51
C	101-200	5	27.00	2.85	14.82	0.24	12.18	2.72
D	201-500	14	27.83	2.18	14.37	0.13	13.46	2.10
E	501-800	7	28.15	0.94	14.03	0.05	14.12	0.96
MEDSu04 (25-Jun)								
A	10-50	8	20.28	1.36	16.12	0.32	4.16	1.48
B	51-100	15	20.03	1.10	15.08	0.53	4.95	1.03
C	101-200	22	20.63	1.31	14.58	0.18	6.05	1.28
D	201-500	34	21.93	1.28	14.13	0.19	7.80	1.27
E	501-800	36	22.89	0.88	13.96	0.09	8.93	0.93

gradient (AHTI) derived from MEDITS data (Tab. 2), two main considerations are immediate: 1) AHTI increases almost regularly from the lowest (A; 2.7-6.6°C) to the deepest (E; 5.8-14.1°C) stratum, and 2) its range is narrower in the spring oriented (2.7-9.1°C) than in the summer (5.3-14.2°C) oriented surveys. When considering all the three variables together, an interesting similarity between the MEDSu04 values and those of the spring oriented surveys emerged, in spite of the different time range (median day 28 June).

GRUND figures (Tab. 3) indicate a more stable hydrological situation,

Table 3

GRUND surveys sea water temperature overview obtained by MiSeAT. HN = Haul number. AHTI denotes the Absolute Haul Temperature Interval (USwT-BsWT). In brackets, the nominal survey time.

Depth Stratum		HN	Upper (USwT)		Bottom (BSwT)		AHTI	
Code	Depth (m)		mean (°C)	s.d.	mean (°C)	s.d.	mean (°C)	s.d.
GRUAu00 (08-Oct)								
A	10-50	8	24.99	1.57	18.01	1.29	6.98	0.73
B	51-100	23	24.55	2.59	16.14	0.91	8.40	2.05
C	101-200	31	24.89	2.30	14.87	0.74	10.02	2.24
D	201-500	78	24.59	2.31	13.82	0.13	10.77	2.32
E	501-800	27	21.88	1.59	13.70	0.21	8.18	1.55
GRUAu01 (11-Oct)								
A	10-50	4	23.19	1.15	19.87	1.20	3.32	1.18
B	51-100	29	25.31	1.85	16.58	1.07	8.73	1.72
C	101-200	39	25.58	2.25	15.24	0.38	10.34	2.01
D	201-500	103	26.60	1.76	13.95	0.26	12.65	1.81
E	501-800	58	25.15	1.32	13.72	0.19	11.43	1.33
GRUAu02 (30-Sep)								
A	10-50	1	22.41	NA	19.01	NA	3.40	NA
B	51-100	8	22.72	2.33	16.21	0.42	6.51	2.31
C	101-200	17	24.35	1.44	15.16	0.36	9.19	1.38
D	201-500	19	23.69	0.90	14.26	0.16	9.43	0.93
E	501-800	21	24.67	1.40	14.00	0.10	10.67	1.48
GRUAu03 (09-Oct)								
A	10-50	4	22.55	2.21	17.06	2.34	5.49	2.03
B	51-100	23	24.07	1.97	15.62	1.02	8.46	1.75
C	101-200	30	24.94	1.80	14.80	0.27	10.13	1.76
D	201-500	75	24.83	1.94	14.08	0.20	10.75	1.98
E	501-800	38	22.89	2.23	13.94	0.07	8.95	2.26
GRUAu04 (29-Sep)								
A	10-50	5	22.88	2.59	17.14	1.39	5.74	2.46
B	51-100	23	25.80	1.33	16.03	1.15	9.77	1.61
C	101-200	32	24.93	1.86	14.95	0.37	9.98	1.68
D	201-500	74	25.78	1.80	13.97	0.22	11.81	1.91
E	501-800	30	24.72	1.76	13.79	0.09	10.93	1.82

both at the upper (21.9-26.6 °C) and bottom (13.7-19.9 °C) water layers and no "cooler" or "warmer" surveys were evident. As for the standard deviations, GRUND computed values reflect MEDITS pattern, with the exception of the A and B strata. On the contrary, the AHTI trend showed an inversion in the last stratum in all surveys except GRUAu02.

