HYDRODYNAMIC MODELING OF A COASTAL LAGOON IN MEXICO

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RESUMEN

SUMMARY

In order to understand the local hydrodynamics of the hypersaline coastal lagoon “Bahia de San Quintín”, located in Northern Mexico, a bidimensional model was applied using Delft3D. The lagoon presents a complex bathymetry, so the mesh was locally refined in the main channels of the lagoon. It was used wind and the main harmonics of the area to force the model. The results obtained for vertical integrated velocity and sea level elevation were compared with data from three Acoustic Doppler Current Profilers placed inside the lagoon, getting a satisfactory representation of the lagoon flow dynamics.

Keywords: hydrodynamic, model, Ddelft3D, coastal lagoon.

1. INTRODUCTION

In coastal lagoons tides are the most important factor in their hydrodynamics. Is for this reason, and because they are generally very shallow, that they tend to be vertically homogeneous and their hydrodynamics may be explained with a two dimensions model. The second, but not less important, factor that defines the hydrodynamics behavior in coastal lagoons are the winds as well as the lagoon internal configuration (FARRERAS, 2004).

The San Quintín Bay (SQB) is a coastal lagoon located in the Mexican State of Baja California between 30 ° 24 'and 30 ° 30' north latitude and 115 ° 57 'and 116 ° 01' west longitude, and covers an area of approximately 42 km2. This lagoon is one of the most important coastal lagoons at the Pacific of Baja California that is characterized by its high capacity of aquaculture and agricultural production (DELGADO et al.,2012).

The wind is generally strong, and the direction does not change very much thus being also an important forcing agent for the lagoon hydrodynamics. Northwest surface dominant winds with a frequency of 72.5% (COMISIÓN NACIONAL DEL AGUA, 2004).

The numerical model solves a coupled system of differential, prognostic equations which describe the conservation of mass and momentum. Delft3D-FLOWsolves the Navier Stokes equations for an incompressible fluid under shallow water, as well as the Boussinesq assumptions (GERRITSEN et al., 2004).

In the vertical momentum equation, the vertical accelerations are neglected, which then leads to the hydro-static pressure equation. This set of partial differential equations, in combination with an appropriate set of both initial and boundary conditions, is solved on a finite difference grid.

2. OBJECTIVES

The objective of this work is to represent the hydrodynamics of a coastal hypersaline lagoon applying a two-dimensional model, using main tidal harmonic components of the study area and wind field as forcing mechanism.

3. METHODOLOGY

The numerical model used in the present study is Delft3D-FLOW, which is a simulation program that calculates non-steady flow resulted from tidal and meteorological forcing on a boundary fitted grid. The hydrodynamic model was used in a two-dimensional form vertically integrated.

An orthogonal mesh of variable dimensions was created (Figure 1): the area of the lagoon was refined locally (40 m x 120 m) to obtain a higher resolution, while the area corresponding to the open ocean has a lower resolution (100 m x 140 m). The bathymetry far from the coast was taken from GEBCO (General Bathymetric Chart of the Oceans), while the bathymetry of the lagoon was taken during campaign of May- June 2004. For open boundary condition, an astronomic forcing type was applied using seven harmonics (main ones): M2, S2, K1, O1, N2, P1 and K2 (DELGADO et al.,2012). Since the entrance to the bay is protected by a sandbar of 3 km long, the open boundary was selected to be far from the entrance to allow the tide to approach the lagoon in a natural way. To start running the model, a constant wind field was used to all the domain, (315° direction and 3 m/s speed) and the water level was set to 1.9 m.

To validate the results, time series for water elevation and currents, from three different ADCP's inside the lagoon (Figure 2), were used. To minimize uncertainty in the optimization process, the calibration was begun 25 days after the model was started.

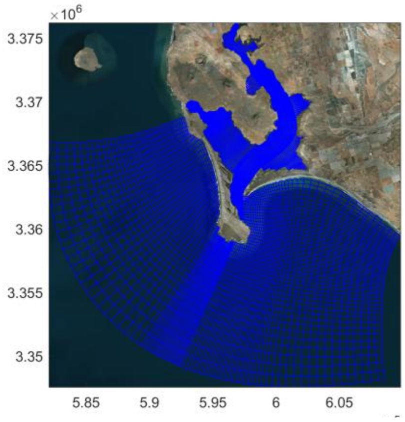

Figure 1. Orthogonal Mesh

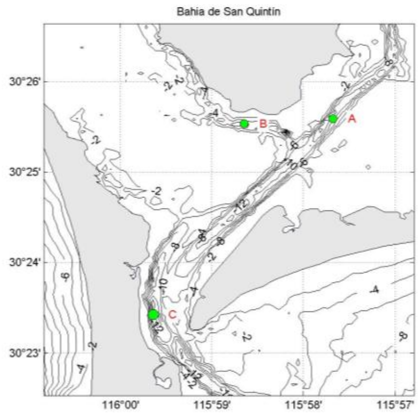

Figure 2. ADCP's location.

