ATYPICAL WESTERN MEDITERRANEAN DEEP WATER FORMATION DURING WINTER 2005

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Abstract
The meteorological conditions in winter 2005, with anomalously low precipitation and unusual persistency of northerlies over the NW Mediterranean, caused a large extension both in time and space of deep convection processes. As a consequence, where convection typically gives rise to the Western Intermediate Waters (WIW) a New Western Mediterranean Deep Water (N-WMDW) was produced, slightly denser (+0.01kg m^{-3}), warmer (+0.05°C) and saltier (+0.03) than the usual WMDW. Moreover, near the continental slope, a cascading of colder and even denser water was found (-0.1°C and +0.025 kg m^{-3}), formed over the shelf (C-WMDW). In both cases it appears the high surface salinity as a responsible for the excess of density. The origin of this higher surface salinity is discussed.
Keywords : Air-sea Interactions, Deep Waters, Deep Sea Processes, Western Mediterranean.

Typical convection processes in the NW Mediterranean in winter give rise to different water masses according to their density. The most dense, WMDW, is formed in the MEDOC area (around 24°N, 5°E) based on surface preconditioned waters + some amount of LIW [1]. Other dense waters, called WIW, are formed in the coastal NW periphery of the MEDOC area [2], where surface AW is less salty than in the central part. WIW are less dense than WMDW and remain above the LIW layer. During cold, windy or dry winters mixing over the continental shelves can reach high densities enough to overflow the shelves and sink through the slope by cascading [3]. The most common fate of this cascading is also above the LIW but some times has been reported below this layer down to the bottom [4]. WMDW is very homogeneous, however, a slightly warmer and salty water has been found near the bottom on some occasions. The origin of this water is still on discussion: Called Bottom Water (BW) in one of the first articles [5], it was assumed that was formed by deep convecton at open sea but not concluded under which conditions. Other more recent papers [4] consider that they originated by cascading.

Data analysed in this paper comes from EFLUBIO cruise in March 2005, covering a part of the NW Mediterranean in open sea, including the MEDOC area. Unfortunately many of the CTD casts only sampled the upper 600 m, only some of them reached 1000 m and very few 2000 m. Sampling was completed with a continuous analysis of surface TS along the shiptrack and a transect of 4 stations across the shelf-slope in front of Barcelona.

The vertical structure found revealed clear signs of a recent deep convection in a large area, confirmed by satellite images, which covered unusual regions more than 100 miles southwards of the MEDOC area. Surface salinity in this area was very high (>38.45) and LIW was found very shallow (at less than 100 m). Curiously, in one of the stations at the E of Menorca, a very "recent" LIW, with salinity >38.6, was found at its typical layer. However, the most interesting, and surprising, finding was the presence of a very thick layer of a slightly saltier and warmer (marked as N in Fig. 1), below the typical WMDW (marked as O). This water, found as shallow as 600 m in certain stations, was almost omnipresent in all the deep stations below 1200 m. Another water mass (marked as C), denser that O, was found on the transect across the slope, as shallow as 25 m over the shelf and close to the bottom on the slope.

Winter 2005 was cold but not extraordinarily cold. However it was very windy and dry. Precipitations were on a historical minimum and northerlies were strong and persistent. These exceptional conditions would explain the extent both in time and space of the DW formation process. As sinking of new DW involves a compensatory upwards flow of LIW, in such a case the amount would be much bigger than usual. This would explain the presence of this water near the surface in a large area and the extraordinarily high salinities found at surface in the zone of the continental slope. While in typical WIW formation is assumed that surface water that sinks is free of the LIW, in the present case all the typical places for WIW formation were occupied by LIW, so that the dense water formed there by open sea convection would produce a water saltier and slightly warmer than the classical WIW, as the one marked with N in Fig. 1. This important turn over of LIW would also accelerate the circulation at this intermediate layer, explaining the presence of the "recent" LIW near Menorca. The drought conditions, reducing river discharges, would also justify high salinity in the coastal waters contributing to the formation of a coastal dense water (marked C in Fig.1) that would reach the bottom of the basin by cascading. A subsequent cruise, in June-July 2005, in the Balearic sea showed that N and C waters were linked by a mixing line in the θSdiagram [6] forming a new Deep Water Mass.

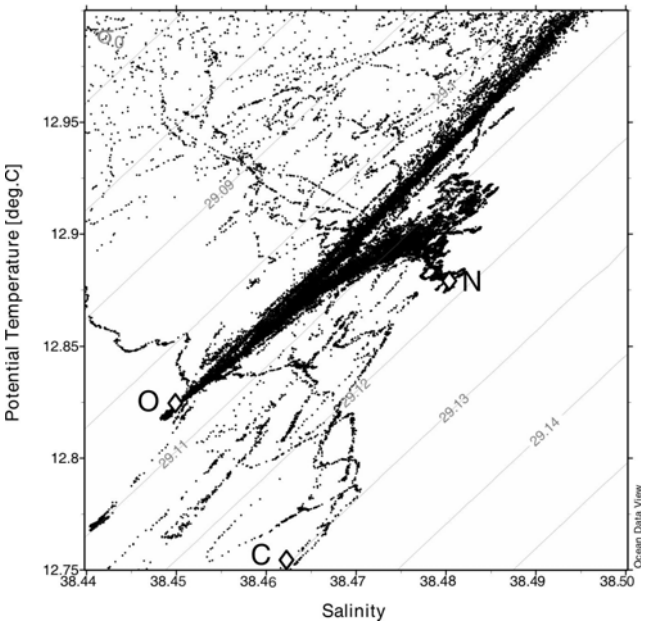

Fig. 1. Detailed θS diagram of all the casts. The points marked with O, N and C are referring to: the typical (Old) deep water, the New deep water and the water formed by Cascading respectively

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