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Environmental factors controlling particulate mass fluxes on the Mallorca continental slope (Western Mediterranean Sea)

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ABSTRACT

Settled material recorded by two near bottom sediment traps deployed from November 2009 to February 2011 at northern (Sóller) and southern (Cabrera) slopes of Mallorca Island (Western Mediterranean) is studied with the aim of discerning their possible origin. The total settled particulate mass fluxes (TMF) at Sóller station were found to be, on average, 2.8 times greater than at Cabrera location during the deployment period, although both time series had a similar temporal evolution. It is suggested that wind episodes affecting the entire area were the common forcing, causing a primary production enhancement and being responsible of the similar temporal behavior. The greater sediment amounts collected in Sóller are explained on the basis of two physical mechanisms: 1) a number of successive eddies generated by instabilities of the Balearic Current that are regularly observed on satellite images, some of which have been reported to reach the seabed, thus increasing near bottom velocities and causing sediment resuspension. And 2) bottom trapped waves that are evidenced from a wavelet analysis in Sóller which could affect the TFM by enhancing sediment resuspension or advecting material from the surrounding areas.

1. Introduction

The Balearic Islands, an archipelago located on the Western Mediterranean, are the natural boundary separating the Balearic and the Algerian sub-basins of the Mediterranean Sea (Fig. 1). These two sub-basins are connected via the channels between the islands. The northernmost channel, located between Menorca and Mallorca Islands (known as Menorca Channel) is the shallowest (100 m depth) and narrowest (35 km). Between Mallorca and Ibiza Islands, there is the Mallorca channel. This connection is around 80 km width and with a maximum depth of 600 m. The deepest channel (~800 m) is the Ibiza channel, located between Ibiza Island and cape La Nao, in the Iberian Peninsula. The continental shelf of the archipelago in the Balearic sea side is relatively narrow (5–20 km) finishing with a steep slope. In the Algerian subbasin side, the width of the shelf is similar but the slope is even steeper, changing in a few kilometers from 500 m to more than 2500 m depth. Further details on the topographic characteristics of the region can be found, for example, in García et al. (1994) or Massutí et al. (2014–in this issue).

Two density fronts define the mean currents in the Balearic Sea. The Northern Current (NC) flows southwards from the Gulf of Lyons down to the Ibiza Channel where partially diverts cyclonically joining the Balearic Current (BC), which flows northeastward along the Islands slope (Fig. 1). Depending on the mesoscale situation, the flow between the channels presents different configurations, with most of the NC leaving the Balearic sub-basin through the Ibiza Channel or being reflected and becoming part of the BC (Pinot et al., 2002). On the contrary, the part of the Algerian subbasin affecting the Balearic Islands does not have a clear current pattern and its hydrodynamics is completely dominated by mesoscale processes such as eddies.

Two different processes mainly contribute to the presence of particles in the water column in the studied area: the primary production (PP) and the resuspended material from the seabed.

PP takes place in the uppermost layers of the ocean, where light and nutrients are available for primary producers to transform CO_2 into organic carbon. The limiting factors to PP are the nutrient availability such as N, Si, P and Fe. Surface chlorophyll concentrations obtained from ocean color satellite-derived measurements (Chl-a) are considered a quantification of phytoplankton biomass and become an indicator of the photosynthetic fixation of C (Falkowski et al., 2002). The process by which the particulate organic carbon is removed from the euphotic zone and transported to the oceanic interiors is known as the biological pump. This process operates ubiquitously in the pelagic ocean (Honjo et al., 2008) and is driven by bio-physical processes that enhance the particle production and settling into the water column.

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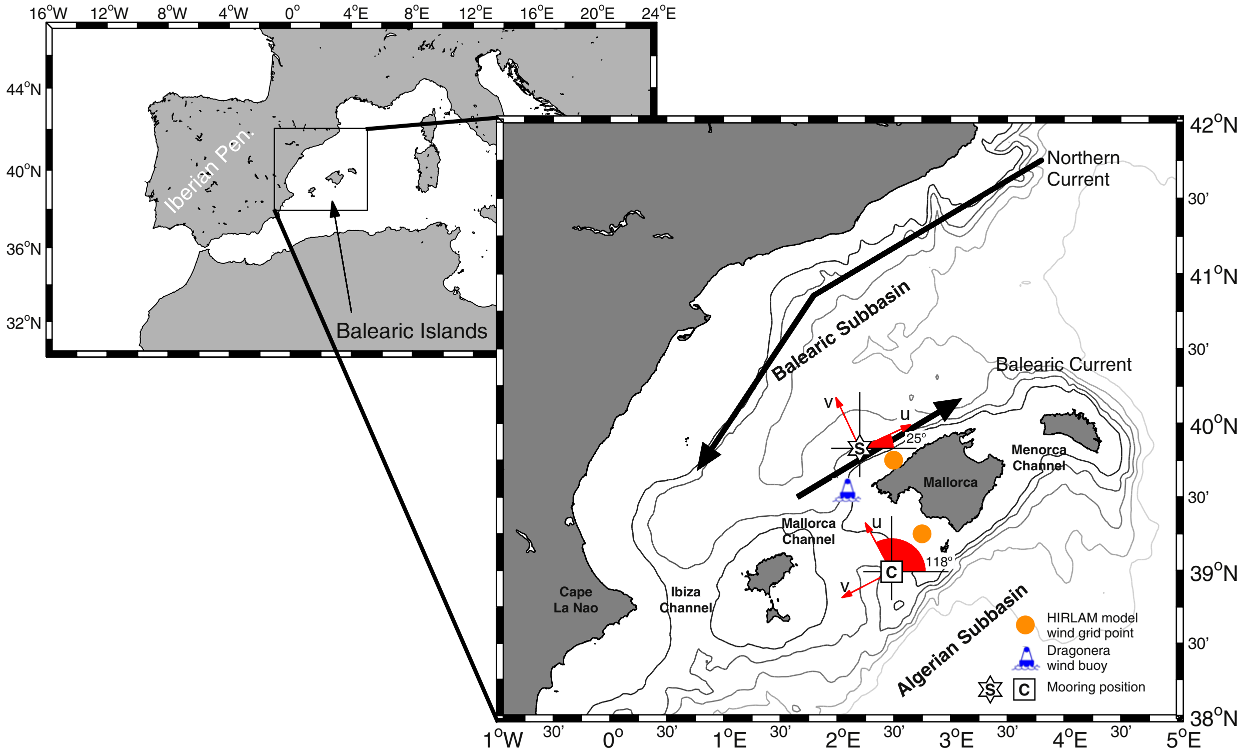

