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Near-surface circulation in the southern Gulf of Cádiz

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Abstract

We have used several data sets (expandable bathythermograph sections, buoy trajectories, current-meter moorings, and surface wind stress) to investigate the temporal variation of the upper-thermocline (North Atlantic Central Waters) circulation patterns in the southern Gulf of Cádiz. The main data set consists of eight expandable bathythermograph sections (two per season) running between the Strait of Gibraltar and Cape Beddouza, just offshore the continental slope and approximately parallel to the Morocco coastline. A salinity–temperature polynomial, obtained from historical conductivity–temperature-depth data, is used to infer dynamic properties (salinity, density, dynamic height, geostrophic velocity and transport). Dynamic heights are calculated referred to the 1027.25 kg m^{-3} neutral density surface, which we justify is a good reference level for this section. These observations are then combined with a process-oriented, one-layer, quasigeostrophic model for the northeastern corner of the North Atlantic subtropical gyre with modified eastern boundary conditions. The results indicate the existence of about 1 Sv onshore transport all year long into a 300 km long coastal transition zone off Morocco, which must follow south as a narrow current. During winter the flow is zonal towards the slope and recirculates south as a very narrow jet of less than 100 km width. During summer the flow probably becomes more intense but is deflected southeastward before reaching the slope, such that the onshore geostrophic transport into the coastal transition zone decreases and the recirculating band widens.

Keywords: Salinity–temperature algorithms; Mass exchange; Quasigeostrophic model; North Atlantic Central Water; Strait of Gibraltar; Gulf of Cádiz (10.5−5.5W/33.5−37.5N)

1. Introduction

The denomination Gulf of Cádiz is commonly left to the zonal embayment in the Atlantic southern end of the Iberian Peninsula, some times even to the region between Cape Santa María and the Atlantic end of the Strait of Gibraltar. In this work, however, we follow several authors (Batteen et al., 2000; Mauritzen et al., 2001) and use this denomination for a much larger embayment: the Atlantic region west of the Strait of Gibraltar that goes from Cape San Vicente, in the southwestern tip of the Iberian Peninsula, to Cape Beddouza, at about 32.6°N in the Morocco coast (Fig. 1).

The Gulf of Cádiz defined with this wide prism is a single oceanographic unit in many regards, particularly in terms of its near-surface circulation.

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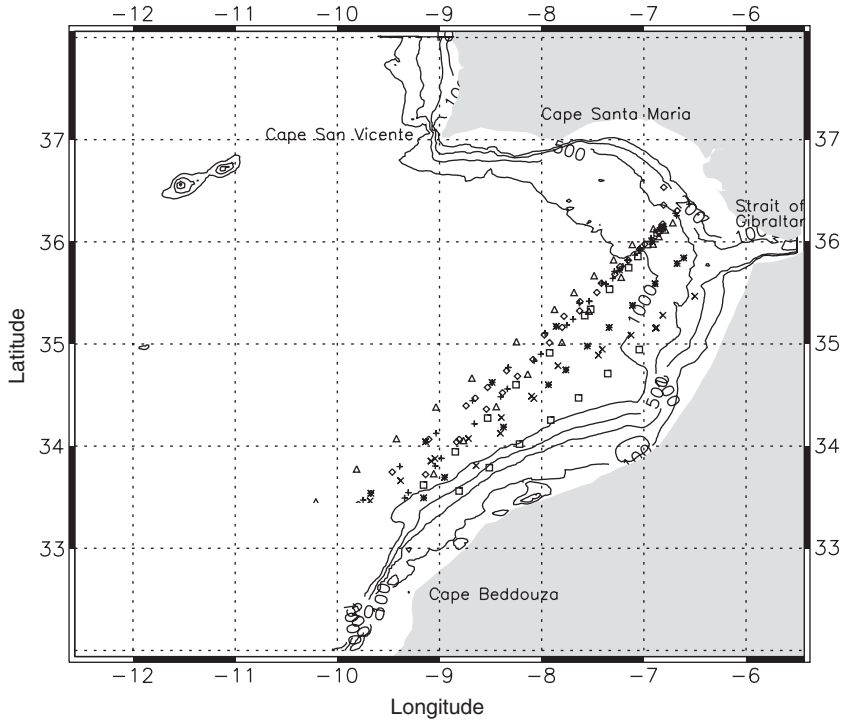

Fig. 1. Location of XBT stations in the southern Gulf of Cádiz.

These near-surface layers are formed by upper-thermocline North Atlantic Central Waters (NACW) that stretch down to at least the level of minimum salinity, some 36.0 units at the Gulf's northern and eastern ends, and down to 35.6 units at its southern end (Ochoa and Bray, 1991; Mauritzen et al., 2001; Ambar et al., 2002). This level is located at about 300 m depth at the outflow from the Strait (some 6.5°W) but reaches about 600 m in the outer and southern portions. Below this level we find Mediterranean Water (MW) and, in the southern portion, possibly Antarctic Intermediate Water (AAIW) (Iorga and Lozier, 1999; Hernández-Guerra et al., 2001). Further down we find North Atlantic Deep Water (NADW) (Mauritzen et al., 2001; Ambar et al., 2002).

What uniquely characterizes the NACW circulation patterns in this region is the existence of water inflow towards the coastal region, not only into the Strait of Gibraltar but also in the region along the African coast to Cape Beddouza. This is a remarkable feature in many flow representations for the surface layers: dynamic heights (Dietrich, 1969a,b; Maillard, 1984; Lozier et al., 1995), integrated transports (Stramma, 1984; Stramma and Siedler, 1988), surface velocities (Johnson and Stevens, 2000) and potential vorticity contours (Pelegrí et al., 2005a). While about 1 Sv (Candela, 2001) flows into the Strait of Gibraltar, the above integrated transports suggest that some 1–2 Sv of near-surface waters recirculate south near the coastal transition zone between the Strait of Gibraltar and Cape Ghir (near 31°N) (Pelegrí et al., 2005b). Another fraction of NACW may recirculate west as the result of its incorporation into MW, but this appears to take place mainly in the outer Gulf of Cádiz (Ochoa and Bray, 1991). Further, Mauritzen et al. (2001) carried out several inverse model experiments and obtained a mean near-surface eastward transport of 2.3 Sv into the Gulf of Cádiz.

Despite its major importance as the easternmost region in the North Atlantic subtropical gyre, adjacent to the Strait of Gibraltar, the Gulf of Cádiz is a relatively under-sampled region. This lack of available measurements is particularly true for the southern portion of the Gulf of Cádiz. To our knowledge the only available hydrographic sections that cross meridionally the whole Gulf, into the slope off Northwest Africa, are two summer sections during the 1958 International Geophysical