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Vertical structure of currents in Algeciras Bay (Strait of Gibraltar): implications on oil spill modeling under different typical scenarios

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Algeciras Bay constitutes a physical environment of special characteristics, due to its bathymetric configuration and geographical location, at the eastern boundary of the Strait of Gibraltar. Hence, the Bay is subject to the complex hydrodynamics of the Strait of Gibraltar, characterized by a mesotidal, semidiurnal regime and the high density-stratification of the water column due to the presence of the upper Atlantic and the lower Mediterranean (more salty and cold) water layers. In addition, this environment is affected by powerful Easterly and Westerly winds episodes. The intense maritime traffic of oil tankers sailing across the Strait and inside the Bay, together with the presence of an oil refinery at its northern coast, imply high risks of oil spilling inside these waters, and unfortunately it has constituted a matter of usual occurrence through the last decades.
The above paragraph clearly manifests the necessity of a detailed knowledge on the Bay's hydrodynamics, and the related system of currents, for a correct management and contingency planning in case of oil spilling in this environment. In order to evaluate the range of affectation of oil spills in the Bay's waters and coasts, the OILMAP oil spill model was used, the currents fields being provided by the three-dimensional, nonlinear, finite-differences, sigma-coordinates, UCA 3D hydrodynamic model. Numerical simulations were carried out for a grid domain extended from the western Strait boundary to the Alboran Sea, having a horizontal spatial resolution of 500 m and 50 sigma-levels in the vertical dimension. The system was forced by the tidal constituents M2 (main semidiurnal) and Z0 (constant or zero-frequency), considering three different typical wind conditions: Easterlies, Westerlies and calm (no wind).
The most remarkable results from the numerical 3D simulations of Algeciras Bay's hydrodynamics were: a) the occurrence of opposite tidal currents between the upper Atlantic and lower Mediterranean water layers (i.e., there is a phase-lag of about 180º among them); b) the presence of high-frequency perturbations due to the penetration of internal waves; and c) high variability in the vertical profiles of both tidal and residual (mean) currents. All these phenomena contribute to obtain differences between the water-surface currents and their depth-averaged values (as they are provided by most of 2D hydrodynamic models).
Resultant currents from the 3D numerical simulations were implemented into the OILMAP model to evaluate the response of a control oil spill inside Algeciras Bay, considering different scenarios. Results were analyzed focusing in the differences between the more realistic surface currents fields given by the UCA 3D model and the depth averaged fields provided by faster 2D schemes, as well as the influence of implementations of wind effects having different complexities. The relative adequacy between the more accurate (but more expensive in computational time) and the faster (but more unrealistic) modeling strategies, especially in cases of emergency and very short decision times, was discussed.