When comparing MEDITS and GRUND figures, it is possible to appreciate different patterns according to the MEDITS time-range and variable considered. Spring-oriented MEDITS surveys showed lower USwT and AHTI than GRUND surveys, whereas the opposite situation occurred with the summer-oriented MEDITS surveys. A more complex situation concerns the BSwT: considering the shelf strata (A and B), GRUND values are conspicuously higher than the MEDITS ones, while on the slope strata (C, D and E), this pattern is reversed and MEDITS values are conspicuously higher than or equal to the GRUND values.

A MiSeAT-estimated haul BSwT-by-depth plot (GRUND surveys) is reported in Figure 2 as an exemplum, to give an insight of the vertical hydrological structure of the Strait of Sicily.

At least three "stanzas" can be singled out: a variable upper layer (14-

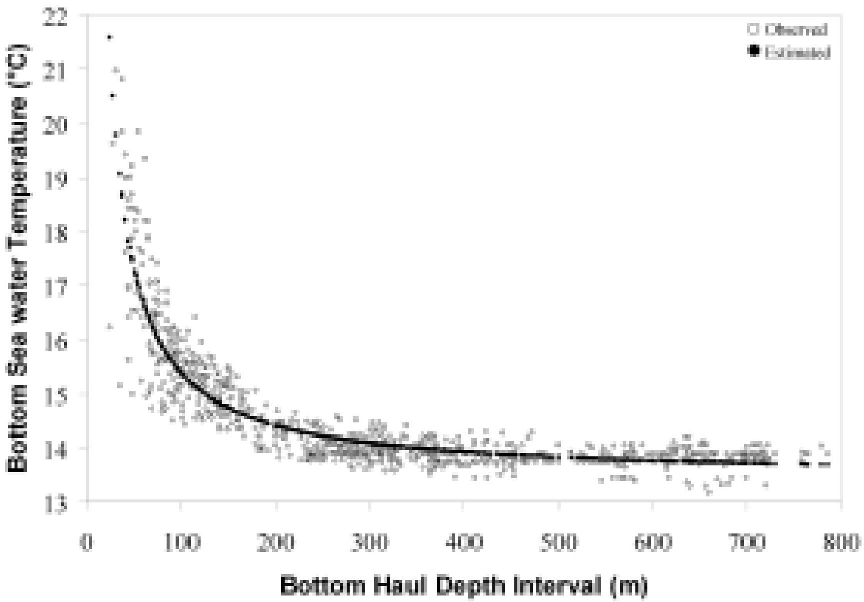

Fig. 2 — MiSeAT single haul bottom-depth-plot of the recorded sea water temperature (BSwT) with over imposed the hyperbolic relationship (y=13.439+195.573*1/depth; r^2 =0.802; Mean Square Error = 0.250).

21°C between 10 and 100m), a transition layer (14-16°C between 101 and 200 m) and a stable layer at about 14°C (down to 800m). The threshold level of about 200 m was supported by fitting an hyperbolic model to the data (y=13.439+195.573*1/depth; r^2 =0.802; Mean Square Error = 0.250).

The basic three-layered hydrological structure of the bottom waters in the Strait of Sicily within the explored depth range (10-800m) is confirmed by the horizontal spatial representation maps (Fig. 3-A), where the "warm" waters on the shelf and the peculiar "hot spots" on the African shelf (lower waters) are evident.

