SCIENTIFIC REPORT

Exchange Grant **3090**

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Host: **Prof. Mikis Tsimplis**

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1. PURPOSE OF THE VISIT.

The visit was undertaken for the purpose of assessing the influence of instrumentation, and its changes, on estimates of steric sea level variability. In particular the following tasks were planned:

1.1 To analyse separately XBT and CTD+bottle oceanographic data from MEDATLAS data base. To estimate correlations between both data sets for different years and depth levels and to finally develop correction algorithms for those years and depth levels when both type of data are available. To develop algorithms which are time and depth dependent.

1.2 To generate corrected and completed temperature and salinity time series for the second half of the twentieth century.

1.3 To complete available TS time series within the Western Mediterranean including corrected MEDATLAS data, recent data from IEO monitoring networks (www.ma.ieo.es/gcc) and TS profiles from ARGO profilers deployed in the Western Mediterranean.

1.4 To estimate decadal and long term variability in both contributions to the steric sea level: Thermosteric and halosteric.

1.5 The corrected and completed temperature and salinity time series and the derived thermosteric, halosteric and steric sea level time series will be analysed to the light of the evolution of ocean atmosphere exchanges and Mediterranean climate variability.

2. WORK CARRIED OUT DURING THE VISIT.

The following work was undertaken during the visit:

2.1 A detailed examination of the Temperature (T) and Salinity (S) records contained in the MEDATLAS/2002 database. I extracted and separated the measurements based to a) bottle data which go back to 1910, b) CTD data which started in the early seventies and c) bathythermograph data which measure only T and do not have a depth or pressure reference but infer depth from the fall rate of the XBT. These data were then analyzed separately.

2.2 Monthly means were derived for T and S from different datasets (bottle, CTD and XBT (only T)) in different regions of the Western Mediterranean (here after WMED).

2.3 Temperature and salinity biases were estimated between bottle and CTD data. These biases have been estimated by pressure levels and for different regions in the WMED.

2.4 Studied and trained in XBT temperature errors corrections in the global ocean.

2.5 Detection of bathythermograph temperature biases in relation to the CTD data.

2.7 The XBT-CTD temperature biases were analyzed taking into account pressure levels, seasonality, long term and different regions in the WMED to decide the best correction factor.

2.8 Development of a custom made correction process for Mediterranean XBT data.

2.9 XBT data were also corrected by applying XBT published correction factors (Levitus et al., 2008; Gouretski & Reseghetti, 2010).

2.10 The effects the instrumentation has on the steric sea level in different regions of the WMED was estimated.

3. OUTLINE OF THE MAIN RESULTS OBTAINED.

The data comparison, correction, estimation of trends and influence on steric sea level has been done for each of the regions in figure 1.

The basic assumption has been that CTD data are the most accurate data available in the oceanographic database, in T, S and pressure. Thus corrections were estimated by reference to these. This does not exclude the possibility of errors due to drift of CTD sensors or bad maintenance or calibration. Table 1 displays a general overview of the accuracy of the instruments used to measure T and S.

Table 1. Accuracy of the instruments measuring T and S data in historical database.

	Pressure(dbar)/depth (m)	Temperature (ºC)	Salinity
Bottle	± 15 m	± 0.02	0.03
XBT	2% of the depth	± 0.2	------
CTD	0.5 % of the depht	± 0.002	±0.005

Because CTD data start in 1970 we focus on the period 1970-2000. The end of the period relates to the last year available in the MEDATLAS database. Of course establishing correction factors for the XBTs permits, on the assumption that these were unaltered in earlier years, to correct XBTs for the whole period when XBTs are available thus improving the whole dataset.

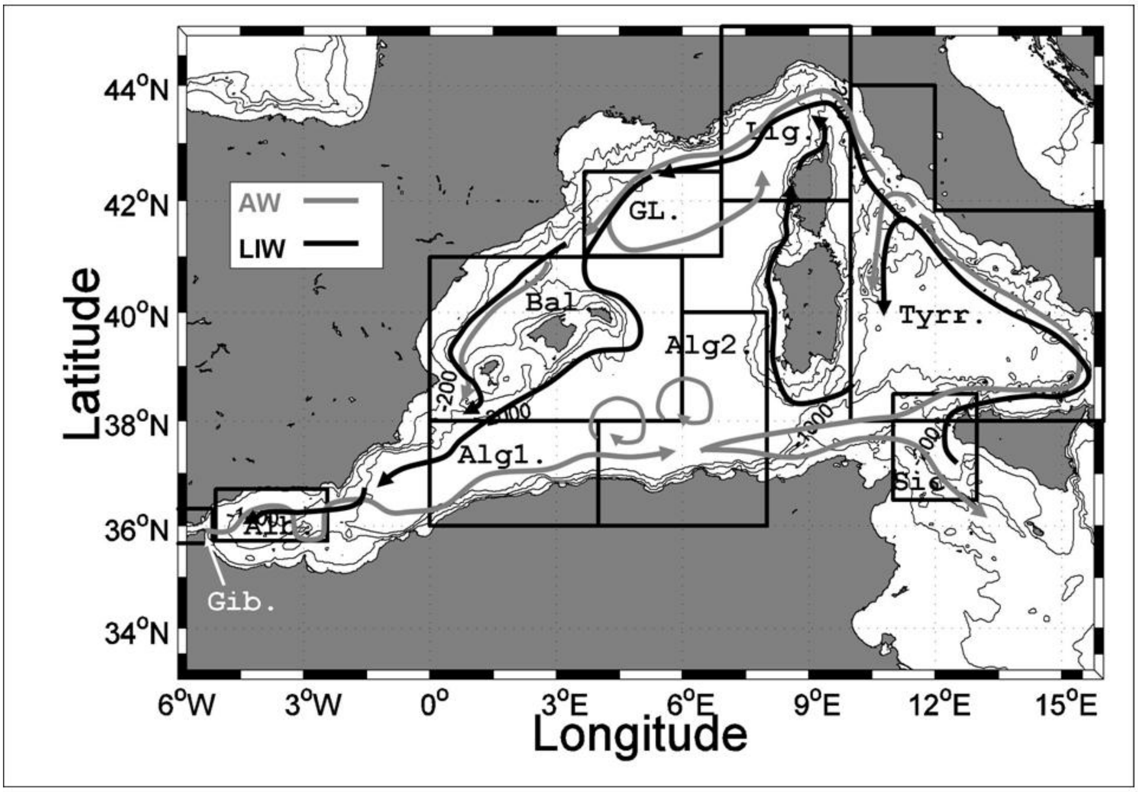

Figure 1. Different regions studied in the WMED.

<u>3.1 Biases between bottle and CTD data in the WMED</u>

For the world ocean XBT, corrections are based on merged CTD and bottle data, because temperature biases between bottle and CTD data have been claimed to be smaller than 0.05ºC (Gourestki & Reseghetti, 2010), witch is lower than the accuracy of XBT.

Nevertheless we started our analysis, by comparing bottle and CTD data in the areas of Fig. 1.

Biases between these two types of data may occur due to mistake in the pressure/depth assigned to bottle data, or because monthly values observed in different parts of the month or in different parts of a region are compared. As an example, figure 2 shows different temperature monthly profiles estimated with bottle (blue lines) and CTD (red lines) data in the section of the Gulf of Lions (GL). Monthly values for both instruments are only available for some periods of times. Significant differences occur but these are not systematic.

