NOAA Technical Report NOS CS 14

EVALUATION OF THE NOS EXPERIMENTAL NOWCAST/FORECAST SYSTEM FOR GALVESTON BAY

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noaa National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Coast Survey Development Laboratory

Office of Coast Survey
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

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Richard A. Schmalz, Jr.
Philip H. Richardson

April 2002

noaa National Oceanic and Atmospheric Administration

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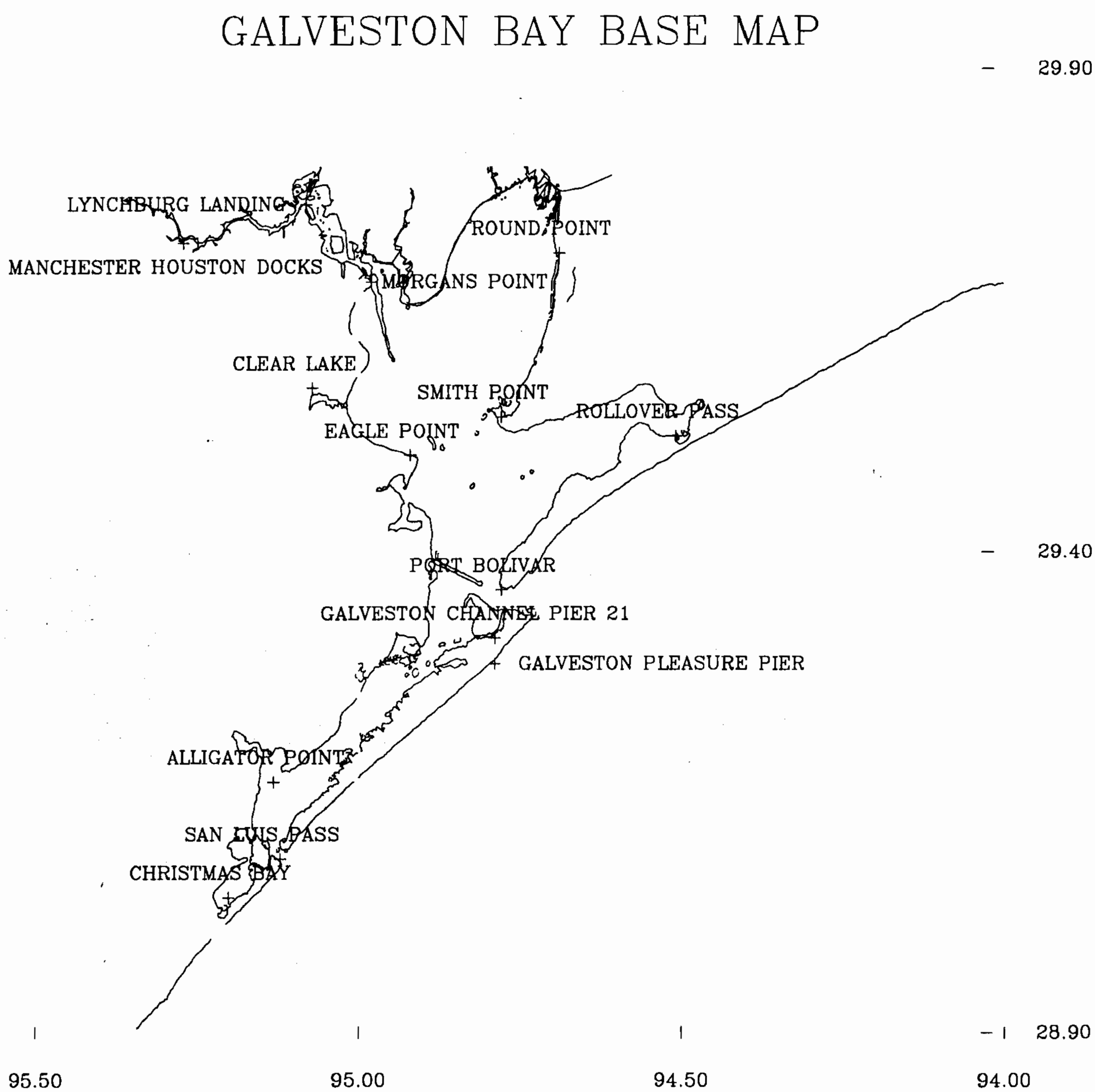


Galveston Bay Base Map

EXECUTIVE SUMMARY

An experimental nowcast/forecast system has been developed based on the NOS three-dimensional Galveston Bay hydrodynamic model (GBM) extended to include a emergence/submergence algorithm, a Flux Corrected Transport (FCT) salinity scheme, and Barnes (1973) meteorological field interpolation routines. To study currents within the Houston Ship Channel a fine resolution one-way coupled Houston Ship Channel Model (HSCM) has also been developed as described in Schmalz (2000). A general overview of the system development and protocol as well as user requirements are presented in Chapter 1, while in Chapter 2 the experimental nowcast/forecast system is described in further detail. This report focuses on the formal statistical evaluation for water levels and currents based on CSDL/CO-OPS formal acceptance criteria (NOS, 1999) over the one-year period from April 2000 through March 2001 as discussed in Chapter 3. Initially in Chapter 3, an astronomical tidal analysis is performed with model and NOS derived tidal constituents compared in Appendix A for both water levels and currents for both models. Next, the nowcast/forecast evaluation results are given. For the forecast an age analysis is performed to determine how the forecast performs over forecast time. In Chapter 4, additional statistical measures are presented for water levels and currents followed by an evaluation of surface salinity and temperature with forecast age analysis results given in Appendix B.

Here, we summarize the nowcast/forecast formal evaluation, which is based on an analysis of the error, defined as model minus observation. The following three statistical measure sets are used: 1) central tendency, 2) outlier duration and frequency, and 3) extrema timing and level frequencies. The water level evaluation results for both the GBM and HSCM are summarized in Table ES.1 for statistical measure sets 1 and 2. Observe that all criteria are satisfied on the nowcast for both models

Table ES.1. Water Level Analysis April 2000 -March 2001: Statistical Measure Sets 1 and 2. Note GPP= Galveston Pleasure Pier, P21= Galveston Pier 21, BR=Bolivar Roads (Port Bolivar), EP=Eagle Point, and MP=Morgans Point. Note the GBM results are in line 1 with the HSCM results given in line2. Note a check mark (✓) indicates that the criterion has been met, while an x mark (×) indicates that the criterion has not been met.

Statistical Measure	Nowcast					Forecast (1-24h)				
NOS Target Value	GPP	P21	BR	EP	MP	GPP	P21	BR	EP	MP
CF (15 cm) [≥0.9]	✓ -	✓ ✓	✓ ✓	✓ ✓	✓ ✓	× -	✓ ✓	✓ ✓	✓ ✓	× ×
NOF (30 cm) [≤0.01]	✓ -	✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ -	✓ ✓	✓ ✓	✓ ✓	✓ ✓
POF (30 cm) [≤0.01]	✓ -	✓ ✓	✓ ✓	✓ ✓	✓ ✓	× -	× ×	× ×	✓ ✓	× ×
MDPO (30 cm) [≤24]	✓ -	✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ -	✓ ✓	✓ ✓	✓ ✓	✓ ✓
MDNO (30 cm) [≤24]	✓ -	✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ -	✓ ✓	✓ ✓	✓ ✓	✓ ✓
WOF (30 cm) [≤0.005]	✓ -	✓ ✓	✓ ✓	✓ ✓	✓ ✓	× -	× ×	× ×	× ×	× ×

for all five stations. Results on the forecast are slightly degraded especially at Galveston Pleasure Pier and Morgans Point. Eagle Point is the most successfully forecast water level station. The reader is referred to Chapter 3 for definitions and the actual numerical values.

In Table ES.2, the results for statistical measure set 3 are given. For central frequency, CF, only the maximum level criterion at Galveston Pleasure Pier, Galveston Pier 21, and Bolivar Roads (Port Bolivar) are met during the nowcast only. For positive outlier frequency, POF, for minimum and maximum levles, the criteria are met for some stations on the nowcast. In general, these statistical measures appear to be very difficult to meet for the present nowcast/forecast system.

Table ES.2. Water Level Analysis April 2000 -March 2001: Statistical Measure Set 3. Note GPP= Galveston Pleasure Pier, P21= Galveston Pier 21, BR=Bolivar Roads (Port Bolivar), EP=Eagle Point, and MP=Morgans Point. Note the GBM results are in line 1 with the HSCM results given in line2. Note a check mark (✓) indicates that the criterion has been met, while an x mark (✗) indicates that the criterion has not been met.

Statistical Measure NOS Target Value	Nowcast GPP	 P21	 BR	 EP	 MP	Forecast (1-24h) GPP	 P21	 BR	 EP	 MP
Min Time: CF (30 min) [≥0.9]	✗ -	✗ ✗	✗ ✗	✗ ✗	✗ ✗	✗ -	✗ ✗	✗ ✗	✗ ✗	✗ ✗
Min Level: CF (15 cm) [≥0.9]	✗ -	✗ ✗	✗ ✗	✗ ✓	✗ ✗	✗ -	✗ ✗	✗ ✗	✗ ✗	✗ ✗
Max Time: CF (30 min) [≥0.9]	✗ -	✗ ✗	✗ ✗	✗ ✗	✗ ✗	✗ -	✗ ✗	✗ ✗	✗ ✗	✗ ✗
Max Level: CF (15cm) [≥0.9]	✓ -	✓ ✓	✓ ✓	✗ ✗	✗ ✗	✗ -	✗ ✗	✗ ✗	✗ ✗	✗ ✗
Min Time: NOF (30 min) [≤0.01]	✗ -	✗ ✗	✗ ✗	✗ ✗	✗ ✗	✗ -	✗ ✗	✗ ✗	✗ ✗	✗ ✗
Min Time: POF (30 min) [≤0.01]	✗ -	✗ ✗	✗ ✗	✗ ✗	✗ ✗	✗ -	✗ ✗	✗ ✗	✗ ✗	✗ ✗
Min Level: NOF (30 cm) [≤0.01]	✗ -	✗ ✓	✗ ✓	✗ ✗	✗ ✗	✗ -	✗ ✗	✗ ✗	✗ ✗	✗ ✗
Min Level: POF (30 cm) [≤0.01]	✓ -	✓ ✓	✗ ✗	✓ ✗	✗ ✗	✗ -	✓ ✗	✗ ✗	✗ ✗	✗ ✗
Max Time: NOF (30 min) [≤0.01]	✗ -	✗ ✗	✗ ✗	✗ ✗	✗ ✗	✗ -	✗ ✗	✗ ✗	✗ ✗	✗ ✗
Max Time: POF (30 min) [≤0.01]	✗ -	✗ ✗	✗ ✗	✗ ✗	✗ ✗	✗ -	✗ ✗	✗ ✗	✗ ✗	✗ ✗
Max Level: NOF (30 cm) [≤0.01]	✓ -	✗ ✓	✗ ✗	✗ ✗	✓ ✓	✓ -	✗ ✗	✗ ✗	✗ ✗	✓ ✗
Max Level: POF (30 cm) [≤0.01]	✗ -	✓ ✓	✓ ✓	✓ ✗	✗ ✗	✗ -	✗ ✗	✗ ✗	✗ ✗	✗ ✗

Principal component direction prediction depth current evaluation results for these three statistical measures are summarized correspondingly in Table ES.3 and Table ES.4. The reader is again referred to Chapter 3 for definitions and the actual numerical values. In Table ES.3, note the central frequency, CF, criterion is not met at both stations during either nowcast or forecast. The positive outlier frequency, POF, criterion is not met, while the negative outlier frequency, NOF, criterion is in general met. The worst case outlier frequency, WOF, is met at Bolivar Roads for the GBM.

Table ES.3. Principal Component Direction (4.7m) Current (cm/s) Analysis April 2000 -March 2001: Statistical Measure Set 1 and 2. BR= Bolivar Roads and MP=Morgans Point. Note the GBM results are in line 1 with the HSCM results given in line2. Note a check mark (✓) indicates that the criterion has been met, while an x mark (X) indicates that the criterion has not been met.

Statistical Measure NOS Target Value	Nowcast BR	 MP	Forecast (1-24h) BR	 MP
CF (26 cm/s) [≥0.9]	X X	X X	X X	X X
NOF (52cm/s) [≤0.01]	✓ X	✓ ✓	✓ X	✓ ✓
POF (52 cm/s) [≤0.01]	X X	X X	X X	X X
MDPO (104 cm/s) [≤24]	✓ ✓	✓ ✓	✓ ✓	✓ ✓
MDNO (104 cm/s) [≤24]	✓ ✓	✓ ✓	✓ ✓	✓ ✓
WOF (52 cm/s) [≤0.005]	✓ X	X X	X X	X X

In Table ES.4, almost all criterion are not met at both stations. The positive outlier frequency, POF, for the maximum level, the negative outlier frequency, NOF, for the minimum level, and the negative outlier frequency, NOF, for slack water time are in general met. As for water levels, statistical measure 3 criteria are difficult to satisfy.

Here we note that for water levels the results are nearly the same for both models, since the GBM provides water levels at the boundary of the HSCM. For statistical measures 1 and 2 the majority of the criteria are met during both nowcast and forecast. The opposite is the case for statistical measure set 3. We also note that for currents, the majority of the criteria are not met in both models. At Bolivar Roads this is due to the fact that there is considerable variability in the current structure, which cannot be captured with the present grid resolutions. The GBM results appear to be better at Bolivar Roads than the HSCM results due the position of the HSCM and the imposition of a water level boundary condition. At Morgans Point, the higher resolution HSCM gives improved results over those obtained in the GBM. However, the results obtained at Morgans Point are not as good as those at Bolivar Roads. This appears due to the influence of freshwater inflows associated with stormwater runoff at Morgans Point, which are not input to the models.

Table ES.4. Direction (4.7m) Current (cm/s) Analysis April 2000 -March 2001: Statistical Measure Set 3. BR= Bolivar Roads and MP=Morgans Point. Note the GBM results are in line 1 with the HSCM results given in line2. Note a check mark (✓) indicates that the criterion has been met, while an x mark (✗) indicates that the criterion has not been met.

Statistical Measure NOS Target Value	Nowcast BR	 MP	Forecast (1-24h) BR	 MP
Slack Water Time: CF (30 min) [≥0.9]	✗ ✗	✗ ✗	✗ ✗	✗ ✗
Min Time: CF (30 min) [≥0.9]	✗ ✗	✗ ✗	✗ ✗	✗ ✗
Min Level: CF (26 cm/s) [≥0.9]	✗ ✗	✗ ✗	✗ ✗	✗ ✗
Max Time: CF (30 min) [≥0.9]	✗ ✗	✗ ✗	✗ ✗	✗ ✗
Max Level: CF (26 cm/s) [≥0.9]	✗ ✗	✗ ✓	✗ ✗	✗ ✗
Slack Water Time: NOF (30 min) [≤0.01]	✓ ✓	✓ ✓	✓ ✓	✓ ✓
Slack Water Time: POF (30 min) [≤0.01]	✗ ✗	✗ ✗	✗ ✗	✗ ✗
Min Time: NOF (30 min) [≤0.01]	✗ ✗	✗ ✗	✗ ✗	✓ ✗
Min Time: POF (30 min) [≤0.01]	✗ ✗	✗ ✗	✗ ✗	✗ ✗
Min Level: NOF (52 cm/s) [≤0.01]	✗ ✓	✓ ✓	✗ ✓	✓ ✓
Min Level: POF (52 cm/s) [≤0.01]	✗ ✗	✗ ✗	✗ ✗	✗ ✗
Max Time: NOF (30 min) [≤0.01]	✗ ✗	✗ ✗	✗ ✗	✗ ✗
Max Time: POF (30 min) [≤0.01]	✗ ✗	✗ ✗	✗ ✗	✗ ✗
Max Level: NOF (52 cm/s) [≤0.01]	✗ ✗	✗ ✓	✗ ✗	✗ ✓
Max Level: POF (52 cm/s) [≤0.01]	✓ ✓	✓ ✗	✓ ✓	✓ ✓

Also in Chapter 4, a forecast age analysis indicates that even out ot 24 hours into the forecast, the central frequency, CF, associated with the 15 cm level, is order 0.8 to 0.9. For the principal component direction current in the GBM at Bolivar Roads, similar results were noted; e.g., for 24 hours into the forecast the CF associated with 26 cm/s is order 0.8. In addition, the water level forecasts are superior to the astronomical tide plus persistence and the astronomical tide at all stations in both models. For principal component direction currents, this is also true for the GBM at Bolivar Roads but not for the HSCM at Bolivar Roads. At Morgans Point, both model forecasts are not superior to the tidal current prediction.

In Chapter 5, a water level event analysis is performed over the one year evaluation period. The analysis focuses on the monthly variability of both high and low water events and the ability of the nowcast/forecast system to accurately simulate both event types as shown in Table ES.5. We note that the nowcast and forecast both are superior to the tidal predictions and serve as a useful tool in providing forecast guidance with respect to water level events.

Table ES.5. Nowcast/Forecast System Skill Measure Set 2 Water Level Event Results: April 2000 - March 2001. Numbers in the numerator indicate the number of months in which the number of successes is greater than the sum of the number of failures and false alarms. The denominator represents the number of months in the evaluation period.

Station/Analysis	Nowcast	Tide Prediction	Forecast	Adjusted Forecast
Galveston Pleasure Pier:				
Total	9/12	2/12	8/12	9/12
High	7/12	0/12	5/12	4/12
Low	5/12	3/12	6/12	6/12
Morgans Point:				
Total	8/12	1/12	7/12	10/12
High	7/12	0/12	4/12	5/12
Low	4/12	1/12	4/12	6/12

In Chapter 6, principal component direction current event analysis is performed. The analysis is not straightforward in that current depth, and principal component direction issues are involved. At Bolivar Roads in the GBM, the current forecasts are superior to the tidal current predictions. This is not the case at Morgans Point in either the GBM or HSCM. However at Morgans Point, it is possible to adjust the HSCM forecast currents using linear regression to be more accurate than the tidal current prediction.

In Chapter 7, the following recommendations are made to further improve the present nowcast/forecast system:

1) Consider alternate forcings during major events. Higher resolution windfields would be used over the Bay during tropical storms and hurricane events. In addition, hourly flow forecasts would be used for the Trinity and San Jacinto Rivers to more accurately depict flood period hydrographs. For major rainfall events, a separate rainfall-runoff model for the City of Houston would be used to define the major inflows along the Port of Houston.
2) Employ horizontal ADCPs for measuring velocity cross-sections at different locations along the channel to define the density currents in the channel. Use monthly or event triggered CTD surveys along the HSC to locate the movement of the salt wedge.
3) Consider a statistical nowcast approach to fill in missing current data.

Based on the evaluation performed, it is difficult to determine a set of statistics and acceptance levels for hydrodynamic model validation within the Experimental Galveston Bay Nowcast/Forecast System. As an alternative, it is useful to consider the NOS (1999) criteria as a set of initial statistical measures based on navigation user requirements used to define target levels for model validation. In this context, the validation of the hydrodynamic model is considered in terms of system performance measures. This allows an initial operational system to be developed with improvements in refined system performance directly assessed.

1. INTRODUCTION

The National Oceanic and Atmospheric Administration installed a Physical Oceanographic Real Time System (PORTS) patterned after Bethem and Frey (1991) in June 1996 to monitor Galveston Bay. In the present system, water surface elevation, currents at prediction depth (4.6m) as well as near-surface and near-bottom temperature and salinity, and meteorological information are available at six-minute intervals (Appell et al., 1994) at locations shown in Figure 1.1 to support safe navigation as well as environmental concerns as discussed by Parker (1996).

1.1. System Overview

To complement the PORTS, an experimental nowcast/forecast system outlined in Table 1.1 has been developed based on the National Ocean Service (NOS) Galveston Bay three-dimensional hydrodynamic model (Schmalz, 1996) and the National Weather Service (NWS) Aviation atmospheric model. To simulate currents within the Houston Ship Channel (HSC), a finer resolution three-dimensional HSC model has been developed. The Galveston Bay model is used to provide Bay wide water level and near entrance current forecasts as well as to directly provide water levels, density, and turbulence quantities to the HSC model for use in a one-way coupling. The models have been extensively validated and several water level sensitivity tests have been conducted as presented in Schmalz (2001).

Table 1.1. NOS Experimental Nowcast/Forecast System Components. Note the three-dimensional hydrodynamic Galveston Bay Model is (GBM) and the three-dimensional hydrodynamic Houston Ship Channel Model is (HSCM).

