Benthic storms in the north-western Mediterranean continental rise caused by deep dense water formation

Pere Puig[1], Albert Palanques[1], Jacobo Martín[2], Marta Ribó[1] and Jorge Guillén[1]

1 Institut de Ciències del Mar (ICM-CSIC), 08003 Barcelona, Spain. ppuig@icm.csic.es
2 Centro Austral de Investigaciones Científicas, 9410 Ushuaia, Argentina.

Abstract: *The north-western Mediterranean Sea is a well-known region where dense water formation occurs on a yearly basis due to winter heat losses and evaporation caused by cold and dry northerly winds. Dense waters are formed offshore by open-sea convection, but also on coastal regions along the Gulf of Lions shelf, from where they overflow the shelf edge and cascade downslope until reaching their equilibrium depth. During severe winters, both convection and cascading can reach the basin (>2000m depth), increasing bottom currents and inducing sediment resuspension. To investigate in detail this process, a focused analysis of time series observations collected in the north-western Mediterranean continental rise during winter 2012 has been conducted. Several peaks of suspended sediment concentration coincident with enhanced current speeds were observed during the spreading phase of newly formed dense water. Maximum concentrations reached ~9mg/l while associated current increases ranged between 20 to 40cm.s^{-1}. Such sediment resuspension events can be considered "benthic storms" and play a major role in the redistribution of sediment particles along this region, presumably contributing to the development of a large field of muddy sediment waves found in the continental rise south from Cap de Creus and La Fonera submarine canyons.*

Key words: *dense water formation, resuspension, benthic storm, sediment waves, north-western Mediterranean.*

INTRODUCTION

Recent studies have evidenced that deep-water formation processes in the north-western Mediterranean can increase deep-sea bottom currents and induce active sediment resuspension on the basin seafloor (Martín et al., 2010; Puig et al., 2012; Stabholz et al., 2013). Such energetic events have been observd in deep-sea regions elsewhere, and based on the Hollister and McCave, (1984) definition, they can be categorized as "benthic storms". However, the exact mechanisms involved in the sediment resuspension and transport are not well elucidated, since these previous studies mainly rely on data collected with moored sediment traps.

Additionally, this region is characterized by a large field of muddy sediment waves that develops south from Cap de Creus and La Fonera submarine canyons (Fig. 1), which has been genetically related to the sediment transported by major (deep) dense shelf-water cascading events (Jallet and Giresse, 2005). This contribution aims to investigate in detail the sediment resuspension events during the "benthic storms" associated to major dense water formation episodes, and asses how the suspended sediments are redistributed along the north-western Mediterranean continental rise.

DATA

As part of the FOFA and PERSEUS projects, an instrumented mooring line was deployed at ~2450m depth (41º 38.9'N / 4º 11.4'E) from 15 October 2011 to 27 July 2012, over a field of sediment waves south of La Fonera canyon mouth (Fig. 1). The array included three levels of measurements (surface, mid-waters and near-bottom) including on each one a current meter and a sequential sediment trap. The near-bottom current meter was moored just 10 meters above the seafloor and included a turbidimeter and a high precision CTD probe. For the purpose of this contribution, only the data from this current meter, which collected data at 10 minutes sampling interval, will be presented. The turbidimeter measured in Formazine turbidity units (FTU) that were converted to suspended sediment concentrations (SSC) using the general equation from Guillén et al. (2000): SSC = 0.79FTU.

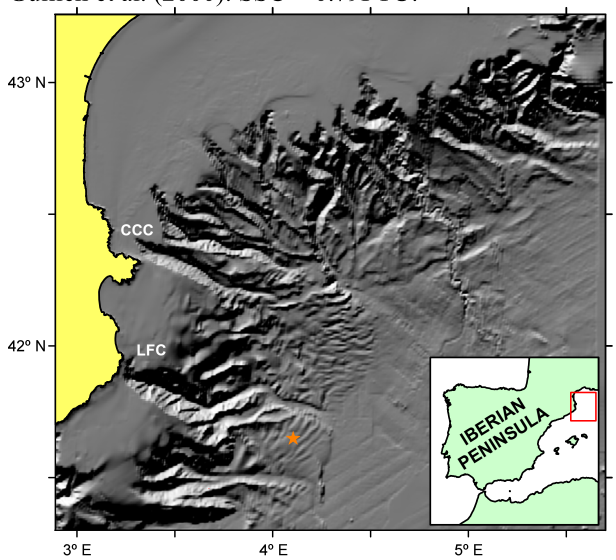

FIGURE 1. Shaded relieve map of the north-western Mediterranean continental margin showing the location of the instrumented mooring (star) and the field of sediment waves that develop on the continental rise. CCC: Cap de Creus Canyon; LFC: La Fonera Canyon.

RESULTS and DISCUSSION

During the first four months of the record, near-bottom potential temperature was quite constant (~12.9ºC), velocities were below 13cm.s^{-1} and SSC displayed constant background values ~0.1mg.l^{-1} with the exception of few isolated peaks <0.3mg.l^{-1} (Fig. 2). On 12 February 2012, current speed increased to values >30 cm/s and SSC peaked to ~1 mg/l for few hours. At the same day, temperature started to decrease gradually until a sharp drop of >0.4ºC, coincident with a second SSC peak ~1.5mg.l^{-1}, occurred four days later, on 16 February. The intrusion of such a cold water mass at the mooring site indicates the arrival to the basin of the signal from a major dense water cascading event that occurred during winter 2012. The fact that the near-bottom currents increased slightly before reflects the occurrence of a concurrent deep open-sea convention event that preceded the cascading process (see Durrieu de Madron et al., 2013 for further details).

