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Hydrodynamic comparison between the north and south of Mallorca Island

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ABSTRACT

A hydrodynamic comparison between two zones of fishing interest, one located to the north and the other to the south of Mallorca Island (Balearic Islands, Western Mediterranean) was done. The comparison was conducted using the data from two moorings, one placed in the middle of the Balearic Current, in the Balearic subbasin (herein, Sóller) and the other in the Mallorca Channel, near the Algerian subbasin (called Cabrera). The instruments moored, continuously recorded the temperature, salinity and currents at different depths, for over 15 months. The data analysis suggests that Sóller is hydrodynamically more active than Cabrera, at least during the time of recording the measurements. The mean currents were higher at Sóller than at Cabrera at all depths, also showing greater maximum speeds and variability. In addition, the presence of more mesoscale eddies in Sóller became evident from the altimetry data. These eddies were not only significantly more energetic near the surface, they also generally reached to greater depths, affecting the velocities of the seabed currents. Subsequent to each significant eddy episode, strong changes in temperature and/or salinity were observed, along the entire water column. Spectral analysis revealed the presence of high frequency oscillations with periods of a few hours. One energy peak, with a period around 3.7 h, was observed at both locations, probably related to trapped waves around Mallorca or the Balearic Islands, while others (3 h and 2 h) were reflected only in Sóller, suggesting they could be associated with some standing resonance waves between the Iberian Peninsula and Mallorca.

1. Introduction

The Balearic Islands, located in the Western Mediterranean, are the natural limit between the Balearic and the Algerian subbasins (Fig. 1). These two areas are connected via channels between the islands. The Ibiza Channel (80 km wide, with a maximum depth of 800 m) is located between Cape La Nao (Iberian Peninsula) and Ibiza Island; the channel between Ibiza and Mallorca is known as the Mallorca Channel (80 km wide and 600 m deep); meanwhile the Menorca Channel, the shallowest (100 m deep) and narrowest (35 km wide) is located between the Mallorca and Menorca Islands (García et al., 1994).

The mean circulation in the Balearic subbasin, situated north of the archipelago up to the Iberian Peninsula, is driven by a density gradient between the fresher coastal water and the relatively saltier water in the center of the subbasin. Due to this density gradient, the Northern Current (NC) flows southward along the Iberian Peninsula slope, following the isobaths. When the NC reaches the Ibiza Channel, two different behaviors are possible, depending on the mesoscale situation (Pinot et al., 2002). Normally, a portion of the NC may leave the Balearic subbasin via the Ibiza Channel and Mallorca Channel while the rest gets reflected northward to form the Balearic Current (BC) which flows along the Islands' northern slope. The resident water between 200 m and 700 m is mostly the Levantine Intermediate Waters (LIW). When the previous winter was particularly cold, the Western Mediterranean Intermediate Waters (WIW) generated in the Gulf of Lion and normally located between 100 m and 300 m, could have displaced the LIW forming the resident water at the intermediate depths (Mertens and Schott, 1998; Millot, 1999; Pinot et al., 2002). When these WIW reach the Balearic Channels in late spring, the NC most often gets blocked and a different configuration of flow through the channels is observed. Most of the NC reflects northwards, reinforcing the BC, and the southward flow through the channels is reduced (Monserrat et al., 2008). The Western Mediterranean Deep Waters (WMDW) are located in the deeper part of the water column, below 700 m (refer Massutí et al., 2014–in this issue; Millot, 1999; Pinot et al., 2002 for a better description of the circulation and the properties of these water masses).

The Algerian subbasin, the zone between the Balearic Islands and the north of Africa, is controlled by a completely different dynamics. The circulation of the Algerian subbasin is driven by the Algerian current which interacts with the Alboran Sea eddies and spreads the Atlantic water towards the Balearic Islands. The northern part of the subbasin has no clear steady current, although its circulation is affected by the changes in the mesoscale structures in the southern part of the subbasin

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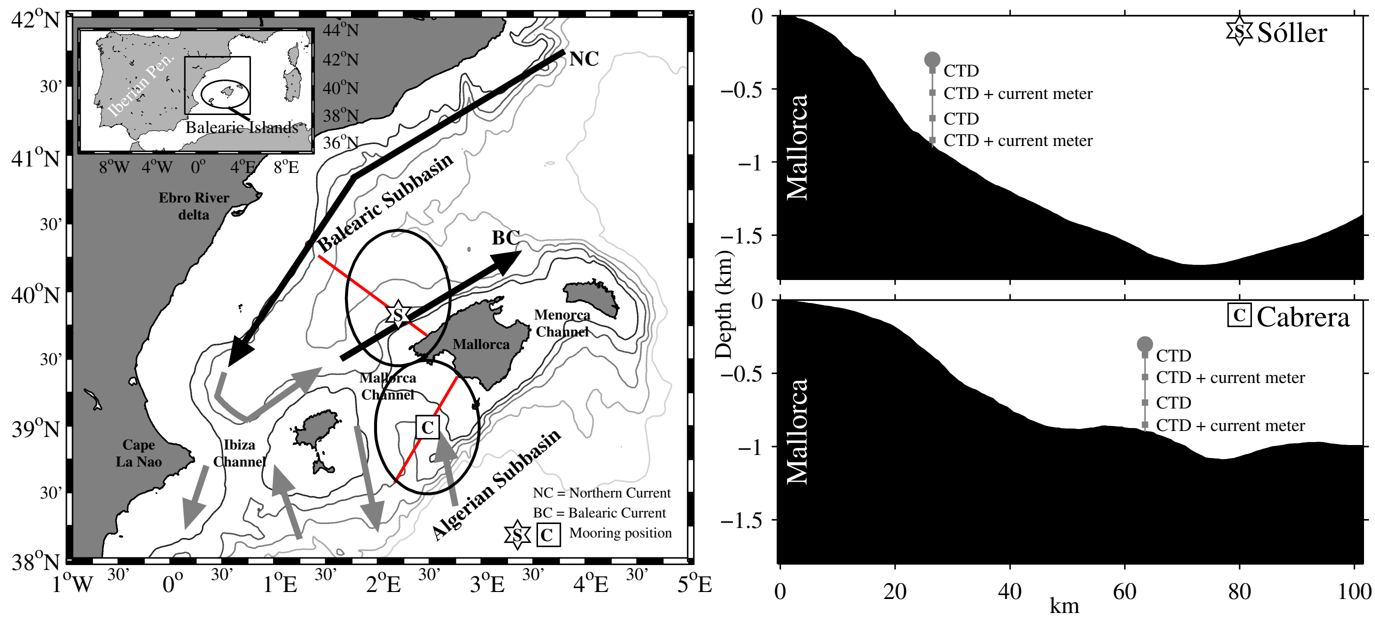

