DOUBLE-DIFFUSION PROCESSES AND LIW CHARACTERISTICS IN THE ALBORAN SEA

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Abstract

The interaction of warm and salty Levantine Intermediate Water (LIW) with colder and fresher environmental water masses in the Alboran basin (western Mediterranean) creates favourable conditions for small-scale mixing processes. The present analysis is based on the 134 CTD profiles gathered in the Alboran Sea during the Spanish expedition "FE-92" in autumn 1992. The values of the Turner angle calculated for the layers above, below and inside the LIW core, showed the predominance of a diffusive regime on the upper limit of LIW, and a salt fingering on its lower limit in few cases in the western part of the region. The analysis of the spatial distribution of small-scale processes activity, calculated using several statistical properties of the termohaline profiles allows to distinguish the areas of predominance of dia- or isopycnal regime in the small-scale mixing processes. The spatial distribution of diapycnal processes in the upper layer of LIW qualitatively correlates with the vertical velocity distribution, associated with mesoscale features of circulation, as diagnosed by other authors through a primitive equation model with mesoscale resolution.

Key-words: Temperature, salinity, vertical profile, Alboran Sea

Introduction

The mixing processes of LIW occur at different scales in space and time. At small scale, inhomogeneities in the thermohaline profiles account for the occurrence of complex turbulent processes (1). Double-diffusion instabilities are one of the characteristic small-scale processes arising from the contrast between warm and salty LIW and colder and fresher environmental water. The presence of small-scale mixing processes manifests in the different forms of fine structure inhomogeneities on the temperature and salinity profiles. These processes are usually divided into two main classes: diapycnal and isopycnal. Diapycnal processes lead, as a rule, to the creation of thermohaline step profiles, whereas isopycnal advection leads to the formation of thermohaline intrusions (2,3). In this manner the shape of thermohaline inhomogeneities in a CTD profile contain information about the processes that formed them. The analysis of the spatial distributions of parameters, calculated from statistical characteristics of fine structure peculiarities in CTD profiles, allows us to determine the type of small-scale processes (dia- oisopycnal) present and detect the areas of their activity in the Alboran Sea.

Materials and methods

To analyse the intensity of the small-scale processes, and how they affect the LIW thermohaline characteristics in the Alboran Sea, 134 CTD profiles from the "FE-92" Spanish cruise in September-October 1992 were analysed.

For the small-scale mixing processes analysis the range of depths was choosen taking into account the typical vertical gradients of temperature and salinity. In this manner three characteristic layers of LIW were determined:

A - the upper layer with positive temperature and salinity gradients;

B - the LIW core with quasi homogeneous distributions of temperature and salinity;

C - the lower layer with negative gradients of temperature and salinity (Fig.1).

To estimate the double-diffusive activity, the Turner angle (Tu) was calculated for each layer with a vertical step of 7 meters:

$Tu = arctg\,(R_\rho) + 45°$,

where $R_\rho = (\alpha dT/dz)/(\beta dS/dz)$ is the density relationship and $\alpha = -(1/\rho)d\rho/dT$, $\beta = (1/\rho)d\rho/dS$ are the thermal expansion and haline contraction coefficients, respectively (4).

The analysis of statistical characteristics of the finestructure inhomogeneities in the thermohaline profiles is based on Pingree's results (5) who showed that:

- for finestructure inhomogeneities resulting from isopycnal advection (isopycnal regime) $\alpha T'/\beta S' = 1$, where T' and S' are the temperature and salinity inhomogeneity, respectively;
- for finestructure inhomogeneities resulting from vertical mixing (diapycnal regime) $\alpha T'/\beta S' = R\rho$.

The finestructure inhomogeneities obtained by separating the original CTD profile into mean and pulsating components by HF filtering, form a cloud of points on the $/\beta S', \alpha T'/$ - plane. This cloud of points has a determined inclination angle φ_p (Pingree angle) to the $\beta S'$-axis. By evaluating the proximity of $tg\varphi_p$ to $tg\varphi_i = 1$ (isopycnal regime) or $tg\varphi_d = R\rho$ (diapycnal regime) we can determine the degree of isopycnicity or diapycnicity of finestructure inhomogeneities. The parameter $\gamma = (tg\varphi_p - tg\varphi_i)/(tg\varphi_d - tg\varphi_i)$ ranges from 0 to 1; when $0<\gamma<0.5$, finestructure temperature and salinity fluctuations are mainly formed by isopycnal processes, and when $0.5<g<1.0$ by diapycnal ones (6,7).

