Application of a Three-Dimensional Hydrodynamic Model for San Quintin Bay, B.C. Mexico. Validation and Calibration using OpenDA.

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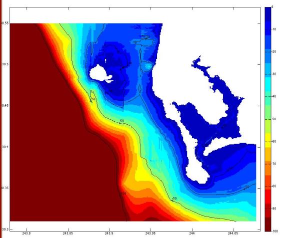
Abstract

A 3D hydrodynamic model (Delf3D) was developed for San Quintin Bay (SQB). Calibration and validations were conducted, using measured bathymetry, water surface elevation, velocities, and temperature. The calibration period was taken in the winter season of 2010. Model predictions were evaluated graphically and statistically against field observations to quantify the accuracy of model predictions and evaluate the success of model calibration. Comparisons between model predictions and field observations of water surface elevations at interior stations indicated that the model was successfully calibrated and model predictions were highly correlated with observed water surface elevations. Agreement between observed and simulated values was based on graphical comparisons, root-mean-square errors, and principal components analysis. The objective of this study was to show that OpenDA can be used to rapidly calibrate a hydrological model.

Keywords: Calibration, San Quintin Bay, OpenDA, Delft3D.

Study Region: San Quintin Bay

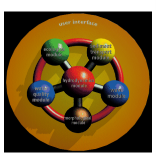


The most important biological process for cultivating organisms like the Japanese oyster, "Crassotrea Gigas" is the reproductive cycle which is principally regulated by the amount and quality of the food as well as by temperature and salinity. Furthermore, the hydrodynamic state has to be known with high accuracy.

Fug 1. SQB is Located in the northwestern coast of the Baja California Peninsula (Mexico), SQB is a coastal lagoon covering an area of approximately 42 km^2.

Delft 3D Model

Delft3D-FLOW is a multi-dimensional (2D or 3D) hydrodynamic (and transport) simulation program which calculates non-steady flow and transport phenomena that result from tidal and meteorological forcing on a rectilinear or a curvilinear, boundary fitted grid. In 3D simulations, the vertical grid is defined following the sigma or z co-ordinate approach.



Delft3D-FLOW solves the Navier Stokes equations for an incompressible fluid, under the shallow water and the Boussinesq assumptions. In the vertical momentum equation the vertical accelerations are neglected, which leads to the hydrostatic pressure equation. In 3D models the vertical velocities are computed from the continuity equation. The set of partial differential equations in combination with an appropriate set of initial and boundary conditions is solved on a finite difference grid. [2]

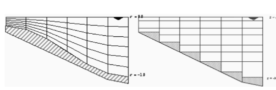


Figure 2. Example of - and Z-grid.

The σ co-ordinate system is defined as:

$$\sigma = \frac{z-\zeta}{d+\zeta} = \frac{z-\zeta}{H},$$

the total water depth, given by

$$H = d + \zeta.$$

- z the vertical co-ordinate in physical space
- ζ the free surface elevation above the reference plane (at $z = 0$)
- d the depth below the reference plane

Model Set Up

The model grid is in Cartesian, 15 layers sigma coordinates, with 3 seconds resolution in the horizontal, (~90 m). Since the main force on the bay is coming from tide [1], one major boundary forcing functions applied at the west side of the domain, the global inverse tide model (TPX0 7.2) is used to initiate Delft3D. To start the computations, it is necessary to specify initial conditions for elevation, velocity, Salinity and temperature. Initial water surface was assumed horizontal, and velocity components were set to zero through the model domain.

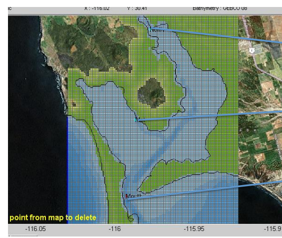


Figure 3. Cartesian Mesh 3 seconds resolution. The bathymetry has shallows areas less than 2 meters depth which are exposed during the low tide making from the bay a system of complex.

Monitoring Data

1. **North Station**
   - Water Level from Model MARV0.9 2010 CICESE Mexico.
2. **Met Station:**
   - Air Temperature, Wind Velocities Components, Atmospheric Pressure, humidity and rain.
3. **Bay Entry Station:**
   - Pressure, water temperature, currents from Navy Secretary of states.