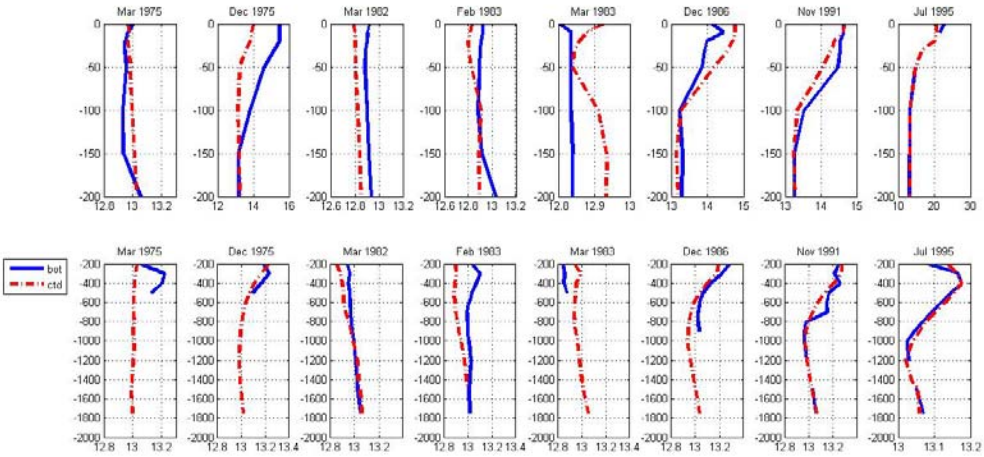

Figure 2. Monthly mean temperature profiles in the Gulf of Lions. Blue lines are bottle temperature and red lines are CTD temperature.

The biases between bottle and CTD temperature become smaller the deeper we go in the water column. Some reference data could be up to 1ºC in the first 100 dbar, 0.4ºC in the intermediate water, and 0.05ºC in the deeper water. This last value is inside the values previously estimated for the bottle-CTD temperature biases, but it should be in mind that XBT only reaches about 700 dbar. The mean values of these biases for the period 1970-2000 in each studied area of the WMED and pressure levels are summarized in table 2.

Another significant finding in the present work is that the available number of data to compare the data measured by the different instruments, referring to bottle or CTD, is very low. Figure 3 is an example of the number of data that exist by month, the upper figure shows the number of bottle data to estimate each monthly mean and the lower figure the same for CTD data. There are few months in which comparisons can be made and in some of them the same number of bottle and CTD profiles are available. This, in turn indicates that they were taken at the same point and time probably corresponding to the same profile. Thus, the reduction of bias with depth is not surprising. However the differences in monthly means in the upper water correspond to bottle and CTD data collected at different times and places within each region. Thus it is clear that although the reported differences of 0.05ºC between bottle and CTD reflect well the operational capabilities of the different methods there is an error of an order of magnitude larger which arises from the sampling of data.

Table 2. Temperature bias means (ºC) between bottle and CTD data for the period 1970-2000 in the different sections of the WMED.

Pressure (dbar)	Gib	Alb	Alg 1	Alg 2	Bal	GL	Lig	Tyrr	Sic
0	0.418	0.327	0.618	0.685	1.219	0.579	1.027	1.145	0.508
10	0.332	0.270	0.350	0.744	1.026	0.348	0.910	1.074	0.416
20	0.304	0.355	0.539	0.661	1.109	0.359	0.991	0.991	0.594
30	0.754	0.423	0.502	0.597	1.144	0.384	1.235	0.885	0.589
50	0.713	0.469	0.354	0.465	0.729	0.310	1.104	0.637	0.599
100	0.270	0.505	0.346	0.421	0.308	0.189	0.415	0.321	0.256
150	0.247	0.385	0.169	0.327	0.178	0.063	0.191	0.266	0.201
200	0.149	0.323	0.140	0.144	0.124	0.061	0.197	0.248	0.125
300	0.050	0.205	0.056	0.128	0.095	0.087	0.213	0.158	0.055
400	0.024	0.121	0.058	0.146	0.095	0.073	0.222	0.133	0.051
500	0.030	0.050	0.060	0.138	0.057	0.056	0.202	0.108	0.079
600	0.033	0.039	0.056	0.013	0.035	0.050	0.059	0.132	0.080
700	0.065	0.012	0.050	0.050	0.035	0.056	0.059	0.121	0.083
800	0.333	0.006	0.041	0.049	0.033	0.038	0.101	0.107	0.089
900		0.007	0.004	0.023	0.020	0.037	0.034	0.194	0.131
1000		0.005	0.005	0.018	0.019	0.023	0.032	0.230	0.121
1200		0.009	0.008	0.015	0.022	0.017	0.027	0.270	0.122
1400			0.016	0.077	0.027	0.018	0.041	0.199	
1500			0.015	0.077	0.022	0.013	0.037	0.145	
1750			0.007	0.088	0.030	0.014	0.029	0.035	
2000			0.014	0.103	0.028	0.022	0.032	0.008	
2250				0.173	0.037	0.029	0.092	0.020	
2500				0.195	0.000	0.030	0.043	0.005	

