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Spatial analysis of the wind field on the western coast of Galicia (NW Spain) from in situ measurements

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Abstract

We used wind data measured at six meteorological stations to study their spatial representativity on atmosphere–ocean interactions along the western shelf of Galicia and inside the Ría of Vigo. The correlation as a function of distance and complex empirical orthogonal functions of the wind field were computed, allowing us to divide the region into three sub-domains: the open ocean, the shelf and the Ría of Vigo. Afterwards, wind gradients among stations were computed to determine specific spatial wind features: results showed an expected wind channelling effect inside the Ría of Vigo, but also a zonal onshore negative frictional gradient on the shelf that generates Ekman pumping during upwelling favourable winds. Finally, the Ekman transport estimated from meteorological stations was compared with measured transport from two moorings located inside the Ría of Vigo and on the shelf, and we determined that the meteorological station most representative of the wind field in the shelf is the one installed in a moored buoy on the shelf.

Keywords: Wind field; Spatial variations; Current meter; Upwelling index; CEOF; Ekman pumping; Galician shelf; Ría de Vigo; Spain

1. Introduction

The western coast of Galicia (NW Spain) constitutes the northern limit of a wind-driven upwelling system that extends along the eastern boundary of the North Atlantic Ocean between latitudes 10°N and 44°N, with a gap at the Strait of Gibraltar (Wooster et al., 1976; Fiuza et al., 1982). Many authors have related the seasonal variability of the shelf dynamics in this region to the evolution of the Azores High and the Iceland Low (Fiuza et al., 1982; Frouin et al., 1990; Vitorino et al., 2002; Álvarez-Salgado et al., 2003; Varela et al., 2005) in a cycle that can be roughly summarized as a summer season dominated by northerly upwelling favourable winds (Fraga, 1981; Fiuza, 1983) and a thermal low over central Iberia (Ferreira, 1984), while the winter season shows higher variability and rather frequent

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downwelling-favourable winds (Fiuza et al., 1982; Vitorino et al., 2002; Álvarez-Salgado et al., 2003).

Along the western coast of Galicia there are four embayments named "Rías Baixas", whose thermohaline and dynamical behaviour is affected by the shelf upwelling system. After analyzing observations and model results several authors conclude that the Rías behave alternating from positive (Fraga and Margalef, 1979) to negative estuaries linked, respectively, to the upwelling or downwelling situations in the shelf (Álvarez-Salgado et al., 1993; Míguez et al., 2001; Torres-López et al., 2001; Souto et al., 2003; Piedracoba et al., 2005).

On the other hand, several studies suggested that the wind field blowing along the western coast of Galicia is far from being spatially homogeneous. Bakun and Nelson (1991) found a strong cyclonic curl during the upwelling season near the coast of Iberia, with a maximum adjacent to the north-western coast. McClain et al. (1986) observed small anticyclonic wind-stress curl features associated to the Rías Baixas. Recently, Torres et al. (2003) performed a complex empirical orthogonal functions (CEOF) analysis of satellite wind field measurements and found a mode of variation in which the wind is opposite at both sides of a line joining Cape Fisterra and the point located at 42°N, 12°W (Fig. 1). As a consequence, wind observations at a single point are unlikely to be fully representative of the oceanographic conditions found both at the shelf and within the Rías Baixas.

This spatial inhomogeneity implies that particular care must be taken in this area to choose a wind time series in oceanographic studies. Historically, most on the shelf and Rías Baixas oceanographical studies used either wind measured at the Spanish Instituto Nacional de Meteorología (INM) Cape Fisterra meteorological station (42° 52′N 9° 15′W), or geostrophic winds estimated from a 2° × 2° cell centred at 43°N 11°W (Lavín et al., 1990, 2000), assuming that these points are representative of the overall Galician coast. But this hypothesis has never been tested.

On the other hand, the synoptic measurements of the wind field made by microwave radar installed on satellites could be, as a first estimate, a good solution for the problem of obtaining the location of wind measurements at different locations. In particular, the Sea Winds instrument of the Quickscat satellite has a spatial resolution of 25 km that enables the identification of fine-scale features in the wind field. Unfortunately, the Quickscat data has a 25 km offshore coastal mask, and its data cannot be reliably used at the Rías Baixas whose interior width is only of few kilometres. Also awkward is that Quickscat wind speed measurements range from 3 to 20 m s^{-1} and have an accuracy of about 2 m s^{-1} (JPL, 2001). The implications of the lowest threshold of the Sea Winds instrument when applied to the winds measured in the studied area will be discussed later.

The main aim of this paper is to quantify the suitability of all available meteorological stations in the western Galician shelf to adequately represent wind data at somewhat large distances. In other words, to answer the question of which meteorological station should be used with more confidence at this particular location. Particular emphasis will be focused on the traditional series of upwelling index and Cape Fisterra meteorological station, since both have been intensively used in the past (McClain et al., 1986; Castro et al., 1994; Álvarez-Salgado et al., 2003) for oceanographic purposes.

To accomplish this main objective, spatial differences among locations (in relevant aspects such as wind intensity and time correlation) will be computed, using a total of six accurate wind data time series obtained from January 2001 to October 2002, plus the Upwelling Index published by the Spanish Instituto Español de Oceanografía (IEO). The first part of the manuscript will be devoted to describe how these data were obtained and also to explain the methodology used in the analysis. Afterwards, results from the wind field correlation function over distance and from the CEOF analysis on the wind time series will be presented and discussed. Gradients in intensity of the wind field to study specific—not detectable in satellite data—spatial features of the shelf wind field will also be studied. The final part of the manuscript deals directly with our raised question, trying to identify which of the existing meteorological