Fig. 1. Map of the zone of interest. Black arrows show the permanent currents of the zone. Sóller and Cabrera moorings are marked with an S surrounded by a star and with a C surrounded by a square. The decomposition in along- and across-slope components is indicated on the mooring position. The position of the Dragonera wind buoy is shown by a blue buoy. Orange dots mark the location of the HIRLAM model wind points used. Isobaths are plotted between 500 m and 2500 m with a step of 500 m.

In the classic work by Gage and Tyler (1991), it was considered that deep ecosystems were generally food-limited ecosystems, where the main entrance of organic matter corresponded to the contributions from the photic zone of the water column. However, in recent years different studies (Danovaro et al., 2001; Pusceddu et al., 2010) have shown that certain parts of the deep basins operate as zones of accumulation of organic matter due to their hydrodynamic, climate or physiographic conditions (Lopez-Fernandez et al., 2013). Among the various proposed mechanisms that would generate resuspension of sediments of the continental slope and the deep basin in the NW Mediterranean Sea are: interaction between geostrophic currents and bathymetry (Puig et al., 2001), the open-sea convection (Martín et al., 2010; Stabholz et al., 2013), cascading of dense shelf waters (Canals et al., 2006; Pasqual et al., 2010) and coastal severe storms (Sanchez-Vidal et al., 2012). These events play an important role in the oceanic carbon cycle and in the maintenance of the nektobenthic deep communities, as for example in the reproductive and recruitment processes of crustacean decapods (Company et al., 2003) and mitigating the general trend of overfishing (Company et al., 2008).

One main feature that distinguishes the Balearic Islands is the absence of fluvial contributions and geomorphologic structures such as submarine canyons. The lack of these characteristics hinders the particle transference from the upper near coast layers to the deeper interior-basin layers, having as a result an oligotrophic environment.

The aim of this work is to identify the environmental factors that take part in the particle fluxes in the Balearic Islands deep slope through the data recorded from two mooring lines each one located in an area of fishing interest (Massutí et al., 2014–in this issue). The isolation from strong lateral continental sediment sources (i.e., river inputs and submarine canyons) allows delimiting the role of atmospheric factors and local dynamics on the particle flux settling. This will be assessed by performing an analysis of the environmental factors and by studying their relation with settled mass particles recovered from sediment traps during more than one year.

The paper is structured as follows: the methodology and the data sets used are described in Section 2. In Section 3 some hypothesis are raised about the origin of the measured sediment fluxes as deduced from their variability and composition. Ecological implications are indicated in Section 4 and some conclusions are presented in the last section.

2. Data sets and methodology

Two mooring lines were deployed over the northern and southern slopes of Mallorca Island (Fig. 1). One mooring was located at the gentle part of continental slope at the Balearic sub-basin (Sóller station, 39°49.682′N–02°12.778′E) and the second one was placed in the eastern side of the Central Depression (Acosta et al., 2003), between the Cabrera Island and the Emile Baudot seamount (Cabrera station, 38°59.484′N–02°28.907′E).

Both lines, deployed at a depth around 900 m, were structurally identical, with 600 m height over the seafloor. They had 4 SeaBird 37 CTD (300 m, 500 m, 700 m and 900 m depth), 2 current meters Nortek Aquadopp (500 m and 900 m) and a PPS3 Technicap sequential sampling sediment trap (12 collecting cups, 0.125 m^2 opening and 2.5 height/diameter aspect ratio for the cylindrical part) located at 30 m above the bottom, paired with one of the Nortek Aquadopp current meter and a SeaBird 37 CTD. A complete description of the hydrodynamic data recorded may be found in Amores and Monserrat (2014).

The mooring lines were continuously recording data from mid-November 2009 to mid-February 2011. During this time, the instruments operated correctly, although the sediment trap records presented some gaps. Data gaps in March 2010 (10/3 to 18/3) were due to mooring maintenances; the longer gaps from 5th July to 21th September