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Spatial and temporal variability of phytoplankton in the Gulf of Cádiz through remote sensing images

Gabriel Navarro[a,b,*], Javier Ruiz[a]

[a]*Departamento de Oceanografía, Instituto de Ciencias Marinas de Andalucía, Consejo Superior de Investigaciones Científicas, 11510 Puerto Real, Cádiz, Spain*

[b]*Departamento de Biología, Facultad de Ciencias del Mar y Ambientales, Universidad de Cádiz, 11510 Puerto Real, Cádiz, Spain*

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Abstract

The temporal and spatial distribution of chlorophyll concentration in the Gulf of Cádiz (SW Spain) was analysed between 1998 and 2002 by remote sensing data from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS). Climatological and monthly averages showed the presence of more productive waters in the inner shelf of the basin, especially during spring and fall, according to the phytoplankton blooms observed. This pattern was further confirmed by the modes obtained with an Empirical Orthogonal Function (EOF) decomposition of weekly chlorophyll composite images performed for the whole period. The first EOF mode explained 20% of the variability and corresponded to the chlorophyll seasonality in the basin. The second EOF mode accounted for 10% of the variability and distinguished several regions with different oceanographic features in the area. Five zones could be identified among which, a coastal zone between Huelva and Cádiz, was found to show the highest chlorophyll concentration values. Local zonal winds, categorized as westerlies and easterlies, were coupled with differences in biological production. The former induced an increase in chlorophyll concentration whereas the latter caused a decrease in phytoplankton biomass. Rainfall and river discharge also affected markedly the chlorophyll concentration.

Keywords: Gulf of Cádiz; SW Spain; SeaWiFS; Chlorophyll patterns; AVHRR; EOF

1. Introduction

The Gulf of Cádiz (Fig. 1) is a wide basin located west of the Strait of Gibraltar between the Iberian Peninsula and the African continent. Surface waters from the North Atlantic feed the Mediterranean through the Strait after crossing this basin. The flux of Atlantic waters affects the oceanographic characteristics of surface waters in the Gulf and plays an important role in the regulation of circulation in the Mediterranean basin. However, little is known of surface dynamics in the Gulf since most of oceanographic research carried out in the basin has been focused on the study of the deep Mediterranean outflow (Baringer and Price, 1999) whose impact on upper waters is limited since it occurs at several hundreds meters depth.

Nevertheless, surface dynamics in the basin are diverse as evidenced from a few studies performed

*Corresponding author. Tel.: +34 956 832612; fax: +34 956 834701.
E-mail address: gabriel.navarro@icman.csic.es (G. Navarro).

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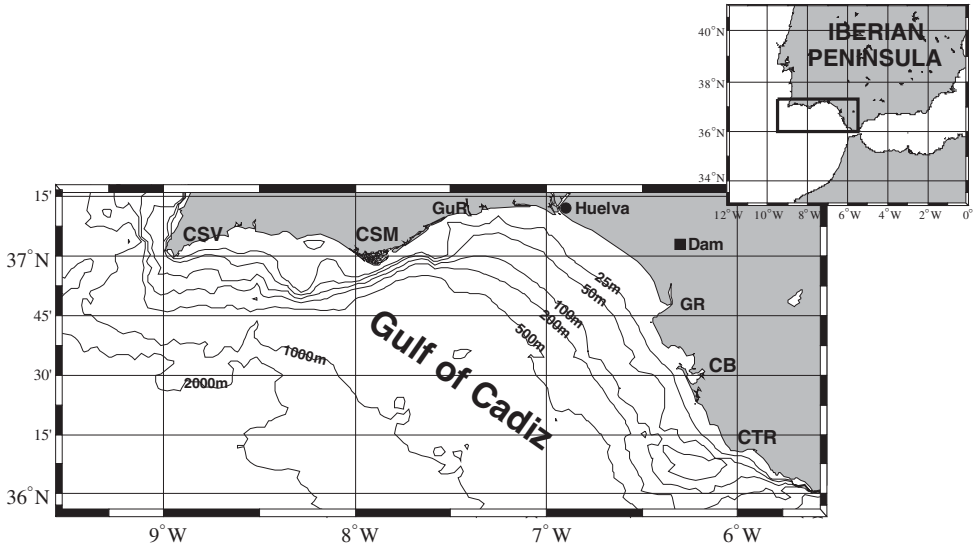

Fig. 1. Bathymetry and location map of the Gulf of Cádiz (square indicates the study area) sited in SW Spain. Letters indicate locations and geographic regions referred in the text: CSV-Cape San Vicente; CSM-Cape Santa María; GuR-Guadiana River; GR-Guadalquivir River; CB-Cádiz Bay; CTR-Cape Trafalgar, Huelva meteorological station (circle symbol) and Alcalá del Río dam. The black lines represent the bathymetry (25, 50, 100, 200, 500, 1000 and 2000 m).

aimed at identifying patterns from thermal images in conjunction with in situ measurements (Stevenson, 1977; Fiúza et al., 1982; Fiúza, 1983; Folkard et al., 1997; Vargas et al., 2003; Relvas and Barton, 2002; García-Lafuente et al., 2006; Criado-Aldeanueva et al., 2006). These studies have evidenced the existence of different structures in the Gulf: (i) a warm–cold–warm structure heading southeastward of Cape Santa María, namely the Huelva Front (Stevenson, 1977); (ii) areas of intense upwelling in the proximities of Cape San Vicente; and (iii) mixing zones at Cape Trafalgar (Fiúza et al., 1982; Fiúza, 1983; Folkard et al., 1997). These descriptive studies have been examined statistically through an Empirical Orthogonal Function analysis (EOF) of a long historical set of thermal images (Vargas et al., 2003). The analysis allowed the identification of a very stable, warm, anti-cyclonic circulation feature in the central part of the basin and another feature at the Iberian shelf, the presence of a fringe of coastal waters located between the Guadalquivir and Guadiana rivers. This fringe has a thermal characteristic, since Sea Surface Temperature (SST) is observed to be warmer with respect to rest of the basin in summer and colder in winter. Recent studies (García-Lafuente et al., 2006) have shown that the heating of waters near the Guadalquivir River mouth may cause the generation of a counter current detected in this area in the summer season.

Although all these oceanographic structures have been described in the basin, the majority of studies have been exclusively based on the analysis of thermal images of the Advanced Very High Resolution Radiometer (AVHRR) sensor but the influence of these structures on the spatial–temporal distributions of chlorophyll in the Gulf has not been examined. Only a few studies that use ocean colour images have been reported. Through daily images of Coastal Zone Colour Scanner (CZCS) sensor, Sousa and Bricaud (1992) precisely illustrated some pigment patterns in the Gulf of Cádiz, for example filaments in the vicinity of Cape San Vicente. In addition, Peliz and Fiúza (1999) presented a complete study on the spatial-temporal variability of surface pigments derived from CZCS around the entire Portuguese coast, which briefly included the Gulf of Cádiz.

The aim of this work was to perform the first combined analysis of both SST and surface chlorophyll concentration estimated from remote sensors between 1998 and 2002 in order to examine the physical and biological coupling in the Gulf of Cádiz. Based on the correlation found between the different patterns of variability and the oceanographic features, several zones are identified and described in the basin.