Nowcast Inputs	Forecast Inputs
NOS/PORTS	NWS/Models
Water Level	Extratropical Storm Surge (ETSS)
Wind/Sea Level Pressure	Aviation Model (AVN)
Water Temperature (Surface and Bottom)	Persistence of SST, Climatological Bounday Conditions
Surface Salinity	SSS no flux, Climatological Boundary Conditions
USGS River Inflows	NWS/WGRFC Models
Trinity River	Trinity River
San Jacinto River	San Jacinto River
Buffalo Bayou	Persistence

Here we summarize the model hindcast validation in Table 1.2. Water level sensitivity experiments conducted for the January 1995 "Norther" events and the October 1994 flood of record indicated:

1) Flows order 20,000 cfs have order 5 cm influence on Upper Bay water levels;
2) During the flood of record, upper Bay water levels influenced Bay water levels order 50 cm;

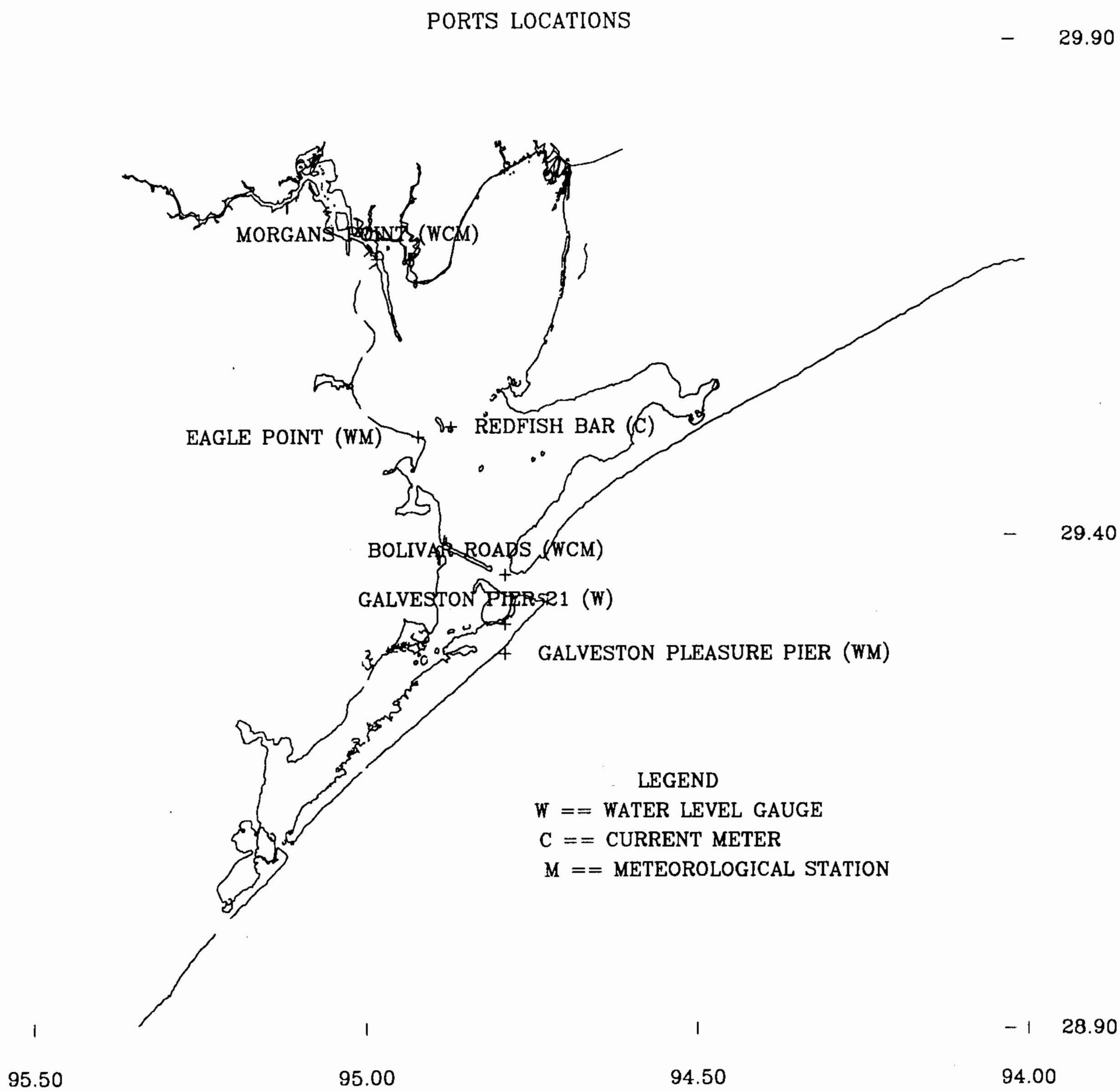


Figure 1.1. PORTS Station Locations

Table 1.2. Three-dimensional Hydrodynamic Model Hindcast Validation Summary. Note z_0 = bottom roughness (m), C_H= Smagorinsky horizontal eddy viscosity coefficient, sd wl = standard deviation of the observed and simulated water level difference, and pcde= principal component direction current error, and peak=peak current strength. Note FCT= Flux Corrected Transport, ES= Emergence/Submergence, and SST= Sea Surface Temperature.

Hindcast	Model State	Model Parameters	Model Result
Astrotide calibration May 1995	GBM-NOS Partnership Project	z_0=0.002 C_H=0.005	sd wl ~ 5 cm
DGPS Hydrosurvey June 1996	GBM-NOS Partnership Project	z_0=0.01 C_H=0.005	sd wl ~10cm
"Northers" Jan 1995	GBM-FCT/ES Heat Flux	z_0=0.01 C_H=0.005	sd wl ~ 10cm
"Flood of Record" October 1994	GBM-FCT/ES Heat Flux	z_0=0.01 C_H=0.005	sd wl ~ 10cm
PORTS Beta Test April 1996	GBM-FCT/ES SST HSCM-FCT/ES SST	z_0=0.002 C_H=0.005	sd wl ~ 10cm pcde~0.2 peak

Table 1.3. Experimental Nowcast/Forecast System Protocol

Perform 00 UTC forecast each day. Use CST time reference.

Consider 21 May 2001:

00 UTC Nowcast/Forecast Timeline

00 UTC NWS/AVN Forecast Available 0 CST
00 UTC NWS/ETSS Forecast Available 1 CST
00 UTC NWS/WGRFC Forecast Available 10 CST (Previous Day)
00 UTC NOS/GBM Forecast Available 3 CST
00 UTC NOS/HSCM Forecast Available 6 CST

```
May 19      May 20     May 21                        May 22
18 CST      18 CST     6 CST                         6 CST
|           |          |                             |
| Nowcast   |Forecast  |Forecast                     |
+-------------------------------------------------------+
-24         0          12                            36
```

3) Bay winds influenced water levels order 10 cm during portions of both months; and
4) Subtidal water level influence was order 50 cm during portions of January 1995.

As a result, accurate freshwater inflows, Bay surface windfields, and near Gulf subtidal water levels are all required as inputs to the nowcast/forecast system for Galveston Bay shown in Table 1.3.

1.2. Summary of User Requirements

Initial user requirements (Schmalz and Richardson, 1996) were refined through visits to the Houston/Galveston maritime community coordinated by Commander Alan R. Bunn, NOAA-Corps retired. The results are discussed by user in turn below and summarized in Table 1.4.

Commander Peter Simons, USCG-VTS Houston, indicated that the principal focus for currents are at the two choke points: Morgans Point and Bolivar Roads. He expressed a desire for either model or statistical nowcast currents at Morgans Point and Bolivar Roads during current meter down times. Primary water level information is now included in the PORTS at Morgans Point and Bolivar Roads. The following additional locations for water level and current nowcasts and forecasts were requested: 1) Houston Turning Basin, 2) Greens Bayou, 3) mouth of San Jacinto River, 4) Fred Hartman Bridge (SR 146), 5) Red Fish Bar, 6) Entrance Channel Buoys 5 and 6, and 7) Galveston Pleasure Pier. Two forecasts per day of 24 hour length with a 1 hour reporting interval are desired using the PORTS screen format for forecast water levels and currents. An air gap forecast at I-610 bridge is also needed.

Messrs. Bill Read and Brian Kyle, NWS-WFO Houston-Galveston, indicated a need for two forecast cycles per day corresponding to the 00z and 12z meteorological model cycles. Their primary focus would be on forecast water levels at Clear Lake, Freeport, High Island, and Anahuac. Complete forecast field water level contours in English units on a 1-3 hr interval are requested.

Based on discussions with Dr. Thomas Minello, NWS-NMFS Galveston, water level forecasts are desired at Atkinson Island, Elmgrove Point, and Jamaica Beach. It would be possible to develop weekly to monthly shrimp productivity maps based on habitat and salinity nowcast fields.

QMC William Segelken, USCG-Search and Rescue Galveston, indicated a need for surface current forecasts in mid Trinity Bay, at Bolivar Roads, Morgans Point, and Redfish Bar, OLD ICWW(#56,#58), East Bay (2 locations, one above Goat Island and a second above Long Point), and West Bay (2 locations each side of Carancahua Reef, below Greens Lake and below Halls Lake). NOAA/HAZMAT requires multiple depth forecast current fields at hourly intervals during each forecast provided on anonymous ftp site for access.

Based on a telephone conversation following the fax of the user survey, the following requirements were provided by Captain Lance Miller, Houston Pilots. Only directional current information is needed at Bolivar Roads. The Houston Pilots are interested in water levels and currents primarily within the Port of Houston proper. Water levels are desired in realtime at Lynchburg Landing and Manchester Dock 2. The pilots would also like to see the Exxon Baytown ADCP readings contained within the PORTS system. From the NOS perspective, there are some sensor performance issues with respect to the type of current meter presently in use at Exxon Baytown. ADCP current meters at ITC Shell Area (Midway through the Port of Houston), Houston Turning Basin, and Lynchburg

Table 1.4. Galveston Bay - Houston Ship Channel Nowcast/Forecast User Requirements Summary

Reqmt	USCG-VTS	NWS-WFO	NWS-NMFS	USCG-SAR	Houston Pilots	Galveston Pilots
Parameters	Water Level and Currents	Water Level	Water Level	Near-surface Currents	Water Level and Currents	Water Level, Currents, Air and Water Temp, Salinity, Water Density, Wind Speed and Direction
Additional Locations	Turning Basin, Greens Bayou, mouth of San Jacinto River, Fred Hartman Bridge (SR 146), Red Fish Bar, Entrance Channels Buoys 5 and 6, and Pleasure Pier	Clear Lake, Freeport, High Island, and Anahuac	Atkinson Island, Elmgrove Point, and Jamaica Beach	Mid-Trinity Bay, Redfish Bar, OLD ICWW (#56,#58), East Bay (2), and West Bay (2)	Lynchburg Landing, Manchestr Dock 2, Exxon Baytown, ITC Shell, and Houston Turning Basin	Texas City Turning Basin, Galveston N/S Jetty
Nowcast/ Forecast Format	Screen Format	Water Level Contour Plots	Water Level Contour Plots	ASCII files	Acquire from PORTS dialup or VTS	Acquire from PORTS dialup or VTS
Forecast Frequency/ Length	2 per day/24 hr	2 per day/24 hr	2 per day/24 hr	-	2 per day/24 hr	-
Forecast Interval	1 hr	1 - 3 hr	1 - 3 hr	-	1 - 3 hr	0.25 hr
Misc	Air Gap Forecast at I-610 Bridge; Rainfall/ runoff inflow within POH		Develop Weekly to monthly Shrimp product-ivity maps	HAZMAT multiple depth forecast current fields on secure ftp	Include TCOON stations and Exxon Baytown ADCP within PORTS	

Landing were also requested. With respect to forecast schedule, the Houston Pilots desire two cycles per day with hourly interval 24 hour forecasts.

Based on information provided by Captain Michael T. Godinich, Galveston-Texas City Pilots, Bolivar Roads PORTS station data needs to be provided reliably (with as little down time as possible for currents) with 15 min updates. The following information is required: 1) current speed and direction, 2) tidal height, 3) air and water temperature, 4) salinity and water density, and 5) wind speed and direction. The same information is needed in real time at the Texas City Turning Basin and outside the entrance of the Galveston North/South Jetty.

In Chapter 2, the experimental nowcast/forecast system development is presented in terms of: 1) PUFFF database construction, 2) system set-up procedures, and 3) hydrodynamic model refinements. In Chapter 3, water level and current evaluation results from the NOS (1999) formal statistical acceptance procedures are presented over the April 2000 through March 2001 one year evaluation period. In Chapter 4, further statistical measures are computed to evaluate the water level and current response. In addition, salinity and temperature are also considered in Chapter 4. Forecast water level event analysis results are given over the one year evaluation period in Chapter 5, while in Chapter 6 the event analysis is extended to principal component direction currents at prediction depth. In Chapter 7, conclusions are drawn and recommendations made to improve the system.

2. EXPERIMENTAL NOWCAST/FORECAST SYSTEM DEVELOPMENT

The experimental system consists of the programs given in Table 2.1. In Section 2.1 we discuss the data construction program, Program Decode_pufff.f. In Section 2.2, the set-up program, Program Nfcst.f, is discussed. Model details for Bay hydrodynamics, Program Hflw.gbm.f, and for the Houston Ship Channel hydrodynamics, Program Hflw.hsc.f, are given in Schmalz (1996, 1998a, 1998b, 2000, 2001). Hydrodynamic refinements related specifically to improvements in the experimental nowcast/forecast system are presented in Section 2.3. Cycle evaluation graphics (Programs Ts.gbm.f, Ts.gbm.fc.f, Ts.hsc.f, Ts.hsc.fc.f, and Ts.pro) are executed each nowcast/forecast cycle to evaluate both nowcast and previous forecast results. Galveston Bay and Houston Ship Channel fields and vertical sections are developed using Convec.sh (IDL graphics) and Fl.hscw.f (NCAR graphics),

Table 2.1. Experimental Nowcast/Forecast System Programs

Program Name	Program Function
Decode_pufff.f	Assemble 6-minute PUFFF files and produce daily station files
Nfcst.f	10 step setup procedure
Hflw.gb.f	Galveston Bay 3-d hydrodynamics
Hflw.hsc.f	HSC 3-d one way coupled hydrodynamics
Ts.gbm.f, Ts.gbm.fc.f	Galveston Bay time series (NCAR graphics/nowcast and forecast statistics)
Ts.hsc.f, Ts.hsc.fc.f	HSC time series (NCAR graphics/nowcast and forecast statistics)
TS.pro	GBM and HSC time series nowcast (IDL color graphics and forecast summaries)
Eval.frm.pro	Monthly error summary (IDL procedure)
Convec.sh	GBM water level, current, salinity, and temperature fields (IDL color graphics)
Fl.hscw.f	HSC water level, current, salinity, and temperature fields and cross-sections (NCAR graphics)
Gbm.eva.f, Hsc.eva.f	GBM and HSC formal nowcast/forecast evaluation

respectively. Monthly evaluations of rms error are performed using Eval.frm.pro (IDL graphics) with formal long term evaluations performed using Gbm.eva.f and Hsc.eva.f.

2.1. PUFFF Database Construction

Every six minutes, the PUFFF files are acquired for water levels and currents. PUFFF files are used to create the six minute PORTS screen as shown in Figure 2.1. Originally, the nowcast/forecast system was run off the PORTS screen (see Schmalz, 1998) with an hourly data update interval. However, the present system works directly from the PUFFF files so that CORMS flags may be directly used and employs a six minute data update interval. The files are checked for proper length. Files that are incomplete due to FTP transfer errors are discarded. Complete files are concatenated to produce daily water level and station files. These files are then archived and serve as a backup to the PORTS Infohub database. In the present system, the water level and current files are accessed at the end of each day and reformatted for ingest by the nowcast/forecast setup program, nfcst.f. All water level, current, and meteorological information are combined in each station file. If data types are not measured at a given station, the value is set to 88888., while if data are measured but are missing a value, the value of 99999. is assigned.

2.2. Nowcast/Forecast Setup Procedures

A modular design of the experimental nowcast/forecast system has been used such that refined hydrodynamic models can be readily substituted for the initial GBM and HSCM models. (Refer to Figures 2.2 and Figures 2.3 and 2.4 for the GBM and HSCM model grids, respectively.) To this end, a separate nowcast/forecast program has been developed to establish hydrodynamic model forecast inputs. The program utilizes the following ten step procedure:

1)Setup 24 hour nowcast and 36 hour forecast time periods,
2)Predict astronomical tide,
3)Predict astronomical currents,
4)Read PUFFF files and develop station time series,
5)Develop GBM subtidal water level signal,
6)Assimilate PORTS salinity and temperature data into GBM and HSCM initial conditions,
7)Establish GBM and HSCM salinity and temperature boundary conditions,
8)Establish GBM and HSCM SST forcings,
9)Establish USGS observed and NWS/WGRFC forecast freshwater inflows, and
10)Establish PORTS based and Aviation Model wind and pressure fields.

Time series files for predicted water surface elevation, and principal direction prediction depth currents are generated as well as PORTS time series data files for water levels, currents, salinity, temperature, wind, and atmospheric pressure. Time series analysis programs to plot nowcast and forecast results in conjunction with the above time series files for both models have also been incorporated within the system. Each step is reviewed in turn below.

Step 1: Presently a 24 hour nowcast is used to spin up both models from the restart at the end of the previous nowcast. Based on PORTS data, realistic initial density fields are established. Due to the processing time(6 hr for AVN and ETSS and 6 hr for GBM and HSCM) a 36 hour forecast is made in which the first 12 hours embrace the processing time. Thus, timelines are setup for the 24 hour nowcast and 36 hr forecast using the CST time reference frame. Next the angles of Bay and HSC grid cell x-directions relative to East are determined. Mid-year node factor and beginning year equilibrium arguments are next determined for use in steps 2 and 3. Note the algorithm handles year crossings.

Step 2: Astronomical tides are predicted at five locations along the GBM boundary and at internal locations of both models over the 60 hour simulation period using the prediction method of Schureman (1958). Harmonic analyses are summarized in Table 2.2. Tidal constituents at the five boundary locations are given in Table 2.3, while tidal constituents at GBM and HSCM stations are given in Tables 2.4 and 2.5, respectively.

Step 3: Principal component direction current predictions are made using the Schureman (1958) prediction formula based on 29 day harmonic analysis as shown in Table 2.6. Principal Component Direction (PCD) harmonic constants at GBM and HSCM stations are given in Table 2.7 and in Table 2.8, respectively.

Step 4: PUFFF data are accessed from the previous two day station files covering the nowcast period. Water level, current speed and direction, surface salinity, and surface and bottom temperature, wind speed and direction, and atmospheric pressure data are available for each of the six PORTS stations. Times series at stations within the GBM and HSCM domains are written for subsequent model/data intercomparison.

Nowcast period average surface salinity and surface and bottom temperatures are computed at Morgans Point and Bolivar Roads. Nowcast period average surface temperatures are computed at Galveston Pleasure Pier and Eagle Point. Nowcast period average surface salinity is computed at Eagle Point. These PORTS station salinity and temperature nowcast period averages are used in step 6.

Step 5: During the 24 hour nowcast period, subtidal water level is developed by subtracting the predicted tide from PORTS water level data at Galveston Pleasure Pier. First the predicted astronomical tide file from step 1 and measured water level file from step 4 at Galveston Pleasure Pier are accessed. Next the predicted water levels are subtracted from the observed water levels to obtain the nowcast period water level residuals. Note in performing this subtraction, the CST time reference is used. For the forecast period, the NWS/ETSS forecast subtidal water levels at Galveston Pleasure Pier, corrected from UTC to CST, are used.

The subtidal water level at Galveston Pleasure Pier is utilized along the entire GBM open boundary. Based upon sensitivity analysis, this approach results in no double counting of near shelf wind response. The ETSS forecast surge is used over the 36 hour forecast period. Finally the residual/subtidal water level GBM boundary file is written.

Table 2.2. Water Surface Elevation Harmonic Analysis Inventory

Station	MTL-MLLW (m) * GEOID-MTL+ (m)	Analysis Method Analysis Period
Galveston Pleasure Pier 677-1510	0.366	365 Day LS 1994
Galveston Pier 21 677-1450	0.253	365 Day LS 1994
Port Bolivar 677-1328	0.244	185 Day LS Oct 29, 1994 - May 1, 1995
Eagle Point 677-1013	0.174	365 Day LS 1994
Clear Lake 677-0933	0.183	365 Day LS 1994
Morgans Point 677-0613	0.198	365 Day LS 1994
Lynchburg Landing 877-0733	0.329	29 Day HA Apr 1-29, 1996
Manchester Houston 877-0777	0.334	29 Day HA Mar 1-29, 1996
GBM open boundary (3,2)	0.030* Advanced 30 minutes	365 Day LS Freeport Oct 1, 1993 - Sep 30, 1994
GBM open boundary (60,2)	0.035* Advanced 18 minutes	365 Day LS Galveston Pleasure Pier 1994
GBM open boundary (120,2)	0.040* Advanced 60 minutes	365 Day LS Galveston Pleasure Pier 1994
GBM open boundary (180,2)	0.035* 1.024 amplification advanced 36 minutes	185 Day LS Port Bolivar Oct 29, 1994 - May 1, 1995 Interpolated Sa and Ssa
GBM open boundary (180,32)	0.030* 1.2 amplification	365 Day LS High Island Jun 1, 1994 - May 31, 1995

+ Note the GEOID-MTL levels are now set to zero as discussed in Section 2.3.

Table 2.3. Galveston Bay Model Open Boundary Harmonic Constants

Note Kp denotes the phase in Greenwich (Kappa Prime).

Constituent	(3,2) Amp (m)	(3,2) Kp (o)	(60,2) Amp (m)	(60,2) Kp (o)	(120,2) Amp (m)	(120,2) Kp (o)
M(2)	0.097	90.3	0.137	92.2	0.139	71.9
S(2)	0.025	83.6	0.031	84.0	0.031	63.0
N(2)	0.024	72.3	0.033	77.9	0.034	58.0
K(1)	0.155	290.5	0.171	293.9	0.175	283.4
M(4)	0.005	154.4	0.006	195.6	0.006	155.0
O(1)	0.145	290.7	0.158	292.8	0.161	283.0
M(6)	0.001	163.3	0.001	45.9	0.001	345.0
MK(3)	0.001	140.5	0.001	90.0	0.001	59.2
S(4)	0.001	289.0	0.001	352.4	0.001	310.4
MN(4)	0.003	101.8	0.002	154.5	0.002	114.3
NU(2)	0.005	78.6	0.006	71.6	0.006	51.7
S(6)	0.001	66.7	0.001	50.2	0.001	347.3
MU(2)	0.003	20.6	0.005	5.0	0.005	345.4
2N(2)	0.004	52.7	0.008	48.2	0.008	28.7
OO(1)	0.005	308.5	0.007	328.8	0.007	317.5
LMD(2)	0.001	50.6	0.001	152.9	0.001	132.3
S(1)	0.009	213.4	0.013	235.0	0.013	224.5
M(1)	0.011	313.5	0.013	310.3	0.013	300.2
J(1)	0.009	279.9	0.010	270.9	0.011	260.0

Table 2.3. Galveston Bay Model Open Boundary Harmonic Constants (Cont.)

Note Kp denotes the phase in Greenwich (Kappa Prime).

Constituent	(3,2) Amp (m)	(3,2) Kp (o)	(60,2) Amp (m)	(60,2) Kp (o)	(120,2) Amp (m)	(120,2) Kp (o)
MM	0.017	303.8	0.032	261.7	0.033	261.3
SSA	0.095	51.2	0.113	56.5	0.116	56.5
SA	0.057	154.4	0.080	171.5	0.082	171.5
MSF	0.015	231.5	0.027	295.2	0.028	294.5
MF	0.016	305.5	0.003	194.1	0.003	193.4
RHO(1)	0.007	296.4	0.008	293.1	0.008	283.6
Q(1)	0.033	274.8	0.035	280.3	0.035	271.0
T(2)	0.004	117.2	0.004	109.6	0.004	88.6
R(2)	0.002	56.4	0.002	11.9	0.002	350.9
2Q(1)	0.004	219.9	0.002	322.5	0.002	313.5
P(1)	0.050	290.4	0.050	290.8	0.051	280.3
2SM(2)	0.001	136.4	0.001	192.7	0.001	171.0
M(3)	0.002	131.0	0.002	129.5	0.002	99.0
L(2)	0.003	132.6	0.005	132.5	0.005	111.9
2MK(3)	0.001	83.7	0.001	71.8	0.001	41.8
K(2)	0.005	97.1	0.005	83.8	0.005	62.8
M(8)	0.001	236.1	0.001	58.9	0.001	337.7
MS(4)	0.002	171.1	0.004	226.7	0.004	185.4

Table 2.3. Galveston Bay Model Open Boundary Harmonic Constants (Cont.)

