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Climate changes in south western Iberia and Mediterranean Outflow variations during two contrasting cycles of the last 1 Myrs: MIS 31–MIS 30 and MIS 12–MIS 11

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ABSTRACT

Grain size analysis and physical properties of Sites U1388, U1389 and U1390 collected in the Contourite Depositional System of the Gulf of Cádiz during the Integrated Ocean Drilling Program (IODP) Expedition 339 "Mediterranean Outflow" reveal relative changes in bottom current strength, a tracer of the dynamics of the Mediterranean Outflow Water (MOW), before and after the Middle Pleistocene Transition (MPT). The comparison of MOW behavior with climate changes identified by the pollen analysis and $\delta^{18}O$ benthic foraminifera measurements of Site U1385, the Shackleton Site, collected in the south western Iberian margin shows that the interval MIS 31–MIS 30, ~1.1–1.05 million years ago (Ma), before the MPT, was marked by wetter climate and weaker bottom current than the interval MIS 12–MIS 11 (0.47–0.39 Ma), after the MPT. Similarly, the increase in fine particles from these glacials to interglacials and in coarse fraction from interglacials to glacials was coeval with forest and semi-desert expansions, respectively, indicating the lowering/enhancement of MOW strength during periods of regional increase/decrease of moisture. While these findings may not necessarily apply to all glacial/interglacial cycles, they nonetheless serve as excellent supporting examples of the hypothesis that aridification can serve as a good tracer for MOW intensity. The strongest regional aridity during MIS 12 coincides with a remarkable increase of coarse grain size deposition and distribution that we interpret as a maximum in MOW strength. This MOW intensification may have pre-conditioned the North Atlantic by increasing salinity, thereby triggering the strong resumption of the Meridional Overturning Circulation that could contribute to the great warmth that characterizes the MIS 11c super-interglacial.

1. Introduction

The warm and saline water plume formed by the Mediterranean Outflow exiting the Strait of Gibraltar between 500 and 1400 mbsl is a prominent feature that presently enhances the water density in the North Atlantic, thereby affecting deep convection in the North Atlantic that regulates the Meridional Overturning Circulation (MOC) (Rogerson et al., 2006; Hernández-Molina et al., 2014). Estimates from coarse resolution climate models suggest that without Mediterranean Outflow Water (MOW), the Atlantic Meridional Overturning Circulation (AMOC) would be reduced by ~15% and North Atlantic sea surface temperatures would fall by up to 1 °C (Rogerson et al., 2012; Ivanovic et al., 2013). Other model simulations show that the position of the North Atlantic subtropical and subpolar gyres is very sensitive to MOW intensity (cf. New et al., 2001). For example, an enhanced MOW induces an amplified current crossing the Atlantic from Florida to the Canary Current leading to a more zonal position of the subtropical gyre and a weakening of the North Atlantic Drift that reaches the subpolar gyre and Nordic Seas. In contrast, a strong decrease in MOW might slowdown this current, thus changing the shape of the subtropical gyre and enhancing the North Atlantic Drift. Variations in the strength of MOW can therefore affect not only the AMOC, but also the climate in general and, in particular, that of Europe (e.g. Lohmann et al., 2009). Conversely, climate in high and low latitudes of the North Atlantic region, affects the present-day Gibraltar water exchange (Rogerson et al., 2012). For example, outbursts of cold dry air in winter from the European continent induce surface water cooling and deep convection in the Mediterranean

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Basin that contribute to the formation of MOW (Candela, 2001). Alternatively, reduced evaporation in the Mediterranean region and more northerly and stronger African monsoon rainfall would reduce salinity in the Mediterranean and, therefore, the Gibraltar exchange (Rogerson et al., 2012).

Previous studies suggest strong relationships between changes in MOW intensity and position, and the orbital and millennial scale variability of Greenland and the North Atlantic; e.g., D–O cycles and Heinrich events (Rogerson et al., 2006, 2012; Voelker et al., 2006; Llave et al., 2006; Toucanne et al., 2007). These studies show that repeated MOW increases occurred during decreases in air surface temperature and precipitation in the western Mediterranean region and, particularly during Heinrich events when AMOC decreased (Voelker et al., 2006). However, few studies address the relationships between MOW variability and regional climate during older periods beyond the last climatic cycle (e.g. Llave et al., 2006; Voelker and Lebreiro, 2010), partly because of the scarcity of paleoclimate records (e.g. Joannin et al., 2011) of air surface temperature and precipitation changes during those periods in the Mediterranean region.

During the Early to the Late Pleistocene including the Middle Pleistocene Transition (MPT, ~0.9–0.65 Ma, Maslin and Ridgwell, 2005), when the dominant cyclicity changed from 41,000 to 100,000 year-cycles, the MOW became sequentially shallower suggesting the increase of the density contrast between Atlantic and Mediterranean water (Rogerson et al., 2012). It has been hypothesized that the shoaling of the MOW and its intensification are indicators of ice volume increase and Mediterranean aridity (e.g. Llave et al., 2006; Rogerson et al., 2012). The objective of this work is testing the second hypothesis using several high-resolution sedimentary sequences and focusing on Marine Isotope Stage (MIS) 31–MIS 30 (from 1.1 to 1.05 Ma) and MIS 12–MIS 11c (from 0.47 to 0.39 Ma) collected during the IODP Expedition 339 "Mediterranean Outflow" in the southwestern Iberian margin and Gulf of Cádiz. These intervals are ideally suited to test the aforementioned hypothesis. The LR04 stack record suggests that the most recent interval is characterized on average by larger ice sheets and more marked cold glacial and warm interglacial periods than the MIS 31–MIS 30 interval (Lisiecki and Raymo, 2005). Previous studies additionally show the regional wet character of the cycle before the MPT (Joannin et al., 2011) when compared with the cycles after 400 ka (e.g. Sánchez Goñi et al., 1999; Roucoux et al., 2006). No data are available for MIS 12 and no indicator of aridity, i.e. pollen percentage of semi-desert plants, has been published for MIS 11 so far.

