Tidal and wind influences on circulation in the southern mouth of the Ría de Vigo (NW Iberian Peninsula)

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ABSTRACT

Tidal and wind influences on the velocity field in the Ría de Vigo were assessed using atmospheric data from two meteorological stations located at Bouzas port and on an oceanic buoy off Silleiro Cape along with oceanic data from an ADCP moored in the Ría for a 72-day period. A two-layer circulation pattern was observed. Near-surface and near-bottom currents are primarily influenced by wind (especially remote winds), separated by an intermediate layer dominated by tidal variability. At subtidal frequencies, residual currents are well correlated with wind variability. Remote wind forcing exhibited a markedly high correlation with surface layer currents, indicating the major role played by wind in the long-term upwelling-modulated circulation of the Ría.

INTRODUCTION

The Ría de Vigo is the southernmost of the Rías Baixas, which define the northern boundary of the Eastern Atlantic Upwelling System [1]. Its waters are in free exchange with the adjacent inner shelf by two mouths separated by a landform: the Cíes Islands. Coastal upwelling/downwelling events in the region are triggered by seasonal variations of the dominant wind component [2]. The drag of the ocean surface in response to Ekman transport caused by the action of wind on the shelf and the forcing due to the local wind generates a two-layer circulation pattern within the Ría de Vigo, positive during upwelling events and negative during downwelling events. Despite this marked seasonality, short time scale variations in the wind pattern produce upwelling/downwelling and transitions events with typical 2-6 days response periods [2,3].

Although the variability in the velocity field in the Ría can be largely explained by tidal influences, ultimately it is the residual circulation (i.e., at subtidal frequencies), that determines the net exchange with the continental shelf. Therefore, it is important to determine to what extent currents are explained by the wind (either remote or local) and how that modulates upwelling and estuarine circulation in the Ría.

The aim of this study is to contribute to the understanding of tidal and local/remote wind influences on the circulation of the Ría. To achieve that, current velocity and pressure data obtained by an ADCP (Acoustic Doppler Current Profiler) moored at the southern mouth of the Ría were analysed along with meteorological data recorded by a station installed in the port of Bouzas and an oceanic buoy located off Silleiro Cape (south of the Ría de Vigo).

MATERIAL AND METHODOLOGY

Velocity, pressure and temperature data were obtained using an Acoustic Doppler Current Profiler (ADCP) moored for 72 days (20/06/2013-02/09/2013) at the southern mouth of the Ría de Vigo (8º45.604'W, 42º14.463'N; 41.6 m depth). Speed and direction of local and remote winds were measured by a meteorological station installed on the Bouzas terminal of the Port of Vigo (8º45.4167'W, 42º 13.967'N) and by an ocean buoy from 'Puertos del Estado' (http://www.puertos.es) located off Silleiro Cape (9.43ºW, 42.12ºN) respectively.

ADCP data were used to calculate the free surface height. Atmospheric pressure effect was corrected using the Bouzas' station data. Finally, harmonic constituents data, pure tidal signal and harmonic fit residues were obtained computing a tidal harmonic analysis using MATLAB toolbox T_TIDE [4].

To assess the influence of each constituent over the water column, a layer by layer (70 layers, 0.5 m width) harmonic analysis to horizontal velocities was computed and determination coefficient (R^2) for each layer harmonic fit was obtained. Equally, tidal ellipses of the four main major constituents (greatest amplitude) were determined at three significant depths of the water column (not shown).

Finally, vectorial cross-correlation [5] between current and wind (local and the remote) horizontal velocity time series were estimated, first including the full-frequency spectrum of both series and later with tidal frequencies filtered out after applying a A24/25/25 filter [6]. These correlations allow for obtaining the percentage of current variance explained by wind variance (R^2) in the water column and the angle at which these time-series best correlate along the vertical profile.

RESULTS AND DISCUSSION

Harmonic analysis of the sea level signal shows a clear semidiurnal tide of mesotidal range [6]. Most energetic constituents were M_2, N_2 and S_2. Along with this, harmonic analysis of the velocity field throughout the water column revealed amplitude variations of the tidal constituents (Fig.1). Influences of M_2, N_2 and S_2 become evident over the entire depth of the southern mouth of the Ría; likewise, only a diurnal constituent, K_1, presented a more or less homogeneous influence. For those major constituents, the absence of changes in amplitude with depth indicates the barotropic behavior of the tidal currents.