Note Kp denotes the phase in Greenwich (Kappa Prime).

Constituent	(180,2) Amp (m)	(180,2) Kp (o)	(180,32) Amp (m)	(180,32) Kp (o)
M(2)	0.068	102.1	0.191	98.5
S(2)	0.010	134.0	0.053	89.1
N(2)	0.020	76.3	0.046	78.4
K(1)	0.133	324.7	0.205	296.8
M(4)	0.002	54.7	0.008	231.6
O(1)	0.120	326.8	0.189	295.6
M(6)	0.002	83.7	0.002	70.2
MK(3)	0.012	202.1	0.002	75.2
S(4)	0.001	66.7	0.003	357.1
MN(4)	0.002	50.4	0.003	187.4
NU(2)	0.005	49.8	0.005	75.6
S(6)	0.000	66.2	0.001	309.3
MU(2)	0.002	35.1	0.005	17.9
2N(2)	0.005	6.0	0.009	67.4
OO(1)	0.016	359.8	0.008	311.3
LMD(2)	0.005	252.8	0.002	295.9
S(1)	0.010	160.1	0.016	197.9
M(1)	0.011	333.1	0.017	328.6
J(1)	0.005	339.7	0.008	309.1

Table 2.3. Galveston Bay Model Open Boundary Harmonic Constants (Cont.)

Note Kp denotes the phase in Greenwich (Kappa Prime).

Constituent	(180,2) Amp (m)	(180,2) Kp (o)	(180,32) Amp (m)	(180,32) Kp (o)
MM	0.007	247.5	0.024	287.5
SSA	0.161	59.0	0.183	60.0
SA	0.091	150.6	0.096	140.1
MSF	0.042	313.6	0.041	287.3
MF	0.032	273.0	0.003	312.0
RHO(1)	0.011	304.2	0.008	327.8
Q(1)	0.026	309.5	0.039	285.6
T(2)	0.006	75.5	0.005	153.6
R(2)	0.014	270.9	0.004	11.0
2Q(1)	0.004	108.0	0.001	128.0
P(1)	0.038	347.0	0.061	289.5
2SM(2)	0.002	137.2	0.001	153.5
M(3)	0.002	65.3	0.001	359.0
L(2)	0.004	203.0	0.009	127.0
2MK(3)	0.010	212.6	0.002	19.0
K(2)	0.023	158.1	0.010	107.1
M(8)	0.000	144.0	0.000	286.5
MS(4)	0.002	57.9	0.004	235.9

Table 2.4. Galveston Bay Water Surface Elevation Harmonic Constants

Note Kp denotes the phase in Greenwich (Kappa Prime).

Constituent	677-1510 Amp (m)	677-1510 Kp (o)	677-1450 Amp (m)	677-1450 Kp (o)	677-1328 Amp (m)	677-1328 Kp (o)
M(2)	0.134	100.895	0.084	122.395	0.067	119.495
S(2)	0.030	93.0	0.023	117.7	0.010	152.0
N(2)	0.032	86.462	0.021	107.262	0.019	93.462
K(1)	0.168	298.454	0.129	324.854	0.110	333.754
M(4)	0.006	212.991	0.004	268.991	0.002	89.491
O(1)	0.155	297.042	0.119	322.642	0.117	335.242
M(6)	0.001	71.986	0.001	101.486	0.002	135.886
MK(3)	0.001	103.249	0.002	251.849	0.012	228.549
S(4)	0.001	10.4	0.001	20.0	0.001	102.7
MN(4)	0.002	171.757	0.002	230.857	0.002	84.857
NU(2)	0.006	80.225	0.003	100.125	0.005	66.924
S(6)	0.001	77.3	0.001	105.2	0.000	120.3
MU(2)	0.005	13.391	0.004	51.291	0.002	51.891
2N(2)	0.008	56.628	0.006	41.828	0.005	22.828
OO(1)	0.007	333.665	0.010	1.065	0.016	9.565
LMD(2)	0.001	161.766	0.001	112.866	0.005	270.566
S(1)	0.013	239.5	0.011	269.8	0.010	169.1
M(1)	0.013	314.72	0.008	347.12	0.011	341.82
J(1)	0.010	275.587	0.009	295.887	0.005	349.087

Table 2.4. Galveston Bay Water Surface Elevation Harmonic Constants (Cont.)

Note Kp denotes the phase in Greenwich (Kappa Prime).

Constituent	677-1510 Amp (m)	677-1510 Kp (o)	677-1450 Amp (m)	677-1450 Kp (o)	677-1328 Amp (m)	677-1328 Kp (o)
MM	0.031	261.934	0.031	262.234	0.007	247.834
SSA	0.111	56.607	0.113	60.607	0.113	60.607
SA	0.079	171.554	0.078	175.454	0.078	175.454
MSF	0.027	295.605	0.026	302.305	0.026	302.305
MF	0.003	194.512	0.001	108.012	0.001	108.012
RHO(1)	0.008	297.171	0.007	334.771	0.011	312.371
Q(1)	0.034	284.408	0.024	306.708	0.026	317.608
T(2)	0.004	118.646	0.003	111.846	0.006	93.546
R(2)	0.002	20.954	0.002	35.554	0.013	288.954
2Q(1)	0.002	326.374	0.002	42.674	0.004	115.774
P(1)	0.049	295.346	0.039	318.446	0.037	356.046
2SM(2)	0.001	202.105	0.001	101.905	0.002	155.905
M(3)	0.002	142.543	0.002	172.443	0.002	91.443
L(2)	0.005	141.429	0.002	234.729	0.004	220.729
2MK(3)	0.001	84.737	0.001	298.237	0.010	238.437
K(2)	0.005	92.907	0.004	192.407	0.023	176.207
M(8)	0.001	93.682	0.000	193.882	0.000	213.582
MS(4)	0.004	244.395	0.002	285.695	0.002	93.295

Table 2.4. Galveston Bay Water Surface Elevation Harmonic Constants (Cont.)

Note Kp denotes the phase in Greenwich (Kappa Prime).

Constituent	677-1013 Amp (m)	677-1013 Kp (o)	677-09330 Amp (m)	677-0933 Kp (o)
M(2)	0.032	204.595	0.038	283.495
S(2)	0.010	200.6	0.010	276.8
N(2)	0.008	183.262	0.008	263.162
K(1)	0.109	10.054	0.112	42.354
M(4)	0.002	220.891	0.002	15.791
O(1)	0.102	3.642	0.103	33.842
M(6)	0.001	243.086	0.000	73.086
MK(3)	0.002	354.349	0.002	130.449
S(4)	0.000	332.4	0.000	211.2
MN(4)	0.001	222.857	0.001	17.557
NU(2)	0.001	174.924	0.002	282.324
S(6)	0.000	208.9	0.000	335.8
MU(2)	0.002	97.591	0.003	123.391
2N(2)	0.003	7.428	0.005	349.728
OO(1)	0.010	15.365	0.011	31.765
LMD(2)	0.001	240.266	0.000	266.466
S(1)	0.008	258.3	0.005	281.9
M(1)	0.010	67.62	0.014	98.42
J(1)	0.004	317.887	0.003	342.387

Table 2.4. Galveston Bay Water Surface Elevation Harmonic Constants (Cont.)

Note Kp denotes the phase in Greenwich (Kappa Prime).

Constituent	677-1013 Amp (m)	677-1013 Kp (o)	677-09330 Amp (m)	677-0933 Kp (o)
MM	0.034	256.334	0.031	247.234
SSA	0.114	61.907	0.119	63.507
SA	0.074	166.054	0.082	164.154
MSF	0.031	312.905	0.039	322.405
MF	0.011	148.212	0.017	134.512
RHO(1)	0.006	1.471	0.006	16.271
Q(1)	0.020	354.408	0.020	31.008
T(2)	0.001	247.946	0.001	320.946
R(2)	0.001	349.754	0.000	272.354
2Q(1)	0.004	69.974	0.005	80.274
P(1)	0.031	8.746	0.031	42.546
2SM(2)	0.002	98.605	0.002	79.905
M(3)	0.000	159.943	0.001	55.343
L(2)	0.003	280.129	0.005	305.029
2MK(3)	0.002	355.237	0.000	93.637
K(2)	0.005	259.407	0.010	281.707
M(8)	0.000	15.282	0.000	177.682
MS(4)	0.001	232.395	0.001	13.695

Table 2.5. Houston Ship Channel Water Surface Elevation Harmonic Constants

Note Kp denotes the phase in Greenwich (Kappa Prime) and "-" designates a constituent that cannot be determined from the 29 day harmonic analysis.

Constituent	677-0613 Amp (m)	677-0613 Kp (o)	677-0733 Amp (m)	677-0733 Kp (o)	677-0777 Amp (m)	677-0777 Kp (o)
M(2)	0.054	252.795	0.078	237.7	0.092	273.9
S(2)	0.013	233.3	0.025	254.4	0.017	278.6
N(2)	0.012	237.062	0.011	251.6	0.025	260.1
K(1)	0.123	24.554	0.160	44.3	0.166	34.6
M(4)	0.001	3.691	0.001	265.0	0.006	79.4
O(1)	0.114	17.342	0.126	23.6	0.125	31.4
M(6)	0.000	244.086	0.001	175.1	0.002	241.2
MK(3)	0.002	192.549	-	-	-	-
S(4)	0.001	356.8	0.001	52.5	0.002	103.4
MN(4)	0.001	323.557	-	-	-	-
NU(2)	0.003	247.424	0.002	254.6	0.005	262.0
S(6)	0.000	78.2	0.001	304.8	0.004	96.9
MU(2)	0.003	115.091	-	-	-	-
2N(2)	0.004	334.628	0.001	229.6	0.003	246.4
OO(1)	0.011	24.265	0.005	65.0	0.005	37.8
LMD(2)	0.001	292.466	0.001	264.7	0.001	276.0
S(1)	0.004	169.8	-	-	-	-
M(1)	0.013	76.22	0.009	33.9	0.009	32.9
J(1)	0.003	313.487	0.010	54.5	0.010	36.2

Table 2.5. Houston Ship Channel Water Surface Elevation Harmonic Constants (Cont.)

Note Kp denotes the phase in Greenwich (Kappa Prime) and "-" designates a constituent that cannot be determined from the 29 day harmonic analysis.

Constituent	677-0613 Amp (m)	677-0613 Kp (o)	677-0733 Amp (m)	677-0733 Kp (o)	677-0777 Amp (m)	677-0777 Kp (o)
MM	0.035	251.434	-	-	-	-
SSA	0.116	64.007	-	-	-	-
SA	0.081	149.654	-	-	-	-
MSF	0.037	320.705	-	-	-	-
MF	0.019	147.112	-	-	-	-
RHO(1)	0.008	359.871	0.005	14.7	0.005	30.0
Q(1)	0.023	7.408	0.025	13.4	0.024	29.7
T(2)	0.002	276.846	0.001	255.2	0.001	278.4
R(2)	0.001	237.554	0.000	253.6	0.000	278.7
2Q(1)	0.005	78.874	0.003	3.1	0.003	28.1
P(1)	0.035	24.446	0.053	42.7	0.055	34.3
2SM(2)	0.001	30.205	-	-	-	-
M(3)	0.001	70.443	-	-	-	-
L(2)	0.006	288.929	0.002	245.1	0.004	253.6
2MK(3)	0.001	257.937	-	-	-	-
K(2)	0.011	270.807	0.007	252.8	0.005	278.9
M(8)	0.000	129.982	0.001	58.4	0.002	23.2
MS(4)	0.000	291.395	-	-	-	-

Table 2.6. Principal Component Direction Current Harmonic Analysis Inventory

Station	Prediction Depth (m) relative to MLLW/ Principal Flood Direction (degrees True)	Analysis Method Analysis Period
GREF1 Galveston Harbor Reference	4.6/273	29 Day HA Several 29 Day Periods 1988
go2010 Galveston Harbor /Houston Ship Channel	4.4/313	29 Day HA October 5-November 3,1988
PORTS Bolivar Roads	4.4/322	29 Day HA April 1-29, 1996
PORTS Redfish Bar	2.3/322	29 Day HA March 8 - April 6, 1996
PORTS Morgans Point	6.8/341	29 Day HA April 1-29, 1996

Table 2.7. Galveston Bay Principal Component Direction Current Harmonic Constants

Note Kp denotes the phase in Greenwich (Kappa Prime) and "-" designates a constituent that cannot be determined from the 29 day harmonic analysis.

Constituent	GREF1 Amp (m/s)	GREF1 Kp (o)	g02010 Amp (m/s)	g02010 Kp (o)	Bolivar Roads Amp (m/s)	Bolivar Roads Kp (o)
M(2)	0.313	126.7	0.267	135.3	0.387	136.2
S(2)	0.106	133.2	0.115	116.7	0.130	119.7
N(2)	0.058	100.8	0.078	85.5	0.077	102.3
K(1)	0.494	281.3	0.455	288.1	0.587	299.0
M(4)	0.040	236.2	0.038	220.7	0.033	233.6
O(1)	0.437	281.5	0.438	280.8	0.503	282.9
M(6)	0.007	271.6	0.009	256.2	0.005	213.3
MK(3)	-	-	-	-	-	-
S(4)	0.010	294.4	0.013	287.3	0.006	33.8
MN(4)	-	-	-	-	-	-
NU(2)	0.011	104.2	0.015	92.2	0.015	106.9
S(6)	0.004	6.4	0.006	178.8	0.004	280.5
MU(2)	-	-	-	-	-	-
2N(2)	0.008	75.2	0.010	35.7	0.010	68.5
OO(1)	0.019	280.1	0.019	295.5	0.022	315.0
LMD(2)	0.002	130.5	0.002	126.7	0.003	128.6
S(1)	-	-	-	-	-	-
M(1)	0.031	281.1	0.031	284.4	0.035	290.9
J(1)	0.034	280.5	0.034	291.8	0.040	306.9

Table 2.7. Galveston Bay Principal Component Direction Current Harmonic Constants (Cont.)

Note Kp denotes the phase in Greenwich (Kappa Prime) and "-" designates a constituent that cannot be determined from the 29 day harmonic analysis.

Constituent	GREF1 Amp (m/s)	GREF1 Kp (o)	g02010 Amp (m/s)	g02010 Kp (o)	Bolivar Roads Amp (m/s)	Bolivar Roads Kp (o)
MM	-	-	-	-	-	-
SSA	-	-	-	-	-	-
SA	-	-	-	-	-	-
MSF	-	-	-	-	-	-
MF	-	-	-	-	-	-
RHO(1)	0.016	281.8	0.016	277.6	0.019	276.0
Q(1)	0.085	281.9	0.085	277.1	0.097	274.9
T(2)	0.006	132.9	0.007	117.4	0.008	120.4
R(2)	0.001	133.4	0.001	115.9	0.001	119.1
2Q(1)	0.011	282.2	0.011	273.5	0.013	267.0
P(1)	0.164	281.3	0.150	287.6	0.194	297.8
2SM(2)	-	-	-	-	-	-
M(3)	-	-	-	-	-	-
L(2)	0.008	94.3	0.011	79.0	0.011	95.8
2MK(3)	-	-	-	-	-	-
K(2)	0.029	133.6	0.031	115.2	0.035	118.4
M(8)	0.007	35.6	0.007	328.8	0.004	15.5
MS(4)	-	-	-	-	-	-

Table 2.8. Houston Ship Channel Principal Component Direction Current Harmonic Constants

Note Kp denotes the phase in Greenwich (Kappa Prime) and "-" designates a constituent that cannot be determined from the 29 day harmonic analysis.

Constituent	Redfish Bar Amp (m/s)	Redfish Bar Kp (o)	Morgans Point Amp (m/s)	Morgans Point Kp (o)
M(2)	0.248	172.9	0.166	185.4
S(2)	0.077	197.6	0.050	167.0
N(2)	0.059	145.2	0.022	155.7
K(1)	0.386	304.6	0.189	306.2
M(4)	0.010	287.9	0.002	190.3
O(1)	0.299	305.7	0.120	290.7
M(6)	0.004	352.8	0.003	33.5
MK(3)	-	-	-	-
S(4)	0.007	71.6	0.002	217.1
MN(4)	-	-	-	-
NU(2)	0.011	148.9	0.004	159.7
S(6)	0.004	129.0	0.004	295.2
MU(2)	-	-	-	-
2N(2)	0.008	117.4	0.003	125.9
OO(1)	0.013	303.6	0.005	321.6
LMD(2)	0.002	184.4	0.001	176.9
S(1)	-	-	-	-
M(1)	0.021	305.1	0.009	298.4
J(1)	0.024	304.1	0.010	313.8

Table 2.8. Houston Ship Channel Principal Component Direction Current Harmonic Constants (Cont.)

Note Kp denotes the phase in Greenwich (Kappa Prime) and "-" designates a constituent that cannot be determined from the 29 day harmonic analysis.

Constituent	Redfish Bar Amp (m/s)	Redfish Bar Kp (o)	Morgans Point Amp (m/s)	Morgans Point Kp (o)
MM	-	-	-	-
SSA	-	-	-	-
SA	-	-	-	-
MSF	-	-	-	-
MF	-	-	-	-
RHO(1)	0.011	306.1	0.005	284.1
Q(1)	0.058	306.2	0.023	283.0
T(2)	0.005	196.6	0.003	167.7
R(2)	0.001	198.6	0.001	166.2
2Q(1)	0.008	306.7	0.003	275.4
P(1)	0.128	304.7	0.063	305.0
2SM(2)	-	-	-	-
M(3)	-	-	-	-
L(2)	0.008	138.6	0.003	149.1
2MK(3)	-	-	-	-
K(2)	0.021	199.6	0.013	165.5
M(8)	0.003	114.6	0.002	309.6
MS(4)	-	-	-	-

Step 6: PORTS station nowcast period average surface salinity and surface and near bottom temperature data determined in step 4 are used to modify seasonal salinity/temperature fields based on Bay climatology (Orlando et al., 1993) and near shelf measurements (Temple et al., 1977) in the following manner. First, the GBM restart file (written at the end of the previous 24hr nowcast cycle) and then the HSC restart file (written at the end of the previous 24hr nowcast cycle) are read. Next SST and SSS adjustment factors (f_s, f_t) and T and S stratification ratios (S_s, T_s) at PORTS locations are developed. Along the Bay model open boundary at cells (3,2), (180,32), and (180,2) surface salinity and temperatures are determined based on table look-up at Port Bolivar and interpolation associations shown in Tables 2.9 and 2.10, respectively. Coast values at (3,2) and offshore values at (180,2) are assigned to boundary cells (60,2) and (120,2), respectively. Salinity and temperature stratification at the five boundary cells is based on monthly climatological values shown in Table 2.11. A fourteen point $1/r^2$ spatial interpolation based on Galveston Pleasure Pier (near Shelf), Bolivar Roads (Lower Bay), Redfish Bar (Middle Bay), and Morgans Point (Upper Bay) plus the five boundary cells, the three freshwater inflows, and East and West Bay mid-points is used to develop GBM adjustment factor and stratification ratio fields. Next adjusted T and S fields are computed at each sigma level based on adjusted surface and sigma level interpolated stratification as given in Equation (2.1).

$$
\begin{aligned}
S^{n}_{i,j,k} &= f_{s_{i,j}} S^{m}_{i,j,1} + [(k-1)/(kb-2)] Ss_{i,j} \\
T^{n}_{i,j,k} &= f_{t_{i,j}} T^{m}_{i,j,1} + [(k-1)/(kb-2)] Ts_{i,j}
\end{aligned}
\qquad (2.1)
$$

$$k = 1, \ldots, kb-1$$

where

$S^{n}_{i,j,k}$ =Nowcast grid cell salinity

$S^{m}_{i,j,1}$ =Model Restart surface grid cell salinity

$f_{s_{i,j}}$ =Surface salinity grid cell adjustment factor

$Ss_{i,j}$ =Salinity grid cell stratification factor

$T^{n}_{i,j,k}$ =Nowcast grid cell temperature

$T^{m}_{i,j,1}$ =Model Restart surface grid cell temperature

$f_{t_{i,j}}$ =Surface temperature grid cell adjustment factor

$Ts_{i,j}$ =Temperature grid cell stratification factor

Note, the sigma level interpolation is not strictly valid. Rather, synthetic multi-point CTD casts should be constructed to develop a depth dependent interpolation evaluated at each sigma-level in each cell. The present approach is reasonably accurate for the modest bottom slopes and stratification values found within Galveston Bay and the near Shelf. Note the navigation channels are not explicitly considered. Finally, the adjusted T and S Bay fields are written onto the restart file replacing

Table 2.9. Port Bolivar Reference Station Surface Salinity Range Associations

Port Bolivar Reference Station Salinity Range (PSU)	W2 -- (3,2) Coastal Signal 1 Associated Salinity Range (PSU)	WW1 -- (180,32) Coastal Signal 2 Associated Salinity Range (PSU)	WW2 -- (180,2) Offshore Signal Associated Salinity Range (PSU)
0 - 5	7 - 12	5 - 10	21 - 26
5 - 10	12 -17	10 - 15	26 - 28
10 - 15	17 - 22	15 - 20	28 - 30
15 - 20	22 - 25	20 - 23	30 - 31
20 - 25	25 - 30	23 - 28	31 - 33
25 - 30	32 - 34	32 - 34	33 - 36
30 - 35	34 - 36	34 - 36	36 - 37

Table 2.10. Port Bolivar Reference Station Surface Temperature Range Associations

Port Bolivar Reference Station Temperature Range (deg C)	W2 -- (3,2) Coastal Signal 1 Associated Temperature Range (deg C)	WW1 -- (180,32) Coastal Signal 2 Associated Temperature Range (deg C)	WW2 -- (180,2) Offshore Signal Associated Temperature Range (deg C)
0 - 5	2 - 7	2 - 7	5 - 10
5 - 10	7 -12	7 - 12	10 - 15
10 - 15	12 - 17	12 - 17	17 - 20
15 - 18	17 - 20	17 - 20	20 - 23
18 - 21	20 - 22	20 - 22	23 - 25
21 - 26	22 - 26	22 - 26	25 - 26
26 - 32	26 - 32	26 - 32	26 - 32

Table 2.11. Monthly Climatological Salinity and Temperature Stratification

Month	Coast Salinity Stratification (PSU)	Offshore Salinity Stratification (PSU)	Coast Temperature Stratification (deg C)	Offshore Temperature Stratification (deg C)
January	1.2	0.3	0.1	-1.0
February	0.	0.	0.	0.1
March	2.8	0.	-0.2	-0.5
April	0.5	0.	-0.2	-0.2
May	0.8	0.	-0.6	-1.1
June	2.7	2.4	-4.0	-3.5
July	0.1	2.3	-1.4	-5.4
August	0.	1.0	-0.1	-0.3
September	0.1	0.4	0.	0.4
October	0.	0.	0.1	-0.2
November	0.	0.	-0.9	-0.2
December	0.4	0.	0.5	0.

the original T and S fields. The adjusted T and S Bay fields are interpolated to the HSCM grid in the horizontal using nearest neighbor and in the vertical by using a sigma-depth-sigma correspondence. The adjusted T and S HSCM fields are then written onto the HSCM restart file replacing the original T and S fields.