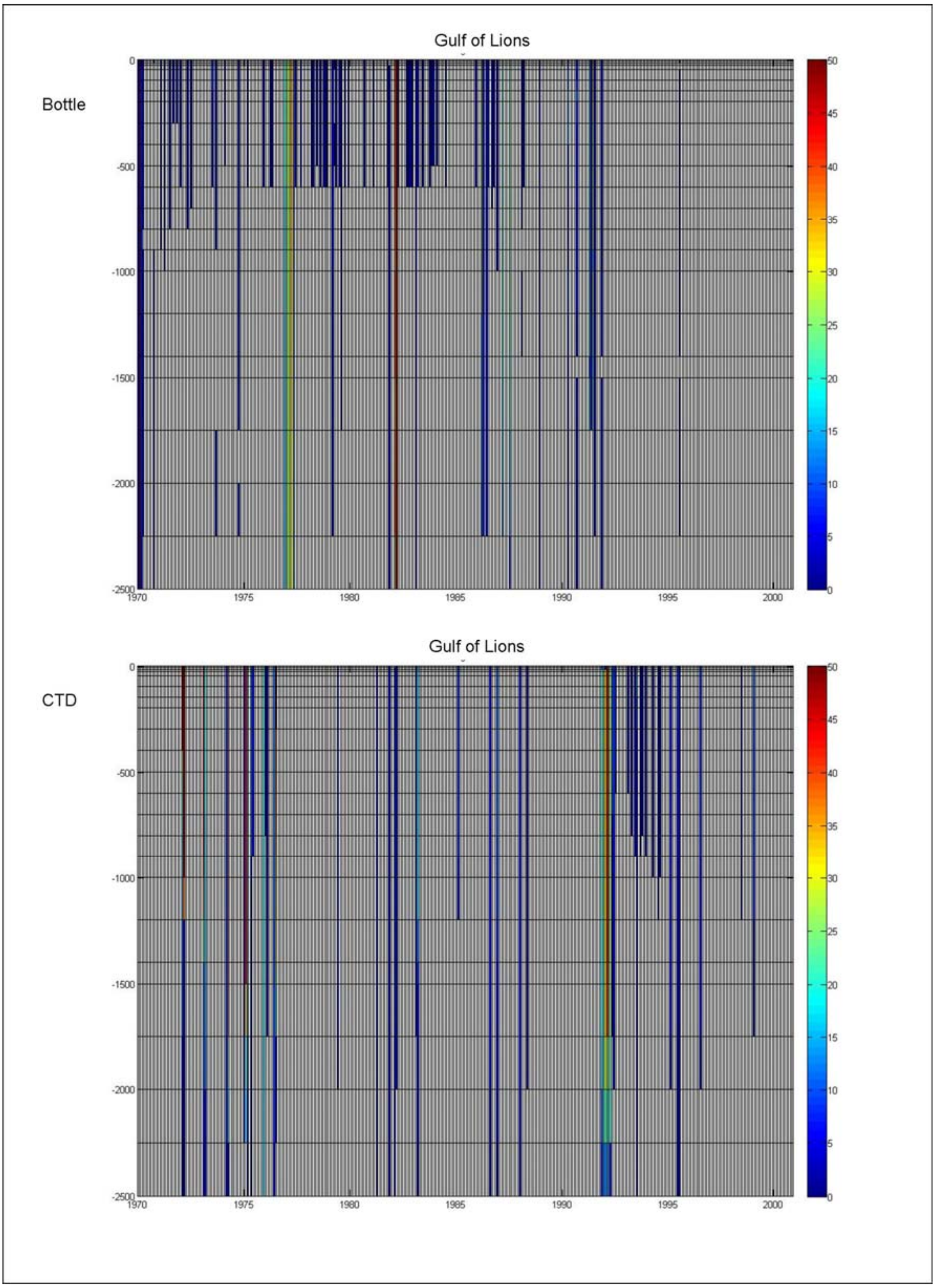

Figure 3. Number of bottle data (upper figure) and CTD data (lower figure), used to estimate each monthly mean profile, in the Gulf of Lions.

We have also studied the differences between salinity monthly means calculated with bottle and CTD data. Table 3 summarizes the mean salinity biases for the different areas in the WMED. In general these values are up to 0.2 psu in the first 100 dbar, 0.1psu in the intermediate water and 0.05 psu in the deep water, corresponding to simultaneous measurements.

The detection of so large differences between temperature and salinity data coming from bottle and CTD is surprising and new information never reported before.

Table 3. Salinity bias means (psu) between bottle and CTD data for the period 1970-2000 in the different sections of the WMED.

Pressure (dbar)	Gib	Alb	Alg 1	Alg 2	Bal	GL	Lig	Tyrr	Sic
0	0.016	0.131	0.071	0.110	0.318	0.179	0.313	0.331	0.261
10	0.084	0.286	0.076	0.188	0.222	0.146	0.167	0.218	0.213
20	0.077	0.201	0.050	0.070	0.268	0.113	0.126	0.138	0.159
30	0.081	0.193	0.076	0.095	0.284	0.114	0.119	0.155	0.132
50	0.182	0.188	0.094	0.109	0.216	0.121	0.119	0.178	0.226
100	0.105	0.274	0.157	0.134	0.109	0.046	0.115	0.126	0.160
150	0.230	0.129	0.070	0.012	0.055	0.035	0.091	0.098	0.102
200	0.154	0.104	0.038	0.018	0.068	0.022	0.078	0.101	0.075
300	0.011	0.041	0.043	0.018	0.046	0.022	0.100	0.054	0.053
400	0.016	0.094	0.048	0.005	0.017	0.025	0.113	0.042	0.035
500	0.003	0.009	0.077	0.006	0.014	0.028	0.092	0.030	0.020
600	0.004	0.010	0.009	0.003	0.009	0.060	0.033	0.041	0.018
700	0.003	0.013	0.006	0.001	0.008	0.029	0.027	0.049	0.016
800	0.002	0.033	0.005	0.004	0.007	0.030	0.042	0.050	0.021
900		0.015	0.002	0.005	0.013	0.026	0.043	0.094	0.031
1000		0.012	0.004	0.002	0.010	0.016	0.049	0.099	0.026
1200		0.015	0.002	0.001	0.008	0.012	0.021	0.112	0.028
1400			0.003	0.002	0.011	0.014	0.064	0.062	
1500			0.003	0.003	0.023	0.012	0.022	0.053	
1750			0.001	0.004	0.008	0.013	0.085	0.004	
2000			0.000	0.004	0.005	0.013	0.021	0.002	
2250				0.003	0.005	0.014	0.037	0.001	
2500				0.003	0.000	0.013	0.021	0.002	

3.2 Biases between bathythermograph and CTD data

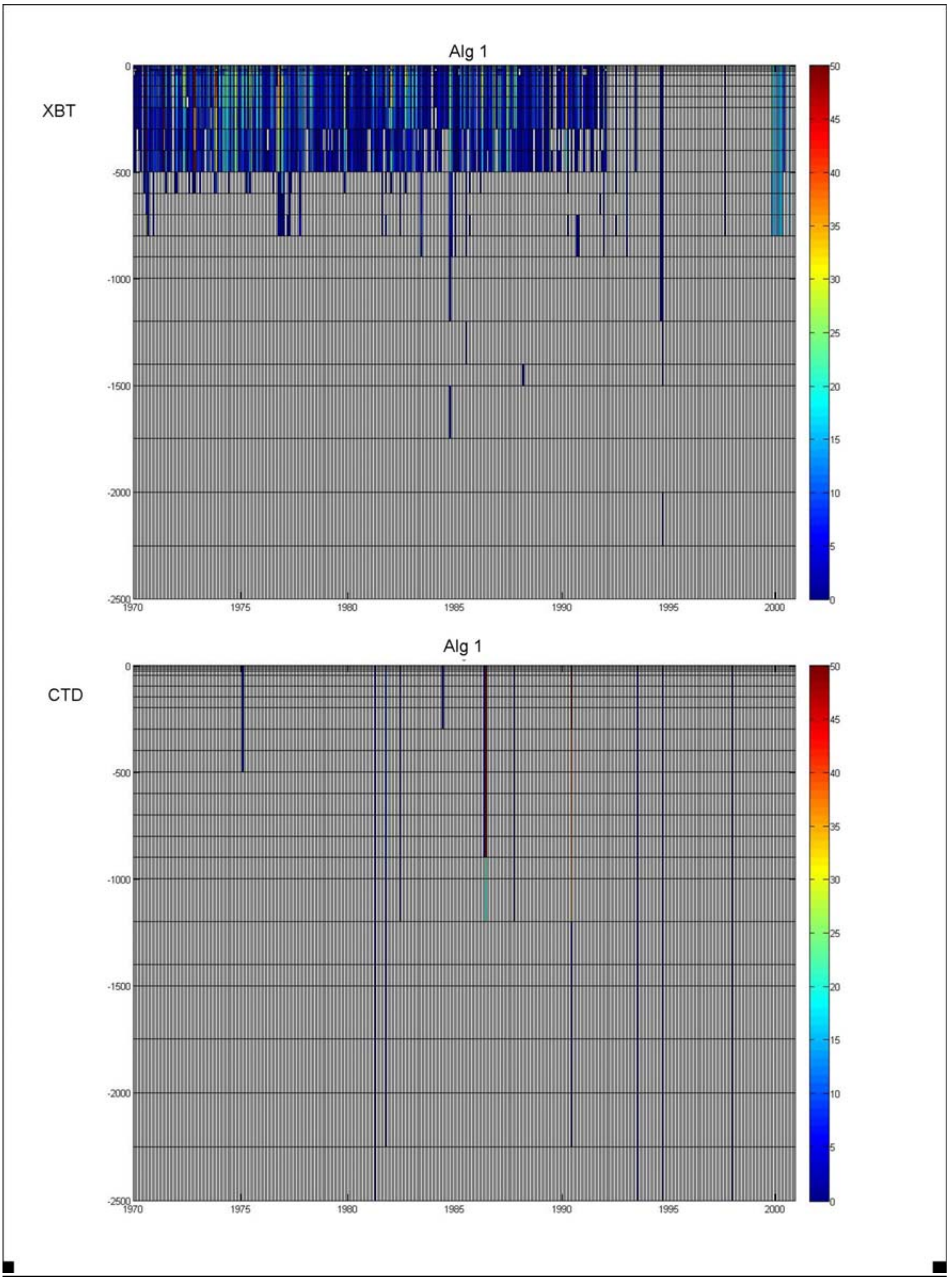

Figure 4. Number of available XBT (upper figure) and CTD (lower figure) data for each pressure level and month in the Alg1 box of figure 1.