Also the spatial representation maps of the USwT (Fig. 3-B) is well repre-

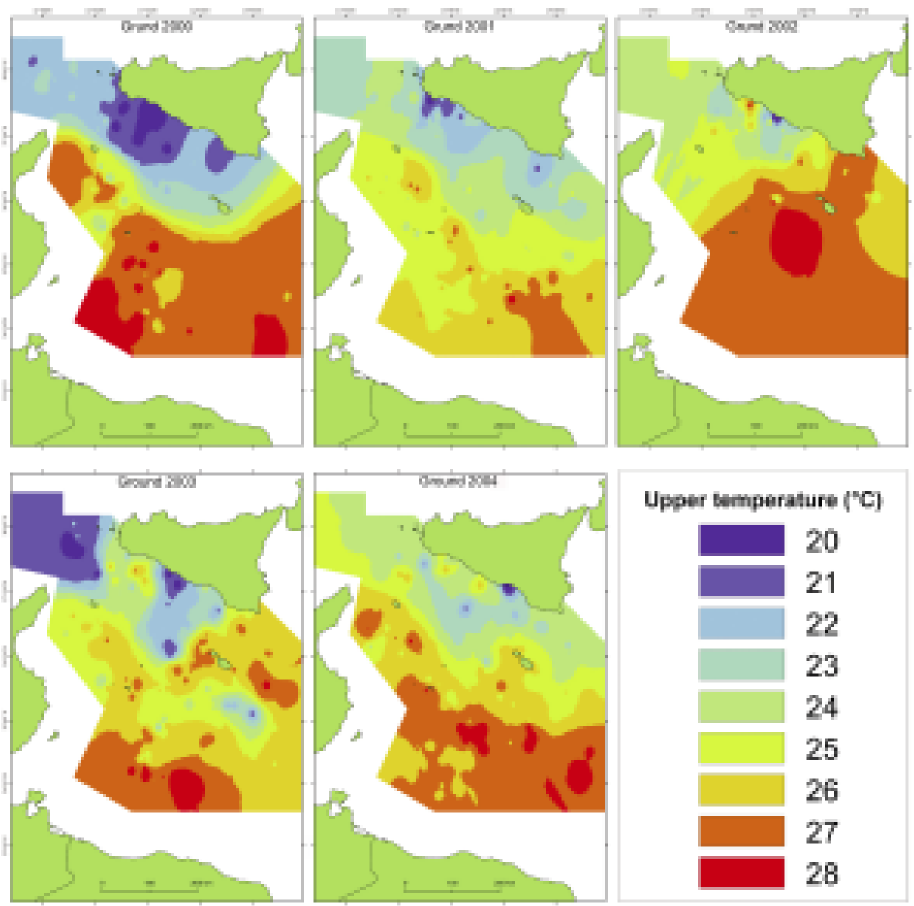

Fig. 3-A — Horizontal spatial representation of the Upper sea water temperature (USwT) in the Strait of Sicily as computed by the MiSeaT software.