Step 7: Boundary conditions are established for Julian start date minus one and Julian end date plus two of the nowcast. River inflow salinities are set to zero. Along the open boundary the surface salinity may be adjusted based on a user specified K1 period amplitude and phase. Both are set to zero. Surface temperature is based on a user specified S2 period amplitude and phase. These procedures are patterned after those used by Schmalz (1994). The amplitude is specified in the range of 0.3-0.5 deg C. Boundary conditions are set such that they are compatible with the adjusted T and S fields in step 6 and are assumed time invariant. Thus, the GBM offshore boundary data are developed based on a persistence of the initial conditions along the open boundary developed in Step 6.

Step 8: Bay and HSC model SST forcings are established. The SST over the Bay domain is set to level 1 of the adjusted T field. Next, we use a nearest neighbor horizontal interpolation to determine the HSC model SST field. Finally, both fields are written to the SST boundary files. The initial SST fields are persisted over the 60 hour simulation period.

Step 9: River inflows are established by first accessing the San Jacinto, Trinity, and Buffalo Bayou USGS stage/discharge data, which are supplied via ftp by the NWS/WGRFC on a daily basis. The latest discharge data are used for the nowcast period. Note the USGS developed stage discharge curve for Lake Houston is used to obtain discharge from lake level stage. Next, 48 hour persistence forecasts are developed from the nowcast values. These forecasts are overridden for the San Jacinto and Trinity Rivers based on the availability of three day duration 6 hour interval forecasts issued by the NWS/WGRFC.

The expansion of the City of Houston has lead to additional runoff and very flashy rainfall/runoff hydrographs (Liscum and East, 1995) and a real time streamflow measurement system has been developed by Harris County. As a result NWS/WGRFC does not at present forecast Buffalo Bayou flows. Presently a persistence of the previous day average daily flow is used in the forecast. It may be necessary in the future to work with Harris County to develop refined flowrates as the City of Houston continues to expand.

Step 10: During the nowcast, PORTS wind station data at four met stations (Galveston Pleasure Pier, Morgans Point, Eagle Point, and Bolivar Roads) are used to produce winds and pressure fields. Galveston Pleasure Pier values are assigned to C-MAN station SRST2 at Sabine Pass and to NDBC Buoy 42035 off Galveston to aid the interpolation. See Figure 2.5 for station locations. Hourly two-step Barnes (1973) interpolation over the Bay grid is performed in which PORTS winds are assumed to represent 10-m overwater values. A nearest neighbor horizontal interpolation is used to determine HSCM wind/pressure fields from the GBM wind/pressure fields.

For the forecast period the NWS/AVN 10-m winds and sea-level pressure fields are accessed. A 25 point cluster $1/r^2$ interpolation is used to set the AVN values at PORTS meteorological station locations. The same two-step Barnes (1973) interpolation at 3 hr intervals over the AVN 48 hour forecast period is used to develop the fields. The Bay model grid land/water mask is used to determine where to adjust AVN overland values to Bay grid overwater values based on a method developed by Hsu (1988). In the present system, prior to the overwater adjustment, winds are reduced by a factor of two as discussed in section 2.3. Next a nearest neighbor horizontal interpolation is used to determine HSC wind/pressure fields from Bay wind/pressure fields. Finally, the Bay and HSC model wind/pressure files are written.

```
                 Houston/Galveston PORTS
                National Ocean Service/NOAA
            at  3:00 pm CST  February  6, 1997
.............................................................
               TIDES                  :          CURRENTS
Pleasure Pier            3.3 ft.,Falling: Bolivar Roads   2.0 kts.(F), 301øT
Pier 21                  2.2 ft.,Rising : Redfish Bar     1.0 kts.(F), 323øT
Bolivar Roads            1.9 ft.,Rising : Morgans Point
Eagle Point              1.1 ft.        : (F)lood,(S)lack,(E)bb,towards øTrue
Morgans Point            0.8 ft.        :...............................
......................................:          Salinity   S.G. Srfc Temp
 Bottom Water Temp. (ADCP) : Pleasure Pier                          56øF
Bolivar Roads        57øF  : Bolivar Roads       22.0 psu  1.017    56øF
Redfish Bar          58øF  : Eagle Point         13.0 psu  1.010    56øF
Morgans Point              : Morgans Point       11.0 psu  1.009    58øF
...........................:.................................
   METEOROLOGICAL       Wind Speed/Dir            Air Pressure    Air Temp
Pleasure Pier   18 knots from NE , gusts to  21   1018 mb,Falling    53øF
Bolivar Roads   13 knots from NE , gusts to  17   1020 mb,Falling    53øF
Eagle Point     16 knots from ENE, gusts to  17   1020 mb,Falling    53øF
Morgans Point   11 knots from ENE, gusts to  14   1020 mb,Rising     52øF
.............................................................
```

```
                 Houston/Galveston PORTS
                National Ocean Service/NOAA
            at  2:30 pm CDT  July  3, 1997
.............................................................
               TIDES                  :          CURRENTS
Pleasure Pier            1.4 ft.,Falling: Bolivar Roads   1.0 kts.(E), 125øT
Pier 21                  1.2 ft.        : Redfish Bar     0.5 kts.(E), 146øT
Bolivar Roads            1.2 ft.,Falling: Morgans Point   0.5 kts.(E), 159øT
Eagle Point              1.0 ft.        : (F)lood,(S)lack,(E)bb,towards øTrue
Morgans Point            1.2 ft.,Falling:...............................
......................................:          Salinity   S.G. Srfc Temp
 Bottom Water Temp. (ADCP) : Pleasure Pier                          81øF
Bolivar Roads        80øF  : Bolivar Roads       20.4 psu  1.012    85øF
Redfish Bar          85øF  : Eagle Point          9.4 psu  1.003    89øF
Morgans Point        86øF  : Morgans Point        6.7 psu  1.001    87øF
...........................:.................................
   METEOROLOGICAL       Wind Speed/Dir            Air Pressure    Air Temp
Pleasure Pier   11 knots from S  , gusts to  12   1014 mb,Falling    83øF
Bolivar Roads    7 knots from SSE, gusts to  11   1015 mb,Falling    86øF
Eagle Point      7 knots from S  , gusts to  11   1015 mb,Falling    89øF
Morgans Point    7 knots from SE , gusts to   9   1015 mb,Rising     91øF
.............................................................
```

```
     Houston/Galveston PORTS, NOAA/NOS at 11:54 am CDT  August 17, 2001
--------------- TIDES -------------------------------- CURRENTS ----------------
Morgans Point        1.0 ft.,Rising : Morgans Point         0.0 kts.(S), 335°T
Eagle Point        ****************: Bolivar Roads         0.1 kts.(S), 317°T
Pier 21              1.1 ft.,Rising :
North Jetty          1.3 ft.,Rising : (F)lood,(S)lack,(E)bb,towards °True
Pleasure Pier        1.5 ft.        :------------------Salinity---S.G.--W.Temp
                                    : Morgans Point       ***************   ****
                                    : Eagle Point         ***************   ****
                                    : North Jetty                           85°F
                                    : Pleasure Pier                         86°F
--- METEOROLOGICAL ----- Wind Speed/Dir ------------- Air Pressure -- Air Temp
Morgans Point        Calm                             1021 mb,Steady      90°F
Eagle Point      ********************                 ***************   *****
North Jetty        10 knots from S  , gusts to  11    1019 mb,Rising      85°F
Pleasure Pier       7 knots from S  , gusts to   9    1020 mb,Rising      85°F
--------------------------------------------------------------------------------
 **** - Data not displayed as a result of quality control monitoring. For more
 information, go to http://co-ops.nos.noaa.gov/corms_status.html, or call CORMS
 at 301-713-2540.
```

Figure 2.1. PORTS screen

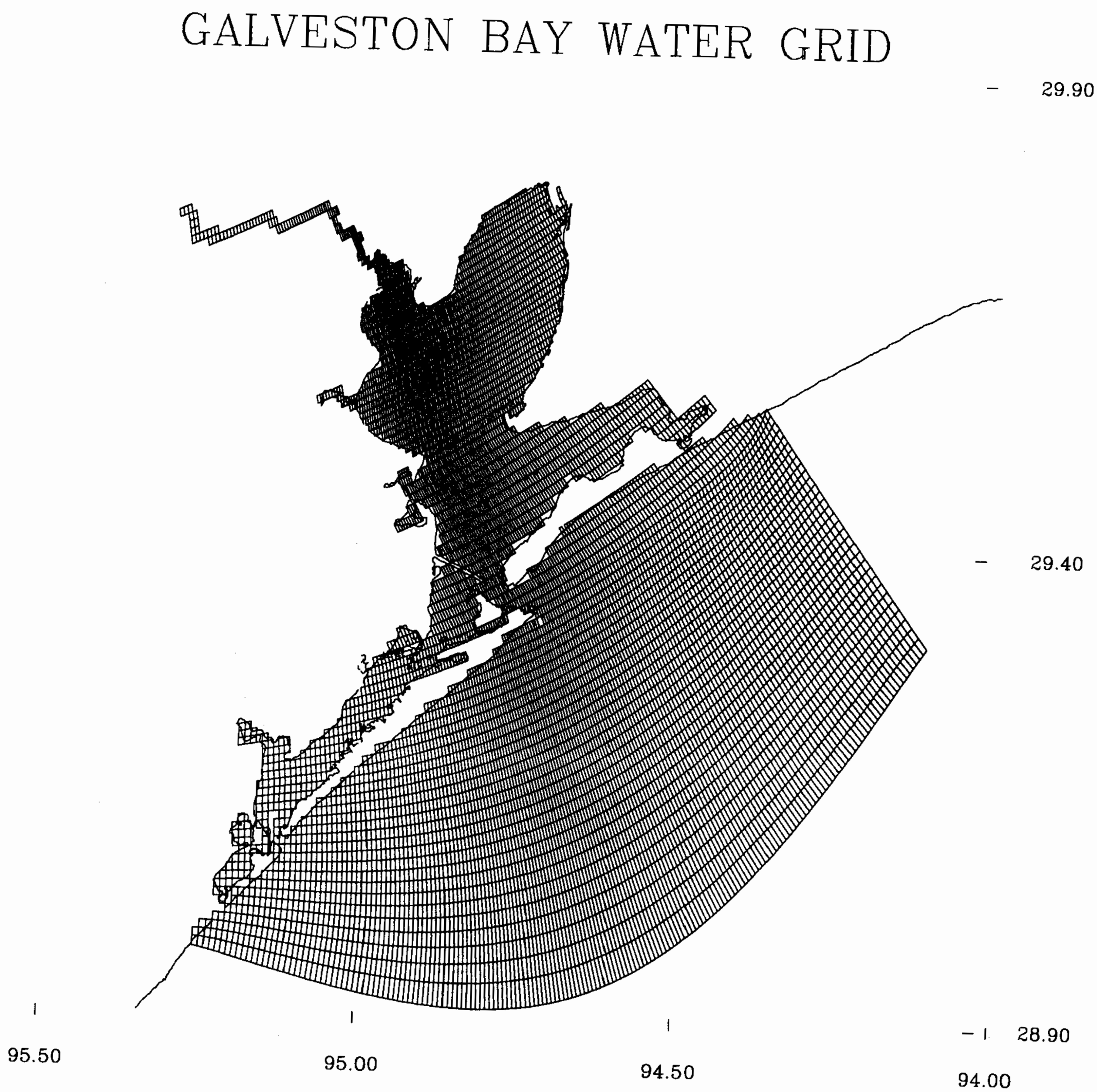


Figure 2.2. Galveston Bay Model Grid

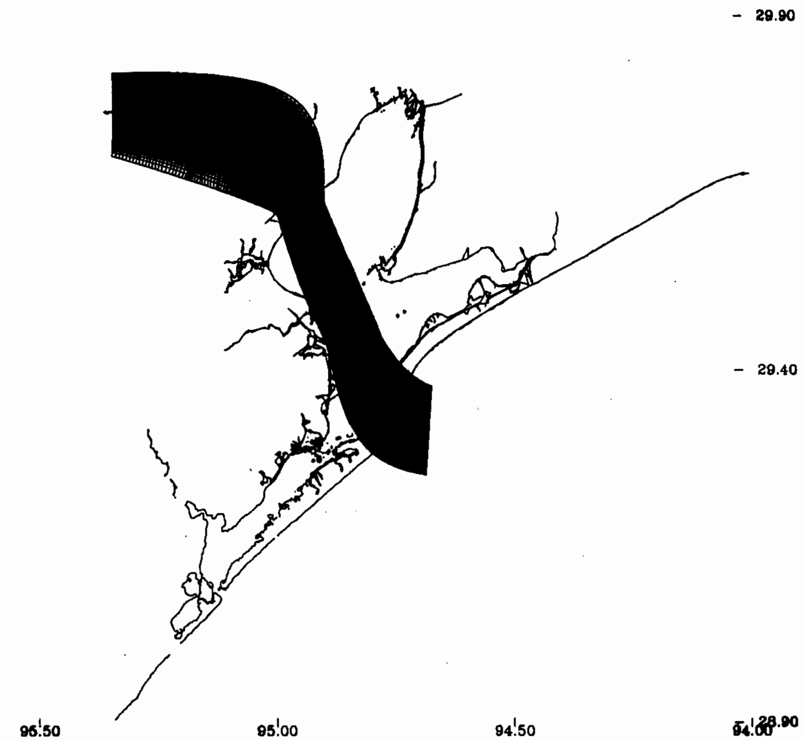
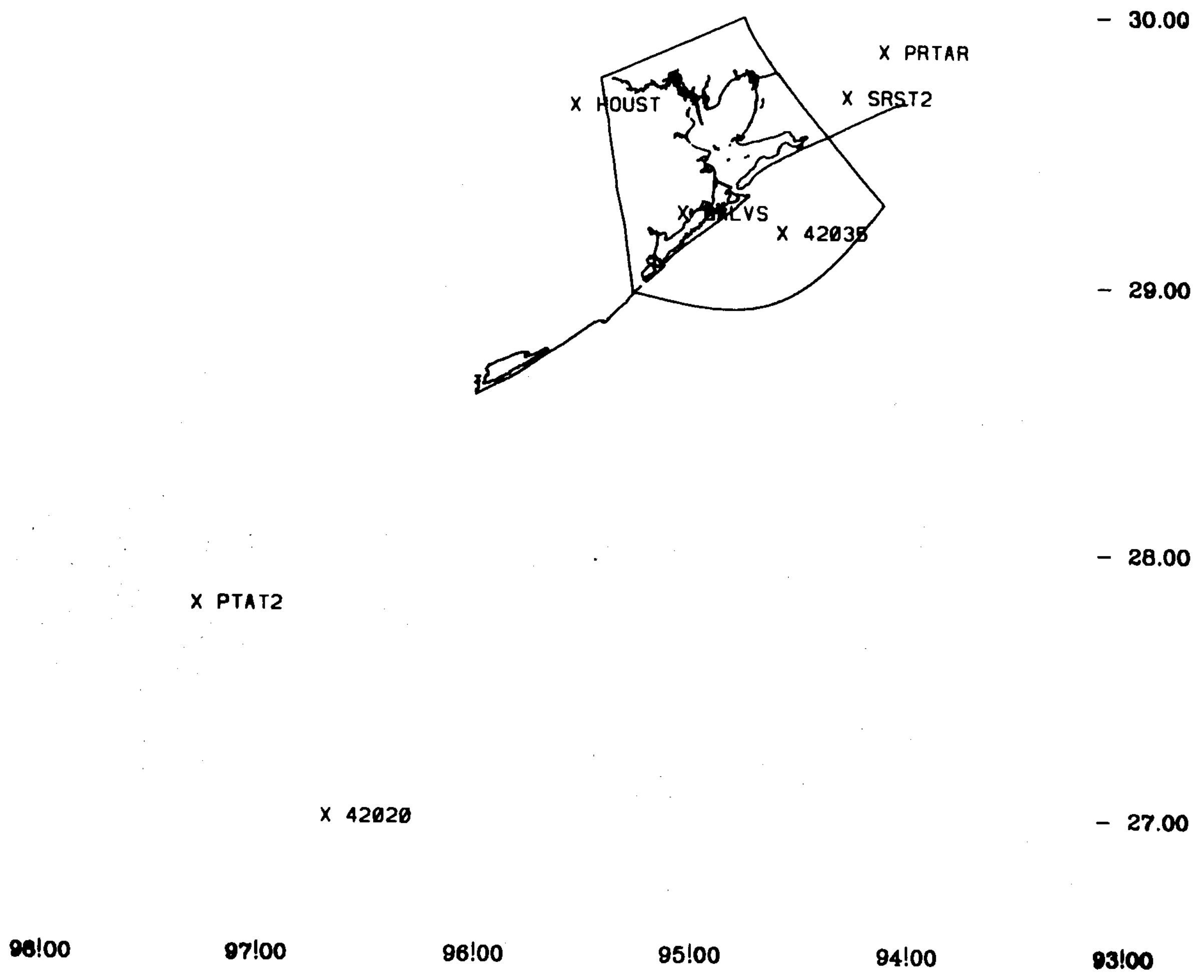


Figure 2.3. Houston Ship Channel Model Grid

Figure 2.4. Houston Ship Channel Model Grid near Galveston Entrance



Note Galveston Bay Model grid boundary is outlined.

Figure 2.5. Meteorological Observation Station Locations

2.3. Hydrodynamic Model Refinements

The experimental nowcast/forecast system has been established under operational accounts (hgops) on OPSEA for set-up procedures and NCAR graphics routines, on OPTIDE for the Galveston Bay Model (GBM) and Houston Ship Channel Model (HSCM), and on OCEAN1 for IDL time series summary and bay-wide field contour plots. The complete system was initially tested for the 14 December 1998 nowcast/forecast cycle prior to performing an initial one-month demonstration.

To test the system, the set-up program was run to establish initial and boundary conditions for the 24 hour nowcast (1800 CST 12 - 13 December) and 36 hour forecast (1800 13 December to 0600 15 December). The Galveston Bay Model (GBM) was first executed to generate boundary conditions for the Houston Ship Channel Model (HSCM). Two cases were considered. Since river flow observations and forecasts were not available due to server problems at the NWS/WGRFC, river inflows were set to zero. In case one, astronomical tide conditions were considered only; wind and water level residual forcings were set to zero. In case two, these two forcings were included. All system components were successfully executed.

The initial one-month demonstration encompassed the period from 9 April to 9 May 1999. The system was run under the UNIX crontab environment and each morning, the script generated mail messages were saved in operational files to document system performance. NCAR graphics programs were used to display nowcast/forecast results for both the Bay and Channel hydrodynamic models. Nowcast results were compared with observations while forecast results were contrasted against tidal predictions when available. In addition, separate NCAR graphics programs were run each day to evaluate the previous day's forecasts against the observations. Nowcast/forecast results were summarized using IDL graphics and displayed on the CSDL Intranet website for selected cycles.

The demonstration period was extended through March 2000 with results placed on the CSDL Intranet website. Nowcast/forecast performance was evaluated for each daily cycle. Nowcast evaluation was for the present nowcast (24 hours in duration), while forecast evaluation was for the first 24 hours of the previous 36 hour forecast. This allowed one to directly assess the performance of each nowcast forecast cycle and to identify persistent errors or problems. The IDL graphics program (EVAL.frm.pro) was used to assess the overall system performance separately for the nowcast and forecast components on a monthly basis. In addition, IDL graphics were utilized to summarize the monthly nowcast and forecast comparsions with observations in terms of RMS error and the dimensionless Willmott et al. (1985) relative error. Water level residual forecasts from the NWS/ Extraptropical Storm Surge Model (ETSS) and freshwater inflow forecasts from the NWS/WGRFC river flow models were also assessed.

An operational test bed was created by saving selected initial condition and restart files. The initial condition files represent a cold start from climatological density initial conditions, which were adjusted for the given nowcast/forecast cycle and were used to reset the density structure to test the tidal dynamics. Several refinements as indicated in Table 2.12 were made during the demonstration period. Additional details may be found in Schmalz and Richardson (2001).

Table 2.12. Experimental Nowcast/Forecast System Refinements. Note the bottom roughness, z_0=1.5 mm, corresponds to values of a bedformed sand (1 - 10 mm) as reported by Black (1987), and represented a very slight change from the tidal calibration value of 2.0 mm (set Table 1.2).

