

# WATER RENEWAL MECHANISMS OF THE BAY OF ALGECIRAS IN THE STRAIT OF GIBRALTAR

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## Abstract

The Bay of Algeciras (BA) is a marine environment subject to high levels of anthropogenic pressure. Here we analyze a number of ADCP observations collected at the bay and the results of an ocean circulation model to investigate its circulation, variability, and the mechanisms involved in the water exchange with the adjacent Strait of Gibraltar. It is found that the flushing of the bay, and therefore also its water quality, is largely dependent on the strength of tidal flows.

*Keywords: Coastal processes, Coastal models, Gibraltar Strait*

The BA is located at the north-eastern end of the Strait of Gibraltar (Fig.1). Covering an area of about 9x11 km and with a maximum depth of nearly 400 m, features by far the mildest surface currents of the strait, a circumstance that has made of this spot the ideal location for the settlement of harbors from the times of early civilizations. Today, the bay is a strategic point within one of the busiest shipping routes in the world and not for nothing holds two major ports in both Algeciras and Gibraltar, along with numerous industrial plants distributed all along its shoreline. Marine pollution is therefore a serious problem in the bay itself and in the surrounding areas.

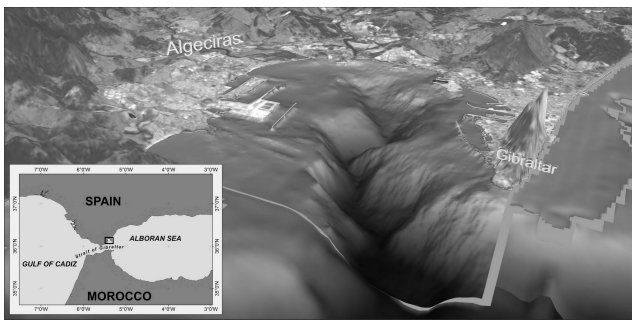


Fig. 1. Location and bathymetry of the Bay of Algeciras.

In order to understanding the circulatory system of the BA and the physical mechanisms involved in its water renewal, water quality, and exchange with the strait's main channel, three mooring lines equipped with autonomous CTs at around 10m above the seafloor and uplooking ADCPs were deployed at different locations of the bay during the Spring and the Fall of 2011. Moreover, with the aim to get a more comprehensible time-spatial data coverage, a high-resolution primitive equation model was used to conduct a hind-cast simulation for the mentioned period, whose results compared very satisfactorily with observations [1, 2].

Model and observations reveal that the mean surface circulation of the BA is characterized by an anti-cyclonic cell fed by a coastal current flowing in opposite direction to the jet of Atlantic Water offshore. The coastal current in question encompasses a narrow stripe along the north coast of the strait of Gibraltar and is within the lateral boundary layer. This circulation pattern is subject to substantial variability and its negative vorticity can be enhanced or diminish, even revert sign, depending upon meridional displacements of the referred jet. These displacements are shown to be linked to atmospheric-pressure driven flows that accelerate or slow down the jet. The second source of variability is due to winds and fulfills the expectations of Ekman dynamics, with surface currents entirely pointing offshore or inshore during westerly or easterly winds, respectively. The third source of variability, though no less important, are tides, able to revert the flow direction with semidiurnal periodicity.

A series of additional model runs tracking the evolution of passive tracers (dye) released in the BA were carried out in order to gain an insight into the mechanisms involved in the water renewal of the BA and discern the most

favorable/unfavorable scenario for the flushing of the Bay. The dye was released within both the Atlantic ( $S < 37.5$ ) and the Mediterranean ( $S > 37.5$ ) layers in order to obtain a more complete picture of the process. For each release of the dye the corresponding  $e$ -flushing time was computed by the exponential fitting the dye concentration curve. The results are shown in Fig.2a and reflect substantial time variability.

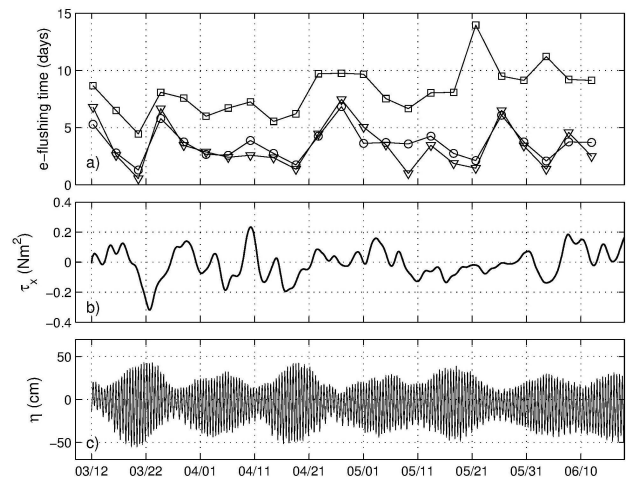


Fig. 2. A) Temporal dependence of the Atlantic (circles), Mediterranean (squares), and surface ( $-5 < z < 0$  m; triangles) layer  $e$ -flushing times. The marks are located at the time of the passive tracer release. b) Horizontal component of wind stress over BA. c) Mean sea surface height.

The most direct outcome is that minimum (maximum) flushing times of the Atlantic (circles) and the very surface layers (triangles) are obtained for releases of the dye during spring (neap) tides (Fig. 2c), which suggests that tidal flows play a major role in the dispersal of the tracer therein. This does not apply, however, to the bottom Mediterranean layer (squares) in which tidal currents are weak, and ventilation of this layer appears to be connected with the variability of the wind forcing that is stronger during the first half of the simulation (Fig. 2b). These results suggest that the marine environment of the BA benefits from the relatively strong tides of the strait, and that its water quality would be significantly worse if it were located just few kilometers eastwards (within the Alboran Sea), where tides are practically absent.

## References

- 1 - Sammartino et al., 2014, Cont. Shelf Res., 72, 34-46.
- 2 - Sánchez-Garrido et al., 2013, Prog. Oceanog., 116, 142-153.