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Hydrographic and atmospheric analysis of an autumnal upwelling event in the Ria of Vigo (NW Iberian Peninsula)

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Abstract

An autumnal upwelling event was observed in the Ria of Vigo (NW Iberian Peninsula) on 15th November 2001. This event was analyzed by means of thermohaline variables measured at CTD stations located in the study area, satellite sea surface temperature and wind data provided by QuikSCAT. Salinity and temperature distributions revealed that the upwelled water mass was Eastern North Atlantic Central Water (ENACW), typically observed during summer upwelling events. However, previous to the upwelling event, the characteristic autumnal body of water was recorded on 31st October 2001. Subsequent sea surface temperature and upwelling index corroborated the presence of an autumnal upwelling event of approximately 15 days duration. The probability of upwelling-favorable winds (from 1999 to 2004) was lower during autumn–winter than during spring–summer, although they may occur at any time of the year. Probabilities of ~45% were calculated for February and November, with the highest probability (65%) corresponding to July.

Keywords: autumnal upwelling; ENACW; thermohaline variables; wind; SST; Galician coast; Iberian Peninsula; QuikSCAT

1. Introduction

Coastal upwelling phenomena, which are attributed to wind forcing, have been largely studied along the worldwide eastern boundary systems. The major upwelling regions of the world in terms of primary production are the Canary Current System (Pelegri et al., 2005), the California Current System (Di Lorenzo, 2003), the Benguela Current (Fennel, 1999; Monteiro and Largier, 1999) and the Peru-Humboldt Current (Nixon and Thomas, 2001; Mesias et al., 2003).

The NW Iberian upwelling system has also attracted the interest of oceanographers since the 1970s (Fraga, 1981; Tenore et al., 1982; Blanton et al., 1984; Alvarez-Salgado et al., 1993; Pérez et al., 1995). The area is situated at the northernmost limit of the Eastern North Atlantic Upwelling System, which extends from 10° to about 44° N (Wooster et al., 1976). The western Galician coast, which lies within the NW Iberian upwelling system, consists of four rias known locally as the *Rias Baixas* (Fig. 1) which are characterized by a positive residual circulation pattern. Upwelling into the *Rias Baixas* is generally a spring–summer process characterized by favorable southward winds along the coast (Blanton et al., 1984), and pumps the cold nutrient-rich deep water mass Eastern North Atlantic Central Water (ENACW) into the rias (Ríos et al., 1992; Fiuza et al., 1998). The relationship between thermohaline variables and upwelling in this area has been extensively studied (Rosón et al., 1995, 1997; Alvarez-Salgado et al., 1996a,b, 2000; Nogueira et al., 1997a,b; Prego and Bao, 1997; Doval et al., 1998; deCastro et al., 2000, 2004; Prego et al., 2001; Pardo et al., 2001; Gómez-Gesteira et al., 2001, 2003; Alvarez et al., 2003; Dale et al., 2004).

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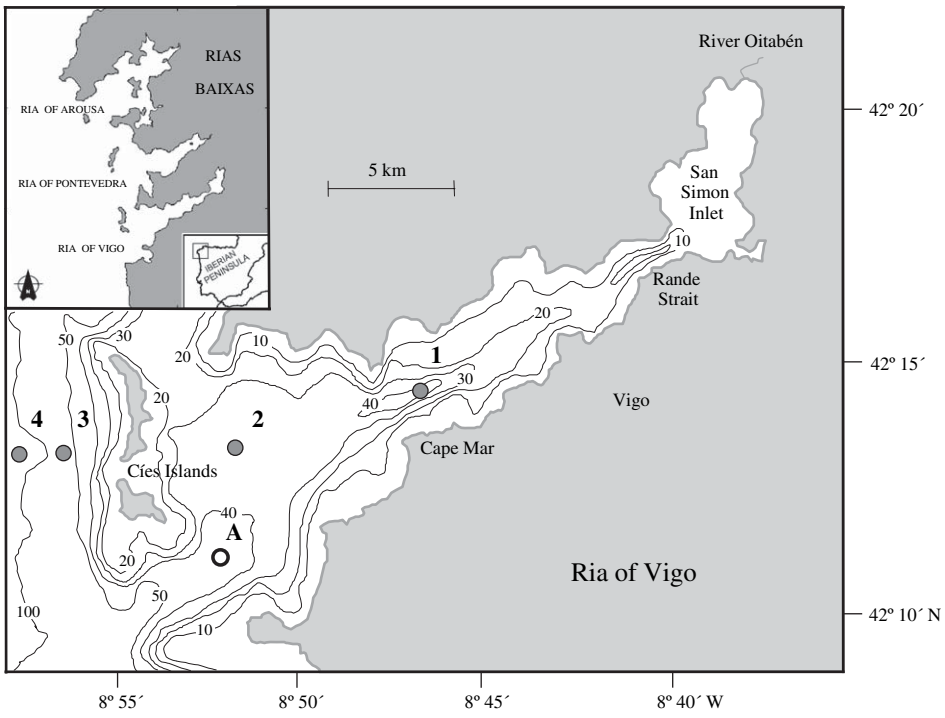

