Performance of the Coastal Modeling System for Various Conditions in the Navigational Waters of the Texas Coastal Bend

Sergey Reid and Philippe Tissot
Texas A&M University-Corpus Christi
Conrad Blucher Institute

Introduction/Background
Corpus Christi Bay is primarily a shallow bay (~4 meters) located off the Gulf of Mexico in South Texas. (Figure 2) The main challenge in modeling this bay and the surrounding area originates from a deep ship channel (~14 meters) running across the bay. The Corpus Christi ship channel provides the main connection with the Gulf of Mexico and has a significant impact on water levels. Another important variable affecting water levels and circulation are strong winds, typically directed from the Southeast or North, that are perpendicular to the ship channel. The hydrodynamic model chosen for this study was the Coastal Modeling System (CMS) developed by the U.S. Army Corps of Engineers. The model was selected for its computational efficiency, ease of implementation and its emphasis on navigation channel performance. The model performance is evaluated based on its accuracy in predicting water levels and currents at four locations within the model area. Average performance based on hourly water levels during 2010 is better than 2.6 cm mean absolute error at all locations. Performance during periods which included several cold fronts is similar to the average yearly performance. Model performance during a two week period which included the passage of 2010 hurricanes Alex and Tropical Depression 2 shows good performance as well with all water levels being within 2.8 cm of the measured values. The research further shows that wind forcing is not a major factor for water level accuracy and that the inclusion of a recent man made inlet, Packery Channel, only impacts the accuracy of the closest station to the inlet (Packery). Based on this research CMS is a good selection for the real-time nowcasting of water levels in the Texas Coastal Bend waterways.

Results:

2010 Full Year Analysis: (Refer to Table 1)
The overall 2010 mean absolute error for all the verification stations fell within 2.6 cm. The lowest mean absolute error of 1.6 cm occurred at the Rockport station and the highest mean absolute error of 2.5 cm occurred at the Port Aransas station. The yearly predictions did not present a notable bias and the slight biases that were computed, averaged themselves out amongst the four stations.

2010 Tropical Storm and Cold Front Analysis: (Refer to Table 1)
The late June to mid-2010 time period which includes Hurricane Alex and Tropical Depression 2 shows an increase in mean absolute error for all the stations when compared to the yearly average. The most notable change occurs at Rockport with a 1 cm increase and Ingleside with a 6 cm increase in the mean absolute error. Unlike the yearly average, the tropical storm and the cold front periods present a bias (negative during storms and positive during cold fronts).

Packery Channel, Wind Impact and Current Analysis: (Refer to Table 1)
The removal of Packery channel from the model showed no effect on verification stations except for the one located along the channel where the mean absolute error increased by 1.2 cm. The removal of wind from the model ran showed that wind does not significantly impact the predictions. Only Rockport and Packery stations were affected (~ 1 cm increase in CMS). The final analysis of the currents along the channel showed that the model follows the correct phase but constantly over-predicts or under-predicts the current velocities (Figure 3).

Discussion:
The yearly average analysis shows that the model is successful at nowcasting with all the mean absolute errors falling within 2.6 cm. The analysis shows that there is no significant bias during the yearly average. The bias is negative for all the stations during the tropical storm time period from January through March and the opposite occurring during the two cold front time periods with positive bias. The wind is not a significant factor in model performance with mean absolute errors only significantly increasing at two stations, Rockport and Packery. The small impact of wind on model performance is likely due to the lag between wind forcing and changes in water levels.

Conclusions:
The 2010 yearly analysis shows that the model implementation was successful with all the stations having a small mean absolute error at no more than 2.5 cm and no significant bias. Small biases were observed during cold fronts and tropical storm passages. The research also shows that the inclusion of the recently dredged Packery channel only affects the Packery Channel station. Furthermore, the analysis shows that wind does not play a significant role for the prediction of water levels. Given the model’s success in nowcasting, the model will be tested for forecasting by forcing it with Artificial Neural Network predictions.

Data and Methods
- National Oceanic and Atmospheric Administration (NOAA) L&B coastline data to define land boundaries
- NOAA digital elevation model to define bathymetry
- Texas Coastal Ocean Observation Network (TCOON) water level and wind measurements
- Surface Water Modeling System (SMS) interface
1. The TCOON measurements were used to force and to analyze model performance
2. To analyze impact of wind on model performance, the model was run with and without wind forcing
3. To analyze the impact of Packery channel, the model ran with the channel and then with the channel removed
4. To conduct the analysis, mean absolute errors, root mean squared errors and biases were computed for each location
5. The currents were analyzed by comparing along channel TCOON current measurements at Port A to model predictions

Table 1: CMS water level performance analysis for 4 verification stations

<table>
<thead>
<tr>
<th>Station</th>
<th>Full 2010 Analysis</th>
<th>Tropical Storm Analysis (June 28 - 74 July, 2010)</th>
<th>Cold Front Analysis (November 1 - December 31, 2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packery</td>
<td>Bias (m) 0.003, 0.004, 0.006</td>
<td>Bias (m) 0.011</td>
<td>Bias (m) 0.001</td>
</tr>
<tr>
<td>Ingleside</td>
<td>Bias (m) 0.024, 0.013</td>
<td>Bias (m) 0.025</td>
<td>Bias (m) 0.005</td>
</tr>
<tr>
<td>Port Aransas</td>
<td>Bias (m) 0.013</td>
<td>Bias (m) 0.011</td>
<td>Bias (m) 0.009</td>
</tr>
<tr>
<td>Rockport</td>
<td>Bias (m) 0.015</td>
<td>Bias (m) 0.015</td>
<td>Bias (m) 0.008</td>
</tr>
</tbody>
</table>

Figure 1: Eddy formations occurring around Port Aransas jetties with higher current speeds (1.4 m/s) occurring inside the ship channel during ebb

Figure 2: Study area map

Figure 3: Histogram of 24 Hour Prediction Residuals for 2003

Figure 4: Model performance during Hurricane Alex (June 2010)

Figure 5: Along current analysis at Port Aransas station (May 1-22, 2010)

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References:

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Figure 4: Model performance during Hurricane Alex (June 2010)

Figure 5: Along current analysis at Port Aransas station (May 1-22, 2010)