We have considered the basic assumption that CTD data are the most accurate data in the oceanographic database. And we have accepted that the XBT data present temperature biases. So, the problem that we have to face up to study long term temperature variability is that the most abundant data are from XBT origin and that the CTD data are still very scarce. See figure 4 as an example of the number of XBT and CTD data available in each pressure level and month in Alg1 box of the figure 1, this is un example, not in all the areas there are so many few data. Therefore all the results that we can obtain regarding long term temperature variability in the WMED present a broad range of uncertainties.

Figure 5 shows the time evolution of T biases between XBT and CTD data on different pressure levels in three of the studied regions. Inter-decadal variability on XBT measurements has been reported due to changes in the shape of XBTs which were not taken into account in the equation used to infer the depth of the measurement. We will examine this later by looking for time variability in the biases. In the present work we first estimated XBT correction factors in the same way that other researches estimated these factors for the global ocean (eg: Levitus et al., 2008; Gourestki & Reseghetti, 2010). However we thought it is reasonable to search for seasonal variation in the biases because the XBT fall rate should be influenced by the stratification of the water column, and this is seasonally dependent.

Figure 6 displays the seasonal cycle of the temperature biases between XBT and CTD data in the Ligurian Sea. Such seasonal biases have not, to our knowledge, been detected before. Physically their presence can be speculated to be due to the fall rate of the XBT depending on oceanic conditions that leads to better or worse agreement between XBTs and CTDs. For example, in figure 6 we can see that for the first 150 meters of the water column, the largest bias is registered in June, when the column water is stratified, so the XBT should sink more slowly than when the water column was homogeneous, and as the depth of the XBT measured is inferred from the lapsed time, the T biases between XBT and CTD temperature is larger.

Due to the seasonal cycle and the scarcity of data in the Western Mediterranean, the internationally suggested correction did not significantly reduce the differences between XBT and CTD data in the WMED.

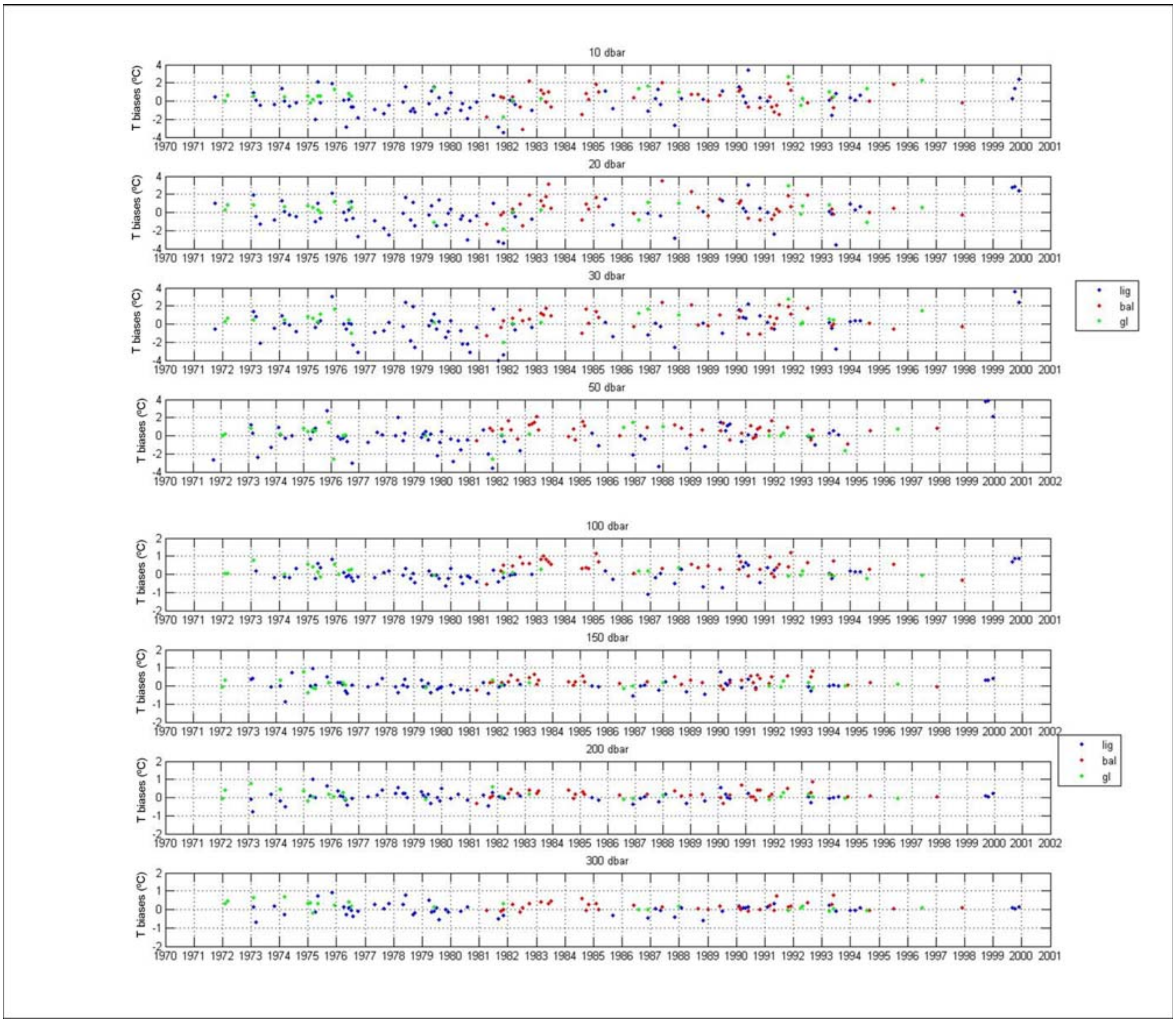

Figure 5. Evolution of temperature biases (ºC) between XBT and CTD data in three different regions of the WMED (in blue the Ligurian Sea, in red the Balearic Sea and in green the Gulf of Lions) and for different pressure levels.

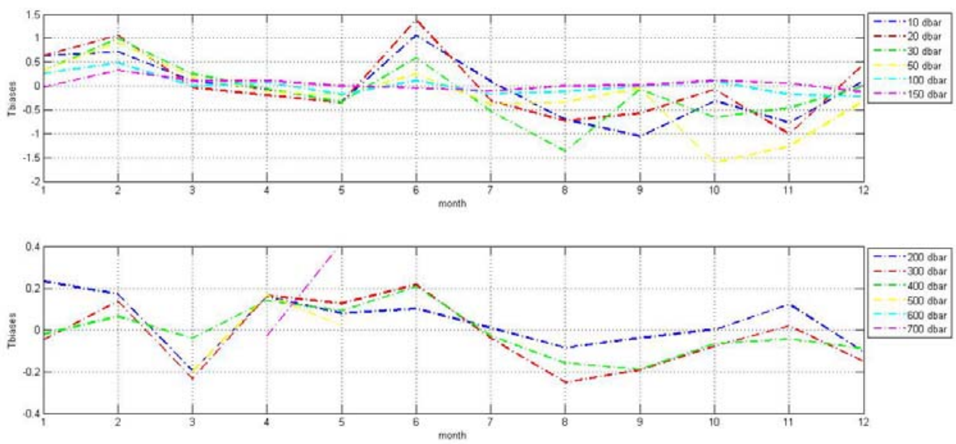

Figure 6. Seasonal cycle of temperature biases between XBT and CTD data in the Ligurian Sea.