No.	Nowcast/ Forecast Cycle	System Problem	System Solution
1	Astrotide 14 Dec 1998 Astrotide 20 Apr 1999	GBM water level signal offset by ~ 13 cm	Sa and Ssa adjusted and 3 cm boundary reference signal set to zero
2	26 Apr 1999	HSCM excessive temperature stratification	Revised temperature initialization
3	26 Apr 1999	GBM excessive water level oscillations	3-hr box car filter of subtidal boundary elevation
4	26 Apr 1999	Jump in wind strength at nowcast/forecast switchover	Multiply AVN winds by 0.5 prior to overwater correction
5	26 Apr 1999	Improve current comparisons for GBM and HSCM	Revised bathymetry, z_0 reduced to 1.5 mm, and cell centered current used

3. NOS FORMAL STATISTICAL EVALUATION

The Experimental Galveston Bay Nowcast/Forecast System for water level and currents at prediction depth over the year period April 2000 through March 2001 are formally evaluated based on the NOS (1999) formal procedures. Principal component direction currents are used since the currents at both ADCP stations are strongly rectilinear. Note over the evaluation period, the ratios of major axis to minor axis speed at Bolivar Roads and Morgans Point were 9.5 and 7.1, respectively. These ratios were computed as the sum of the major axis components divided by the sum of the minor axis components for current strengths greater than 26 cm/s. If one were to average the ratios of the major axis to minor axis speeds for current strengths greater than 26 cm/s, the average speed ratios are 25.6 and 22.0 at Bolivar Roads and Morgans Point, respectively. Initially the statistical measures are presented followed by assessment of the astronomical tide, nowcast/forecast assessment, and forecast age. Additional statistical evaluations are presented in Chapter 4.

3.1. Statistical Measures

At present, one target is given for both nowcast and forecast. The NOS formal evaluation procedures consist of the following three statistical measure sets (NOS, 1999).

Statistical Measure Set 1

The frequency distribution of the error (defined as model prediction minus observation) is examined using the following measures.

SM = Mean error. *Informal working targets for water levels and prediction depth current strengths, are 6 cm, and 12 cm/s, respectively.*
STD = Standard deviation of the error. *Informal working targets for water levels and prediction depth current strengths are 8 cm and 16 cm/s, respectively.*
RMSE = Root mean square error. *Informal working targets for water levels, prediction depth current strengths, surface salinity, and surface temperature are 10 cm and 20 cm/s, respectively. Note working targets are such that* $RMSE^2 = SM^2 + STD^2$.

CF=Central frequency associated with a given reference level (15 cm, 26 cm/s). *The NOS formal target is to equal or exceed 0.9.*
POF=Positive outlier frequency associated with a given positive reference level (30 cm, 52 cm/s). *The NOS formal target is to be equal or less than 0.01.*
NOF=Negative outlier frequency associated with a given negative reference level (-30 cm, -52 cm/s). *The NOS formal target is to be equal or less than 0.01.*

Statistical Measure Set 2

The following outlier duration and frequency measures are used for water levels and principal component direction currents at prediction depth.

MDPO= Maximum Duration of Positive Outliers, equal to the number of consecutive hours during which the error (model - obs) exceeds a given positive reference level (30 cm, 52 cm/s). *The NOS formal target is to be equal or less than 24.*
MDNO= Maximum Duration of Negative Outliers, equal to the number of consecutive hours during which the error (model - obs) is less than a given negative reference level (-30 cm, -52 cm/s). *The NOS formal target is to be equal or less than 24.*
WOF=Worst Case Outlier Frequency associated with the occurrence of when the error magnitude exceeds a given reference level (30 cm, 52 cm/s) and that (1) the model prediction exceeds the tidal prediction and the observation is less than the tidal prediction or (2) the opposite circumstance to (1) holds. *The NOS formal target is to be equal or less than 0.005.*

Statistical Measure Set 3

The third set of measures involves the difference in times between the observed and model predictions for zero crossing times, times of maxima, and times of minima associated with water levels and principal component direction currents (flood is considered positive) at prediction depth.

CF=Central frequency associated with a given reference time (15 min for water level zeros and 30 min for water level max and mins and principal component direction currents zeros, max, and mins). *The NOS formal target is to equal or exceed 0.9.*
POF=Positive outlier frequency associated with a given positive reference level (15 min for water level zeros and 30 min for water level max and mins and principal component direction currents zeros, max, and mins). *The NOS formal target is to be equal or less than 0.01.*
NOF=Negative outlier frequency associated with a given negative reference level (15 min for water level zeros and 30 min for water level max and mins and principal component direction currents zeros, max, and mins). *The NOS formal target is to be equal or less than 0.01.*

Associated with the times of maxima and minima are the amplitudes of the maxima and minima themselves. The corresponding central frequency measure of the error, defined as model prediction minus observation, was considered.

CF=Central frequency associated with a given reference level (15 cm, 26 cm/s). *The NOS formal target is to equal or exceed 0.9.*
POF=Positive outlier frequency associated with a given positive reference level (30 cm, 52 cm/s). *The NOS formal target is to be equal or less than 0.01.*
NOF=Negative outlier frequency associated with a given negative reference level (-30 cm, -52 cm/s). *The NOS formal target is to be equal or less than 0.01.*

3.1. Astronomical Tide Assessment

For the April 1996 simulation, 29-day harmonic analysis results of water levels and currents for both models have been performed as discussed by Schmalz (2001). Constituent comparisons are given in Appendix A for both models. Results are summarized here in Table 3.1 where RMSE is estimated using techniques outlined by Hess (1994). The weighted gain corresponds to the ratio of model to observation harmonic constituent weighted by the observation constituent amplitude averaged over each of the standard 24 constituents. The weighted phase corresponds to the difference in model phase minus observation phase weighted by observation constituent amplitude averaged over each of the standard 24 constituents. Thus for negative phase values, the model lags the observation. RMSEs are order 3 to 4 cm. Some phase errors are noted of order 1 hour at Eagle Point.

Table 3.1. GBM and HSCM April 1996 Galveston Bay 29-day Harmonic Analysis Results. Line 1 corresponds to Galveston Bay Model and line 2 to Houston Ship Channel simulation results. Mean Diurnal Range (MDR) is also given for reference.

Station	**Weighted Gain (-)**	**Weighted Phase (hr)**	**RMSE (cm)**	**MDR (cm)**
Galveston Pier 21: 877-1450	0.79 0.81	0.25 0.26	4 3	 43
Galveston Pier 21: 677-1450	0.85 0.88	0.13 0.04	3 3	 43
Port Bolivar: 677-1328	0.86 0.90	-0.43 -0.66	3 3	 43
Eagle Point: 677-1013	0.91 0.90	0.98 0.79	4 4	 30
Morgans Point : 677-0613	0.87 0.87	0.01 0.08	3 3	 30
Lynchburg Landing: 877-0733	0.95 0.82	-0.02 -0.27	2 4	 43
Manchester Dock 2: 877-0777	0.66 0.83	-0.69 -0.22	7 4	 43

Table 3.2. April 1996 Principal Flood Direction Comparisons. Note GBM comparisons are in Line1 with HSCM comparisons in line 2.

PORTS Station	Observed Principal Flood Direction (deg T)	Model Principal Flood Direction (deg T)
Bolivar Roads	322	342 321
Redfish Bar	322	336 331
Morgans Point	341	313 318

Principal flood direction comparisons are presented over the April 1996 simulation period in Table 3.2. In general errors can be order 10 to 20 degrees.

Principal component direction current 29-day harmonic analysis over April 1996 is given in Table 3.3. A somewhat damped response in the HSCM at the Galveston Reference and in the GBM at Morgans Point is indicated. Additional details may be found in Schmalz (2000).

Table 3.3. Galveston Bay Current Station 29-day Harmonic Analysis Principal Component Direction at Prediction Depth. Note line 1 corresponds to April 1996 Galveston Bay Model, and line 2 corresponds to the April 1996 Houston Ship Channel Model results. Mean Diurnal Range (MDR) is also given.

Station	Weighted Gain (-)	Weighted Phase (hr)	RMSE (cm/s)	MDR (cm/s)
Galveston Reference	0.78 0.49	-0.33 -0.44	19.4 31.3	 200
HSC Secondary	0.91 0.75	0.75 0.08	14.2 15.9	 200
Bolivar Roads PORTS	0.78 0.63	0.36 -0.27	17.0 26.8	 195
Redfish Bar PORTS	0.70 0.70	-0.17 -0.66	14.4 16.6	 130
Morgans Point PORTS	0.42 0.68	-0.77 -0.49	13.1 8.6	 65

To study the characteristics of the nowcast/forecast system under nearly pure astronomic tidal conditions, the following approach is taken. Statistical measure set 1 is considered during times when the difference between the observed and tidally predicted water levels and principal component direction currents at prediction depth are within 5 cm and 10 cm/s, respectively. Using this approach the error distribution (model prediction minus observation) is investigated under conditions which approach the pure tide. Results for water levels are given in Table 3.4 and demonstrate the error is reduced under nearly pure tidal conditions than over the full range of meteorological induced response given in Table 3.6. In Table 3.5 the results for the principal component direction currents under nearly pure tidally driven conditions are given. These results also show that these errors are reduced from the Table 3.7 results for the tide plus meteorological induced response.

3.3. Nowcast/Forecast Assessment

Water Level Evaluation Results

Statistical measure set 1 results are given in Table 3.6 for the error. The model datums are considered MTL and CO-OPS tidal datum adjustments from MTL to MLLW are used to put the model results on MLLW. All PORTS water levels are provided with respect to MLLW. No further datum adjustments are made and therefore the SM of the model levels and observations are not required. The only required adjustments are in the difference between the MTL and MLLW at each station. These differences change much more slowly than the actual values of the two tidal datums themselves, which must be updated order every 4 years due to subsidence effects. All formal NOS targets are met by the nowcast results for both models. Slightly degraded results were obtained for the forecast in both models with

Table 3.4. Tidal Water Level Analysis April 2000 -March 2001: Statistical Measure Set 1. Note GPP= Galveston Pleasure Pier, P21= Galveston Pier 21, BR=Bolivar Roads (Port Bolivar), EP=Eagle Point, and MP=Morgans Point. Note the GBM results are in line 1 with the HSCM results given in line2.

Statistical Measure NOS Target Value	Nowcast GPP	 P21	 BR	 EP	 MP	Forecast (1-24h) GPP	 P21	 BR	 EP	 MP
Number of 6 min samples	19786 -	21117 20779	19451 19212	17027 16851	15306 15217	19786 -	21117 20784	19451 19222	17027 16862	15306 15217
CF (15 cm) [≥0.9]	0.968 -	0.962 0.958	0.977 0.980	0.978 0.977	0.967 0.966	0.887 -	0.910 0.894	0.920 0.919	0.912 0.910	0.835 0.835
NOF (30 cm) [≤0.01]	0.002 -	0.000 0.003	0.002 0.002	0.001 0.001	0.001 0.002	0.001 -	0.001 0.005	0.002 0.004	0.002 0.002	0.001 0.001
POF (30 cm) [≤0.01]	0.002 -	0.003 0.004	0.002 0.002	0.000 0.000	0.000 0.004	0.017 -	0.015 0.015	0.015 0.020	0.015 0.015	0.017 0.018

Table 3.5. Tidal Principal Component Direction Prediction Depth Current Analysis April 2000 -March 2001: Statistical Measure Set 1.BR= Bolivar Roads and MP=Morgans Point. Note the GBM results are in line 1 with the HSCM results given in line2. Prediction depth equal to 4.7m.

Statistical Measure NOS Target Value	Nowcast BR	 MP	Forecast (1-24h) BR	 MP
Number of 6 min samples	17661 17335	24202 23871	17660 17334	24202 23871
CF (26 cm/s) [≥0.9]	0.855 0.697	0.843 0.851	0.819 0.675	0.836 0.893
NOF (52cm/s) [≤0.01]	0.005 0.029	0.000 0.000	0.005 0.029	0.000 0.001
POF (52 cm/s) [≤0.01]	0.007 0.007	0.000 0.004	0.018 0.015	0.000 0.003

some of the CF and POF criteria not met. Statistical measure 2 results are shown in Table 3.7. All NOS formal targets are met at each water level station in both models. Forecast results are slightly degraded from those obtained during the nowcast. Statistical measure 3 results are given in Table 3.8 for central tendency. Due to the flatness of the water level curves, an interval based method was used to compute the time of zero crossings and water level extrema. The zero crossing time criteria are met at Eagle Point and Morgans Point in the GBM and at Morgans Point for the HSCM on both nowcast and forecast. At all other stations, the zero crossing time criteria are not met. Extrema time criteria are not met at any of the stations for both models. Forecast results are slightly degraded from nowcast results. Minimum and maximum levels nearly meet the criteria. Maximum levels are generally improved over minimum levels at most stations. Outlier frequency measures are presented in Table 3.9. Criteria are met for the NOF of the zero crossing time at all stations during both nowcast and forecast for both models. The minimum level POF criteria for the nowcast are met at Galveston Pleasure Pier for the GBM and at Galveston Pier 21 for both models. The maximum level POF criteria are met during the nowcast at all stations except Morgans Point in both models. Both models do not meet the minimum and maximum time criteria.

Table 3.6. Water Level Analysis April 2000 -March 2001: Statistical Measure Set 1. Note GPP= Galveston Pleasure Pier, P21= Galveston Pier 21, BR=Bolivar Roads (Port Bolivar), EP=Eagle Point, and MP=Morgans Point. Note the GBM results are in line 1 with the HSCM results given in line2.

Statistical Measure	Nowcast					Forecast (1-24h)				
NOS Target Value	GPP	P21	BR	EP	MP	GPP	P21	BR	EP	MP
SM	3.5	3.7	1.1	-1.3	5.6	2.8	3.3	1.2	0.7	8.1
	-	3.7	0.8	-1.5	5.3	-	3.4	0.7	0.4	7.8
SD	6.5	6.3	7.5	5.9	6.9	10.6	9.5	10.2	9.3	9.8
	-	6.5	7.6	6.1	7.1	-	10.1	10.5	9.3	10.0
RMSE	7.4	7.3	7.6	6.1	8.9	10.9	10.1	10.3	9.3	12.7
	-	7.4	7.6	6.3	8.8	-	10.7	10.5	9.3	12.6
CF (15 cm) [≥0.9]	0.966	0.966	0.973	0.977	0.940	0.888	0.914	0.919	0.920	0.826
	-	0.966	0.975	0.975	0.947	-	0.906	0.918	0.919	0.832
NOF (30 cm) [≤0.01]	0.002	0.000	0.002	0.001	0.001	0.002	0.002	0.003	0.001	0.001
	-	0.001	0.002	0.001	0.001	-	0.003	0.005	0.002	0.001
POF (30 cm) [≤0.01]	0.003	0.002	0.004	0.001	0.007	0.015	0.013	0.015	0.010	0.022
	-	0.003	0.005	0.002	0.006	-	0.014	0.015	0.010	0.021

Table 3.7. Water Level Analysis April 2000 -March 2001: Statistical Measure Set 2.Note GPP= Galveston Pleasure Pier, P21= Galveston Pier 21, BR=Bolivar Roads (Port Bolivar), EP=Eagle Point, and MP=Morgans Point. Note the GBM results are in line 1 with the HSCM results given in line2.

Statistical Measure	Nowcast					Forecast (1-24h)				
NOS Target Value	GPP	P21	BR	EP	MP	GPP	P21	BR	EP	MP
MDPO (30 cm) [≤24]	6	5	6	3	15	19	19	19	18	16
	-	5	6	6	8	-	19	19	18	16
MDNO (30 cm) [≤24]	3	1	3	2	3	15	7	7	2	2
	-	4	3	2	3	-	7	8	3	2
WOF (30 cm) [≤0.005]	0.002	0.001	0.004	0.000	0.002	0.014	0.011	0.011	0.006	0.011
	-	0.002	0.004	0.001	0.003	-	0.013	0.013	0.006	0.012

Principal Component Direction Current Evaluation Results

Statistical measure set 1 results for principal component direction prediction depth currents at Bolivar Roads and at Morgans Point for both models are presented in Table 3.10. Note in the analysis sigma level 1 model cell centered currents were used. To place the results in context, the peak current strengths decrease from order 100 cm/s at Bolivar Roads to order 50 cm/s at Morgans Point. NOS criteria are nearly met at Bolivar Roads for the GBM and are not met at Morgans Point by either model. Note the ADCP at Morgans Point was not in service during most of August 2000 due to a cabling problem. Observed current strengths after the redeployment remained at levels seen in May 2000, while model currents did not change even after increasing the channel depths to the new project

Table 3.8. Water Level Analysis April 2000 -March 2001: Statistical Measure Set 3 Central Tendency. Note GPP= Galveston Pleasure Pier, P21= Galveston Pier 21, BR=Bolivar Roads (Port Bolivar), EP=Eagle Point, and MP=Morgans Point Note the GBM results are in line 1 with the HSCM results given in line2.

Statistical Measure	Nowcast					Forecast (1-24h)				
NOS Target Value	GPP	P21	BR	EP	MP	GPP	P21	BR	EP	MP
Min Time:	0.695	0.672	0.748	0.737	0.612	0.702	0.646	0.728	0.637	0.524
CF (30 min) [≥0.9]	-	0.642	0.753	0.763	0.602	-	0.642	0.736	0.639	0.504
Min Level:	0.895	0.860	0.831	0.880	0.775	0.809	0.806	0.762	0.829	0.734
CF (15 cm) [≥0.9]	-	0.891	0.856	0.900	0.785	-	0.823	0.793	0.823	0.732
Max Time:	0.801	0.724	0.757	0.716	0.761	0.792	0.701	0.681	0.680	0.729
CF (30 min) [≥0.9]	-	0.703	0.769	0.723	0.774	-	0.726	0.685	0.692	0.724
Max Level:	0.921	0.935	0.909	0.884	0.862	0.855	0.877	0.852	0.800	0.812
CF (15cm) [≥0.9]	-	0.934	0.927	0.875	0.862	-	0.876	0.854	0.804	0.797

Table 3.9. Water Level Analysis April 2000 -March 2001: Statistical Measure Set 3 Outlier Frequency. Note GPP= Galveston Pleasure Pier, P21= Galveston Pier 21, BR=Bolivar Roads (Port Bolivar), EP=Eagle Point, and MP=Morgans Point Note the GBM results are in line 1 with the HSCM results given in line2.

Statistical Measure	Nowcast					Forecast (1-24h)				
NOS Target Value	GPP	P21	BR	EP	MP	GPP	P21	BR	EP	MP
Min Time:	0.105	0.140	0.126	0.155	0.163	0.145	0.165	0.163	0.203	0.237
NOF (30 min) [≤0.01]	-	0.127	0.109	0.116	0.168	-	0.166	0.158	0.213	0.251
Min Time:	0.200	0.189	0.126	0.108	0.225	0.152	0.189	0.109	0.159	0.240
POF (30 min) [≤0.01]	-	0.231	0.138	0.120	0.230	-	0.192	0.106	0.149	0.245
Min Level:	0.041	0.018	0.011	0.028	0.027	0.059	0.052	0.029	0.036	0.041
NOF (30 cm) [≤0.01]	-	0.010	0.009	0.024	0.032	-	0.039	0.014	0.032	0.041
Min Level:	0.000	0.003	0.017	0.008	0.012	0.014	0.005	0.034	0.012	0.027
POF (30 cm) [≤0.01]	-	0.008	0.020	0.012	0.015	-	0.016	0.037	0.012	0.027
Max Time:	0.066	0.119	0.106	0.178	0.133	0.110	0.161	0.148	0.182	0.170
NOF (30 min) [≤0.01]	-	0.104	0.112	0.174	0.120	-	0.151	0.162	0.192	0.175
Max Time:	0.132	0.157	0.137	0.107	0.106	0.098	0.138	0.171	0.138	0.101
POF (30 min) [≤0.01]	-	0.193	0.119	0.103	0.106	-	0.124	0.154	0.116	0.101
Max Level:	0.006	0.011	0.015	0.013	0.009	0.003	0.011	0.015	0.013	0.009
NOF (30 cm) [≤0.01]	-	0.008	0.015	0.013	0.009	-	0.015	0.015	0.018	0.014
Max Level:	0.025	0.000	0.000	0.004	0.023	0.025	0.023	0.019	0.022	0.078
POF (30 cm) [≤0.01]	-	0.008	0.000	0.013	0.018	-	0.023	0.012	0.031	0.078

design values. Efforts to adjust the forecast currents at Morgans Point are discussed in Chapter 6. Statistical measure set 2 results are given in Table 3.11. Maximum duration criteria are met at the 104

104 cm/s level, but were exceeded for the 52 cm/s level. Statistical measure set 3 results for central tendency are given in Table 3.12. One notes the difficulty experienced by the HSCM in meeting the minimum (ebb) time criteria on both nowcast and forecast and the difficulty of the GBM in meeting both minimum (ebb) and maximum (flood) current strength criteria. For the HSCM, the maximum (flood) strength is not met at Bolivar Roads. Results at Bolivar Roads are significantly improved from those obtained at Morgans Point, where ebb current strengths on nowcast and forecast are reduced from observations. In Table 3.13 the outlier frequency criteria are considered. Similar results to those experienced by the water levels are to be noted; e.g, the zero crossing time criteria and maximum level POF criteria are the only criteria that are satisfied.

Table 3.10. Principal Component Direction (4.7m) Current (cm/s) Analysis April 2000 -March 2001: Statistical Measure Set 1.BR= Bolivar Roads and MP=Morgans Point. Note the GBM results are in line 1 with the HSCM results given in line2.

Statistical Measure	Nowcast		Forecast (1-24h)	
NOS Target Value	BR	MP	BR	MP
SM	5.3 -1.7	7.9 16.8	5.2 -0.8	5.9 13.1
SD	20.5 28.4	23.2 20.8	22.8 29.6	23.3 20.8
RMS	21.2 28.4	24.5 26.7	23.4 29.6	24.0 24.6
CF (26 cm/s) [≥0.9]	0.828 0.627	0.686 0.650	0.795 0.599	0.700 0.720
NOF (52cm/s) [≤0.01]	0.005 0.030	0.001 0.001	0.005 0.029	0.001 0.001
POF (52 cm/s) [≤0.01]	0.011 0.013	0.013 0.030	0.025 0.025	0.012 0.025

Table 3.11. Principal Component Direction (4.7m) Current (cm/s) Analysis April 2000 -March 2001: Statistical Measure Set 2. BR= Bolivar Roads and MP=Morgans Point. Note the GBM results are in line 1 with the HSCM results given in line2.

