SHYFEM, a numerical tool for investigating environmental processes in coastal seas and lagoons

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SHYFEM (http://www.ve.ismar.cnr.it/shyfem) is a software package consisting on a set of integrated numerical tools based on the finite element method developed to investigate, with a multi scale approach, the hydrodynamic and the main physical and biogeochemical processes occurring in both open ocean and coastal seas.

The core of the system is a fully coupled 3D current and wave numerical model based on unstructured meshes. The hydrodynamic module solves the Shallow Water equation with the hydrostatic and Boussinesq approximation. It uses a semi-implicit algorithm for the time integration and a finite element approach for the horizontal spatial integration (Umgiesser, 1997, Umgiesser et al., 2004). The model takes into account the main physical forcings characterizing the water circulation such as barotropic and baroclinic forcing, horizontal and vertical viscosity effects and non-linear inertial processes. Both z and sigma layers are adopted in order to solve the vertical dimension and a state of the art turbulence model, GOTM (Umlauf et al., 2007), is used to reproduce the vertical mixing. The 3D two way wave-currents interaction is computed by using the algorithm proposed by Xia et al. (2007), which takes into account the main physical processes that occur in very shallow areas such as shoaling, breaking and Stokes drift.

The current model is fully coupled via FIFO Pipes with a 3rd generation spectral wave model, called WWM (Wind Wave Model; Hsu et al., 2005a) which solves the WAE Wave Action Equation on unstructured spatial grids. The WWM adopts state of the science source term formulation for the generation, nonlinear interaction and decay of wave energy. The fractional step method (Yanenko, 1971) is used to split the wave action balance equation into spatial, frequency and directional space. These three parts are integrated successively, which makes it possible to apply efficient numerical algorithms to solve the WAE in the certain dimension. The source term integration is done in another separate fractional step where various methods can be used like, e.g., the dynamic source term integration method following (Tolman, 1997). The wave model has been verified in different environments (Hsu et al., 2005b, 2006; Roland et al., 2005, 2006).

The 3D coupled current and wave model is integrated with a set of numerical tools such as a sediment transport and morphological model (SEDTRANS05, Li and Amos, 2001; Neumeier et al., 2008), an ecosystem model (BFM, Vichi et al., 2007) and an oil spill model which allows to deal with most of the main environmental processes interesting the coastal areas.

The integrated model has been applied with success to several sites around the Mediterranean Sea. We present a set of different applications of the SHYFEM package consisting in: reproduction of water circulation, wave propagation and sediment transport in coastal areas and tidal active lagoons, computation of water transport time scales in lagoons and semi-enclosed basins and implementation of operational systems for predicting waves, currents, water levels and trajectories followed by pollutants released in shallow water areas.

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