2. Present-day environmental context

Climate in the southern Iberian continental margin, including the Gulf of Cádiz, is directly affected in winter by the North Atlantic westerlies, while a high pressure cell develops in the North Atlantic during summer. This seasonality of climate is characterized by mild winters (m: 5–1 °C; M: 13–8 °C) and hot and dry summers (*P*ann < 600 mm) (Peinado Lorca and Martínez-Parras, 1987), and lead to the development of a Mediterranean vegetation in the adjacent landmasses dominated by deciduous oak at middle elevation, and evergreen oak, olive tree, *Pistacia*, *Phillyrea* and rockroses (*Cistus*) at lower elevations (Blanco Castro et al., 1997). Experimental studies on the pollen representation of western Iberian vegetation in the sediments of its margin (Naughton et al., 2007) show that marine pollen assemblages give an accurate and integrated image of the regional vegetation occupying the adjacent continent. Present-day Mediterranean and Atlantic forest communities of Iberia are well discriminated by south and north marine pollen spectra, respectively (Naughton et al., 2007).

The dynamics of the North Atlantic subtropical gyre dominate the oceanic surface currents on the southern Iberian margin (Stramma and Siedler, 1988). The waters are under the influence of the Portuguese Current, the southern branch of the North Atlantic Current a part of the eastern North Atlantic subtropical gyre (Péliz et al., 2005). The intermediate layers are directly affected by the MOW that causes the formation of contourite deposits along the middle slope (e.g. Llave et al., 2007).

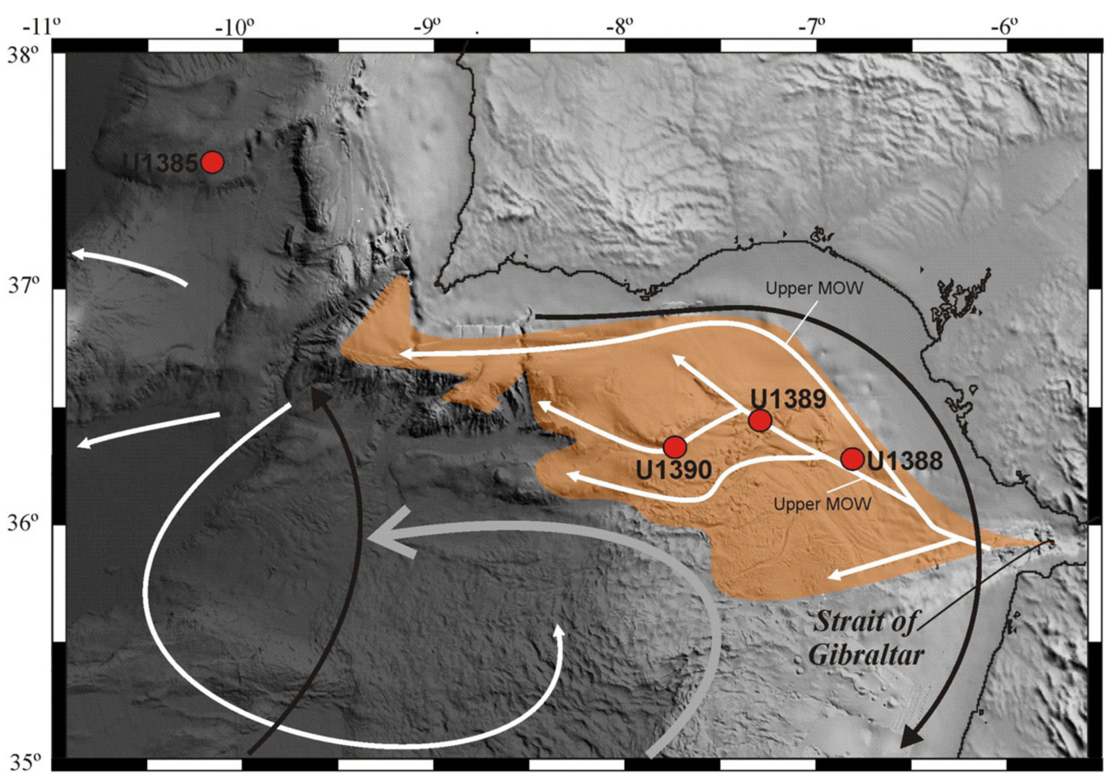

Fig. 1. Location of the cores on the CDS (Contourite Depositional System of the Gulf of Cadiz) (orange area), and circulation of the main water masses. Black arrows: NASW (North Atlantic Surficial Water); white arrows: MOW (Mediterranean Outflow intermediate Water); gray arrow: NADW (North Atlantic deep Water).