Fig. 1. Map showing the main characteristics of the ocean circulation in the Balearic subbasin. The positions of the moorings are marked with an S inside a star for Sóller mooring and a C inside a square for Cabrera mooring. Isobaths are plotted between 500 m and 2500 m with a step of 500 m. Black arrows indicate the permanent currents, while the gray ones indicate the temporal features. The enclosed areas are 0.5° radius circles where the occurrence of eddies is checked (they seem to appear as ellipsoids due to the map projection). The bathymetric profiles correspond to the red lines indicated in the map.

and the entrance of Mediterranean water coming in from the Balearic subbasin via the channels.

The main objective of this study, which is included in the IDEADOS project (Massutí et al., 2014–in this issue), is to analyze the similarities and differences in the hydrodynamic conditions between two zones of fishing interest, one situated in the Balearic subbasin, to the north of Mallorca Island and the other in the northern part of the Algerian subbasin, to the south of Mallorca. The results found are to be of significance for IDEADOS when assessing the manner in which the variability of the fishery resources in both areas might be driven by a different hydrodynamic frame. With this objective in mind, a mooring line was deployed in each zone to retrieve a set of hydrodynamic data to facilitate a comparison. One instrument line was located in the Balearic subbasin, near Sóller, while a second one was placed in the Mallorca Channel, in the northern part of the Algerian subbasin, close to Cabrera Island. The terms Sóller and Cabrera are used to identify these two regions throughout the manuscript (Fig. 1).

In this work, we first present the mooring lines, instrumentation and the data set measured. Then, the methodology used is described and the most interesting results are shown. A detailed comparison between the two zones is elaborated. The last section includes the summary and conclusions drawn.

2. Data and methods

Hydrodynamic data were acquired using two identical mooring lines. The line from Sóller was placed on the northwest side of Mallorca Island (39°49.682′ N–2°12.778′ E) and the line from Cabrera was located on the southwest side of the island, into the Mallorca Channel (38°59.484′ N–2°28.907′ E) (Fig. 1).

The moorings were deployed at about 900 m depth to a height of 600 m above the seabed. Each mooring consisted of four CTD (conductivity, temperature and depth) Seabird 37 sensors placed at fixed depths at around 300 m, 500 m, 700 m and 900 m. In addition, two Nortek Aquadopp current meters were installed in the middle levels (at about 500 m) and near the bottom (around 900 m depth). A sediment trap (not used in this study) was placed 30 m above the bottom. Observations of the thermohaline properties and currents were collected at sampling rates of 10 min for the CTD and 30 min for the current meters.

The moorings were continually recording data from mid-November 2009 until mid-February 2011. During this period, two maintenances were required because of the selected sampling rate for the sediment traps. These maintenances took place in mid-March and in mid-September 2010. The depth where the instruments were located did not change significantly after the maintenances. The instruments encountered no significant problems during the whole period. The only exceptions were the CTDs at 500 m and 900 m in Sóller and the one at 300 m in Cabrera which ran out of batteries around January 2011, about 1 month prior to the end of the experiment.

Simultaneous surface information was obtained from the AVISO service available at http://www.aviso.oceanobs.com, which provides gridded Sea Surface Height (SSH) fields with a map sampling of 1/8° × 1/8°. The absolute dynamic topography is obtained as the sum of the sea level anomalies provided, measured by the altimetry satellites and the mean dynamic topography based on 7 years of observations (1993–1999) (Rio et al., 2007). The regional sea level anomalies for the Mediterranean Sea are a multi-mission product with up to 4 satellites at a given time, spanning the period from 1992 to the present. The data provided are corrected to include all standard geophysical corrections, including Dynamic Atmospheric Correction (DAC). This latter correction combines the high frequency of the Mog2D model (Carrère and Lyard, 2003) with the low frequency of the classical inverted barometer correction.

The formation and evolution of the eddies in the region of interest have been studied by applying an automated eddy detection scheme (Nencioli et al., 2010). This scheme is a flow geometry based scheme. The method fixes the center of the eddy as the local velocity minimum into an area with rotating flow, and the eddy boundaries are defined as the outermost closed streamline around the center, for which the velocity continues to radially increase.

In order to improve the algorithm performance of the automatic method of detecting the eddies, the AVISO velocity fields are linearly interpolated from the 1/8° × 1/8° grid to 1/16° × 1/16° as performed by Liu et al. (2012). The number of grid points from a reference one