Fig. 1. Area under scope and thermohaline sampling stations 1–4. The circle A represents an additional thermohaline station situated at the southern mouth of Ria. The bathymetry (m) embraces the Cies Islands nature reserve and the Ria of Vigo.

During the upwelling events, a fraction of the plankton biomass produced inside the rias is exported offshore by the surface outgoing current. The organic material then undergoes remineralization in the water column or on the continental shelf (Fraga, 1981). This enrichment of the landward bottom currents with new and remineralized nutrients (Alvarez-Salgado et al., 1993) leads to the highly productive *Rias Baixas*. This cycle greatly influences the distribution patterns of larvae (Fusté and Gili, 1991; Riveiro et al., 2004) and reared mussel production (Blanton et al., 1987; Figueiras et al., 2002) and sustains large sardine fisheries (Guisande et al., 2004). However, a decline in zooplankton and phytoplankton in the North Atlantic and subsequent declines in the sardine fishery off the Portuguese coast have been associated with increased northerly winds (Dickson et al., 1988; Borges et al., 2003). In fact, Santos et al. (2001) statistically showed that the intensity and frequency of upwelling events during the spawning season (winter) have a negative impact on the recruitment of small pelagic Portuguese fisheries.

Over the last decades significant changes in the upwelling patterns have been observed off the western coast of the Iberian Peninsula, particularly the increase in winter upwelling events associated with an increasingly positive North Atlantic Oscillation (NAO) index (Borges et al., 2003). Dickson et al. (1988) showed how increased northerly winds during the 1970s were coupled with increasing upwelling off Portugal. In addition, a winter upwelling has recently been characterized in a Galician *Ria Baixa* for the first time (Alvarez et al., 2003). Thermohaline variables demonstrated that the upwelled water mass originated from the poleward current, which passes along the western coast of the Iberian Peninsula during winter.

The aim of this paper is to analyze an autumnal upwelling event which occurred in the Ria of Vigo in November 2001. Thermohaline data measured inside the estuary, sea surface temperature (SST) and wind data are used to characterize the upwelled water mass as well as its intensity and duration. This unusual thermohaline pattern, which has never been observed in the Galician rias in autumn, is compared with the typical autumnal pattern measured two weeks previously on 31st October 2001. Finally, the monthly probability of obtaining upwelling-favorable winds is analyzed from 1999 to 2004 using QuikSCAT data.

2. Materials and methods

2.1. Study area

The Galician *Rias Baixas* are characterized by an oceanic climate which tends to aridity in summer. The annual average air temperature is 14–15 °C with a thermal amplitude of 10 °C. The survey area is the Ria of Vigo, located between 42° 09′ and 42° 21′ N, 8° 36′ and 8° 54′ W (Fig. 1). This ria is the most meridional of the *Rias Baixas* and has an ENE–WSW orientation from its head to mouth (~20° anticlockwise with the parallel). The surface:volume ratio is 0.05, typical of v-shaped basin systems that gradually deepen and widen towards the mouth. In the innermost zone, this ratio is 0.4 which is the more characteristic of a typical estuarine system.