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A 3D numerical model for stratified free surface flows

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ABSTRACT

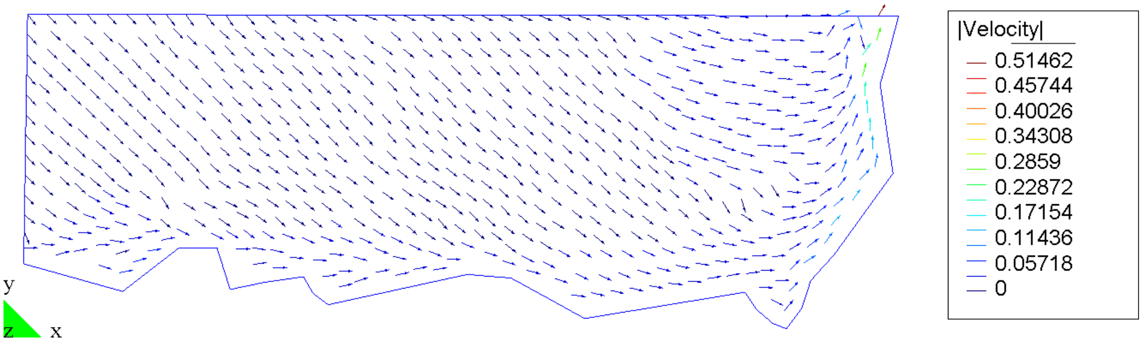
In this work, a 3D stabilized finite element coastal circulation model, capable of simulating a limited oceanic region, has been developed and validated. The length scale of application can be of the order of the continental shelf width or smaller and the time scale threshold between the tidal wave period and that of the waves due to the wind.

The model, named HELIKE (Maidana, 2007), is based on the 3D incompressible Navier-Stokes equation and takes into account non-hydrostatic pressures, the two components of the Coriolis acceleration (tangent and normal to the Earth's surface), density gradients (baroclinic forcing), turbulence, bottom friction, wind stress and the evolution of the free surface height (barotropic forcing). The model is applicable over irregular sea-beds. The kinematic equation is used to compute the free surface height without resorting to vertical averages.

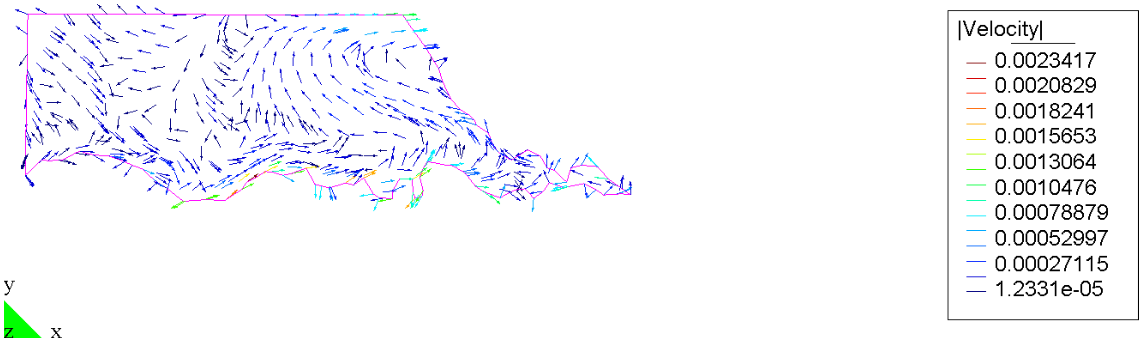
The combined use of the finite element discretization and unstructured meshes gives the model flexibility to fit the complex geometry of the coastline and sea-bed, and allows for mesh refinement in areas of interest and for the application of the appropriate boundary conditions in each part of the boundary.

Numerical results for the application case are presented. The corner of the Bay of Biscay is the case study wherein HELIKE was applied to simulate the current forcing by wind and a horizontal density gradient. The domain considered is the lower portion of the Bay of Biscay bounded approximately by latitudes 43 to 44 N and longitudes 1 to 4 W. The computational mesh used for the simulation has 9,992 nodes and 7,541 elements.

One of the main features of the surface water circulation within the Bay of Biscay is the presence of the slope circulation named the Iberian Poleward Current (IPC). Its direction and location depends upon the prevailing wind regime as shown in the figure 1(a) for a characteristic SW wind event during winter. The presence of canyons and talus alters the velocity current fields in different water depths (figure 1(b)) moreover, it generates an important component of the non-hydrostatic pressure (figure 2). This relationship between the topography and non-hydrostatic pressure demonstrates the necessity to simulate this phenomena by means of non-hydrostatic numerical models. The numerical results obtained show the applicability, accuracy and efficiency of the model in simulating coastal processes.



(a) $Depth = 0\,m$



(b) $Depth = 1300\,m$

Figure 1: Velocity fields for a characteristics SW wind regime

Figure 2: Non-hydrostatic pressure fields

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