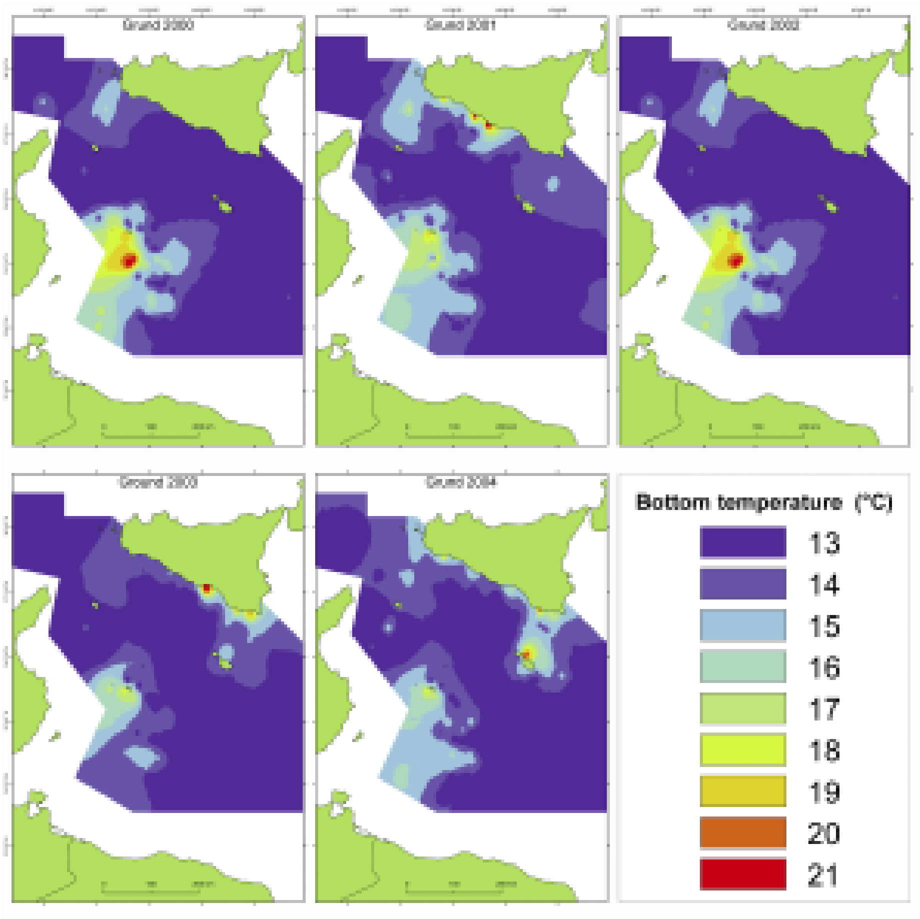

Fig. 3-B — Horizontal spatial representation of the Bottom sea water temperature (BSwT) in the Strait of Sicily as computed by the MiSeaT software.

sentative of the hydrological situation observed; here, the income of the colder Atlantic waters that become warmer flowing eastwards (along the southern coast of Sicily) and southwards, and even warmer approaching the African coasts, is shown. In this case, some variability is evidenced, depending on the survey time-range. Although only five surveys were compared, in fact, the "cool" AW is more evident in the October than in the September oriented surveys (GRUND).

Results of the analysis of the USwT (rather variable and not stable) and BSwT (quite stable) patterns, indicate a rather limited value of the synoptic descriptive statistic for the former, but support the potential use of the latter as a benchmark to compare upper and bottom waters circulation.

As a by product of the analysis, the redundancy of the AHTI estimate was evidenced (Fig. 3-C), since AHTI actually mirrors the USwT pattern, given the relative stable configuration of the bottom water layers.

