HYDRODYNAMIC MODELING OF TIDAL CURRENTS IN PERSIAN GULF USING FINITE VOLUME METHOD

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1.INTRODUCTION

In this paper, simulation of tidal currents in the Persian Gulf is performed by the solution of the hydrodynamics equations. The hydrodynamic equations utilized in this work consist of depth average equations of continuity and motion in two dimensional horizontal planes (SWE). The effects evaporation is considered in the continuity equation and the effects of bed slope and friction, as well as the Coriolis effects are considered in two equations of motion. The overlapping cell vertex finite volume method is applied for solving the governing equations on triangular unstructured meshes. Using unstructured meshes provides great flexibility for modeling the flow in arbitrary and complex geometries, such as Persian Gulf flow domain. The results of the hydrodynamic model for fluctuating flow on the variable bed slope are compared with available analytical solution. The accuracy of the developed flow solver to simulate circulating flow patterns is assessed by comparison between numerical results and reported data in the literature for deep flow in a canal with sudden expansion. The performance of the computer model to simulate tidal flow in Persian Gulf domain is examined by imposing tidal fluctuations to the main flow boundary during a limited period of time.

2. GOVERNING EQUATIONS

The convection-diffusion equation, which is formed by both transport and diffusion terms, is applied to model the transient depth average currents. The depth averaged equations (Shallow Water Equations) are chosen as the governing equation of the flow in the Persian Gulf. The governing equations are written in vector form as follows:

$$\frac{\partial W}{\partial t}+\left(\frac{\partial F^{c}}{\partial x}+\frac{\partial G^{c}}{\partial y}\right)=\left(\frac{\partial F^{d}}{\partial x}+\frac{\partial G^{d}}{\partial y}\right)+S \qquad (1)$$

$$W=\begin{pmatrix} h \\ hu \\ hv \end{pmatrix},\ F^{c}=\begin{pmatrix} hu \\ hu^{2} \\ huv \end{pmatrix},\ G^{c}=\begin{pmatrix} hv \\ huv \\ hv^{2} \end{pmatrix},\ F^{d}=\begin{pmatrix} 0 \\ h\nu_{Th}\frac{\partial u}{\partial x} \\ h\nu_{Th}\frac{\partial v}{\partial x} \end{pmatrix},\ G^{d}=\begin{pmatrix} 0 \\ h\nu_{Th}\frac{\partial u}{\partial y} \\ h\nu_{Th}\frac{\partial v}{\partial y} \end{pmatrix},$$

$$S=\begin{pmatrix} q_{z} \\ -gh\frac{\partial \eta}{\partial x}+hvf_{cx}-\frac{\tau_{bx}}{\rho_{w}}+\frac{\tau_{wx}}{\rho_{w}} \\ -gh\frac{\partial \eta}{\partial y}-huf_{cy}-\frac{\tau_{by}}{\rho_{w}}+\frac{\tau_{wy}}{\rho_{w}} \end{pmatrix}$$

3. NUMERICAL FORMULATIONS

The equations are explicitly solved using Cell Vertex Finite Volume Method on triangular unstructured meshes. Application of unstructured mesh facilitates considering the effects of geometrical irregularities of coasts and islands.

The governing equations are discretized by the application of cell vertex (overlapping) scheme of the finite volume method. This method ends up with the following formulation,Sabbagh-Yazdi et al (2003):

$$W_i^{t+\Delta t} = W_i^t - \frac{\Delta t}{\Omega_i} \cdot \sum_{k=1}^{N_{sides}} [(\overline{F}^c \Delta y - \overline{G}^c \Delta x) - (F^d \Delta y - G^d \Delta x)]_k^t + S_i^t \Delta t \qquad (2)$$

4. VERIFICATION TESTS

In this section, firstly the hydrodynamic model, which is developed by the first author, is examined for fluctuating flow on the variable bed slope and the numerical results are compared with available analytical solution. The analytical solution of ξ in a frictionless quadrant with a parabolic bed test is used to evaluate the performance of tidal numerical models, Chen (1989).

Secondly, the accuracy of the model to simulate circulating deep flow in a canal with sudden expansion is assessed by comparison between numerical results and reported data in the literature. The channel with sudden expansion in a side wall is used to test for verification of numerical model for the flow patterns formed by advection and diffusion effects Denham (1974).

5. APPLICATION OF MODEL ON PERSIAN GULF

The numerical simulation of currents in Persian Gulf is presented after evaluation of the accuracy of the developed hydrodynamic model. The performance of the computer model to simulate tidal flow in Persian Gulf domain is examined by imposing tidal fluctuations to the main flow boundary during a limited period of time. The described hydrodynamic model, which is developed by the first author, is used to compute flow patterns in Persian Gulf due to tidal fluctuations at east boundary, river inflow at west coast, evaporations from water surface, Corilios effect, friction and irregularities of coasts and bed. In order to verify the quality of the results, the tidal fluctuations at DIDAMAR island, obtained from Admiralty Tide Table for the period of 12 days from December 2003, are imposed at Hormoz Strait (flow boundary). Considering the evaporations from the water surface and Coriolis effects, the flow patterns are formed due to the coasts and bed three dimensional surface geometry and roughness.

6. CONCLUSIONS

The numerical results of fluctuating flow on flow domain with variable bed elevations presents acceptable agreements with the analytical solution. The model is examined for simulation of turbulent flow on a frictionless bed with two dimensional circulations and the numerical results demonstrate good agreements with reported experimental measurements. Considering tidal fluctuations at flow boundary, inflow from rivers, evaporations and Coriolis effects, bed surface geometry and roughness, the tidal flow patterns in Persian Gulf are successfully modeled.

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