Figure 7 displays some trend profiles of the errors between XBT and CTD temperature in four different sections of the WMED (Alboran Sea, Balearic Sea, Gulf of Lions and Ligurian Sea). The trends are represented in blue lines and their respective 90% confidence intervals in red lines. Some trends are significant and there seems to be depth dependent pattern for trends.

Therefore, after some experimentation, we have decided that the best way to correct the XBT data in the WMED is to apply a pressure and seasonally dependant correction including a linear trend.

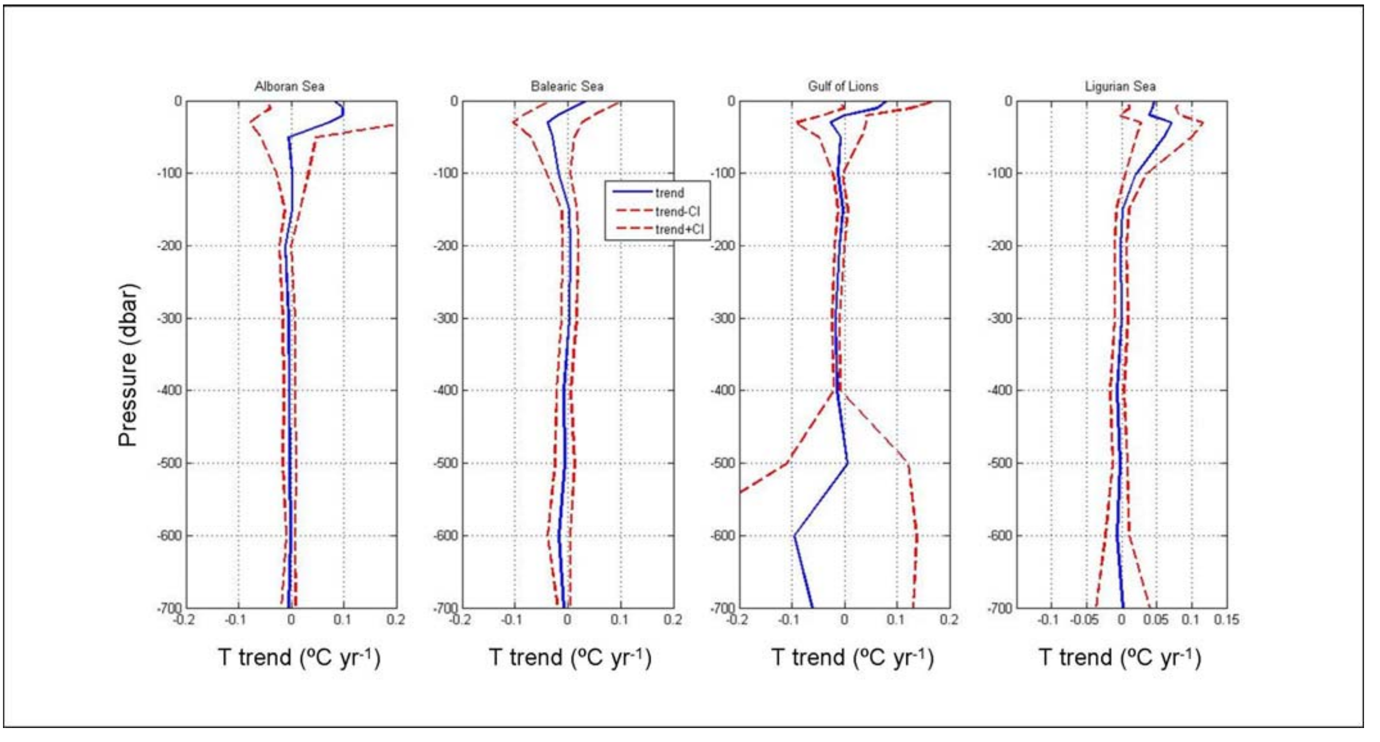

Figure 7. Temperature bias (BT-CTD) trends in some different regions of the WMED. Blue lines represent the T bias trends, and the red lines are the respective 90% confidence intervals.

3.3 <u>Bathytermograph correction factors in the Western Mediterranean.</u>

The differences between XBT and CTD temperature could be up to 3ºC in the surface layer and 1ºC in the intermediate water. Therefore, we have demonstrated that large T biases exists between both instrument in the WMED, and moreover, that the quantity of T measured by XBT is larger than the measured by CTD. Therefore, on the assumption that CTD data represent the sparsely sampled "truth" we proceed in correcting the XBT data.

Various XBT correction factors for the world ocean have been published (Levitus et al., 2009; Gourestki & Reseghetti, 2010; Wijffels et al.,2008; Ishii & Kimoto, 2009). The first two authors obtained the correction factors estimating XBT and CTD + bottle temperature biases, doing it time and depth dependent. Wijffels et al. (2008) and Ishii & Kimoto (2009) obtained the correction factors correcting the pressure level registered by the XBT as they considered that the error on the equation fall rate is more important than the instrumental one. But none has considered the seasonality. We have applied the first two corrections factors over the WMED data, but the biases between corrected XBT and CTD data still remains, so, we decided to estimate regionally correction factors for the WMED.

Thus we have developed a different correction factor estimation. Our new methodology has been:

1. T biases between XBT and CTD monthly means on pressure levels from 1970 to 2000 have been calculated.
2. Trends in the estimated biased have been calculated.
3. The bias time series on each pressure level were then detrended
4. Monthly averaging has been applied over the detrended bias time series obtaining our XBT monthly correction factors for each of our studied regions in the WMED. That is, we obtain twelve (one for each month) correction factors profiles for each region studied in the WMED.

Table 4 and 5 display the correction factors profiles for the Ligurian Sea and Balearic Sea respectively. It will be seen that the correction factors are not the same in both areas, putting in evidence that the generation of XBT correction factors regionally is necessary. Showing it clearly, figure 7 displays the correction factors in 5 different pressure levels for the Ligurian Sea (in blue), and for the Balearic Sea (in red).

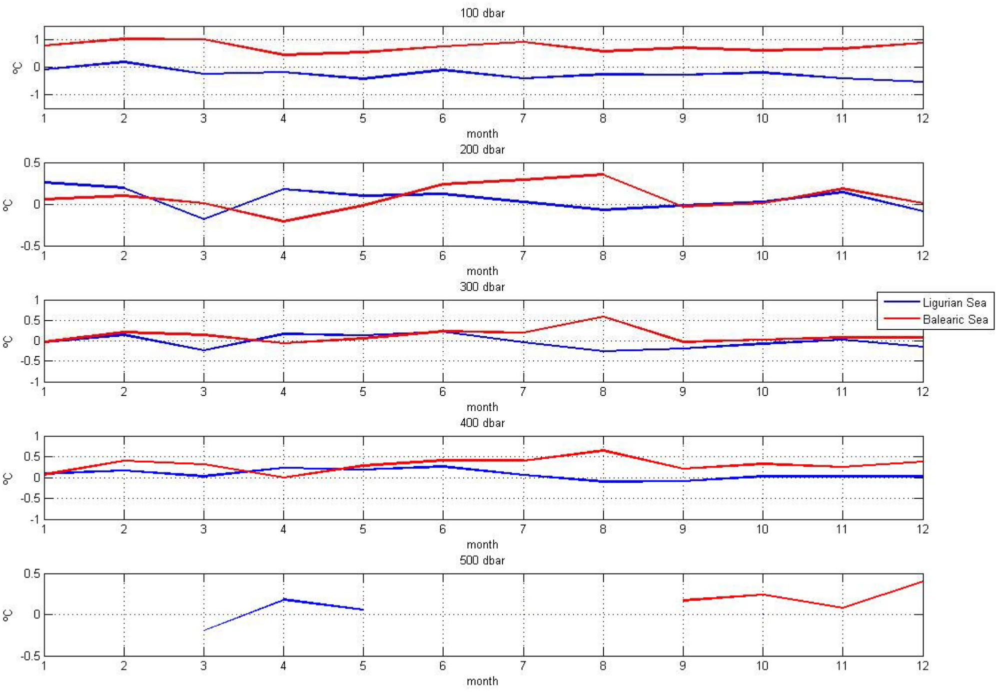

Figure 7. XBT correction factors in some pressure levels for the Ligurian Sea (in blue) and the Balearic Sea (en red).