Statistical Measure	Nowcast		Forecast (1-24h)	
NOS Target Value	BR	MP	BR	MP
MDPO (104 cm/s) [≤24]	4 2	0 0	6 6	0 0
MDNO (104 cm/s) [≤24]	3 4	0 0	0 1	0 0
WOF (52 cm/s) [≤0.005]	0.009 0.024	0.015 0.033	0.021 0.031	0.014 0.026

Table 3.12. Principal Component Direction (4.7m) Current (cm/s) Analysis April 2000 - March 2001: Statistical Measure Set 3 Central Tendency. BR= Bolivar Roads and MP=Morgans Point. Note the GBM results are in line 1 with the HSCM results given in line2.

Statistical Measure NOS Target Value	Nowcast BR	 MP	Forecast (1-24h) BR	 MP
Slack Water Time: CF (30 min) [≥0.9]	0.763 0.733	0.870 0.752	0.780 0.729	0.851 0.804
Min Time: CF (30 min) [≥0.9]	0.583 0.720	0.536 0.182	0.580 0.726	0.564 0.278
Min Level: CF (26 cm/s) [≥0.9]	0.668 0.443	0.313 0.505	0.644 0.424	0.336 0.576
Max Time: CF (30 min) [≥0.9]	0.832 0.807	0.683 0.506	0.842 0.788	0.523 0.544
Max Level: CF (26 cm/s) [≥0.9]	0.696 0.235	0.389 0.911	0.680 0.209	0.366 0.892

Table 3.13. Principal Component Direction (4.7m) Current (cm/s) Analysis April 2000 - March 2001: Statistical Measure Set 3 Outlier Frequency. BR= Bolivar Roads and MP=Morgans Point. Note the GBM results are in line 1 with the HSCM results given in line2.

Statistical Measure NOS Target Value	Nowcast BR	 MP	Forecast (1-24h) BR	 MP
Slack Water Time: NOF (30 min) [≤0.01]	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.000
Slack Water Time: POF (30 min) [≤0.01]	0.237 0.267	0.130 0.248	0.220 0.271	0.149 0.196
Min Time: NOF (30 min) [≤0.01]	0.222 0.117	0.120 0.371	0.267 0.106	0.100 0.278
Min Time: POF (30 min) [≤0.01]	0.195 0.163	0.343 0.447	0.152 0.168	0.336 0.444
Min Level: NOF (52 cm/s) [≤0.01]	0.024 0.000	0.000 0.008	0.024 0.003	0.000 0.000
Min Level: POF (52 cm/s) [≤0.01]	0.043 0.073	0.123 0.068	0.051 0.130	0.113 0.045
Max Time: NOF (30 min) [≤0.01]	0.044 0.074	0.134 0.077	0.051 0.090	0.191 0.100
Max Time: POF (30 min) [≤0.01]	0.123 0.119	0.183 0.417	0.108 0.122	0.286 0.355
Max Level: NOF (52 cm/s) [≤0.01]	0.016 0.305	0.027 0.004	0.028 0.322	0.034 0.008
Max Level: POF (52 cm/s) [≤0.01]	0.000 0.003	0.000 0.015	0.006 0.000	0.000 0.000

3.4. Forecast Age Assessment

Here we investigate the quality of the water level and principal component direction current forecasts by forecast hour. Three forecast types are considered: 1) model forecast, 2) astronomical tide plus persistence forecast, and 3) astronomical tide forecast. Forecast type 2 is obtained by using a persistence of the initial nontidal water level or nontidal principal component direction curent over the entire 24 hour forecast. The first 24 hours of the 36 hour model forecast period are used for the evaluation.

Water Level Evaluation Results

Statistics are given by forecast age in hours for water levels at Galveston Pleasure Pier, Bolivar Roads (Port Bolivar), Galveston Pier 21, Eagle Point, and Morgans Point in Tables 3.14 - 3.18, respectively. Both GBM and HSCM forecasts are considered. Note N represents the total number of samples with a maximum of 3560 possible. Note for each hour, 10 six-minute samples are possible for 365 days. The error is equal to model minus observation. The signal mean, SM, RMS error, RMS, and standard deviation, STD, are given, although no target levels have been set. A frequency level of 15 cm is used to determine the central frequency, CF, with 30 cm levels used to determine the negative outlier frequency, NOF, and positive outlier frequency, POF. The number of six-minute intervals associated with each hour during which the model exceeded the observation by more than 30 cm, MDPO, or was less than the observation by more than 30 cm, MDNO, are also given. Note to convert to consecutive hours, one must divide the numbers in the tables by 10. The worst case outlier frequencies, WOF, associated with a reference level of 30 cm and the forecast utility frequency using a 5 cm reference level (here denoted by BOF) are also given. The five (5), fifty (50) , and ninety five (95) percentile error levels are also included. Note at all of the water level stations, the quality of the forecast does not degrade significantly over the 24 hour period. In addition, both model forecasts are nearly the same and superior to the other two forecast types at all stations.

Principal Component Direction Current

Statistics are given by forecast age in hours for principal component direction currents at Bolivar Roads in Table 3.19 and at Morgans Point in Table 3.20. Again both model forecasts are considered. Note N represents the total number of samples with a maximum of 3560 possible. The error is equal to model minus observation. The signal mean, SM, RMS error, RMS, and standard deviation, STD, given, although no target levels have been set. A frequency level of 26 cm/s is used to determine the central frequency, CF, with 52 cm/s levels used to determine the negative outlier frequency, NOF, and positive outlier frequency, POF. The number of six-minute intervals associated with each hour during which the model exceeded the observation by more than 52 cm/s, MDPO, or was less than the observation by more than 52 cm/s, MDNO, are also given. Note to convert to consecutive hours, one must divide the numbers in the tables by 10. The worst case outlier frequencies, WOF, associated with a reference level of 52 cm/s and the forecast utility frequency using a 10 cm/s reference level (here denoted by BOF) are also given. The five (5) , fifty (50) , and ninety five (95) percentile error levels are also included. Note at both current stations, the quality of the forecast does not degrade significantly over the 24 hour period. At Bolivar Roads, in the GBM, the model forecast is superior to the other two forecast types. Note this is not the case at Morgans Point. In Chapter 6, we seek to adjust the Morgans Point forecast to see if it can be improved relative to the astronomic tidal current prediction.

Table 3.14. Galveston Pleasure Pier Water Level Forecast April 2000 -March 2001 Evaluation Statistics. Note the reference level is 15 cm.

GBM Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1874	0.04	0.09	0.08	0.94	0.00	0.01	4	0	0.01	0.86	-0.04	0.03	0.10
1	19	2835	0.04	0.09	0.08	0.94	0.00	0.01	8	0	0.01	0.85	-0.04	0.03	0.11
2	20	3134	0.05	0.09	0.08	0.93	0.00	0.01	9	0	0.01	0.82	-0.04	0.04	0.13
3	21	3479	0.05	0.11	0.09	0.89	0.00	0.01	10	0	0.01	0.80	-0.04	0.04	0.15
4	22	2833	0.06	0.12	0.10	0.87	0.00	0.02	8	0	0.01	0.79	-0.06	0.04	0.17
5	23	3132	0.05	0.12	0.10	0.87	0.00	0.02	9	0	0.01	0.77	-0.07	0.04	0.16
6	24	3347	0.05	0.12	0.11	0.86	0.00	0.02	9	0	0.01	0.75	-0.07	0.04	0.17
7	1	2783	0.05	0.12	0.11	0.86	0.00	0.02	8	3	0.01	0.75	-0.08	0.04	0.16
8	2	3089	0.04	0.11	0.11	0.90	0.00	0.01	9	9	0.02	0.80	-0.08	0.04	0.14
9	3	3387	0.04	0.11	0.11	0.90	0.00	0.01	10	10	0.02	0.80	-0.08	0.03	0.13
10	4	2749	0.03	0.11	0.11	0.92	0.00	0.02	8	7	0.02	0.80	-0.09	0.03	0.13
11	5	3111	0.03	0.11	0.10	0.92	0.00	0.01	9	9	0.01	0.79	-0.08	0.02	0.12
12	6	3384	0.03	0.10	0.10	0.92	0.00	0.02	10	10	0.02	0.81	-0.08	0.02	0.13
13	7	2765	0.02	0.11	0.10	0.91	0.00	0.02	8	8	0.02	0.80	-0.09	0.01	0.13
14	8	3086	0.02	0.11	0.11	0.90	0.00	0.02	9	9	0.02	0.80	-0.11	0.00	0.13
15	9	3393	0.01	0.11	0.11	0.88	0.00	0.02	10	10	0.02	0.80	-0.12	-0.01	0.12
16	10	2727	0.00	0.11	0.11	0.88	0.00	0.01	8	3	0.02	0.80	-0.13	-0.01	0.11
17	11	3034	0.00	0.11	0.11	0.88	0.00	0.01	9	9	0.02	0.79	-0.12	-0.01	0.11
18	12	3305	0.00	0.11	0.11	0.87	0.00	0.01	10	10	0.01	0.75	-0.13	-0.01	0.13
19	13	2716	0.00	0.11	0.11	0.85	0.00	0.01	7	8	0.01	0.73	-0.13	-0.01	0.13
20	14	3009	0.00	0.11	0.11	0.86	0.00	0.01	9	1	0.01	0.76	-0.13	-0.01	0.13
21	15	3372	0.01	0.11	0.11	0.86	0.01	0.02	10	6	0.02	0.75	-0.13	0.00	0.13
22	16	2773	0.02	0.11	0.11	0.87	0.00	0.01	8	3	0.01	0.77	-0.11	0.00	0.14
23	17	3035	0.02	0.11	0.11	0.85	0.00	0.01	9	9	0.02	0.76	-0.11	0.02	0.14
24	18	1525	0.03	0.11	0.11	0.86	0.00	0.01	4	3	0.01	0.79	-0.10	0.03	0.15

HSCM Forecast

Not available at this station as this station is not contained within the computaitonal domain of the HSCM

Table 3.14. Galveston Pleasure Pier Water Level Forecast April 2000 -March 2001 Evaluation Statistics (Continued). Note the reference level is 15 cm.

Astronomical plus Persistence Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1875	0.00	0.11	0.11	0.88	0.01	0.02	5	5	0.02	0.75	-0.11	-0.01	0.12
1	19	2835	0.01	0.12	0.12	0.87	0.01	0.02	8	8	0.02	0.75	-0.10	-0.01	0.12
2	20	3134	0.01	0.12	0.12	0.86	0.01	0.02	9	9	0.02	0.74	-0.10	-0.01	0.14
3	21	3479	0.01	0.13	0.13	0.86	0.01	0.03	10	10	0.03	0.73	-0.12	0.00	0.13
4	22	2833	0.01	0.13	0.13	0.86	0.01	0.03	8	8	0.03	0.75	-0.12	-0.01	0.13
5	23	3132	0.00	0.13	0.13	0.86	0.02	0.03	9	9	0.03	0.74	-0.13	-0.01	0.13
6	24	3347	0.00	0.14	0.14	0.84	0.02	0.03	10	10	0.02	0.74	-0.14	-0.01	0.13
7	1	2783	0.00	0.13	0.13	0.84	0.02	0.03	8	8	0.02	0.73	-0.14	-0.01	0.13
8	2	3089	0.00	0.11	0.11	0.91	0.01	0.02	9	9	0.01	0.80	-0.11	-0.01	0.10
9	3	3387	0.00	0.10	0.10	0.92	0.01	0.02	10	10	0.01	0.80	-0.10	0.00	0.10
10	4	2749	0.00	0.10	0.10	0.92	0.01	0.02	8	8	0.01	0.80	-0.10	-0.01	0.10
11	5	3111	0.01	0.10	0.10	0.92	0.00	0.02	9	3	0.01	0.79	-0.10	0.00	0.11
12	6	3384	0.01	0.10	0.10	0.91	0.00	0.02	10	0	0.00	0.78	-0.09	0.00	0.12
13	7	2765	0.01	0.11	0.11	0.90	0.00	0.02	8	1	0.01	0.76	-0.10	0.00	0.12
14	8	3086	0.01	0.11	0.11	0.88	0.00	0.02	9	8	0.01	0.75	-0.12	0.00	0.12
15	9	3393	0.00	0.11	0.11	0.87	0.01	0.02	10	10	0.01	0.73	-0.12	-0.01	0.10
16	10	2727	0.00	0.11	0.11	0.87	0.02	0.01	8	8	0.01	0.73	-0.13	-0.01	0.11
17	11	3034	0.00	0.11	0.11	0.87	0.01	0.01	9	9	0.01	0.72	-0.12	-0.01	0.11
18	12	3305	0.00	0.11	0.11	0.86	0.01	0.01	10	10	0.01	0.73	-0.12	-0.01	0.12
19	13	2716	0.00	0.11	0.11	0.86	0.01	0.01	8	8	0.01	0.74	-0.12	0.00	0.12
20	14	3009	0.00	0.11	0.11	0.86	0.01	0.01	8	8	0.01	0.77	-0.12	-0.01	0.11
21	15	3372	0.00	0.10	0.10	0.89	0.01	0.01	10	10	0.01	0.78	-0.11	-0.01	0.10
22	16	2773	0.00	0.11	0.11	0.88	0.01	0.01	8	8	0.01	0.78	-0.12	-0.01	0.11
23	17	3035	0.00	0.11	0.11	0.87	0.01	0.01	9	8	0.01	0.76	-0.12	-0.01	0.12
24	18	1525	0.00	0.11	0.11	0.87	0.01	0.02	4	4	0.02	0.75	-0.12	-0.01	0.12

Astronomical Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1875	0.04	0.15	0.14	0.77	0.01	0.04	12	5	0.00	0.00	-0.14	0.02	0.20
1	19	2835	0.04	0.15	0.15	0.76	0.01	0.05	20	8	0.00	0.00	-0.13	0.03	0.22
2	20	3134	0.04	0.15	0.15	0.75	0.01	0.05	19	9	0.00	0.00	-0.13	0.03	0.22
3	21	3479	0.04	0.16	0.15	0.74	0.01	0.05	30	10	0.00	0.00	-0.13	0.02	0.22
4	22	2833	0.04	0.16	0.16	0.74	0.01	0.05	26	7	0.00	0.00	-0.15	0.02	0.22
5	23	3132	0.03	0.16	0.16	0.73	0.01	0.04	27	9	0.00	0.00	-0.15	0.03	0.21
6	24	3347	0.03	0.16	0.16	0.73	0.02	0.04	31	10	0.00	0.00	-0.16	0.03	0.21
7	1	2783	0.03	0.16	0.15	0.73	0.02	0.04	26	8	0.00	0.00	-0.15	0.03	0.21
8	2	3089	0.03	0.15	0.15	0.74	0.01	0.03	28	10	0.00	0.00	-0.15	0.03	0.21
9	3	3387	0.03	0.16	0.15	0.73	0.01	0.04	26	11	0.00	0.00	-0.15	0.03	0.22
10	4	2749	0.04	0.15	0.15	0.74	0.02	0.04	17	8	0.00	0.00	-0.14	0.03	0.22
11	5	3111	0.04	0.15	0.15	0.74	0.01	0.04	27	9	0.00	0.00	-0.13	0.04	0.21
12	6	3384	0.04	0.15	0.14	0.76	0.00	0.03	22	10	0.00	0.00	-0.12	0.04	0.21
13	7	2765	0.04	0.15	0.14	0.75	0.00	0.04	22	5	0.00	0.00	-0.13	0.04	0.22
14	8	3086	0.04	0.15	0.14	0.75	0.00	0.04	22	4	0.00	0.00	-0.14	0.03	0.21
15	9	3393	0.04	0.14	0.14	0.77	0.01	0.04	21	10	0.00	0.00	-0.14	0.03	0.20
16	10	2727	0.03	0.14	0.14	0.76	0.01	0.04	17	8	0.00	0.00	-0.14	0.02	0.20
17	11	3034	0.03	0.14	0.14	0.78	0.01	0.03	16	9	0.00	0.00	-0.13	0.03	0.19
18	12	3305	0.04	0.14	0.14	0.77	0.01	0.03	20	10	0.00	0.00	-0.13	0.03	0.19
19	13	2716	0.03	0.15	0.14	0.76	0.01	0.03	17	8	0.00	0.00	-0.14	0.03	0.20
20	14	3009	0.03	0.15	0.14	0.75	0.01	0.03	17	9	0.00	0.00	-0.15	0.03	0.19
21	15	3372	0.03	0.15	0.14	0.75	0.01	0.03	29	10	0.00	0.00	-0.14	0.03	0.21
22	16	2773	0.03	0.15	0.14	0.74	0.02	0.04	26	8	0.00	0.00	-0.15	0.03	0.20
23	17	3035	0.03	0.15	0.14	0.74	0.01	0.04	26	9	0.00	0.00	-0.15	0.03	0.20
24	18	1525	0.04	0.15	0.15	0.75	0.01	0.04	9	4	0.00	0.00	-0.15	0.03	0.21

Table 3.15. Bolivar Roads (Port Bolivar) Water Level Forecast April 2000 -March 2001 Evaluation Statistics. Note the reference level is 15 cm.

GBM Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1660	0.01	0.09	0.09	0.95	0.01	0.01	3	5	0.01	0.88	-0.07	0.00	0.09
1	19	2518	0.01	0.09	0.09	0.97	0.01	0.01	7	7	0.01	0.90	-0.06	0.00	0.09
2	20	2806	0.02	0.09	0.09	0.95	0.00	0.01	9	1	0.01	0.89	-0.07	0.01	0.11
3	21	3089	0.03	0.10	0.09	0.92	0.00	0.02	11	0	0.01	0.87	-0.06	0.01	0.13
4	22	2520	0.03	0.10	0.10	0.91	0.00	0.02	8	0	0.01	0.83	-0.07	0.01	0.14
5	23	2776	0.03	0.10	0.09	0.92	0.00	0.02	9	0	0.01	0.84	-0.07	0.01	0.13
6	24	2988	0.02	0.09	0.09	0.94	0.00	0.02	10	0	0.01	0.84	-0.08	0.01	0.12
7	1	2524	0.02	0.10	0.10	0.94	0.00	0.02	8	3	0.01	0.84	-0.09	0.01	0.11
8	2	2748	0.02	0.11	0.11	0.94	0.00	0.02	18	8	0.01	0.85	-0.10	0.01	0.10
9	3	3023	0.01	0.11	0.11	0.95	0.00	0.02	10	10	0.01	0.85	-0.09	0.01	0.09
10	4	2430	0.01	0.10	0.10	0.95	0.00	0.01	8	8	0.01	0.86	-0.09	0.00	0.09
11	5	2749	0.01	0.10	0.10	0.95	0.00	0.01	9	9	0.01	0.86	-0.09	0.00	0.10
12	6	3023	0.02	0.11	0.11	0.94	0.01	0.02	10	10	0.02	0.85	-0.08	0.00	0.10
13	7	2443	0.02	0.12	0.12	0.91	0.01	0.02	16	8	0.02	0.82	-0.08	0.00	0.11
14	8	2731	0.02	0.11	0.11	0.90	0.01	0.02	9	9	0.02	0.83	-0.09	0.00	0.12
15	9	2935	0.01	0.10	0.10	0.89	0.00	0.02	10	0	0.02	0.82	-0.10	0.00	0.12
16	10	2357	0.01	0.11	0.11	0.90	0.00	0.02	8	2	0.02	0.81	-0.11	-0.01	0.12
17	11	2661	0.00	0.10	0.10	0.89	0.00	0.02	9	0	0.01	0.81	-0.12	-0.01	0.11
18	12	2920	0.00	0.10	0.10	0.89	0.00	0.01	10	3	0.01	0.80	-0.12	-0.01	0.11
19	13	2370	0.00	0.10	0.10	0.90	0.00	0.01	8	8	0.01	0.79	-0.13	-0.01	0.11
20	14	2661	-0.01	0.10	0.10	0.90	0.00	0.01	7	9	0.00	0.77	-0.12	-0.01	0.10
21	15	2957	-0.01	0.10	0.10	0.90	0.00	0.01	10	10	0.00	0.77	-0.13	-0.02	0.09
22	16	2402	-0.01	0.11	0.11	0.90	0.01	0.01	8	8	0.01	0.78	-0.12	-0.01	0.10
23	17	2671	0.00	0.11	0.11	0.88	0.01	0.01	9	8	0.01	0.79	-0.13	-0.01	0.11
24	18	1370	0.00	0.12	0.12	0.86	0.01	0.01	4	4	0.02	0.80	-0.13	0.00	0.12

HSCM Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1650	0.00	0.09	0.09	0.96	0.01	0.01	3	5	0.01	0.89	-0.07	0.00	0.08
1	19	2505	0.01	0.09	0.08	0.97	0.01	0.01	7	7	0.01	0.90	-0.07	0.00	0.08
2	20	2788	0.02	0.09	0.08	0.95	0.00	0.01	9	1	0.01	0.90	-0.07	0.00	0.10
3	21	3071	0.03	0.10	0.09	0.92	0.00	0.01	10	0	0.01	0.87	-0.06	0.00	0.12
4	22	2504	0.03	0.10	0.10	0.92	0.00	0.02	8	0	0.01	0.83	-0.07	0.00	0.14
5	23	2759	0.02	0.09	0.09	0.93	0.00	0.02	9	0	0.01	0.84	-0.07	0.01	0.13
6	24	2971	0.02	0.09	0.09	0.94	0.00	0.02	10	0	0.01	0.84	-0.08	0.00	0.12
7	1	2515	0.01	0.10	0.10	0.94	0.00	0.02	8	3	0.01	0.84	-0.09	0.00	0.11
8	2	2738	0.01	0.11	0.11	0.94	0.00	0.02	18	8	0.01	0.86	-0.10	0.00	0.10
9	3	3012	0.01	0.11	0.11	0.94	0.01	0.02	10	10	0.01	0.85	-0.10	0.00	0.09
10	4	2420	0.00	0.11	0.11	0.94	0.01	0.01	8	8	0.01	0.85	-0.10	-0.01	0.09
11	5	2735	0.01	0.11	0.11	0.95	0.01	0.01	9	9	0.02	0.86	-0.09	0.00	0.09
12	6	3002	0.01	0.11	0.11	0.93	0.01	0.02	10	10	0.02	0.84	-0.09	0.00	0.10
13	7	2426	0.02	0.12	0.12	0.91	0.01	0.02	16	8	0.02	0.82	-0.09	0.00	0.11
14	8	2711	0.01	0.12	0.12	0.90	0.01	0.02	9	9	0.02	0.82	-0.10	0.00	0.11
15	9	2916	0.01	0.11	0.11	0.89	0.00	0.02	10	7	0.02	0.81	-0.11	-0.01	0.12
16	10	2339	0.00	0.11	0.11	0.89	0.00	0.02	8	4	0.02	0.80	-0.12	-0.01	0.12
17	11	2633	0.00	0.11	0.11	0.89	0.00	0.02	9	4	0.01	0.81	-0.12	-0.01	0.11
18	12	2890	0.00	0.11	0.11	0.89	0.00	0.02	10	3	0.01	0.81	-0.12	-0.01	0.11
19	13	2345	-0.01	0.11	0.11	0.89	0.01	0.01	8	8	0.01	0.78	-0.13	-0.01	0.11
20	14	2634	-0.01	0.10	0.10	0.89	0.00	0.01	7	9	0.01	0.77	-0.13	-0.02	0.10
21	15	2932	-0.02	0.10	0.10	0.90	0.00	0.01	10	10	0.00	0.76	-0.13	-0.02	0.09
22	16	2389	-0.01	0.11	0.11	0.90	0.01	0.01	8	8	0.01	0.78	-0.12	-0.02	0.10
23	17	2656	-0.01	0.11	0.11	0.89	0.01	0.01	9	8	0.01	0.79	-0.12	-0.01	0.11
24	18	1361	0.00	0.12	0.12	0.87	0.01	0.01	4	4	0.02	0.80	-0.12	-0.01	0.11

Table 3.15. Bolivar Roads (Port Bolivar) Water Level Forecast April 2000 -March 2001 Evaluation Statistics(Continued). Note the reference level is 15 cm.