4. RESULTS

The simulation results for 2004 satisfactorily represented (according to current knowledge about local dynamics) the sea level (Figure 3) and the velocity magnitudes (Figure 4). The statistical indicators are summarized in Table 1.

Table 1. Statistical indices comparing the model results with measured data.

ADCP	**Sea Level time Series**		**ADCP**	**Depth Averaged Velocity**		
	RMSE (m)	MAE (m)		RMSE (Vx) [cm/s]	MAE (Vx) [cm/s]	R^2
A	0.0998	0.0808	**A**	5.1047	4.2437	0.9281
B	0.09697	0.0777		RMSE (Vy)	MAE (Vy)	R^2
C	0.09889	0.0798		10.7072	8.0646	0.9413

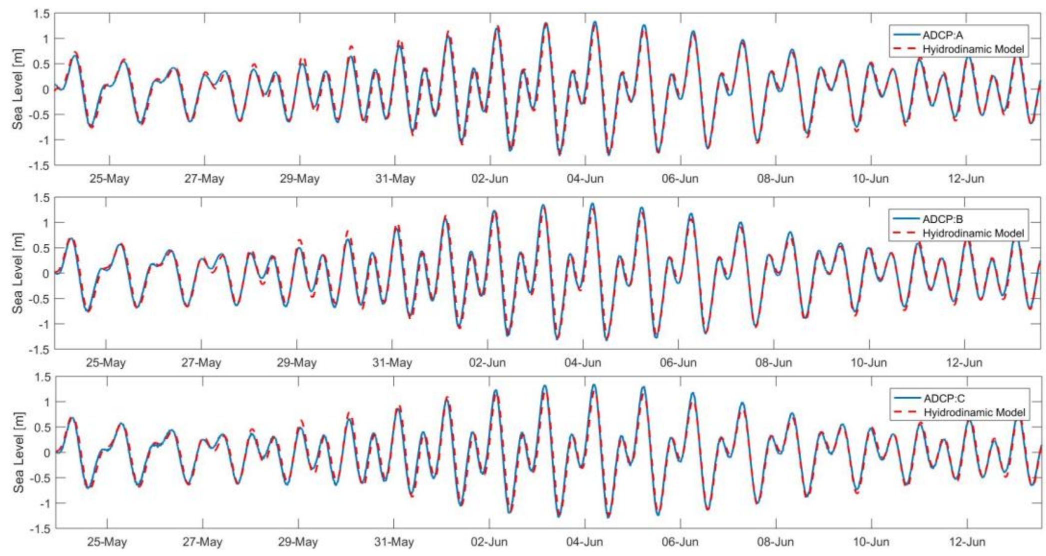

Figure 3. Time series comparison for sea level between measured data (blue line) and modeled results (red line) in three different points (ADCP's) inside the lagoon.

For the velocity field, a vertical depth averaged velocity was used to validate the model against observations. The observed current data was taken from the A point for each component of the velocity, Vx and Vy (Figure 4). The statistical analysis is summarized for point A in Table 1.