Table 4. Correction factors for XBT temperature in the Ligurian Sea

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10	-0.11	0.14	-0.43	-0.65	-0.84	0.60	-0.50	-1.03	-1.64	-0.79	-1.26	-0.60
20	-0.03	0.69	-0.46	-0.69	-0.82	0.97	-0.85	-1.02	-1.09	-0.51	-1.45	-0.17
30	-0.88	0.14	-0.59	-0.95	-1.20	-0.15	-1.50	-1.89	-1.03	-1.44	-1.26	-1.15
50	-0.69	0.19	-0.54	-0.87	-0.94	-0.37	-1.20	-0.78	-0.86	-2.28	-1.95	-1.27
100	-0.08	0.18	-0.25	-0.18	-0.42	-0.10	-0.41	-0.27	-0.28	-0.20	-0.41	-0.55
150	-0.05	0.31	0.10	0.09	-0.02	-0.06	-0.12	-0.01	0.00	0.09	0.04	-0.15
200	0.26	0.19	-0.18	0.18	0.10	0.12	0.03	-0.07	-0.02	0.02	0.14	-0.09
300	-0.04	0.15	-0.23	0.17	0.13	0.22	-0.04	-0.25	-0.18	-0.07	0.02	-0.14
400	0.09	0.16	0.03	0.22	0.18	0.26	0.06	-0.10	-0.09	0.03	0.03	0.03
500	-0.05		-0.19	0.18	0.06		0.18			0.00		
600	0.07				0.24		0.27			0.07		
700	-0.10			-0.06	0.38					0.12		

Table 5. Correction factors for XBT temperature in the Balearic Sea

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10	-0.18	1.33	0.75	-0.63	-0.50	0.07	-0.92	-1.64	0.19	1.05	0.31	0.26
20	0.00	1.65	1.18	-0.13	0.99	1.55	0.66	-0.57	0.69	1.13	0.67	0.70
30	0.59	1.73	1.59	0.33	1.23	1.83	1.65	-0.47	0.81	1.08	0.98	1.35
50	0.63	1.56	1.57	0.59	0.86	1.33	1.28	0.33	0.56	0.79	0.72	1.96
100	0.78	1.02	1.01	0.44	0.54	0.75	0.91	0.57	0.70	0.61	0.66	0.87
150	0.29	0.23	0.21	-0.06	0.28	0.29	0.37	0.20	0.03	0.15	0.18	0.17
200	0.05	0.10	0.01	-0.21	-0.02	0.24	0.29	0.35	-0.03	0.01	0.19	0.01
300	-0.03	0.21	0.15	-0.06	0.06	0.23	0.20	0.59	-0.02	0.03	0.08	0.08
400	0.07	0.40	0.31	-0.01	0.28	0.41	0.40	0.64	0.20	0.33	0.25	0.38
500					0.19		0.29		0.17	0.24	0.08	0.40
600							0.33		0.43	0.35	0.33	0.34
700							0.15		0.21	0.19	0.18	0.33
800							0.69		0.78	0.60	0.59	0.83
900									0.74	0.52		

3.4 Temperature trends with the 3 datasets: CTD, XBT and corrected XBT.

The next step was to estimate temperature trends with the three different datasets. The period of time analyzed was 1970-2000. Figure 8 displays temperature trend profiles for three different areas of the WMED and with the three datasets. The results obtained with CTD data are represented in red, with XBT data in blue and with corrected XBT in green. Corrected XBT data are the XBT data corrected by our correction factors. The trends are not consistent in fact some of them are contradictory. For example, in Alboran Sea, in the intermediate waters the T trend estimated with XBT data (blue line) is negative and significant; however, the trend obtained with the CTD data (in red) is positive, although it is not statistically significant. In the Balearic sea, in the intermediate water trends obtained with XBT and with CTD data are both statistically significant but with opposite sign. The same happens in the upper water in the Ligurian Sea, where the trend is statistically significant, being positive if it is estimated with XBT data and negative if CTD data are used. Thus the T trends in the WMED differ

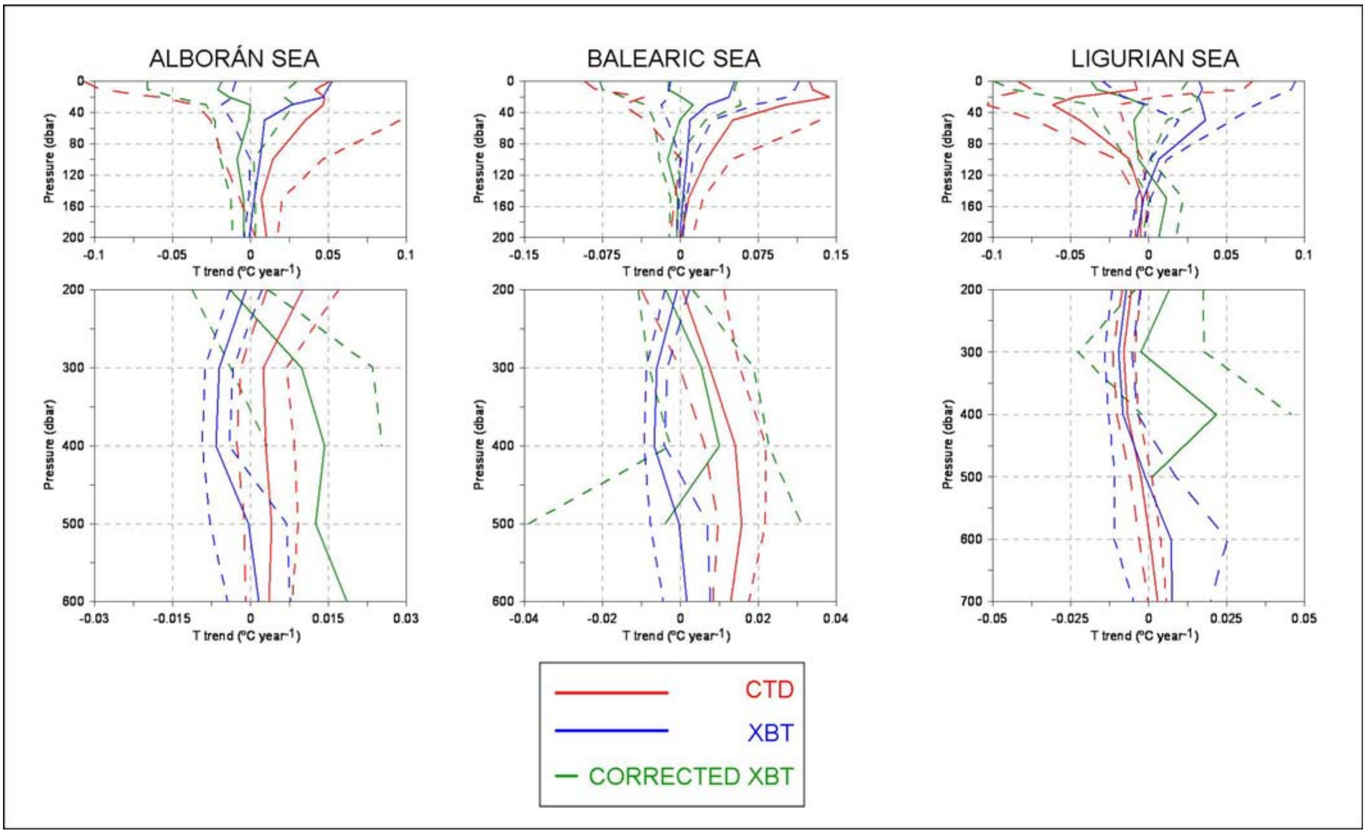

Figure 8. Temperature trends for Alboran Sea, Balearic Sea and Ligurian Sea estimated with XBT data (in blue), with CTD data (in red) and with XBT data corrected with our correction factors (in green). Continuous line is the trend values and the discontinuous lines are the respective 95% confidence intervals.

depending on the datasets used to estimate the trends. This proves the need to corrected XBT data in the WMED.

