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Distribution and circulation of water masses in the Gulf of Cadiz from in situ observations

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Abstract

From data collected during GOLFO 2001 survey, a study was conducted on the circulation and distribution of water masses in the Gulf of Cadiz in the spring of 2001. The general surface circulation in the Gulf of Cadiz is anticyclonic with short-term, meteorologically induced variations. North Atlantic Central Water (NACW) ($\gamma_t = 26.6-27.3\,\mathrm{kg\,m^{-3}}$) is a representative water mass of the upper 1000 m of the water column. To the north, the lower part of the NACW layer ($\gamma_t = 27.3\,\mathrm{kg\,m^{-3}}$) is entrained by Mediterranean Water (MW) towards the open ocean while the upper layer ($\gamma_t = 26.6\,\mathrm{kg\,m^{-3}}$) forms part of the anticyclonic surface circulation of the Gulf of Cadiz. NACW mainly upwells in the vicinity of Capes St. Vincent and St. Maria. The upwelling off Cape St. Vincent is an open-sea process linked to a positive wind curl over the area, whereas the upwelling off Cape St. Maria is a more likely coastal process with a short time response to changes in the wind regime. The waters upwelled off Cape St. Vincent move eastwards following the main current until reaching ~7.5 °W, where they form the filament of Cape St. Maria, whose core flows at about 40–50 m. Wind changes from westerlies to easterlies produce important temporal variability in some spatial features (the upwelling off Cape St. Maria, the surface signature of the Huelva Front or the region of warm coastal waters) in a relatively shallow layer. Below this surface layer, the hydrological characteristics are fairly independent of meteorological forcing.

Keywords: Gulf of Cadiz; Water masses; Geostrophic circulation; Upwelling processes; Cape St. Maria filament; Wind-induced variability

1. Introduction

The Gulf of Cadiz is the sub-basin of the North Atlantic nearest to the Strait of Gibraltar. Its northern, eastern and southern boundaries are well-defined by the southwest coasts of the Iberian Peninsula and by the Strait of Gibraltar and the Atlantic coast of Morocco, respectively. The western limit can be defined by the 9 °W meridian. On the Iberian coast, the most relevant geographical features are Cape St. Maria, Cape St. Vincent, and Cape Trafalgar (Fig. 1). To the east of Cape St. Maria the continental shelf is very wide (some

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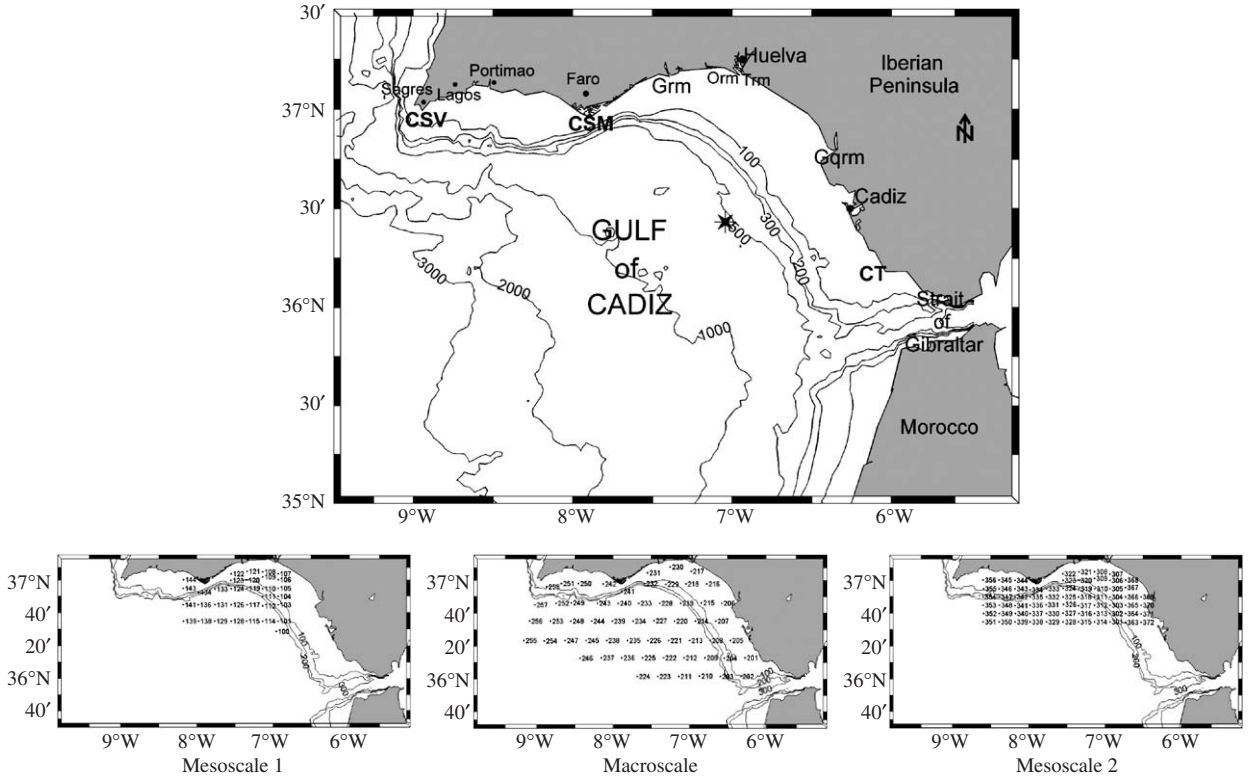

