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Tidal dynamics in the Bay of Algeciras (Strait of Gibraltar) by a numerical experiment

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The Bay of Algeciras (southwest of Spain) is located at the eastern part of the Strait of Gibraltar where the well-known two-way exchange between the Atlantic Ocean and the Mediterranean Sea occurs. The bay and its port have a strategic relevance in terms of maritime traffic and supply of fuel and goods, making the whole area a high risk environment for pollution derived from its commercial activities. Thus, a complete knowledge of the hydrodynamics of the bay is crucial to cope with an efficient management of its environment. A high-resolution numerical three-dimensional model has been applied to the study of the dynamics of the bay at the tidal scale. After a satisfactory validation, based on a comprehensive set of measurements collected in the area in 2011, the model outputs are used for a detailed analysis of the local hydrodynamics. The bay is characterized by a standing-wave pattern of the barotropic dynamics, inherited by the strait region, with a flow across the mouth of $2.7 x 10^{-3}$ Sv, in quadrature with the SSH oscillations. However, the harmonic analysis of the meridional velocity in the cross-bay section at its mouth and in the longitudinal section between the mouth and the head reveals a marked baroclinic structure of the flow, with values one order higher than the barotropic flow. The upper layer and the lower layer flows are clearly in antiphase with a very thin layer of maximum change of phase and minimum amplitude, roughly coinciding with the average location of the isohaline S=37.5. The origin of this structure is the important internal tide acting into the area, characterized by a clear shorewards propagation, with the possible presence of an amphidromic point in the west side of the mouth and a quarter-wave resonance amplifying the internal oscillations. The analysis of the zonally integrated meridional transport (meridional stream function) reveals a circulation scheme opposite to the one of the strait. During the flood tide, while in the strait the Mediterranean water flows inside the channel and displaces the isohalines upwards, in the bay, the Atlantic water flows shorewards, forcing the isohaline downwards and pushing the Mediterranean water out of the bay, where it joins the Mediterranean flow directed westwards. During the ebb tide, the Mediterranean water flowing eastwards penetrates inside the bay producing the raising of the isohalines and pushing the superficial Atlantic water out in the channel, where it joins the Atlantic jet moving eastwards.