THE EFFECT OF DATA PROCESSING METHODS ON THE DETECTION OF WARMING AND SALTING TRENDS IN THE WESTERN MEDITERRANEAN.

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INTRODUCTION

Many studies have reported positive trends for the salinity and temperature in the upper, intermediate and deep layers within the Western Mediterranean (WMED; Rholing and Bryden, 1992; Bethoux and Gentili, 1996); Krahmann and Schoot, 1998; Tsimplis and Baker, 2000; Rixen et al.,2005). The comparison of this works reveals some discrepancies between results obtained due to the different periods of time analysed, the exact situation of the areas studied, the data type used or the methodology applied. These results make it difficult to assess which have been the mean trends of these variables along the second half of the 20th century.

Gouretski and Koltermann (2007) suggest that there is a bias in the warming trends for the World Ocean caused by errors in XBT data. In this work, we analyse the impact of Bathytermograph data (both mechanical and expendable) on the temperature trends estimated for the WMED.

In order to complete the study carried out by Vargas-Yañez et al, 2008; we have extended the geographical areas considered in that previous work and we attempt provide reliable values of salinity and temperature trends.

DATA AND METHOD

We have collected all temperature and salinity profiles from 1943 to 2000 from MEDATLAS/2002 data base. We have used bathythermographs (BT), Conductivity-Temperature-Depth (CTD) and hydraphic bottles data at 23 pressure levels (0, 5, 10, 20, 30, 50, 75, 100, 125, 150, 200, 250, 300, 400, 500, 600, 800, 1000, 1200, 1500, 2000, 2500 dbar). We have divided the WMED into nine sectors (see fig. 1) to detect possible differences throughout the WMED. All the temperature data were converted into potential temperature.

In order to remove the seasonal cycle, we have used two different data analysis methods: First we subtracted a monthly climatology using the period 1960-1990 as a reference. Second we obtained annual means.

Heat variability along the water column was calculated using the following equation:

$$Q = \sum_{k=z_1}^{z_2} c_p(k)\,\rho(k)\,\Delta T(k)\,S(k)\,\Delta Z$$

where C_p is the specific heat, ρ is the density, ΔT is the temperature difference from the reference period and ΔZ is the depths increment between vertical levels.

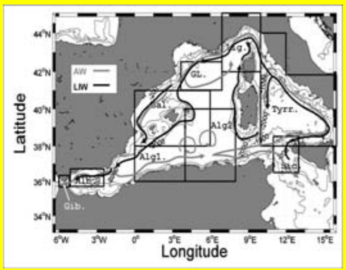

Figure 1. Selected area in the WMED.

RESULTS

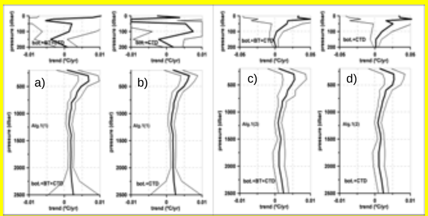

Figure 2. Temperature trends profiles in the west of Algerian Basin (Alg 1 in figure 1). Using monthly anomalies time series with BT data, b) using monthly anomalies without BT data, c) using annual means with BT data and d) using annual means without BT data.

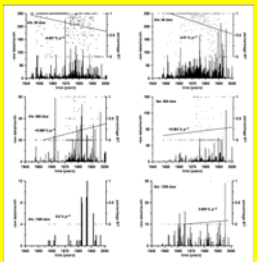

Figure 3. Evolution with time of percentage use of BT data. Left: Alboran Sea (Alb in fig. 1). Right: Balearic Sea (Bal in fig. 1).

Table1. Trends for the WMED for different sectors (see fig.1) and vertical layers.Surface is the area for each sector selected. Period is the time interval for which trends were calculated. Statistically significant results are typed in white

	Period	Linear trend (Wm^{-2})	95% C.I. (Wm^{-2})	Linear trend yr^{-1}	95% C.I. yr^{-1}
STRAIT OF GIBRALTAR (Gib in fig 1)					
0-200 m	1947-1999	0.003	0.18	0.01	0.007
200-600 m	1948-1999	0.002	0.07	0.01	0.008
600-800 m	1948-1999	0.02	0.015	0.003	0.002
Surface: 2.84×10^{9} m^2					
ALBORAN SEA (Alb in fig 1)					
0-200 m	1947-1998	-0.005	0.19	-0.005	0.008
200-600 m	1947-1998	0.14	0.13	0.001	0.003
600-1400 m	1948-1997	0.21	0.07	0.003	0.001
total	1948-1993	0.27	0.22		
Surface: 2.56×10^{10} m^2					
ALGERIAN BASIN 1 (Alg1 in fig 1)					
0-200 m	1948-1999	0.48	0.49	-0.008	0.009
200-600 m	1948-1999	0.18	0.14	0.003	0.001
600-2500 m	1951-1997	0.36	0.26	0.0014	0.001
total	1951-1993	1.09	0.63		
Surface: 5.82×10^{10} m^2					
BALEARIC SEA (Bal in fig 1)					
0-200 m	1948-1997	0.31	0.33	-0.001	0.002
200-600 m	1948-1997	0.02	0.12	0.001*	0.001
600-2500 m	1948-1997	0.17	0.13	0.001	0.0003
total	1948-1997	0.43	0.38		
Surface: 16.36×10^{10} m^2					