Fig. 1. Upper panel: Map of the Gulf of Cadiz showing the position of locations and other geographical features mentioned in the text. CT, CSM and CSV stand for Cape Trafalgar, Cape St. Maria and Cape St. Vincent, respectively. Grm, Orm, Trm and Gqrm stand for the mouths of Guadiana, Odiel, Tinto and Guadalquivir rivers, respectively. The star marks the position of the Red de Aguas Profundas (RAP) oceanographic buoy mentioned in the text. Lower panels show the station grid of the three legs (Mesoscale 1, Macroscale and Mesoscale 2) of GOLFO 2001 survey.

30–50 km) and has a gentle slope, whereas to the west it is narrow (<15 km) and its bottom is dotted with submarine canyons (Faro, Lagos, Portimao, St. Vincent, etc.).

The surface circulation of the Gulf of Cadiz, less studied than its deep circulation, is integrated into the general circulation of the Northeast Atlantic: the Azores current, which transports some 15 Sv between latitudes 35°N and 40°N to feed the Canary Current, frequently forms meanders that separate themselves from the main flow (Alves et al., 2002). Thus, the surface circulation of the Gulf of Cadiz could be understood as the last meander of the said Azores current. Part of this meander enters the Mediterranean Sea through the Strait of Gibraltar to balance evaporation and buoyancy losses within this Sea.

Stevenson (1977), combining in situ and sea-surface temperature (SST) satellite observations, identified an interesting thermal feature formed by a sequence of warm–cold–warm waters in NW–SE direction in the northeast part of the Gulf of Cadiz. Specifically, this feature is found between Cadiz and Huelva; Stevenson (1977) called it the 'Huelva Front'. Fiúza (1983), using wind data and SST images corresponding to the summer of 1979, correlated the occurrence of upwelling off the southwest coast of Iberia (and the appearance of the Huelva Front) with westerlies and the development of a warm coastal countercurrent stretching east–west with easterlies (Fiúza et al., 1982; Fiúza, 1983).

Folkard et al. (1997) analysed infrared SST satellite images throughout the year between July 1989 and March 1990 to provide a description of seasonal circulation patterns. An interesting outcome is the identification, at least in the summer months, of a bimodal pattern in SST images related to the wind regime. One of the patterns (related to westerlies) is characterised by an extension to the east of the upwelling off Cape St. Vincent, along with a signature of cold waters in the SE direction