PROGRESSIVE WARMING OF THE WESTERN MEDITERRANEAN DEEP WATER AT THE BALEARIC AREA SINCE MID NINETIES.

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Abstract

The interanual variability of the heat stored on intermediate and deep water at the Balearic Sea is analyzed from two deep hydrographic stations repeated frequently from year 1996. A statistically significant warming trend, equivalent to approximately 0.015 °C per year, has been found below the 700 db in both stations. Thickness of DW (Deep Water) layer as classically defined at the area has been dramatically reduced whereas the LIW (Levantine Intermediate Waters) layer has increased.

Keywords: heat content, warming, Balearic Sea

The accumulation of evidences in favour of an anthropogenic induced climate change scenario have increased in the last decades the interest on the behaviour of long term properties of intermediate and deep water around the oceans of the world. All data available for the whole ocean shows a warming of 0.03 °C for the 300 m depth upper layer during the previous century [1]. Some studies regarding the Mediterranean Sea have also found warming and salinity increase for deep and intermediate waters [2], [3].

In this paper we will explore the recent changes on heat content of the central and deep waters at the Balearic Sea from a series of hydrographic cruises repeated almost once a year in the period between 1996 and 2003. The base of this work is the data set from the "Canales" and "Cirbal" projects (Instituto Español de Oceanografía) [4]. Under those projects several transects were reoccupied in different seasons (Fig. 1). Deep hydrographic stations 25 and 33, located on the northern entrance of both the Ibiza and Majorca channels have been sampled more than 10 times for the whole water column, their respective depths are 1250 and 1360 m.

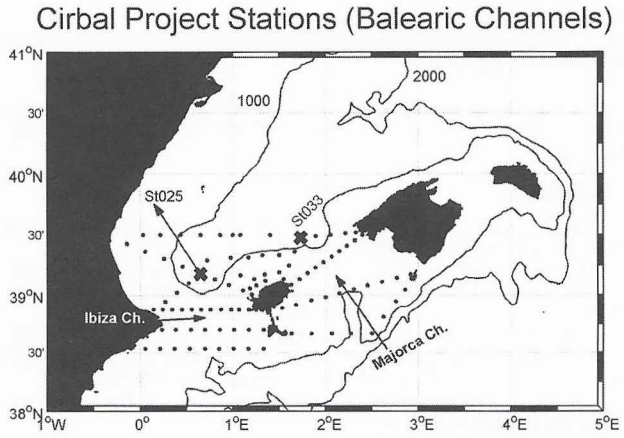

Fig. 1. Stations for the "Canales" and "Cirbales" Projects (1996-2003) at the Balearic Channels. The two chosen for this work are marked.

Water masses at the Mediterranean Sea are characterized by the no existence of permanent thermocline which maintains a stratified situation controlled by density. This particular feature makes impossible to use isopycnal levels to define water masses so $\Delta\theta/\Delta s$ bounded regions are used instead. Below the upper mixing layer at the studying area we find the seasonal Winter Intermediate Water (WIW, [12.5-13.0 37.9-38.3])[4], Levantine Intermediate Water (LIW, [13.0-13.5 38.4-38.55]) and Deep Water (DW, [12.70-12.90 38.4-38.50]). The mean depth of the core of LIW, from an averaged profile for the whole data set, is located around 500 db and the top level of DW waters as previously defined is around 1100 db.

A noticeable warming of the water column is observed from the data. Levantine Intermediate Water (LIW) shows yearly dependence on the climatic atmospheric forcing and higher values of temperature and salinity appeared on year 1998 coinciding within the warmest year ever recorded on the north Atlantic. Both DW and the transition branch from the LIW have experimented a progressive warming which resulted in a reduction of the thickness of DW, as previously defined, from more than 300 db (years 96 and 97) to around 100 db (year 2003). A linear fit of the evolution of heat content stored by 100 db thickness layers gives positive trend at 95% confidence intervals for all depths below 700 db (station 33 on Figure 2 and similar result for station 25). The mean value from 700 db to the bottom is 58 ± 25 kJ/m^{3}year heat increase (which would result on 0.014 ± 0.006 °C/year if applied on standard (s=35,θ=10,p=0) seawater). Confidence intervals reduces with depth showing a lesser noisy warming signal (better linear fitting) as we approach to the bottom layer.

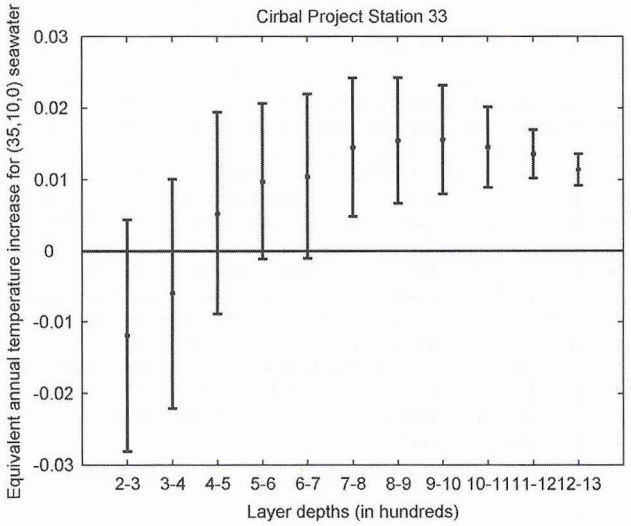

Fig. 2. Trend found for a linear fitting of the evolution of the heat stored between isobaric layers, showed as a temperature equivalent if applied on (s=35,θ=10,p=0) seawater, for the time series at station 33. Confidence interval 95%.

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