After this first cascading outburst, near-bottom temperature, current speed and SSC progressively tended to recover previous values until a second drop in temperature (>0.3ºC) occurred on 25 February 2012. On this occasion, currents exceeded 40cm.s^{-1} and several SSC peaks ~9mg.l^{-1} were recorded (Fig. 2). These high concentrations contrast with previous observations in the same region that recorded SSC increases <6mg.l^{-1} during similar resuspension events linked to deep water formation processes, when cascading was less intense (Puig et al., 2012). Low temperature values persisted for more than a month and high current speeds lasted for almost four months, showing a fluctuating pattern of few days or weeks, presumably related to the passage of near-bottom eddies. During this period, SSC displayed several increases (>1mg.l^{-1}), not always coincident with maximum velocities, which denote the formation and maintenance of a bottom nepheloid layer that was being advected and redistributed along the rise and basin.

ACKNOWLEDGEMENTS

This work has been funded by PERSEUS (FP7-OCEAN-2011-3-287600) and FORMED (CGL2012-33989) projects.

REFERENCES

Durrieu de Madron, X., Houpert, L., Puig, P., Sanchez-Vidal, A., Testor, P., et al., 2013. Interaction of dense shelf water cascading and open-sea convection in the Northwestern Mediterranean during winter 2012. Geophysical Research Letters 40, 1379-1385.

Guillén, J., Palanques, A., Puig, P., Durrieu de Madron, X., Nyffeler, F., 2000. Field calibrations of optical sensors for measuring suspended sediment concentrations in the Western Mediterranean. Scientia Marina 64, 427-435.

Hollister, C.G., McCave, I.N., 1984, Sedimentation under deep-sea storms. Nature 309, 220-225.

Jallet, L., Giresse, P., 2005. Construction of the Pyreneo-Languedocian Sedimentary Ridge and associated sediment waves in the deep western Gulf of Lions (Western Mediterranean). Marine and Petroleum Geology 22, 865-888.

Martín, J., Miquel, J.C., Khripounoff, A., 2010. Impact of open sea deep convection on sediment remobilization in the western Mediterranean. Geophysical Research Letters 37, L13604.

Puig, P., Palanques, A., Martín, J., Ribó, M., Font, J., 2012. Sediment resuspension events in the northwestern Mediterranean continental rise. Geo-Temas 13, 1840-1843.

Stabholz, M., Durrieu De Madron, X., Canals, M., Khripounoff, A., Taupier-Letage, I., et al., 2013. Impact of open-ocean convection on particle fluxes and sediment dynamics in the deep margin of the Gulf of Lions. Biogeosciences 10, 1097-1116.

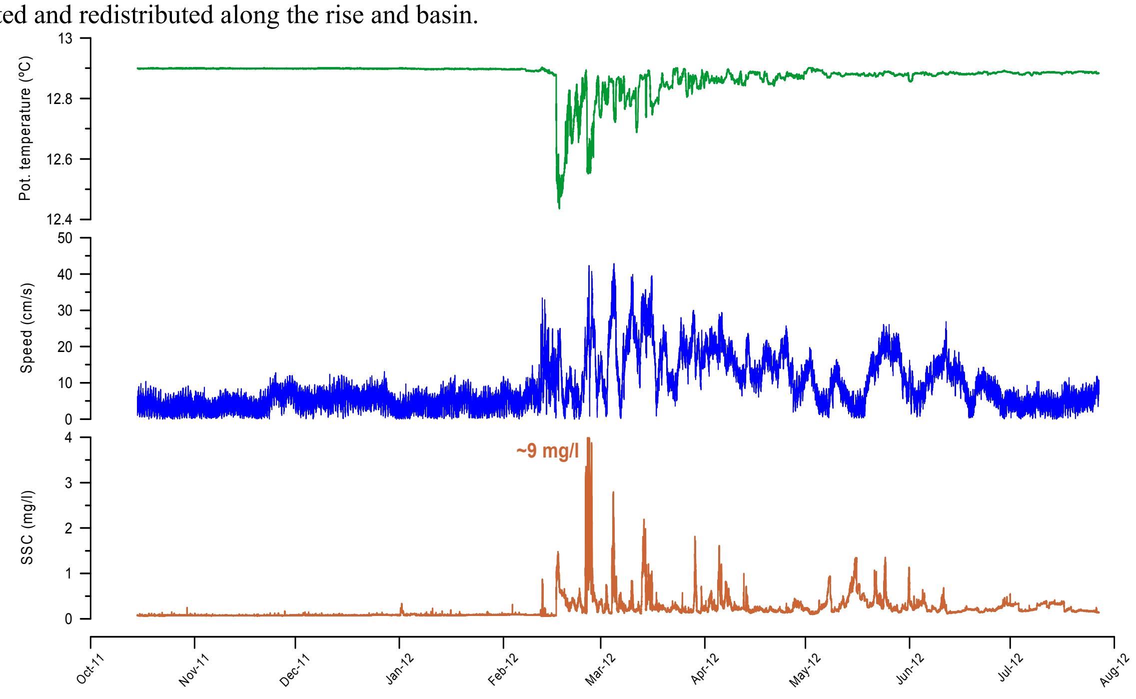

FIGURE 2. Time series of potential temperature, current speed and suspended sediment concentration (SSC) during the studied deployment.