Astronomical plus Persistence Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1661	0.02	0.12	0.12	0.86	0.01	0.01	5	5	0.02	0.67	-0.11	0.02	0.14
1	19	2518	0.03	0.12	0.12	0.84	0.01	0.02	14	8	0.02	0.63	-0.11	0.02	0.16
2	20	2806	0.04	0.13	0.12	0.83	0.01	0.02	13	9	0.02	0.63	-0.11	0.03	0.17
3	21	3089	0.04	0.13	0.13	0.82	0.01	0.03	10	9	0.03	0.65	-0.11	0.02	0.18
4	22	2520	0.03	0.13	0.13	0.83	0.02	0.02	8	7	0.03	0.67	-0.10	0.02	0.17
5	23	2776	0.02	0.13	0.13	0.85	0.01	0.02	9	7	0.03	0.69	-0.11	0.01	0.14
6	24	2988	0.01	0.13	0.13	0.85	0.01	0.03	10	9	0.03	0.67	-0.13	-0.01	0.13
7	1	2524	-0.01	0.14	0.14	0.84	0.02	0.03	8	8	0.03	0.69	-0.14	-0.02	0.11
8	2	2748	-0.01	0.12	0.12	0.89	0.01	0.03	18	6	0.02	0.76	-0.12	-0.03	0.08
9	3	3023	-0.02	0.12	0.12	0.90	0.01	0.02	10	9	0.01	0.76	-0.12	-0.03	0.07
10	4	2430	-0.02	0.11	0.11	0.89	0.01	0.02	8	8	0.01	0.75	-0.13	-0.03	0.08
11	5	2749	-0.01	0.12	0.12	0.89	0.01	0.02	9	9	0.01	0.74	-0.13	-0.02	0.09
12	6	3023	0.00	0.13	0.13	0.88	0.01	0.02	10	10	0.01	0.73	-0.13	-0.02	0.11
13	7	2443	0.01	0.14	0.13	0.87	0.01	0.03	16	8	0.02	0.72	-0.13	-0.01	0.13
14	8	2731	0.01	0.13	0.13	0.87	0.01	0.03	9	8	0.02	0.71	-0.12	-0.01	0.13
15	9	2935	0.01	0.11	0.11	0.88	0.01	0.03	9	9	0.02	0.72	-0.11	0.00	0.12
16	10	2357	0.00	0.12	0.12	0.88	0.01	0.02	8	8	0.02	0.69	-0.12	-0.01	0.12
17	11	2661	0.00	0.11	0.11	0.88	0.01	0.01	9	7	0.02	0.68	-0.12	-0.01	0.11
18	12	2920	-0.01	0.11	0.11	0.89	0.01	0.01	10	10	0.02	0.68	-0.13	-0.01	0.09
19	13	2370	-0.01	0.10	0.10	0.90	0.01	0.01	8	6	0.02	0.69	-0.13	-0.02	0.10
20	14	2661	-0.02	0.10	0.10	0.91	0.01	0.01	9	7	0.01	0.71	-0.13	-0.02	0.09
21	15	2957	-0.01	0.09	0.09	0.91	0.01	0.00	10	10	0.01	0.76	-0.12	-0.01	0.08
22	16	2402	-0.01	0.11	0.11	0.90	0.01	0.00	8	8	0.01	0.73	-0.13	-0.01	0.08
23	17	2671	0.00	0.11	0.11	0.88	0.01	0.01	9	9	0.01	0.68	-0.12	0.01	0.10
24	18	1370	0.01	0.12	0.12	0.85	0.02	0.01	4	4	0.02	0.66	-0.13	0.02	0.13

Astronomical Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1661	0.01	0.14	0.14	0.78	0.02	0.01	5	5	0.00	0.00	-0.17	0.01	0.17
1	19	2518	0.02	0.14	0.14	0.77	0.01	0.02	18	7	0.00	0.00	-0.16	0.02	0.17
2	20	2806	0.03	0.14	0.13	0.77	0.01	0.02	14	8	0.00	0.00	-0.14	0.02	0.19
3	21	3089	0.03	0.15	0.14	0.77	0.01	0.03	17	10	0.00	0.00	-0.14	0.01	0.20
4	22	2520	0.02	0.14	0.14	0.78	0.02	0.03	16	10	0.00	0.00	-0.13	0.01	0.19
5	23	2776	0.01	0.14	0.14	0.80	0.02	0.03	18	16	0.00	0.00	-0.14	-0.01	0.17
6	24	2988	0.00	0.14	0.14	0.78	0.02	0.02	20	19	0.00	0.00	-0.16	-0.02	0.16
7	1	2524	-0.01	0.15	0.15	0.77	0.02	0.03	13	15	0.00	0.00	-0.17	-0.04	0.15
8	2	2748	-0.02	0.16	0.16	0.75	0.02	0.03	18	15	0.00	0.00	-0.19	-0.04	0.15
9	3	3023	-0.03	0.16	0.16	0.72	0.03	0.03	20	19	0.00	0.00	-0.20	-0.05	0.15
10	4	2430	-0.03	0.16	0.16	0.72	0.03	0.03	16	16	0.00	0.00	-0.21	-0.05	0.16
11	5	2749	-0.02	0.16	0.16	0.72	0.03	0.03	9	19	0.00	0.00	-0.21	-0.05	0.16
12	6	3023	-0.02	0.16	0.16	0.73	0.03	0.03	10	20	0.00	0.00	-0.21	-0.04	0.16
13	7	2443	0.00	0.17	0.17	0.72	0.03	0.04	16	17	0.00	0.00	-0.20	-0.02	0.18
14	8	2731	0.00	0.16	0.16	0.73	0.02	0.04	9	13	0.00	0.00	-0.18	-0.01	0.18
15	9	2935	0.00	0.14	0.14	0.75	0.01	0.03	10	10	0.00	0.00	-0.17	0.00	0.18
16	10	2357	0.00	0.14	0.14	0.76	0.01	0.02	8	9	0.00	0.00	-0.17	-0.01	0.16
17	11	2661	-0.01	0.13	0.13	0.79	0.01	0.01	9	8	0.00	0.00	-0.17	-0.02	0.14
18	12	2920	-0.01	0.13	0.13	0.80	0.01	0.01	10	10	0.00	0.00	-0.17	-0.02	0.13
19	13	2370	-0.02	0.13	0.13	0.80	0.01	0.01	8	7	0.00	0.00	-0.18	-0.02	0.13
20	14	2661	-0.03	0.13	0.13	0.79	0.02	0.01	9	15	0.00	0.00	-0.19	-0.04	0.12
21	15	2957	-0.02	0.13	0.13	0.80	0.02	0.01	10	10	0.00	0.00	-0.19	-0.03	0.11
22	16	2402	-0.02	0.14	0.13	0.80	0.02	0.01	8	8	0.00	0.00	-0.18	-0.02	0.12
23	17	2671	-0.01	0.14	0.14	0.79	0.02	0.01	9	9	0.00	0.00	-0.18	-0.01	0.14
24	18	1370	0.00	0.14	0.14	0.77	0.02	0.01	4	4	0.00	0.00	-0.18	0.00	0.16

Table 3.16. Galveston Pier 21 Water Level Forecast April 2000 -March 2001 Evaluation Statistics. Note the reference level is 15 cm.

GBM Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1886	0.03	0.08	0.08	0.95	0.00	0.01	3	2	0.01	0.86	-0.05	0.02	0.11
1	19	2868	0.04	0.09	0.07	0.96	0.00	0.01	7	0	0.01	0.87	-0.04	0.03	0.11
2	20	3189	0.05	0.09	0.08	0.93	0.00	0.01	9	0	0.01	0.83	-0.04	0.04	0.13
3	21	3512	0.05	0.10	0.08	0.90	0.00	0.01	10	0	0.01	0.79	-0.04	0.04	0.15
4	22	2856	0.06	0.11	0.09	0.87	0.00	0.02	8	0	0.01	0.78	-0.04	0.04	0.16
5	23	3154	0.06	0.11	0.09	0.89	0.00	0.01	9	0	0.01	0.77	-0.05	0.04	0.16
6	24	3376	0.05	0.10	0.09	0.91	0.00	0.01	10	0	0.01	0.78	-0.06	0.04	0.15
7	1	2822	0.05	0.10	0.09	0.92	0.00	0.01	8	0	0.01	0.78	-0.06	0.04	0.14
8	2	3124	0.04	0.10	0.09	0.94	0.00	0.01	9	7	0.01	0.80	-0.07	0.03	0.13
9	3	3431	0.03	0.10	0.09	0.95	0.00	0.01	10	10	0.01	0.82	-0.07	0.03	0.11
10	4	2809	0.03	0.10	0.09	0.95	0.00	0.01	8	8	0.01	0.82	-0.07	0.03	0.12
11	5	3156	0.03	0.09	0.09	0.95	0.00	0.01	9	9	0.01	0.81	-0.06	0.02	0.11
12	6	3447	0.04	0.10	0.09	0.95	0.00	0.01	10	10	0.02	0.80	-0.06	0.03	0.12
13	7	2810	0.04	0.10	0.09	0.93	0.00	0.01	8	8	0.01	0.80	-0.06	0.02	0.13
14	8	3147	0.04	0.11	0.10	0.92	0.00	0.02	9	9	0.02	0.80	-0.07	0.02	0.13
15	9	3441	0.04	0.11	0.10	0.90	0.00	0.02	10	1	0.02	0.78	-0.08	0.02	0.13
16	10	2780	0.03	0.11	0.10	0.90	0.00	0.02	8	0	0.02	0.79	-0.09	0.02	0.13
17	11	3078	0.03	0.11	0.10	0.89	0.00	0.02	9	0	0.01	0.80	-0.09	0.01	0.13
18	12	3366	0.02	0.10	0.10	0.90	0.00	0.01	10	1	0.01	0.79	-0.10	0.01	0.14
19	13	2747	0.01	0.10	0.10	0.90	0.00	0.01	8	7	0.01	0.78	-0.12	0.01	0.13
20	14	3065	0.01	0.10	0.10	0.89	0.00	0.01	9	7	0.01	0.79	-0.12	0.00	0.12
21	15	3407	0.01	0.10	0.10	0.90	0.00	0.01	10	1	0.01	0.78	-0.12	0.00	0.11
22	16	2796	0.01	0.10	0.10	0.89	0.00	0.01	8	0	0.01	0.79	-0.11	0.01	0.12
23	17	3080	0.02	0.10	0.10	0.88	0.00	0.01	9	6	0.01	0.78	-0.11	0.01	0.13
24	18	1546	0.03	0.11	0.10	0.88	0.00	0.01	4	3	0.01	0.76	-0.10	0.02	0.13

HSCM Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1868	0.03	0.08	0.07	0.96	0.00	0.01	3	2	0.01	0.87	-0.05	0.02	0.10
1	19	2841	0.04	0.08	0.07	0.96	0.00	0.01	7	0	0.01	0.87	-0.04	0.03	0.11
2	20	3159	0.05	0.09	0.08	0.94	0.00	0.01	9	0	0.01	0.84	-0.04	0.04	0.13
3	21	3480	0.05	0.10	0.08	0.91	0.00	0.01	10	0	0.01	0.80	-0.04	0.04	0.15
4	22	2829	0.06	0.11	0.09	0.88	0.00	0.01	8	0	0.01	0.77	-0.04	0.04	0.16
5	23	3124	0.06	0.11	0.09	0.88	0.00	0.01	9	0	0.01	0.78	-0.05	0.04	0.16
6	24	3344	0.05	0.11	0.09	0.90	0.00	0.01	10	0	0.01	0.77	-0.06	0.04	0.15
7	1	2801	0.05	0.11	0.10	0.89	0.00	0.01	8	1	0.01	0.76	-0.07	0.04	0.14
8	2	3098	0.04	0.11	0.10	0.92	0.00	0.01	9	7	0.01	0.78	-0.08	0.04	0.13
9	3	3398	0.03	0.11	0.10	0.93	0.01	0.01	10	10	0.02	0.80	-0.08	0.03	0.12
10	4	2783	0.03	0.11	0.10	0.93	0.01	0.01	8	8	0.02	0.78	-0.07	0.03	0.12
11	5	3126	0.03	0.10	0.10	0.94	0.01	0.02	9	9	0.02	0.79	-0.07	0.03	0.11
12	6	3414	0.04	0.11	0.10	0.94	0.01	0.02	10	10	0.02	0.78	-0.07	0.03	0.12
13	7	2782	0.04	0.11	0.10	0.92	0.01	0.02	8	8	0.02	0.78	-0.07	0.03	0.12
14	8	3117	0.04	0.12	0.11	0.90	0.01	0.02	9	9	0.02	0.78	-0.07	0.03	0.13
15	9	3408	0.04	0.12	0.11	0.89	0.00	0.02	10	6	0.02	0.77	-0.08	0.03	0.14
16	10	2753	0.03	0.12	0.11	0.88	0.00	0.02	8	0	0.02	0.79	-0.09	0.02	0.14
17	11	3048	0.03	0.12	0.11	0.88	0.00	0.02	9	0	0.02	0.80	-0.10	0.02	0.14
18	12	3333	0.02	0.11	0.11	0.88	0.00	0.02	10	5	0.01	0.79	-0.10	0.02	0.14
19	13	2720	0.01	0.11	0.11	0.88	0.01	0.01	8	8	0.01	0.79	-0.12	0.01	0.13
20	14	3035	0.01	0.11	0.11	0.89	0.01	0.01	9	10	0.01	0.79	-0.12	0.01	0.12
21	15	3374	0.01	0.10	0.10	0.90	0.00	0.01	10	4	0.01	0.78	-0.12	0.00	0.11
22	16	2769	0.01	0.10	0.10	0.89	0.00	0.01	8	0	0.01	0.78	-0.11	0.01	0.12
23	17	3050	0.02	0.11	0.10	0.88	0.00	0.01	9	2	0.01	0.78	-0.11	0.02	0.13
24	18	1532	0.03	0.11	0.10	0.89	0.00	0.01	4	3	0.01	0.76	-0.09	0.02	0.14

Table 3.16. Galveston Pier 21Water Level Forecast April 2000 -March 2001 Evaluation Statistics (Continued). Note the reference level is 15 cm.

Astronomical plus Persistence Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1887	0.00	0.09	0.09	0.91	0.01	0.01	5	5	0.02	0.82	-0.10	-0.01	0.09
1	19	2868	0.01	0.10	0.10	0.90	0.01	0.02	8	8	0.02	0.81	-0.10	0.00	0.10
2	20	3189	0.01	0.10	0.10	0.89	0.01	0.02	9	9	0.02	0.81	-0.10	-0.01	0.12
3	21	3512	0.01	0.11	0.11	0.88	0.01	0.02	10	10	0.03	0.79	-0.10	-0.01	0.12
4	22	2856	0.00	0.11	0.11	0.88	0.01	0.02	8	8	0.02	0.80	-0.10	-0.01	0.11
5	23	3154	0.00	0.12	0.12	0.88	0.01	0.03	9	9	0.03	0.80	-0.11	-0.01	0.10
6	24	3376	0.00	0.13	0.13	0.86	0.02	0.03	10	10	0.03	0.78	-0.12	-0.02	0.11
7	1	2822	-0.01	0.13	0.13	0.85	0.02	0.03	8	8	0.03	0.76	-0.13	-0.02	0.11
8	2	3124	-0.01	0.10	0.10	0.91	0.01	0.02	9	9	0.02	0.83	-0.11	-0.01	0.07
9	3	3431	-0.01	0.09	0.09	0.93	0.01	0.01	10	10	0.01	0.83	-0.09	-0.01	0.07
10	4	2809	0.00	0.09	0.09	0.93	0.01	0.01	8	8	0.01	0.82	-0.10	-0.01	0.08
11	5	3156	0.00	0.09	0.09	0.94	0.01	0.01	9	9	0.01	0.81	-0.09	-0.01	0.08
12	6	3447	0.01	0.10	0.10	0.92	0.01	0.01	10	10	0.01	0.82	-0.09	0.00	0.09
13	7	2810	0.01	0.10	0.10	0.92	0.01	0.02	8	8	0.01	0.83	-0.09	0.00	0.09
14	8	3147	0.01	0.10	0.10	0.90	0.01	0.02	9	9	0.01	0.82	-0.10	0.00	0.10
15	9	3441	0.01	0.10	0.10	0.90	0.01	0.02	10	10	0.01	0.81	-0.10	0.00	0.10
16	10	2780	0.00	0.11	0.11	0.89	0.01	0.02	8	8	0.01	0.80	-0.10	0.00	0.10
17	11	3078	0.00	0.11	0.11	0.89	0.01	0.02	9	9	0.01	0.79	-0.11	-0.01	0.10
18	12	3366	0.00	0.10	0.10	0.91	0.01	0.01	10	10	0.01	0.81	-0.11	-0.01	0.09
19	13	2747	-0.01	0.10	0.10	0.91	0.01	0.01	8	8	0.01	0.81	-0.12	-0.01	0.09
20	14	3065	-0.01	0.09	0.09	0.92	0.01	0.01	9	8	0.01	0.81	-0.11	-0.01	0.09
21	15	3407	-0.01	0.09	0.09	0.93	0.00	0.00	10	10	0.01	0.84	-0.10	-0.01	0.08
22	16	2796	-0.01	0.09	0.09	0.93	0.01	0.01	8	8	0.01	0.82	-0.11	-0.01	0.08
23	17	3080	-0.01	0.09	0.09	0.92	0.01	0.01	9	9	0.01	0.81	-0.11	-0.01	0.08
24	18	1546	0.00	0.09	0.09	0.91	0.01	0.01	4	4	0.01	0.81	-0.11	-0.01	0.09

Astronomical Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1887	0.03	0.13	0.13	0.78	0.01	0.02	11	5	0.00	0.00	-0.14	0.02	0.17
1	19	2868	0.03	0.14	0.13	0.79	0.01	0.03	24	8	0.00	0.00	-0.13	0.03	0.18
2	20	3189	0.03	0.14	0.13	0.80	0.01	0.03	19	8	0.00	0.00	-0.13	0.02	0.19
3	21	3512	0.03	0.14	0.14	0.79	0.01	0.04	21	10	0.00	0.00	-0.14	0.02	0.20
4	22	2856	0.03	0.15	0.14	0.78	0.01	0.04	17	8	0.00	0.00	-0.13	0.01	0.19
5	23	3154	0.03	0.15	0.14	0.78	0.01	0.03	18	9	0.00	0.00	-0.14	0.01	0.19
6	24	3376	0.02	0.15	0.15	0.77	0.01	0.03	21	16	0.00	0.00	-0.14	0.01	0.19
7	1	2822	0.02	0.15	0.15	0.77	0.02	0.03	26	14	0.00	0.00	-0.14	0.01	0.19
8	2	3124	0.02	0.15	0.14	0.78	0.01	0.03	29	15	0.00	0.00	-0.14	0.02	0.19
9	3	3431	0.02	0.15	0.14	0.77	0.01	0.03	27	18	0.00	0.00	-0.15	0.01	0.19
10	4	2809	0.02	0.15	0.15	0.75	0.02	0.03	20	17	0.00	0.00	-0.15	0.02	0.20
11	5	3156	0.03	0.15	0.14	0.77	0.01	0.03	22	11	0.00	0.00	-0.14	0.03	0.20
12	6	3447	0.03	0.15	0.14	0.77	0.01	0.03	31	9	0.00	0.00	-0.14	0.02	0.19
13	7	2810	0.03	0.15	0.14	0.76	0.01	0.03	25	7	0.00	0.00	-0.13	0.03	0.20
14	8	3147	0.03	0.15	0.14	0.74	0.01	0.03	17	8	0.00	0.00	-0.13	0.03	0.21
15	9	3441	0.03	0.15	0.14	0.76	0.01	0.04	17	10	0.00	0.00	-0.14	0.03	0.20
16	10	2780	0.03	0.15	0.14	0.77	0.01	0.04	17	8	0.00	0.00	-0.14	0.03	0.20
17	11	3078	0.03	0.14	0.14	0.78	0.01	0.02	13	9	0.00	0.00	-0.13	0.02	0.18
18	12	3366	0.03	0.14	0.14	0.79	0.01	0.02	10	10	0.00	0.00	-0.13	0.02	0.17
19	13	2747	0.02	0.14	0.14	0.79	0.01	0.02	8	8	0.00	0.00	-0.14	0.02	0.17
20	14	3065	0.02	0.14	0.14	0.79	0.01	0.02	9	9	0.00	0.00	-0.15	0.02	0.17
21	15	3407	0.02	0.14	0.13	0.79	0.01	0.02	10	10	0.00	0.00	-0.15	0.02	0.16
22	16	2796	0.02	0.13	0.13	0.79	0.01	0.02	17	8	0.00	0.00	-0.15	0.02	0.17
23	17	3080	0.02	0.13	0.13	0.78	0.01	0.02	16	9	0.00	0.00	-0.15	0.02	0.17
24	18	1546	0.02	0.14	0.13	0.78	0.01	0.02	9	4	0.00	0.00	-0.15	0.02	0.17

Table 3.17. Eagle Point Water Level Forecast April 2000 -March 2001 Evaluation Statistics. Note the reference level is 15 cm.