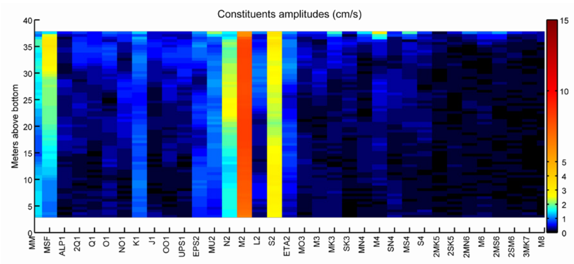

Fig.1. Harmonic constituents amplitudes throughout the water column

Vertical distribution of R^2 for the tidal fit (Fig.2a) shows the existence of a surface layer of less tidal influence and affected by other processes such as local wind, waves, river discharge and Ekman transport induced by remote shelf winds. There is also a central layer where tidal currents dominate the circulation and a bottom layer with less tidal dominance (greater than in the surface layer) and influenced by other processes (mainly friction with the bottom). This two-layer circulation (almost three-layer) observed at tidal time scales, fits the residual bidirectional circulation (mainly) induced by the coastal upwelling, but also by the local wind and the river, widely described in the literature.
Local (not shown) and remote wind correlation with full-spectrum currents velocities revealed a similar inverse distribution in accordance to that for the tidal fit, with greater influence at surface and bottom (Fig.2a). Even though both local and remote wind R^2 profiles had similar shapes, the latter presented higher values.
When tidal frequencies are removed from the signals, the best R^2 values appear. Although R^2 profiles preserve the previous shape, remote wind correlates better with residual velocities and it is in perfect accordance with the R^2 distribution for the tidal fit (Fig.2a), evidencing the vital

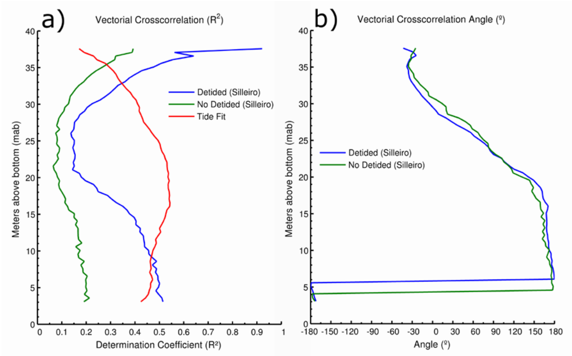

Fig.2. a) R^2 for the tidal fit and between remote wind and current velocities (both detided and no detided). b) Cross-correlation angle beween remote wind and currents (both detided and no detided)

role played by remote wind in the hydrodynamics of the Ría.
Regarding the vectorial correlation angle between remote wind and residual velocities, in the surface layer the best correlation is with a 30° angle of the current relative to the wind, counterclockwise. As is the case with local wind (not shown), this angle increases with the depth clockwise until 180º, showing again the two-layer circulation in the Ría. This two-layer structure differs in its circulation pattern (positive and negative) in response to the wind field characteristics (especially remote winds) and hence to the incidence of upwelling/downwelling events.

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REFERENCES

1 – Arístegui, J. et al., 2009. Sub-regional ecosystem variability in the Canary Current upwelling. *Prog Oceanogr*, 83 (1-4), pp. 33–48.
2 - Piedracoba, S. et al., 2005. Short-timescale thermohaline variability and residual circulation in the central segment of the coastal upwelling system of the Ría de Vigo (northwest Spain) during four contrasting periods. *J Geophys Res*, 110 (C3), p.C03018.
3 - Pardo, P.C., Gilcoto, M. & Pérez, F.F., 2001. Short-time scale coupling between termohaline and meteorological forcing in the Ría de Pontevedra. *Sci Mar* 65, supplement, pp. 229–240.
4 - Pawlowicz, R., Beardsley, B. & Lentz, S., 2002. Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE. *Computers & Geosciences*, 28 (8), pp. 929–937.
5 - Kundu, P.K., 1976. Ekman Veering Observed near the Ocean Bottom. *J Phys Oceanogr*, 6 (2), pp. 238–242.
6 - Godin, G., 1972. The analysis of tides, Liverpool: University of Toronto Press.