CONTRIBUTION OF INTENSE CASCADING TO MODIFICATIONS OF WESTERN MEDITERRANEAN DEEP WATER AS SHOWN BY HYDROCHANGES MOORING

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Abstract
The effects of the cold, anomalously dry, and very windy winter 2005 in the deep water thermohaline properties are evidenced by a time series of hydrographic data recorded by the ICM HydroChanges mooring in the deep slope of the NW Mediterranean. In late January 2005 intense dense shelf water cascading was observed in the Gulf of Lions' submarine canyons, and almost simultaneously a dense deep water mass, warmer and saltier than usual, reached the deep mooring site. After 30 days, the colder, fresher and even denser waters originated on the shelf arrived at the mooring, and their signature could be detected for 35 days. By late spring 2005 the mixture of both dense water masses reached new stable thermohaline properties with higher values than those that characterized the deep layer before 2005.
Keywords : Deep Waters, Continental Slope, Time Series, Hydrography, Balear Sea.

The NW Mediterranean Sea is the formation region for the dense Western Mediterranean Deep Water (WMDW), in a typical winter convection process that involves the salty Levantine Intermediate Water (LIW). Over the wide shelf of the Gulf of Lions and adjacent areas winter heat losses and evaporation caused by cold and dry northerly winds induce cooling and mixing of the low salinity coastal waters, which eventually become denser than the surrounding waters and sink. These dense waters flow down the continental slope, in a process known as cascading, until they reach their density equilibrium at sub-surface. Sometimes these cascading waters can be denser, reach deeper layers, and interact with the saltier LIW. In exceptional occasions, as the abnormally cold 1999 winter, waters generated over the shelf have been traced down to 1000 m together with intense down slope velocities [1]. During autumn and winter 2004-05 precipitation on the NW Mediterranean was very scarce. For some time air temperatures were lower than the climatologic average, and northerlies were dry, strong and persistent (values above 100 km/h recorded during 30 days, as reported by MétéoFrance). Winter 2005 was certainly anomalous and very favourable for dense water formation in the region.

A mooring line with a SeaBird 37 CTD recorder and an Aanderaa RCM8 currentmeter near the bottom was installed by ICM-CSIC in the deepest part of the continental slope (1890 m depth) off the Catalan coast (41° 28'N, 3° 40.4'E) as contribution to the CIESM HydroChanges program.

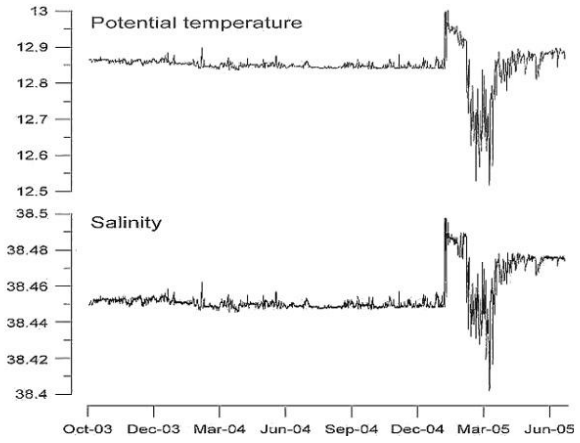

Fig. 1. Potential temperature and salinity recorded by the ICM-CSIC HydroChanges mooring in the NW Mediterranean at 1875 m of depth during 21 months, including the exceptional 2004-2005 winter.

A first deployment period lasted from October 2003 to July 2005. Some 120 km upstream of this location, other moorings installed in submarine canyons to analyse sediment transfer processes recorded during winter 2003-2004 shelf water cascading events characterized by decreases in temperature and increases in current speed for few days. During winter 2004-05, the persistent northerly winds and the reduction of river discharges helped to dramatically enhance the intensity of the cascading mechanism. From late January a major cascading event occurred continuously until late March, as recorded in the Cap de Creus Canyon, with a temperature decrease of the order of 3°C and down-canyon steady currents between 40 and 80 cm/s at a depth of 750 m [2].

Potential temperature and salinity values recorded at the HydroChanges station at 1875 m (Figure 1) were almost unchanged from October 2003 until the end of January 2005, indicating a water mass stable situation with typical WMDW characteristics, without any seasonal signal. Then both variables suddenly increased to 12.99°C and 38.50. In early March a drop of more than 0.2°C and 0.05 occurred, both variables remained during one month in a range of low values, and afterwards gradually increased until reaching quite steady values above the initial ones. These sudden variations precede or coincide in time with changes in the structure of deep CTD profiles in the NW Mediterranean observed by other authors after the 2004-05 winter [3, 4, 5]. These authors explain the θ and S increase as corresponding to an anomalous WMDW formed during this exceptional winter, either by involving a larger amount of LIW than usual, or this LIW having higher temperature and salinity values.

The important drop in both temperature and salinity in early March, together with an extraordinary increase in speed recorded by the moored current meter (up to 60 cm/s), seems to be a clear indication of a very intense shelf water cascading. The extremely low precipitation occurred in the region during winter 2004-05 resulted in a strong reduction of river discharges and then a remarkable increase of salinity in shelf waters [4]. As a consequence, this year the cascading waters became extremely dense and crossed our moored instruments at 1875 m with a σ_θ peak of more than 29.15 kg/m^3, while spreading to the deepest part of the basin. Once this cascading event finished, the densest cold and fresh water was replaced and mixed with the new 2005 WMDW, until stabilizing around 12.88°C, 38.48, and 29.12 kg/m^3. The resulting water was slightly warmer (+ 0.03°C) and saltier (+ 0.03), and markedly denser than the previously present WMDW, in agreement with the positive θ/S anomaly found in deep CTD casts conducted in several areas of the western Mediterranean during the first half of 2005 [3, 4, 5].

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