Data from a field campaign during the wet season (August – September 2010) was used to establish the numerical scenario to simulate the hydrodynamics of SQB.

Model Skill Assessment

The model was calibrated by adjusting the depth, the bottom frictional drag coefficient, the semidiurnal M2 and S2 tide coefficients. These coefficients are adjusted to reproduce measured tidal elevations and currents.

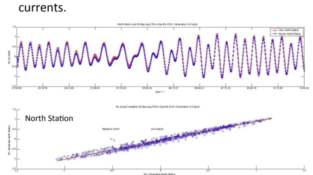


Figure 4a. Comparison of Instantaneous Water Levels at the **North Station**. 14 days simulation from Aug 27th,2010. RMSE: 0.1036 R^2=0.98624

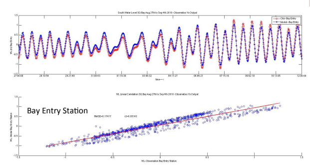


Figure 4b. Comparison of Instantaneous Water Levels at the **Bay Entry Station**. 14 days simulation from Aug 27th,2010. RMSE: 0.17417 R^2=0.95143

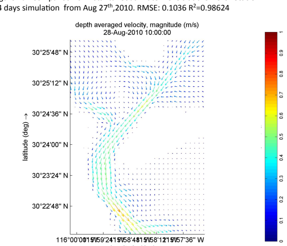


Figure 5a. Depth Average Velocity, Magnitude during low tide.

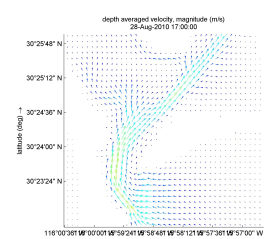


Figure 5b. Depth Average Velocity, Magnitude during High tide.

Open DA Algorithms

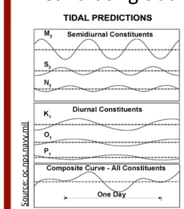
OpenDA is an open interface standard for (and free implementation of) a set of tools to quickly implement data-assimilation and calibration for arbitrary numerical models [3].

Calibration: The aim is to tune a set of parameters that is fixed in time.

Ex: Depth, Amplitude, Phase, roughness

Data Assimilation: aims to improve the starting position of the model for a forecast, so the estimates are different each cycle.

Calibrating tidal constituents



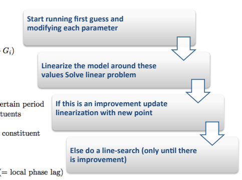
The general formula for the astronomical tide is:

$$H(t) = A_0 + \sum_{i=1}^{k} A_i F_i \cos\left(\omega_i t + (V_0 + u)_i - G_i\right)$$

in which:

$H(t)$	water level at time t
A_0	mean water level over a certain period
k	number of relevant constituents
i	index of a constituent
A_i	local tidal amplitude of a constituent
F_i	nodal amplitude factor
ω_i	angular velocity
$(V_0 + u)_i$	astronomical argument
G_i	improved kappa number (= local phase lag)

Dud Algorithm



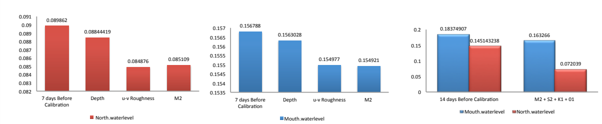


Fig 6 . Root Mean Square Error comparison before and after the parameter calibration: Depth, friction and the tidal constituents M2 S2 K1 01

CONCLUSION

The model results so far show that the Delft3D model is capable of simulation the essential processes in the San Quintin Bay, and can be forced by the tidal model.

Calibration using OpenDA, did improve the first model implementation, getting better results in the north station than the Bay Entry Station, after 14 days calibration. Results show this tool has the potential to deliver real time forecasting/nowcasting capabilities in this region.

References

[1] I. Ramirez, R. Blanco, et all. The simulation of the circulation of San Quintin Bay. Submited to Ocean Dynamics 2012.

[2] http://oss.deltares.nl/web/delft3d

[3] http://www.openda.org

Acknowledge.

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