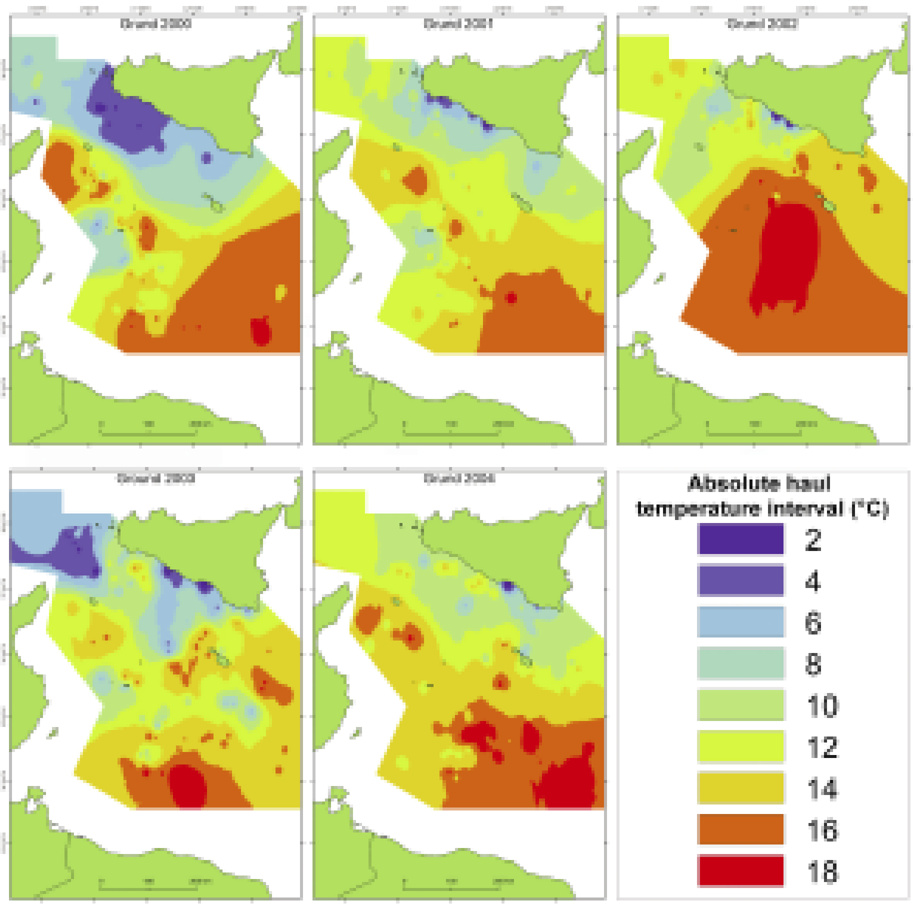

Fig. 3-C — Horizontal spatial representation of the Absolute Haul Temperature Interval (AHT=USwT - BSwT) in the Strait of Sicily.

Discussion

Bottom trawls are complex and flexible gears, the design, rigging and usage of which requires sound knowledge, long studies and standardization efforts. Bottom trawls performance, in particular, should be monitored regularly with specific sensors in order to highlight the different sources of variability in catch rates due to both sampling errors and bias (cfr., ENGAS, 1994). This goal was at the base of the implementation of Minilog devices.

Strictly speaking, Minilogs were designed as economic and friendly-to-use devices to get quick and simple records of depth and temperature; loosing or malfunctioning events, in fact, are few and affordable.

As for data elaboration, however, the difficulties encountered strongly recommend to standardize the procedures; subjectivities cannot be totally excluded, but MiSeAT users are required to be cautious in modify default parameters and should be prepared to well justify the changes made.

Minilogs should not be included among devices suitable to monitor gear performances, given the above mentioned difficulties in setting the beginning of readings with the haul start-time and the limitation in the precision/accuracy of the readings. However, present analysis confirmed what was already pointed out by BERTRAND *et al.* (2002b): Minilog results are excellent supports to the information gathered by more sophisticated devices (such as acoustic equipments).

Sea water temperature is one of the main environmental parameters responsible for different fish behaviours (reactions) toward the gear (ENGAS, 1994), and explains at least part of bottom trawl surveys catches variability, especially in the open waters of the oceans (BYRNE *et al.*, 1981).

Although less important, some variability is expected also in the more homogeneous and warmer Mediterranean Sea, therefore Minilog - MiSeAT outputs may play an important role within operative oceanography therein.

Mediterranean surface seawater temperature and circulation, in fact, can be easily and continuously investigated by remote sensing. On the contrary, Mediterranean deep water temperature and circulation is difficult to monitor and poorly understood given the overlapping flows and local mixing of different layers of sea waters (SARDÀ *et al.*, 2004).

The Mediterranean Sea is a warm, oligotrophic body of waters (HOPKINS, 1985; LLEONART, 2005), where the hydrological circulation is characterized by the overlapping of three main layers: the surface, intermediate and deep (winter) waters layers.

The surface layer corresponds to the waters coming from the Atlantic, through the Gibraltar Strait (Atlantic Water, AW). Its lower limit is marked by a minimum of temperature in the Western basin, and its depth decreases as it flows towards the Eastern basin. Generally the AW is found between 0- and 100-250 m (somewhere down to 500 m) in the Western and Central Mediterranean, and between 0-50 m in the Eastern Mediterranean, at least in summer (BERLAND *et al.*, 1988).

The intermediate layer mainly originates in the Levantine basin (intermediate Levantine Water, LW) and, to a lesser extent, in the Western basin (Western Mediterranean Intermediate water, WMIW; HOPKINS, 1985). It derives from the AW (when this layer becomes saltier in summer then colder during winter) and is characterized by a maximum of salinity. The LW flows westwards, below the AW, and a layer where the two masses of water mix up is often recognized (e.g., GRANCINI & MICHELATO, 1987). Generally, the LW is found at 200-600 m, but somewhere it is situated deeper and in the Levantine basin it goes up to 40-50 m, at least in summer (BERLAND *et al.*, 1988). A transition layer is found at the lower limit of the LW (i.e., between 600-1.500 m), where both temperature and salinity decrease rapidly.

