A review of the stepped structure in the Tyrrhenian Sea

by
R. MOLCARD
Saclant ASW Research Centre, La Spezia (Italy)

Résumé

Plusieurs croisières océanographiques à bord du navire *Maria Paolina G.* ont permis d'étudier la structure en escalier découverte en mer Tyrrhénienne. La colonne d'eau entre 500 et 1500 m est formée d'une dizaine de couches homogènes s'étendant sur environ 400 (nautiques)^2 là où la profondeur du bassin est maximum. L'existence de « doigts de sel » fut prouvée par photographie directe, mais correspondant à la structure plus fine à travers l'interface. La double diffusion ne suffirait donc pas à expliquer la présence de ces grandes couches homogènes. Celles-ci pourraient aussi être formées par l'instabilité d'un système d'ondes internes. Cette seconde hypothèse est corroborée par la corrélation trouvée entre l'épaisseur des couches et le gradient moyen de densité.

Abstract

The stepped structure discovered in the Tyrrhenian Sea is described. From 500 m to 1500 m ten thick ($\sim$ 100 m) homogeneous layers are separated by thin interfaces ($\sim$ 7 m). This structure expands over 400 n.mi.^{2} in the deepest part of the basin. Salt fingering happen to be correlated with mini stepped structure within the interfaces. Internal gravity waves of lowest modes give an up and down movement to the whole medium while higher modes are trapped within the density gradient (10^{-7} g. cm^{-4}).

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Introduction

Repeated cruises (1972-73-74) have now been performed in the Tyrrhenian Sea on board the R/V *Maria Paolina G.* of the Saclant ASW Research Centre, to study the particular structure of the area. The water column happen to be a multilayer system. The main hypothesis to be verified are double diffusive process of salt fingers type and internal waves breakings. Some of the observations have already been discussed in the open literature (Refs. 1-2). The present results are summarized here, updated by the last *in situ* measurements in October 1974.

General Description

The staircase structure is predominant from 500 to 1500 m below the maxima of temperature and salinity produced by the Levantine water core.

Temperature and salinity differences between successive layers are :

$$5\times10^{-2}\ ^\circ\text{C} \leqslant T \leqslant 10^{-1}\ ^\circ\text{C} \qquad 1.5\times10^{-2}\ ‰ \leqslant S \leqslant 4\times10^{-2}\ ‰$$

Giving a stable density jump 10^{-6} g/cm^3. The corresponding interfaces are 7 m thick and the homogeneous layers average around 100 m. These layers expand over 60 n.mi. with remarkably constant temperature. Salinity characteristics are stable up to $\pm\ 5 \times 10^{-3}$ ‰ and 5×10^{-3} °C. They are located over the deepest part of the Tyrrhenian basin 100 n.mi. west of Naples.

Rapp. Comm. int. Mer Médit., **23**, 5, pp. 23-24 (1976).

Two sets of layers thicknesses are always present :

50 m	from	500 to 900 m
150 m	from	900 to 1500 m

Transition layers between these two sets around 900 m showed changes over different years. A strong correlation was found between density gradient and layer thickness. The product of Brunt-Väisälä frequency and layer thickness falls always between 13 and 21 mcph.

Variability observed with repeated profile spacially close reveals first mode internal gravity waves in phase for all the interfaces with a period of about 2 hours equal to the Brunt-Väisälä period calculated for the density gradient average over the 1000 m. Higher modes were also detected, making internal waves riding within the interfaces and modulating the corresponding temperature and salinity gradients.

Finer measurements with microstructure probe (N.L. BROWN) from an " autoprobe " (K.H. BURT) reveal mini step like structure within the interface and salt fingers were photographed correlated with this finer structure (A.J. WILLIAMS IIIRD).

The possibility of Levantine water inspection in the area through the Messina Strait has been investigated during the last cruise. Horizontal and vertical current measurements were also performed with the collaboration of the Museum d'Histoire Naturelle (J.C. GASCARD).

Strong inertial component and burst of vertical motions are the preliminary results of their first processing.

Discussion

Salts fingers exist in the area and therefore increase the downware transport of salt and heat. They however are correlated with the fine scale ($\sim$1 m) within the interfaces. Salt finger theories are therefore to be compared with this small structure. Whether an old stage of the double diffusive system could be such big homogeneous layers separated by thin one where salt fingers are still acting has not been yet shown in laboratories because large time scales involved, remained still an hypothesis to be verified, but the correlation arising from density gradient and layer thicknesses is also an important fact related to dynamical process. The amplitude of internal gravity waves will decrease with increasing frequency for the same amount of energy and breaking of them will mix column of water of the order of magnitudes of these amplitudes.

References

[1] CORTECCI (G.), MOLCARD (R.) & NOTO (P.), 1974. — Isotopic analysis in the deep staircase structure in the Tyrrhenian Sea. *Nature*, **250**, pp. 134-36.

[2] MOLCARD (R.) & WILLIAMS 3RD (A.J.), 1974. — Stepped structure in the Tyrrhenian Sea. *Proceedings of sixth Liège Colloquium on ocean hydrodynamics. (under press)*.