Computers & Geosciences 33 (2007) 1204–1209

COMPUTERS & GEOSCIENCES

www.elsevier.com/locate/cageo

Short Note

Application of the Mohid-2D model to a mesotidal temperate coastal lagoon

Nuno Vaz[a,*], João Miguel Dias[a], Paulo Chambel Leitão[b], Rita Nolasco[c]

[a]CESAM, Departamento de Física, Universidade de Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal
[b]Hidromod, Modelação em Engenharia, Lda., Av. Manuel da Maia, no. 36, 3° esq., 1000-201 Lisboa, Portugal
[c]Centro de Geofísica da Universidade de Lisboa, Campo Grande, C8, 1749-016 Lisboa, Portugal

Received 30 March 2006; received in revised form 10 January 2007; accepted 2 February 2007

Keywords: Mohid-2D; Hydrodynamics; Calibration; Validation; Coastal lagoon; Ria de Aveiro

1. Introduction

A mathematical model can be considered as an approximate reconstruction of a real phenomenon. All parameterizations and approximations used in models lead to deviations of the model results from nature. It is an accepted requirement that a numerical model of estuarine hydrodynamics should be verified, calibrated and validated before used in a practical application. However, the procedures to perform these tasks are not widely accepted (Cheng et al., 1991). Calibration and validation methods appear in several forms, depending on data availability, water mass characteristics and researchers' opinion (Hsu et al., 1999).

In this work, the Mohid-2D model implementation for the Ria de Aveiro lagoon is presented, describing its assessment through calibration and validation against several different data sets. Due to the lagoon complex geometry and the large number of calibration stations used, this goal constitutes a very challenging task.

The model is calibrated using as a first approach a qualitative comparison of the temporal evolution of sea surface elevation (SSE) data measured in 1987/1988 at several locations. When a good match is obtained for all stations, the model's accuracy is evaluated through the determination of the root mean square (RMS) error and also through the comparison between amplitude and phase of the main tidal constituents determined from harmonic analysis of the observed and computed data. The validation procedure is performed using two independent data sets, which includes observations of current velocities and SSE values (1997 data) and measured water fluxes at the lagoon's inlet for the period of October 2002.

2. The study area

Ria de Aveiro (Fig. 1) is a shallow mesotidal lagoon located in the Northwest coast of Portugal (40°38′N, 8°44′W). It is 45 km long and 10 km wide, being characterized by narrow channels and by the existence of large intertidal areas. In spring tide the water covers an area of 83 km^2 at high tide reducing to 66 km^2 at low tide (Dias et al., 2000). Ria de Aveiro receives freshwater mainly from two rivers:

*Corresponding author. Tel.: +351 234370356; fax: +351 234424965.
E-mail address: nuno@fis.ua.pt (N. Vaz).