The deep layer is found only at great depths (typically below 1.900 m) and its temperature is fairly constant (about 12-13°C).

Only the AW and LW, with the corresponding transitional layer, play a relevant role in the hydrological circulation studied in the present case, considering the depth interval explored by trawl surveys (10-800 m). These masses of waters overlap and even partially mix with each other during their displacement across the Mediterranean basin, according to the general topography of the lands and the bottoms. Other different veins (e.g. the Modified Atlantic Waters, MAW**,** and the modified Levantine Intermediate Waters, MLIW) and special gyres or meanders, such as the Atlantic Ionian Stream (AIS), also originate and can be located according to their specific temperature and density parameters. River flows and discharge (especially when enriched with large amounts of nutrients) and winds action, represent additional minor (although relevant in local areas) driving forces for the Mediterranean circulation.

As for the upper seawater layers, up-welling phenomena and rivers runoff enhancing the primary production are the most streaking environmental variables to be considered and those for which there is evidence of similarity/correspondence with the climatic changes external to the Mediterranean Sea, such as the North Atlantic Oscillation, NAO (LLORET *et al.*, 2001).

Considering the Strait of Sicily and the depth interval explored (10-800m), the classic hydrological portray derived by the available literature (e.g., GORGY & SHAHEEN**,** 1963; BOMBACE & SARÀ,1972; GRANCINI & MICHELATO, 1987) consists in the following water layers: the AW (down 50-100 or 150-250 m, depending on locations) with a minimum water temperature of 14-15°C in winter, the LW (down to 500-700 m, where the temperature goes down to about 13-14°C), and a deep transitional layer (below 600-700 m; 12.8°C). Recently, however, this situation changed, since the deep transitional layer previously defined (and likely the Deep Winter Waters) was pushed away as a consequence of the invasion of the so called Transitional Eastern Mediterranean Deep (tEMD or EMT) water. This is a slightly warmer

(13.53°C) and much denser vein of water, originated some years ago in the Eastern Mediterranean, on the causes of the origin of which there is no general consensus (e.g., BRIAND, 2000).

Even being a simplified version of the actual, more complex and dynamic situation of the circulations in the first 800 m of the water column (e.g., TZIPERMAN & MALANOTTE RIZZOLI, 1991, for the Mediterranean Sea, and ASTRALDI *et al.*, 1996, SORGENTE *et al.*, 2002, for the Strait of Sicily), this schematic representation works its basic purpose and it is commonly used.

Although limited in time and space and affected by precision and accuracy constraints, present data support the classic basic three layers structure of the investigated area, along with the indications of a recent general "warming up" of the water masses therein. Clearly it is too early to valuate the effects of this new situation, but also it is evident that the increase in the temperature (and, likely, in the salinity) of the deep waters masses is going to interact with the local fauna and flora, affecting the life cycle of the resident species. For example, the observed disappearance of *Loligo forbesi* from the Strait of Sicily, since the end of the 80', and the increasing appearance of tropical species, may depend on the new hydrological situation.

MEDITS and GRUND bottom trawl surveys, even at the present stage of countries involvement (nine countries from Morocco northward and eastward to Hellas; BERTRAND *et al.*, 2002a) may allow to record millions of easy-to-use and relatively cheap Minilog data (depth and temperature) at the bottom and the production of continuous or synthetic values for thousands of hauls; these invaluable information, after a proper elaboration and spatial representation, might be used also to integrate and tune the more sophisticated and precise oceanographic models, and could contribute in improving the monitoring of Mediterranean hydrological pattern at a very low cost.

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Authors' address — A. DE SANTI, S. GANCITANO, G. NARDONE, P. JEREB & S. RAGONESE, IAMC-CNR, Mazara, via L. Vaccara, 61 - 91026 Mazara (TP) Italy; D. OTTONELLO, University of Palermo, via Archirafi, 38 - 90123 Palermo, (I); correspondingauthor: sergio.ragonese@iamc.cnr.it