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Water mass circulation on the continental shelf of the Gulf of Cádiz

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Abstract

Acoustic Doppler Current Profiler data collected during three successive surveys in the Gulf of Cádiz in May–June 2001 have been used to analyse the surface circulation on the continental shelves of the Gulf of Cádiz and how this circulation matches the circulation in the ocean side of the Gulf. The wider and larger eastern continental shelf holds a cyclonic circulation bounded at the south by a shelf-break jet that is identified with the Huelva front. The coastal current that closes the gyre at the north is identified with the warm counterflow mentioned in the literature. Under westerly winds, this counter current recirculates toward the east while recent upwelled water near Cape Santa Maria is advected downstream by the shelf-break jet, leaving the cold signature at the surface that has been identified historically with the Huelva front. Under easterlies, part of the coastal counterflow invades the western continental shelf while the remaining recirculates eastward to close the cyclonic cell. The western continental shelf and slope is occupied by a larger-scale cyclonic eddy that extends into the deep ocean. This eddy has vertical length scale of hundreds of metres and is linked to the general wind forcing in the area. Both cyclonic structures are bounded at the south by a jet that enters in the Gulf of Cádiz moving around the second eddy and eastward to feed the Atlantic inflow through the Strait of Gibraltar.

Keywords: Cape Santa Maria; Cape San Vicente; Upwelling filaments; Huelva front; Wind-driven flow

1. Introduction

The continental shelf in the Gulf of Cádiz is bounded by the isoline of 100 m depth. Off Santa Maria Cape (Fig. 1) the continental shelf is very narrow (less than 5 km wide) and ends in a continental slope that descends steeply to more than 600 m depth in less than 4 km. To the west, between Cape San Vicente and Cape Santa Maria (CSV and CSM hereinafter, respectively), the shelf widens to 15–20 km and it is cut by the Portimao submarine canyon, which extends down to 2000 m depth. East of CSM the continental shelf quickly widens to more than 40 km off Guadalquivir River (Fig. 1). Therefore, CSM divides the continental shelf into two halves, which may make the circulation in each half independent from the other.

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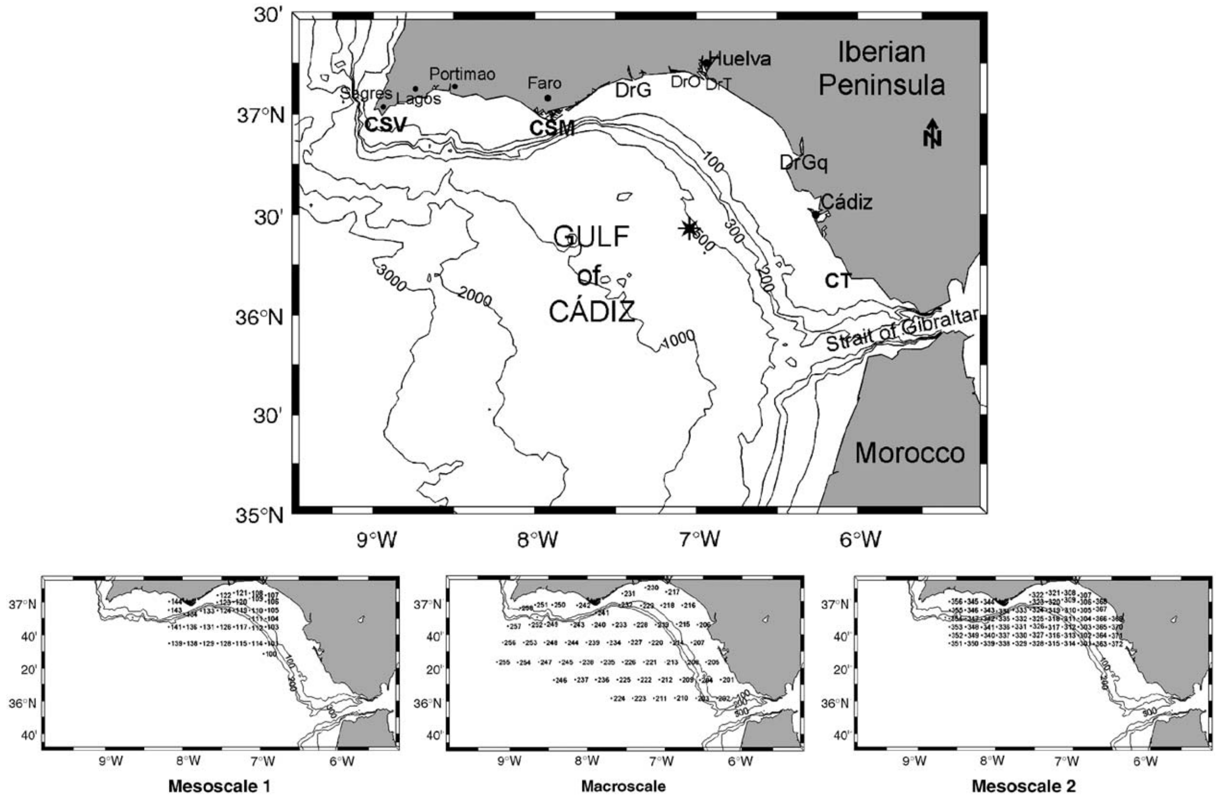