In the figure 8 we can see T trend profiles calculated with corrected XBT data (in green). The trends are now consistent. For example, in the Alboran Sea, in the intermediate water, trends obtained with CTD and corrected XBT data are both positive, although any of them are statistically significant. In the intermediate water of the Balearic Sea, where opposite trends were obtained with CTD and XBT data, the corrected XBT data provide a positive trend as the trend obtained with CTD data. And finally, in the upper Ligurian Sea water the trends obtained with CTD and with corrected XBT data show a T decrease during the studied period, although the corrected XBT trend is not statistically significant.

With these observations we can say that the correction factors applied remove the difference between results obtained with CTD and with XBT data. Therefore we are offering a good tool to unify the estimates of long term temperature variability in the

Western Mediterranean. But at the same time it must be realized that in essence we are shifting the less accurate but more dense XBT measurements of the upper layers to match the more accurate but sparse CTD measurements. Thus unavoidably the question of whether in fact we have sufficient information to determine trends everywhere in the Mediterranean is posed.

3.5 Steric sea level.

The steric sea level (SSL) has thermostheric and halosteric component. The XBT does not measure salinity, so, we have evaluated SSL using the CTD salinity. Therefore, the obtained differences are representative of the thermostheric sea level only. All the SSL results showed in the present report are for the first 200 meters of the water column. We have selected this depth as reference after checking how deep the available profiles are, so, this depth is the best commitment between how deep the temperature change could affect the thermosteric sea level and the available number of monthly data to compare the results obtained by the different datasets.

a) Steric sea level obtained by the different datasets.

We have investigated how sea level can be affected by the origin of the temperature measures.

Figure 9 shows the SSL (in cm) time series obtained by the different datasets, in blue the CTD, in red the XBT and in green the corrected XBT in 4 different regions of the WMED.

Table 6 shows SSL trends estimated with data represented in figure 9. We can see that the three datasets trends have the same sign, although only the CTD trends are statistically significant. In general, the SSL trends obtained with both corrected and uncorrected XBT data are smaller than the obtained trend by CTD.

b) Comparison of the steric sea level obtained by the different datasets.

Figure 10 shows differences between SSL estimated with XBT and with CTD data (in blue), and between the calculated with corrected XBT and CTD data (in red), in four different regions of the WMED (Alboran Sea, Balearic Sea, Gulf of Lions and Ligurian Sea). We can not give any general conclusion about the obtained results because there are not any agreements between them. For example, in the Balearic Sea the mean biases between XBT and CTD SSL is negative and between corrected XBT and CTD SSL is positive and in the Ligurian Sea is exactly the contrary.

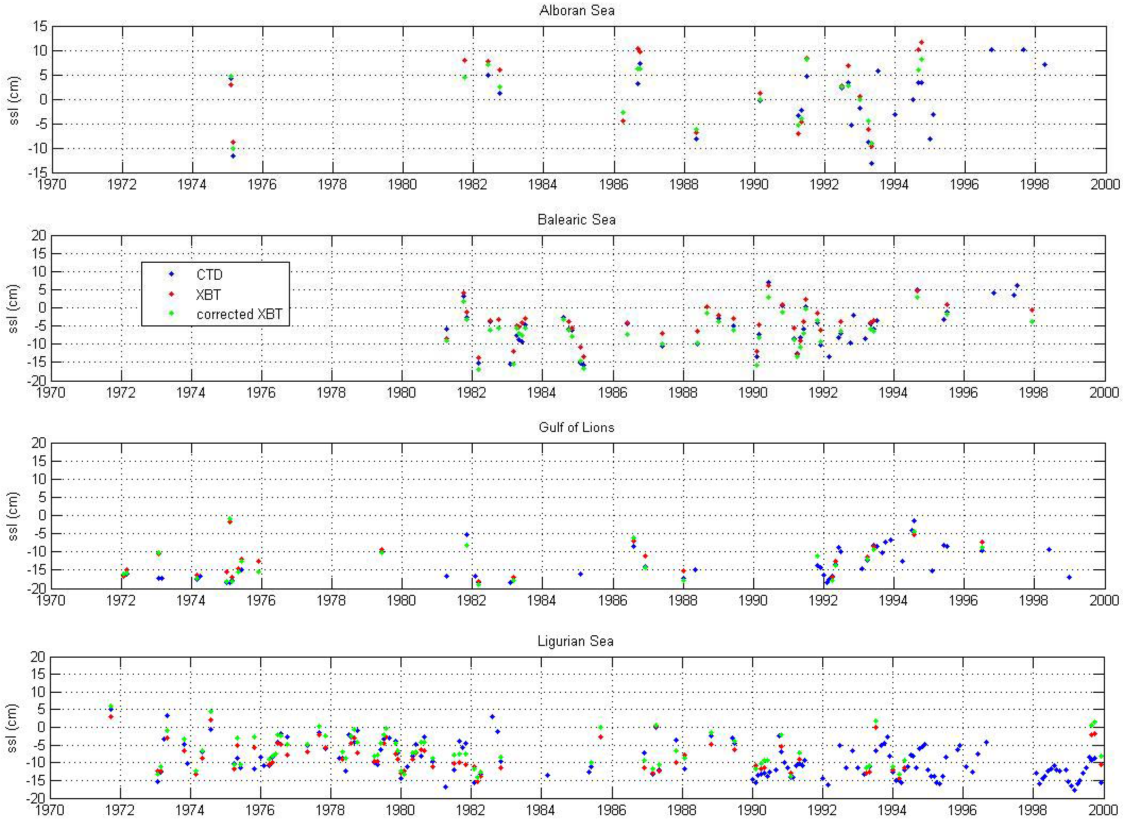

Figure 9. SSl time series obtained by the 3 different datasets in the Alboran Sea, Balearic Sea, Gulf of Lions and Ligurian Sea. In blue CTD ssl, in red XBT ssl and in green corrected XBT ssl.

Table 6. SSL trend (cm yr^{-1}) estimated with all the available CTD, XBT and corrected XBT data in the Alboran Sea, Balearic Sea, Gulf of Lions and Ligurian Sea. In the table is indicated the period of time corresponding to the estimated trend.