Table 1. Continuation

	Period	Linear trend (Wm^{-2})	95% C.I. (Wm^{-2})	Linear trend yr^{-1}	95% C.I. yr^{-1}
GULF OF LION (GL in fig 1)					
0-200 m	1951-1999	0.15	0.33	0	
200-600 m	1949-1999	0.15	0.14	0.0012	0.0010
600-800 m	1952-1995	0.28	0.23	0.0012	0.0010
total	1949-1999	0.47	0.51		
Surface: 4.5×10^{10} m^2					
LIGURIAN SEA (Lig in fig 1)					
0-200 m	1950-1999	0.05	0.24	0.0023	0.0020
200-600 m	1950-1999	0.10*	0.10	0.0014	0.0010
600-2500 m	1950-1996	0.57	0.23	0.0015	0.0010
total	1950-1999	0.54	0.37		
Surface: 5.16×10^{10} m^2					
TYRRHENIAN SEA (Tyrr in fig 1)					
0-200 m	1948-1999	0.05	0.36	0.0016	0.006
200-600 m	1948-1999	0.05	0.17	0.002	0.001
600-2500 m	1951-1992	0.17	0.27	0.0009	0.0005
total	1948-1999	0.16	0.51		
Surface: 19.56×10^{10} m^2					
ALGELIN BASIN 2 (Alg2 in fig 1)					
0-200 m	1948-1994	0.42	0.57	-0.0004	0.0006
200-600 m	1948-1995	0.04	0.15	0.003	0.001
600-2500 m	1948-1994	0.22*	0.23	0.0014	0.001
total	1948-1994	0.75	0.58		
Surface: 12.17×10^{10} m^2					
STRAIT OF SICILY (Sic in fig 1)					
0-200 m	1948-1995	-0.05	0.49	0.0025	0.0037
200-600 m	1948-1992	-0.07	0.11	0.002	0.001
600-1200 m	1955-1992	0.04	0.12	0.001	0.002
Surface: 3.73×10^{10} m^2					

DISCUSION AND CONCLUSIONS

Using different methods to estimate trends yields different results, being the differences larger in the upper layer.

The BT data percentage is higher in upper layer and it was reduced with the time at this layer and with depth at all the sectors of the WMED (see figure 3). Comparing figure 2a) with 2b) and figure 2c) with 2d), the largest discrepancies are found in the surface layer, in the intermediate and deep layer the results are similar. We can suggest that BT data of the WMED can be used to estimate temperature trends and provide significant results in the intermediate and deep layer.

Therefore estimated trends in water deeper than 200 meters provide similar temperature trends with and without the use of BT data.

In table 1 is resumed the heat content trends for each layer and sector in the WMED. In deep layer, all the trends estimated are positive significant less in Tyrrhenian Sea and Strait of Sicily. In the intermediate layer the trend is positive but not significant in all sectors. The heat content trend in the water column (total in table 1) in all sectors is positive less in Tyrrhenian Sea. Averaging the heat content in WMED (without taking into account the Straits), the heat gain is 0.32 Wm^{-2} [0.12, 0.52] Wm^{-2} . We can conclude that WMED is heating

Concerning the salinity, in all the sectors selected in the WMED in this work, the trends calculated for deep water provide positive significant results, averaging it, the salinity trend in the deep layer in WMED is 1.2×10^{-3} $year^{-1}$. In the intermediate layer, in 7 of the 9 place that we have divided de WMED de increase salinity is significant and we can conclude that the intermediate layer of WMED was increasing the salinity (1.9×10^{-3} $year^{-1}$) during the second half of XX century coinciding with Rohling and Bryden,1992; Benthoux and Gentili, 1996; Rixen et al., 2005. For the surface layer, the trends estimated aren't significant in all sectors, therefore we can't argue that the surface layer in the WMED is salting since the second half of XX century.

Conclusions: the use of BT data has no influence in the estimation of temperature trends in the WMED contrary to what is observed in other parts of the world ocean (Gouretski et al, 2007).Not all the sectors in the WMED seem to have the same behaviour when dealing with long term changes. The WMDW is heating and salting since (at least) the second half of the XX century. We can't estimate robust heat and salinity trends for the surface layer.

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