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Improvement of the free-surface tension model in shallow water basin by using in-situ bottom-friction measurements

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Wind stress on the free surface is the main driving force behind the circulation of the upper part of the ocean, which in hydrodynamic models are usually defined in terms of the coefficient of surface tension (Zhang et al., 2009, Davies et al., 2003). Moreover, wave motion impacts local currents and changes sea level, impacts the transport and the stratification of the entire water column. Influence of surface waves at the bottom currents is particularly pronounced in the shallow coastal systems. However, existing methods of parameterization of the surface tension have significant limits, especially in strong wind waves (Young et al., 2001, Jones et al., 2004) due to the difficulties of measuring the characteristics of surface waves in stormy conditions. Thus, the formula for calculating the coefficient of surface tension in our day is the actual problem in modeling fluid dynamics, particularly in the context of strong surface waves.

In the hydrodynamic models usually a coefficient of surface tension is calculated once at the beginning of computation as a constant that depends on the averaged wind waves characteristic. Usually cases of strongly nonlinear wind waves are not taken into account, what significantly reduces the accuracy of the calculation of the flow structures and further calculation of the other processes in water basins, such as the spread of suspended matter and pollutants. Thus, wave motion influencing the pressure on the free surface and at the bottom must be considered in hydrodynamic models particularly in shallow coastal systems.

A method of reconstruction of a free-surface drag coefficient based on the measured in-situ bottom pressure fluctuations is developed and applied in a three-dimensional hydrodynamic model MARS3D, developed by the French laboratory of IFREMER (IFREMER - French Research Institute for Marine Dynamics). MARS3D solves the Navier-Stokes equations for incompressible fluid in the Boussinesq approximation and with the hydrostatic assumption (Lazure and Dumas, 2008, Blumberg et al., 1986).

Precisely, we introduce a formulation of the surface drag coefficient as a logarithmic function of the sea surface roughness (Zhang et al., 2009), which in turn can be predicted from the height and steepness of the waves (Taylor and Yelland, 2000), measured by the bottom pressure sensors. Using numerous field data, Taylor and Yelland (2000) showed that the surface drag coefficient values in lakes and sheltered waters are typically significantly higher than is observed in the open ocean. In particular, the effect of limited water depth is very significant in the case of the strong wind forcing. Wind waves propagating into shoaling water begin to be limited by bottom friction and become "younger".

This kind of approach is used to predict a more relevant surface drag coefficient for the coastal areas of the Mediterranean Berre lagoon (France) for which experimental data of pressure measurements under storm conditions are available (Paquier, 2014). This is important to better understand the development problematics of the nearshore submerged aquatic vegetation (Alekseenko et al., 2013).

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