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The Río de la Plata estuary response to wind variability in synoptic time scale: Salinity fields and salt wedge structure

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The Río de la Plata estuary is located in the eastern coast of southern South America, approximately at 35° S. It has a northwest to southeast oriented funnel shape approximately 300 km long that narrows from 220 km at its mouth to 40 km at its upper end. With a mean discharge of 25,000 m3 s-1 and a drainage area of 3.5 × 106 km2 it ranks fourth and fifth worldwide in freshwater discharge and drainage area, respectively. The interaction between estuarine and shelf waters originates an intense and active salinity front which plays an important role in the flow dynamics and the distribution of properties on the shelf. As a result of the constant displacement of the surface front and the steadiness of the bottom front whose location is controlled by the bathymetry, a time-variable salt wedge structure is observed in the estuary during most of the year.

In this work, Estuary, Coastal and Ocean Model (ECOM) was applied to study the processes associated to the salinity fields and the salt wedge structure in the Río de la Plata estuary. It was found that salinity fields in the Río de la Plata rapidly respond -order of 3 days- to wind variability. Therefore, the traditional conceptual scheme that considers seasonal variability as the main feature of the salinity field in this estuary does not longer hold and conditions classically though as characteristic of ‘winter’ or ‘summer’ can take place during any season with high variability. The estuary response to wind variability can be explained in terms of four characteristic patterns associated to winds that blow with dominant components perpendicular and parallel to the estuary axis. North-easterly winds produce a southwestward retraction of the surface salinity front. The results are consistent with upwelling motion along the Uruguayan coast under this wind direction. Southwesterly winds produce a northward displacement of the surface salinity front towards the Uruguayan coast and, according to our simulations, a downwelling motion in that region. In both cases, upwelling or downwelling result of the perpendicular to the coast Ekman transport in that region. Northwesterly winds produce net outflow of surface continental waters and inflow of bottom shelf waters resulting in an intensification of the vertical stratification along the salinity front. Finally, southeasterly winds produce a net inflow of surface continental waters and outflow of bottom shelf waters and, therefore, a weakening of the stratification along the salinity front.

Salinity data available in the estuary have the limitations of their low spatial and temporal resolution, which limit the possibility of extracting the same patters found in the numerical simulations. Nevertheless an attempt to validate the former conclusions from historic CTD observations was done with successful results.

A similar response to upstream/downstream winds has been observed in other estuaries. But, the enormous breadth of the Río de la Plata allows for the occurrence of another wind-forced mode of circulation related to cross-river winds in which lateral currents dominate. In fact, in what concerns circulation, the Río de la Plata behaves more as a semienclosed basin than as a typical estuary.

Wind conditions necessary to break down the salt wedge structure and the persistence of the signal after a disruptive event were also studied. Stratification is completely destroyed by strong -approximately 13 m s-1- or persistent -around 3 days for 10 m s-1 intensity- southeasterly winds. Nevertheless this kind of events is not frequent in the region. Moreover, stratification completely recovers in a relatively short period of time -between 10 and 15 days- after the strong wind relaxation. Consequently, even though the salt wedge structure is a consequence

of the large discharge and the bathymetry, its existence is favored by prevailing winds.
Results presented in this work have important implications in biology. The strong picnocline of the Río de la Plata estuary is connected to plankton retention and accumulation, including eggs of certain species that spawn and nurse in the estuary. This way, retentive properties of the system can be altered during a disruptive event exposing larvae to abrupt changes in salinity conditions. Nevertheless, these events can occur few times along the year and besides the system can relatively quickly reconstruct the vertical halocline. As a result the salt wedge structure is presented along most part of the year. This implies that significant mixing events producing exchanges of water, sediments, nutrients and other properties between the estuary and the open ocean are limited to occur only under strong or persistent southeasterly winds. The Río de la Plata estuary would show strong retentive features favoring biota to retain eggs and larvae, but also favoring pollutant accumulation.