Fig. 1. Upper panel: map of the Gulf of Cádiz showing the position of locations and other geographical features mentioned in the text. CT, CSM and CSV stand for Cape Trafalgar, Cape Santa Maria and Cape San Vicente, respectively. DrG, DrTO and DRGq stand for the mouths of Guadiana, Tinto-Odiel, and Guadalquivir Rivers, respectively. The star marks the position of the *Red de Aguas Profundas* (RAP) oceanographic buoy mentioned in the text. Lower panels show the grid of stations of the three legs (Mesoscale1, Macroscale and Mesoscale2) of GOLFO 2001 survey.

Historically, studies on physical oceanography of the Gulf of Cádiz have focused on the Mediterranean water outflow more than the surface circulation. The reason is the importance that this warm and salty plume has for the large scale circulation of the Atlantic Ocean and, probably, in the global ocean (Ambar and Howe, 1979; Baringer and Price, 1997; Mauritzen et al., 2001; Ambar et al., 2002; Potter and Lozier, 2004). The surface circulation has not been investigated so extensively and the scientific literature is rather limited. Most of the studies deal with remotely sensed sea-surface temperature (SST), or climatological data (Fiúza et al., 1982; Fiúza, 1983; Folkard et al., 1997; Vargas et al., 2003; Sánchez and Relvas, 2003) and only a few papers analyse quasi-synoptic in situ data to depict the three-dimensional (3-D) structure of the mass field and its dynamics.

One of the first studies on the Gulf of Cádiz surface circulation was the descriptive work by Stevenson (1977) who, using infrared SST and visible satellite imagery, identified and named a series of surface thermal features. Stevenson (1977) identified the ‘‘Portuguese upwelling zone’’, the ‘‘Huelva front’’, the ‘‘Tarifa eddy’’, and the accumulation of warm surface water over the Spanish continental shelf. Nowadays, these features are better known but they are still far from being well understood.

The ‘‘Portuguese upwelling zone’’ corresponds to the noticeably colder signature of the upwelling area off CSV. According to Mazé et al. (1997) and Sánchez and Relvas (2003), its origin is related to the prevailing positive z-component of the wind-stress curl in the zone, which produces Ekman pumping and, consequently, a cyclonic circulation in the interior to match the isopycnal upraise. The extension of the upwelling area changes following the direction of winds. Westerlies induce coastal upwelling that enhances the former open-sea process and increases the upwelling area, whereas easterlies reduce its extension. Westerlies originate a