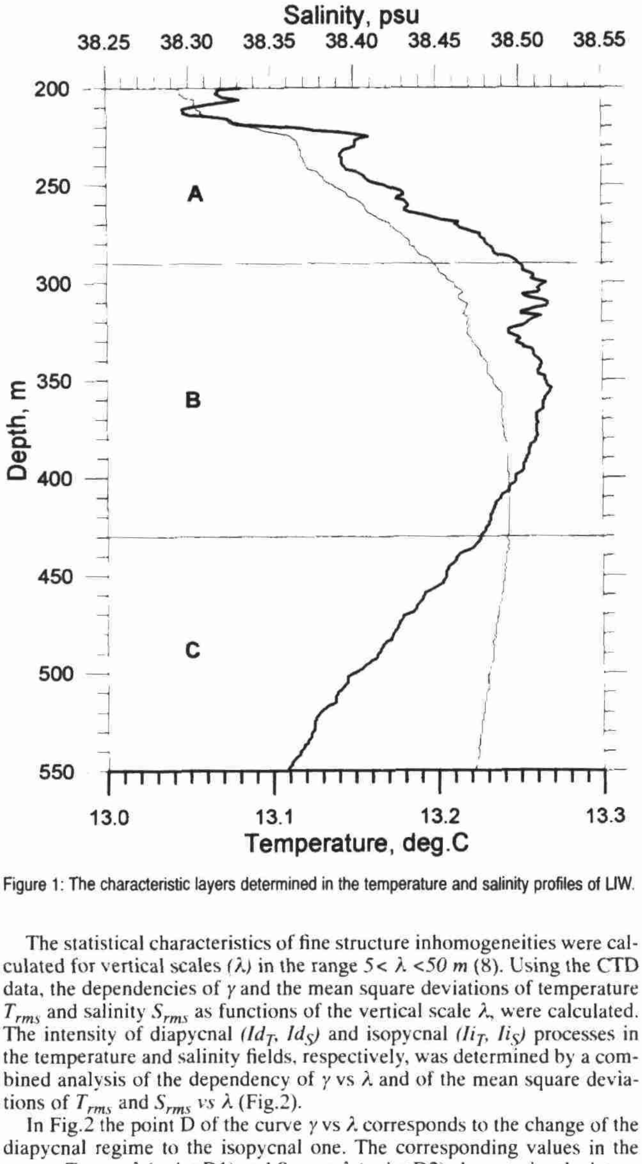

Figure 1: The characteristic layers determined in the temperature and salinity profiles of LIW.

The statistical characteristics of fine structure inhomogeneities were calculated for vertical scales (λ) in the range $5< \lambda <50\ m$ (8). Using the CTD data, the dependencies of γ and the mean square deviations of temperature T_{rms} and salinity S_{rms} as functions of the vertical scale λ, were calculated. The intensity of diapycnal (Id_T, Id_S) and isopycnal (Ii_T, Ii_S) processes in the temperature and salinity fields, respectively, was determined by a combined analysis of the dependency of γ vs λ and of the mean square deviations of T_{rms} and S_{rms} vs λ (Fig.2).

In Fig.2 the point D of the curve γ vs λ corresponds to the change of the diapycnal regime to the isopycnal one. The corresponding values in the curves T_{rms} vs λ (point D1) and S_{rms} vs λ (point D2) characterize the intensity of diapycnal processes in the temperature (Id_T) and salinity (Id_S) fields, respectively. In the same figure the point E of the curve γ vs λ corresponds to its stable regime (the weak deviation of the curve from the stable regime lies in the range of CTD sensors sensibility). The corresponding values in the curves T_{rms} vs λ (point E1) and S_{rms} vs λ (point E2) characterize the intensity of diapycnal processes in the temperature (Ii_T) and salinity (Ii_S) fields, respectively.