	Alboran Sea 1970-2000	Balearic Sea 1980-2000	Gulf of Lions 1970-2000	Ligurian Sea 1970-2000
CTD	0.1267±0.3877	**0.4821±0.3088**	**0.2762±0.1269**	**-0.2395±0.0841**
XBT	0.0348±0.5679	0.3125±0.3365	0.1549±0.2072	-0.0837±0.1317
Corrected XBT	0.0235±0.4504	0.2814±0.3513	0.1570±0.2373	-0.0876±0.1514

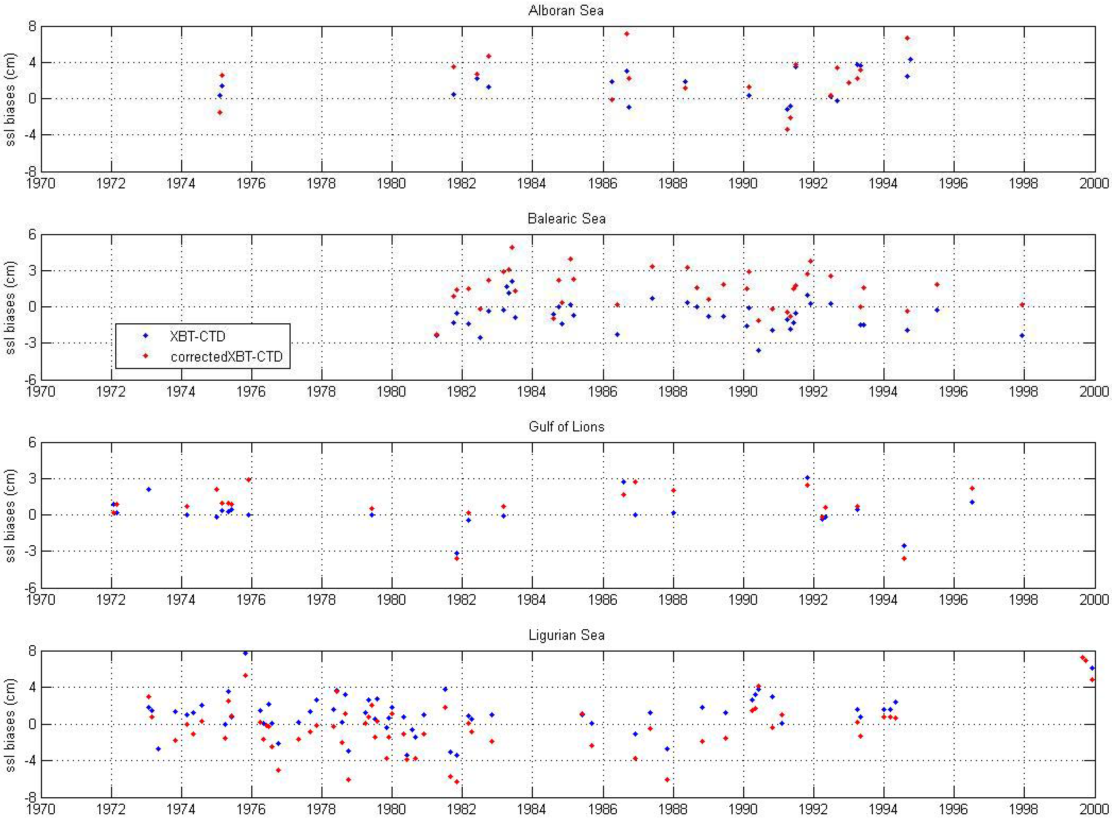

Figure 10. SSL differences (cm) between SSL estimated with XBT and CTD temperature data (in blue) and with corrected XBT and CTD data (in red) in four different regions of the WMED (Alboran Sea, Balearic Sea, Gulf of Lions and Ligurian Sea).

Table 7. Differences between calculated SSL with XBT and CTD data and between SSL calculated with corrected XBT and CTD data. The period of time analyzed are also showed in the table.

Area in the WMED Analyzed period		Alboran Sea 1970-2000	Balearic Sea 1980-2000	Gulf of Lions 1970-2000	Ligurian Sea 1970-2000
XBT-CTD	Mean bias	2.1700	1.5674	0.8704	-0.1863
	Trend(cm yr^{-1})	0.021±0.224	-0.019±0.127	-0.026±0.098	**0.121±0.103**
CorXBT-CTD	Mean bias	1.2244	-0.9800	-0.1033	1.6475
	Trend(cm yr^{-1})	0.035±0.150	-0.033±0.098	-0.003±0.074	**0.130±0.096**

The SSL mean differences are between 1 or 2 cm with – or + sign, depending on the studied regions, so we can not give any general conclusion about the influence of the XBT correction in the estimation of steric sea level.

We have also calculated the trend of the SSL biases (showed in table 7) and only in the Ligurian Sea the result is statistically significant by both comparison, XBT with CTD data and corrected XBT with CTD data which mean that both no corrected and corrected XBT biases related with the CTD result are larger at the end of the studied period.

Table 8 summarizes the SSL trend estimated by the 3 datasets, using monthly data only when both, XBT and CTD data exist. Only in the Gulf of Lions, the trend is positive

Table 8. Steric sea level (upper 200 m of the column of water) trends calculated with CTD, XBT and corrected XBT data.

Area	dataset	Time period analyzed	Trend (cm yr^{-1})
Alboran Sea	CTD	1975-1995	-0.0889±0.4876
	XBT	1975-1995	-0.0675±0.5741
	Corrected XBT	1975-1995	-0.0536±0.4578
Balearic Sea	CTD	1981-1998	0.3508±0.4063
	XBT	1981-1998	0.3315±0.3633
	Corrected XBT	1981-1998	0.3175±0.3773
Gulf of Lions	CTD	1972-1997	**0.2741±0.2338**
	XBT	1972-1997	**0.2482±0.1903**
	Corrected XBT	1972-1997	**0.2706±0.2167**
Liguria Sea	CTD	1973-2000	**-0.1769±0.1517**
	XBT	1973-2000	-0.0557±0.1271
	Corrected XBT	1973-2000	-0.0466±0.1496

and significant with the 3 datasets, with values very similar being the corrected XBT result closer to the CTD result. In the other areas showed in table 8 the results are not statistically significant, but at least, all of them present the same sign.

In general, for each of our studied sections, the estimated SSL trend using the three different temperature dataset give the same sign, that is, positive or negative trend. But sometime the estimated trend is larger when it is estimated with CTD data, other when XBT data are used and other when the corrected XBT data are considered, so, we can not detect any robust influence of the correction of XBT data on the steric sea level in the WMED.

4. FUTURE COLLABORATION WITH HOST INSTITUTION

Not all planned activities were fulfilled during the visit. The reason for this was that new findings in the form of discrepancies between the various types of instrumentation which are above the global averages were found and needed to be addressed. However because of the significance of the work undertaken continuing collaboration with the host institution is envisaged to resolve the problem adequately for Mediterranean Climate Variability estimates. Therefore, the work carried out during these 7 weeks should continue as part of the PhD work.

5. PROJECTED PUBLICATIONS/ARTICLES RESULTING FROM THE GRANT.

The results obtained during these 7 weeks will be presented in:

a) European Geosciences Union General Assembly 2011 in Vienna (Austria).
b) MedCLIVAR Final Conference in Lecce (Italy).

We will also prepare at least a paper to submit in a high impact index journal.

6. OTHER COMENTS

During this visit we have obtained important results which have the potential of reassessing the estimates for heat content and temperature change in the Mediterranean Sea. The large biases found indicate that in addition to instrumentation discrepancies which are important for XBT data estimates obtained by statistically interpolating profiles are likely to be biased on the basis of where and how the measurements have been obtained. Taking into account that at least originally oceanographic expeditions focused on particular features it is not surprising that these measurements will be more represented in the collection of data. Thus the position has become very close to claiming that the trends in temperature and heat content available in the literature significantly underestimate the errors associated with instrumentation and sampling. We hope to be able to provide soon improved error bars.