0098-3004/$ - see front matter
doi:10.1016/j.cageo.2007.02.001

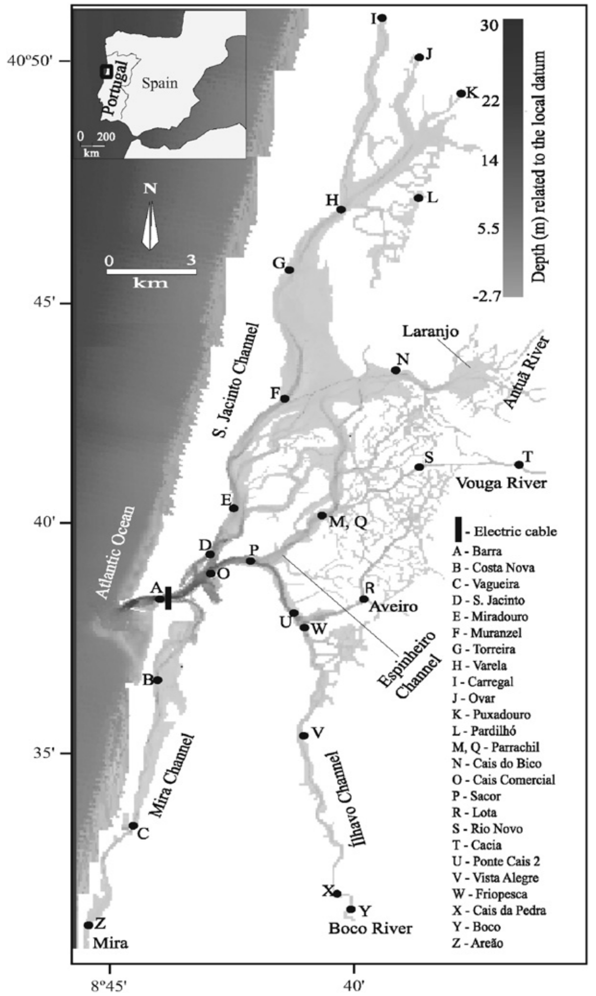

Fig. 1. Ria de Aveiro lagoon, with locations of stations used in calibration and validation. The electric cable used to measure water flows is marked.

Antuã ($5\,\mathrm{m^3\,s^{-1}}$ average flow) and Vouga ($50\,\mathrm{m^3\,s^{-1}}$ average flow) (Dias et al., 1999). Vouga River is responsible for ~66% of the freshwater input into the lagoon (Dias et al., 1999). Tides, which are semi-diurnal, are the main forcing of circulation within the lagoon.

A prior hydrological characterization lead to the conclusion that Ria de Aveiro can be considered vertical homogeneous during dry seasons (Dias et al., 1999).

3. The numerical model

The numerical model used in this study is Mohid (Martins et al., 2001), a three-dimensional finite volume model with the ability to simulate flows in shallow systems like Ria de Aveiro. Due to the lagoon's characteristics the model equations were discretized with only one layer in order to simulate the lagoon's hydrodynamic.

The model solves the three-dimensional incompressible primitive equations. Hydrostatic equilibrium is assumed as well as the Boussinesq approximation. The momentum and mass balance equations are

$$\begin{aligned}\frac{\partial u_i}{\partial t}+\frac{\partial (u_i u_j)}{\partial x_j} = & -\frac{1}{\rho_0}\frac{\partial p_{atm}}{\partial x_i} - g\frac{\rho(\eta)}{\rho_0}\frac{\partial \eta}{\partial x_i} \\ & -\frac{g}{\rho_0}\int_{x_3}^{\eta}\frac{\partial \rho'}{\partial x_i}\,\mathrm{d}x_3 \\ & +\frac{\partial}{\partial x_j}\left(\upsilon\frac{\partial u_i}{\partial x_j}\right) - 2\varepsilon_{ijk}\Omega_j u_k, \end{aligned} \tag{1}$$

$$\frac{\partial u_1}{\partial x_1}+\frac{\partial u_2}{\partial x_2}+\frac{\partial u_3}{\partial x_3}=0, \tag{2}$$

where u_i are the velocity vector components in the horizontal Cartesian x_i directions ($i=1,2$), u_j are the velocity vector components in the three Cartesian directions x_j ($j=1-3$), υ is the turbulent viscosity and p_{atm} is the atmospheric pressure. ρ is the specific mass, ρ' is its anomaly, ρ_0 is the reference specific mass, $\rho(\eta)$ represents the specific mass at the free surface, g is the acceleration of gravity, t is the time, Ω is the Earth's velocity of rotation and ε is the alternate tensor. Integrating Eq. (2) over the whole water column (between the free surface elevation $\eta(x,y)$) and the bottom $-h$, the free surface equation is obtained:

$$\frac{\partial \eta}{\partial t} = -\frac{\partial}{\partial x_1}\int_{-h}^{\eta} u_1\,\mathrm{d}x_3 - \frac{\partial}{\partial x_2}\int_{-h}^{\eta} u_2\,\mathrm{d}x_3, \tag{3}$$

where h is the depth.

The bottom shear stress, $\vec{\tau}$, is represented as a quadratic function of velocity (Eq. (4)) (Dronkers, 1964) and the drag coefficient (C_D) can be parameterized in terms of Manning's friction coefficient (n), by applying Eq. (5):

$$\vec{\tau} = C_D|\vec{V}|V, \tag{4}$$

$$C_D = gn^2H^{1/3}, \tag{5}$$

where $\vec{V}$ is the horizontal velocity vector and H ($H=h+\eta$) is the total depth of the water column.

The model discretization is fully described in Martins et al. (2001).

Due to the lagoon's complex geometry a grid with variable spatial step was developed. This grid has 429 by 568 cells, with dimensions of 40 by 40 m in