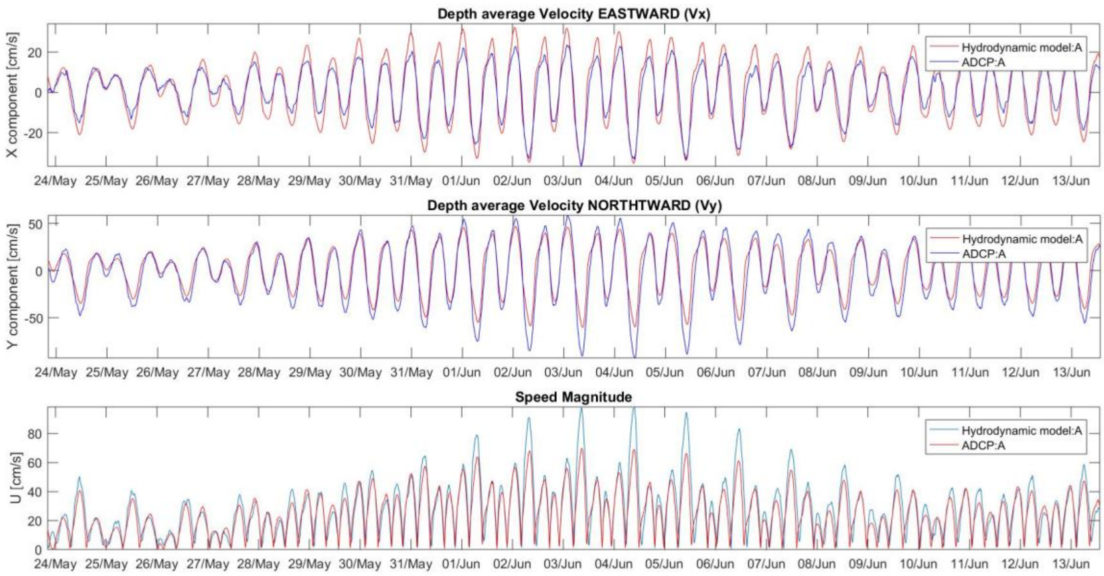

Figure 4. Comparison of velocity components between measured data (blue line) and modeled results (red line).

The velocity magnitude and direction pattern of incoming and outcome flow are shown in Fig. 5. For the simulated period, the greatest magnitude of flow was found for July 3, where there was a lunar phase of increasing quarter, presenting a maximum low tide at 01:00:00 hours, and a maximum flood- tide at 8:00:00. It is important to highlight that for Vy component of the velocity, the velocity scale presented is greater than that for the Vx component.

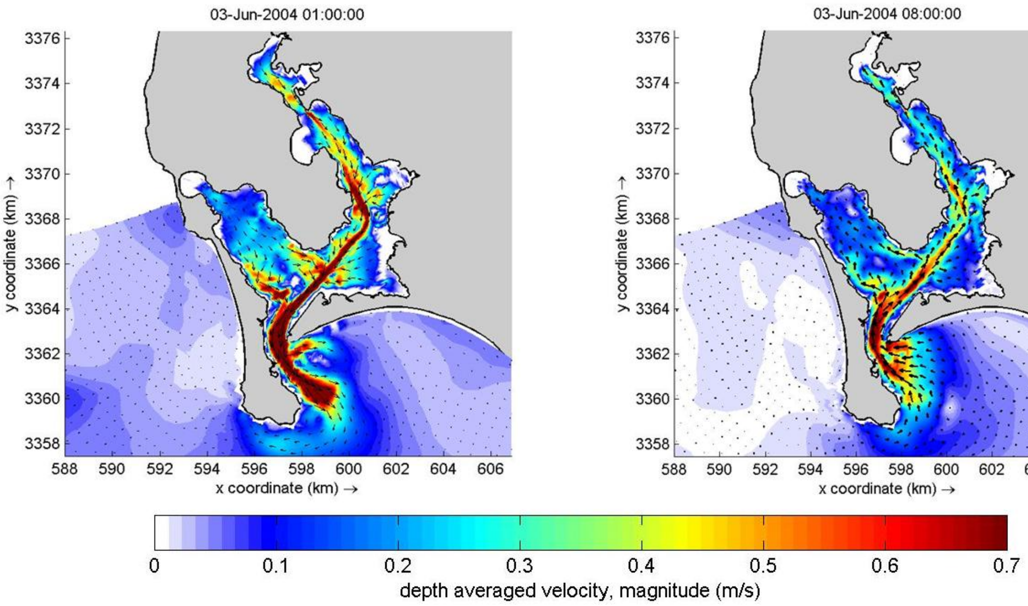

Figure 5. Left: higher velocity magnitude found for flood tide. Right:higher value found for magnitude velocity in ebb tide.

4. CONCLUSIONS

The model results show that the Delft3D model is capable of reproduce the essential processes in the San Quintin Bay, and can be forced by astronomical tide and wind. Delft3D in 2D mode was able to capture changes in water level with a high correlation with the data measured by three different ADCP'c inside the lagoon.

The statistical analysis of the errors corresponding to the time series for the sea level show a good performance of the model. The model follows the semidiurnal mixed regime.

For the velocities, the Vy component for the three points presented a higher correlation with the measured data than Vx component. The maximum velocities for low and high tide are observed in the deepest sections of the lagoon, following the main deeper channels. The highest flow intensity is observed during the ebb tide, while during the flood tide the magnitude velocity appears to be lower. It is believed that this is mainly due to the fact that during the low tide, a large area of the lagoon is completely dry and exposed leaving great everglade areas, which probably contributes in the speed reduction during high tide.

ACKNOWLEDGEMENTS

M.F.M acknowledge the research grant from CAPES, the NationalAgency for Postgraduate Education. The provided data by Dr. Adam Mejia Trejo of the Oceanological Research Institute are greatfully apreciated.

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