GBM Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1617	-0.02	0.08	0.08	0.94	0.00	0.00	0	3	0.00	0.87	-0.11	-0.03	0.06
1	19	2465	-0.02	0.07	0.07	0.96	0.00	0.00	0	7	0.00	0.89	-0.11	-0.02	0.05
2	20	2715	-0.01	0.07	0.07	0.96	0.00	0.00	7	9	0.00	0.89	-0.10	-0.02	0.07
3	21	3011	0.00	0.07	0.07	0.97	0.00	0.00	8	7	0.00	0.91	-0.09	-0.01	0.08
4	22	2425	0.01	0.08	0.08	0.97	0.00	0.00	7	0	0.00	0.91	-0.08	0.00	0.08
5	23	2681	0.01	0.08	0.08	0.96	0.00	0.01	9	0	0.00	0.92	-0.08	0.00	0.08
6	24	2877	0.01	0.08	0.08	0.96	0.00	0.01	9	0	0.00	0.91	-0.08	0.00	0.08
7	1	2397	0.01	0.08	0.08	0.95	0.00	0.01	8	0	0.01	0.90	-0.08	0.01	0.08
8	2	2647	0.02	0.09	0.08	0.94	0.00	0.01	9	0	0.01	0.91	-0.08	0.01	0.09
9	3	2926	0.02	0.08	0.08	0.95	0.00	0.01	10	0	0.01	0.92	-0.09	0.01	0.08
10	4	2385	0.02	0.09	0.09	0.95	0.00	0.01	8	0	0.01	0.89	-0.08	0.01	0.09
11	5	2651	0.02	0.09	0.09	0.95	0.00	0.01	8	0	0.01	0.90	-0.08	0.01	0.10
12	6	2898	0.02	0.09	0.09	0.93	0.00	0.01	10	0	0.01	0.89	-0.08	0.01	0.10
13	7	2341	0.02	0.10	0.09	0.93	0.00	0.01	8	2	0.01	0.88	-0.09	0.02	0.11
14	8	2651	0.03	0.10	0.10	0.92	0.00	0.02	9	0	0.01	0.86	-0.09	0.02	0.12
15	9	2882	0.02	0.10	0.10	0.91	0.00	0.02	9	0	0.01	0.86	-0.10	0.02	0.12
16	10	2342	0.02	0.10	0.10	0.90	0.00	0.02	8	0	0.01	0.85	-0.10	0.01	0.12
17	11	2586	0.02	0.10	0.10	0.89	0.00	0.02	9	1	0.01	0.83	-0.10	0.01	0.13
18	12	2820	0.02	0.11	0.11	0.88	0.00	0.02	10	2	0.01	0.81	-0.11	0.01	0.13
19	13	2318	0.01	0.11	0.11	0.86	0.00	0.01	8	0	0.01	0.81	-0.13	0.00	0.13
20	14	2572	0.00	0.11	0.11	0.86	0.00	0.01	7	0	0.00	0.81	-0.14	0.00	0.11
21	15	2877	-0.01	0.11	0.11	0.86	0.00	0.01	10	8	0.00	0.79	-0.15	-0.01	0.11
22	16	2366	-0.01	0.11	0.11	0.84	0.00	0.01	7	1	0.00	0.79	-0.16	-0.01	0.10
23	17	2595	-0.01	0.11	0.11	0.84	0.01	0.01	9	4	0.00	0.77	-0.16	-0.02	0.11
24	18	1315	-0.01	0.11	0.11	0.86	0.01	0.01	4	4	0.01	0.75	-0.15	-0.02	0.11

HSCM Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1605	-0.02	0.08	0.08	0.94	0.00	0.00	0	3	0.00	0.88	-0.11	-0.03	0.05
1	19	2448	-0.02	0.07	0.07	0.96	0.00	0.00	0	7	0.00	0.90	-0.10	-0.02	0.04
2	20	2696	-0.02	0.07	0.07	0.96	0.00	0.00	7	9	0.00	0.89	-0.10	-0.02	0.06
3	21	2989	-0.01	0.07	0.07	0.97	0.00	0.00	8	7	0.00	0.92	-0.09	-0.01	0.07
4	22	2408	0.00	0.08	0.08	0.97	0.00	0.00	7	0	0.00	0.91	-0.09	0.00	0.08
5	23	2663	0.01	0.08	0.08	0.96	0.00	0.01	9	0	0.00	0.91	-0.09	0.00	0.08
6	24	2857	0.01	0.08	0.08	0.95	0.00	0.01	9	0	0.00	0.90	-0.09	0.00	0.08
7	1	2388	0.01	0.08	0.08	0.95	0.00	0.01	8	0	0.01	0.90	-0.08	0.01	0.08
8	2	2633	0.01	0.09	0.09	0.94	0.00	0.01	9	0	0.01	0.91	-0.09	0.01	0.08
9	3	2907	0.01	0.09	0.08	0.95	0.00	0.01	10	0	0.01	0.92	-0.09	0.01	0.08
10	4	2367	0.01	0.09	0.09	0.94	0.00	0.01	8	0	0.01	0.89	-0.09	0.01	0.09
11	5	2632	0.01	0.09	0.09	0.94	0.00	0.01	8	0	0.01	0.90	-0.08	0.01	0.09
12	6	2878	0.02	0.09	0.09	0.93	0.00	0.01	10	6	0.01	0.89	-0.09	0.01	0.10
13	7	2323	0.02	0.10	0.09	0.92	0.00	0.01	8	2	0.01	0.87	-0.09	0.01	0.10
14	8	2633	0.02	0.10	0.10	0.92	0.00	0.02	9	0	0.01	0.86	-0.10	0.01	0.11
15	9	2860	0.02	0.10	0.10	0.91	0.00	0.02	9	0	0.01	0.86	-0.10	0.01	0.11
16	10	2323	0.01	0.10	0.10	0.90	0.00	0.02	8	0	0.01	0.85	-0.11	0.01	0.11
17	11	2568	0.01	0.10	0.10	0.89	0.00	0.02	9	1	0.01	0.83	-0.11	0.01	0.12
18	12	2799	0.01	0.11	0.11	0.88	0.00	0.02	10	1	0.01	0.82	-0.12	0.00	0.13
19	13	2300	0.01	0.11	0.11	0.87	0.00	0.02	8	0	0.01	0.81	-0.13	0.00	0.12
20	14	2553	0.00	0.11	0.11	0.86	0.00	0.01	7	0	0.00	0.81	-0.14	-0.01	0.11
21	15	2855	-0.01	0.11	0.11	0.86	0.00	0.01	10	8	0.00	0.79	-0.15	-0.01	0.11
22	16	2349	-0.01	0.11	0.10	0.85	0.00	0.01	7	1	0.00	0.79	-0.16	-0.01	0.10
23	17	2575	-0.01	0.11	0.11	0.85	0.00	0.01	8	4	0.00	0.78	-0.15	-0.02	0.10
24	18	1306	-0.01	0.11	0.11	0.86	0.00	0.01	4	4	0.01	0.76	-0.15	-0.02	0.11

Table 3.17. Eagle Point Water Level Forecast April 2000 -March 2001 Evaluation Statistics (Continued). Note the reference level is 15 cm.

Astronomical plus Persistence Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1606	-0.01	0.11	0.11	0.88	0.01	0.01	4	5	0.01	0.77	-0.12	-0.01	0.09
1	19	2448	-0.01	0.11	0.11	0.87	0.02	0.01	8	8	0.02	0.75	-0.12	-0.01	0.10
2	20	2696	-0.01	0.11	0.11	0.87	0.02	0.01	9	9	0.02	0.74	-0.13	-0.01	0.10
3	21	2989	-0.01	0.12	0.12	0.86	0.02	0.02	10	10	0.02	0.73	-0.14	-0.01	0.10
4	22	2408	-0.01	0.12	0.12	0.84	0.02	0.02	8	8	0.02	0.72	-0.15	-0.01	0.11
5	23	2663	-0.01	0.12	0.12	0.84	0.03	0.02	9	9	0.02	0.73	-0.15	-0.01	0.11
6	24	2857	-0.01	0.14	0.14	0.82	0.03	0.02	10	10	0.03	0.72	-0.16	-0.01	0.12
7	1	2388	-0.01	0.14	0.14	0.82	0.03	0.03	8	8	0.03	0.72	-0.17	-0.01	0.11
8	2	2633	-0.01	0.11	0.11	0.89	0.02	0.02	9	9	0.02	0.80	-0.13	-0.01	0.08
9	3	2907	-0.01	0.10	0.10	0.89	0.01	0.01	10	10	0.01	0.79	-0.13	-0.01	0.08
10	4	2367	-0.01	0.10	0.10	0.89	0.01	0.01	8	8	0.01	0.80	-0.12	-0.01	0.08
11	5	2632	-0.01	0.10	0.10	0.90	0.01	0.01	9	9	0.01	0.79	-0.12	-0.01	0.08
12	6	2878	-0.01	0.11	0.11	0.90	0.01	0.01	10	10	0.01	0.80	-0.13	-0.01	0.09
13	7	2323	0.00	0.11	0.11	0.88	0.01	0.01	8	8	0.01	0.79	-0.13	-0.01	0.10
14	8	2633	0.00	0.12	0.12	0.87	0.01	0.02	9	9	0.01	0.77	-0.13	-0.01	0.11
15	9	2860	-0.01	0.12	0.12	0.87	0.02	0.02	10	10	0.01	0.77	-0.12	-0.01	0.10
16	10	2323	-0.01	0.12	0.12	0.87	0.03	0.02	8	8	0.02	0.77	-0.13	-0.01	0.10
17	11	2568	-0.01	0.12	0.12	0.87	0.03	0.02	9	9	0.02	0.78	-0.13	-0.01	0.10
18	12	2799	-0.01	0.12	0.12	0.86	0.03	0.02	10	10	0.02	0.75	-0.14	-0.01	0.10
19	13	2300	-0.01	0.12	0.12	0.86	0.03	0.02	8	8	0.02	0.75	-0.15	-0.01	0.10
20	14	2553	-0.01	0.11	0.11	0.89	0.02	0.01	9	9	0.01	0.80	-0.14	-0.01	0.08
21	15	2855	-0.01	0.10	0.10	0.90	0.02	0.01	10	10	0.01	0.80	-0.13	-0.01	0.07
22	16	2349	-0.01	0.10	0.10	0.89	0.02	0.00	8	8	0.01	0.80	-0.13	-0.01	0.07
23	17	2575	-0.01	0.11	0.10	0.88	0.02	0.00	9	9	0.01	0.77	-0.12	-0.01	0.09
24	18	1306	-0.01	0.11	0.11	0.88	0.02	0.00	3	4	0.01	0.74	-0.11	-0.01	0.09

Astronomical Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1606	-0.02	0.15	0.15	0.74	0.04	0.02	11	23	0.00	0.00	-0.21	-0.02	0.15
1	19	2448	-0.02	0.15	0.15	0.73	0.04	0.02	16	34	0.00	0.00	-0.20	-0.02	0.16
2	20	2696	-0.02	0.15	0.15	0.74	0.03	0.02	18	20	0.00	0.00	-0.20	-0.02	0.16
3	21	2989	-0.02	0.15	0.15	0.74	0.04	0.02	20	24	0.00	0.00	-0.19	-0.02	0.15
4	22	2408	-0.01	0.15	0.15	0.74	0.03	0.03	11	17	0.00	0.00	-0.19	-0.02	0.16
5	23	2663	-0.02	0.15	0.15	0.73	0.04	0.03	16	19	0.00	0.00	-0.19	-0.03	0.16
6	24	2857	-0.02	0.16	0.16	0.72	0.04	0.03	21	20	0.00	0.00	-0.19	-0.02	0.17
7	1	2388	-0.02	0.16	0.16	0.71	0.04	0.03	16	16	0.00	0.00	-0.19	-0.03	0.16
8	2	2633	-0.02	0.16	0.16	0.70	0.04	0.03	19	18	0.00	0.00	-0.20	-0.03	0.17
9	3	2907	-0.02	0.16	0.16	0.68	0.03	0.03	21	19	0.00	0.00	-0.21	-0.03	0.16
10	4	2367	-0.02	0.16	0.16	0.68	0.03	0.03	15	16	0.00	0.00	-0.21	-0.03	0.17
11	5	2632	-0.02	0.17	0.16	0.68	0.03	0.03	18	18	0.00	0.00	-0.21	-0.03	0.18
12	6	2878	-0.02	0.16	0.16	0.68	0.03	0.02	10	20	0.00	0.00	-0.21	-0.02	0.17
13	7	2323	-0.01	0.17	0.17	0.67	0.03	0.03	8	17	0.00	0.00	-0.21	-0.02	0.18
14	8	2633	-0.01	0.17	0.17	0.68	0.04	0.03	9	19	0.00	0.00	-0.22	-0.03	0.18
15	9	2860	-0.02	0.16	0.16	0.68	0.04	0.03	10	21	0.00	0.00	-0.22	-0.02	0.17
16	10	2323	-0.02	0.16	0.16	0.70	0.05	0.03	8	17	0.00	0.00	-0.21	-0.02	0.17
17	11	2568	-0.02	0.16	0.16	0.70	0.05	0.03	9	18	0.00	0.00	-0.21	-0.02	0.16
18	12	2799	-0.02	0.16	0.16	0.70	0.05	0.03	10	21	0.00	0.00	-0.22	-0.02	0.16
19	13	2300	-0.02	0.16	0.16	0.71	0.06	0.02	8	32	0.00	0.00	-0.21	-0.02	0.15
20	14	2553	-0.02	0.16	0.16	0.73	0.06	0.02	9	39	0.00	0.00	-0.21	-0.02	0.15
21	15	2855	-0.02	0.16	0.16	0.74	0.06	0.02	10	40	0.00	0.00	-0.21	-0.02	0.15
22	16	2349	-0.02	0.16	0.16	0.73	0.05	0.01	8	34	0.00	0.00	-0.21	-0.02	0.14
23	17	2575	-0.02	0.16	0.15	0.75	0.04	0.01	9	38	0.00	0.00	-0.23	-0.02	0.14
24	18	1306	-0.02	0.16	0.16	0.73	0.05	0.02	7	18	0.00	0.00	-0.23	-0.02	0.15

Table 3.18. Morgans Point Water Level Forecast April 2000 -March 2001 Evaluation Statistics. Note the reference level is 15 cm.

GBM Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1732	0.04	0.09	0.08	0.92	0.00	0.01	3	3	0.00	0.86	-0.05	0.03	0.13
1	19	2661	0.04	0.08	0.07	0.94	0.00	0.01	7	8	0.00	0.89	-0.04	0.03	0.11
2	20	2958	0.04	0.09	0.07	0.93	0.00	0.01	9	9	0.00	0.88	-0.04	0.03	0.11
3	21	3256	0.05	0.09	0.07	0.94	0.00	0.01	9	2	0.00	0.86	-0.03	0.05	0.12
4	22	2651	0.07	0.10	0.08	0.92	0.00	0.01	14	0	0.00	0.82	-0.02	0.06	0.14
5	23	2940	0.07	0.10	0.08	0.91	0.00	0.02	16	0	0.01	0.82	-0.01	0.06	0.15
6	24	3168	0.08	0.11	0.08	0.89	0.00	0.02	19	0	0.01	0.81	-0.01	0.07	0.16
7	1	2627	0.09	0.12	0.09	0.84	0.00	0.02	11	0	0.01	0.74	0.00	0.08	0.18
8	2	2948	0.10	0.13	0.09	0.82	0.00	0.02	9	0	0.01	0.71	-0.01	0.09	0.18
9	3	3191	0.10	0.13	0.09	0.80	0.00	0.02	9	0	0.01	0.70	-0.01	0.09	0.19
10	4	2617	0.10	0.14	0.09	0.78	0.00	0.02	8	0	0.01	0.69	-0.01	0.09	0.19
11	5	2913	0.10	0.14	0.09	0.78	0.00	0.02	9	0	0.01	0.69	-0.01	0.10	0.19
12	6	3196	0.11	0.15	0.10	0.74	0.00	0.03	10	0	0.02	0.68	0.00	0.10	0.20
13	7	2625	0.11	0.15	0.10	0.75	0.00	0.03	8	0	0.02	0.67	-0.01	0.10	0.20
14	8	2920	0.11	0.15	0.10	0.76	0.00	0.04	9	0	0.02	0.70	-0.01	0.10	0.20
15	9	3198	0.11	0.15	0.10	0.77	0.00	0.03	10	1	0.02	0.71	-0.01	0.10	0.20
16	10	2535	0.10	0.14	0.10	0.79	0.00	0.03	8	0	0.01	0.71	-0.02	0.09	0.21
17	11	2831	0.10	0.14	0.10	0.78	0.00	0.03	9	0	0.02	0.71	-0.02	0.08	0.21
18	12	3124	0.09	0.14	0.11	0.78	0.00	0.03	10	0	0.02	0.71	-0.03	0.08	0.21
19	13	2542	0.09	0.14	0.11	0.77	0.00	0.04	8	0	0.02	0.73	-0.03	0.07	0.21
20	14	2834	0.08	0.14	0.11	0.80	0.00	0.03	9	0	0.02	0.74	-0.05	0.07	0.20
21	15	3162	0.07	0.13	0.11	0.81	0.00	0.03	10	2	0.02	0.76	-0.06	0.06	0.20
22	16	2582	0.06	0.13	0.11	0.83	0.00	0.02	8	6	0.02	0.78	-0.08	0.04	0.18
23	17	2878	0.05	0.12	0.11	0.83	0.00	0.02	9	0	0.02	0.77	-0.09	0.03	0.18
24	18	1472	0.05	0.12	0.12	0.82	0.00	0.02	4	0	0.02	0.74	-0.10	0.03	0.18

HSCM Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1719	0.04	0.09	0.08	0.93	0.00	0.01	3	3	0.00	0.86	-0.05	0.03	0.12
1	19	2637	0.03	0.08	0.07	0.95	0.00	0.01	7	8	0.00	0.90	-0.04	0.03	0.10
2	20	2927	0.04	0.08	0.07	0.94	0.00	0.01	9	9	0.00	0.89	-0.04	0.03	0.10
3	21	3228	0.05	0.09	0.07	0.96	0.00	0.01	9	4	0.00	0.88	-0.04	0.04	0.11
4	22	2628	0.06	0.10	0.07	0.93	0.00	0.01	15	0	0.00	0.84	-0.02	0.06	0.13
5	23	2910	0.07	0.10	0.08	0.92	0.00	0.01	16	0	0.00	0.83	-0.02	0.06	0.14
6	24	3140	0.08	0.11	0.08	0.90	0.00	0.01	19	0	0.01	0.81	-0.02	0.07	0.15
7	1	2607	0.09	0.12	0.09	0.85	0.00	0.02	15	0	0.01	0.75	-0.01	0.08	0.17
8	2	2927	0.09	0.13	0.09	0.83	0.00	0.02	9	0	0.01	0.71	-0.01	0.09	0.18
9	3	3165	0.09	0.13	0.09	0.81	0.00	0.02	9	1	0.01	0.71	-0.01	0.09	0.18
10	4	2591	0.10	0.14	0.09	0.79	0.00	0.02	8	0	0.01	0.71	-0.01	0.09	0.19
11	5	2887	0.10	0.14	0.10	0.78	0.00	0.01	9	3	0.01	0.70	-0.01	0.09	0.19
12	6	3169	0.10	0.14	0.10	0.76	0.00	0.02	10	8	0.02	0.69	-0.01	0.10	0.19
13	7	2602	0.10	0.14	0.10	0.75	0.00	0.03	8	6	0.02	0.69	-0.01	0.10	0.19
14	8	2891	0.10	0.15	0.10	0.76	0.00	0.03	9	0	0.02	0.70	-0.01	0.10	0.20
15	9	3167	0.10	0.14	0.10	0.77	0.00	0.03	10	0	0.02	0.71	-0.02	0.09	0.20
16	10	2512	0.10	0.14	0.10	0.78	0.00	0.03	8	0	0.01	0.71	-0.02	0.09	0.21
17	11	2804	0.10	0.14	0.11	0.78	0.00	0.03	9	0	0.02	0.71	-0.03	0.08	0.21
18	12	3096	0.09	0.14	0.11	0.79	0.00	0.03	10	0	0.02	0.70	-0.04	0.08	0.21
19	13	2516	0.09	0.14	0.11	0.76	0.00	0.04	8	0	0.02	0.72	-0.04	0.07	0.21
20	14	2806	0.08	0.14	0.11	0.79	0.00	0.03	12	0	0.02	0.73	-0.06	0.06	0.21
21	15	3132	0.07	0.13	0.11	0.81	0.00	0.03	10	2	0.01	0.76	-0.07	0.05	0.20
22	16	2557	0.05	0.13	0.11	0.82	0.00	0.02	8	6	0.01	0.77	-0.08	0.04	0.18
23	17	2857	0.04	0.12	0.11	0.83	0.00	0.02	9	0	0.02	0.77	-0.10	0.03	0.17
24	18	1461	0.04	0.12	0.12	0.83	0.00	0.02	4	0	0.02	0.74	-0.10	0.03	0.17

Table 3.18. Morgans Point Water Level Forecast April 2000 -March 2001 Evaluation Statistics (Continued). Note the reference level is 15 cm.

Astronomical plus Persistence Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1720	-0.01	0.13	0.13	0.83	0.02	0.02	10	5	0.02	0.68	-0.14	-0.02	0.14
1	19	2637	-0.01	0.13	0.13	0.82	0.02	0.02	14	8	0.02	0.69	-0.15	-0.02	0.15
2	20	2927	-0.01	0.13	0.13	0.82	0.02	0.02	12	9	0.02	0.67	-0.15	-0.01	0.14
3	21	3228	-0.01	0.13	0.13	0.81	0.02	0.02	10	10	0.02	0.66	-0.15	-0.01	0.15
4	22	2628	-0.01	0.14	0.14	0.79	0.02	0.02	8	8	0.03	0.64	-0.17	-0.01	0.16
5	23	2910	-0.01	0.14	0.14	0.79	0.02	0.03	9	9	0.03	0.63	-0.17	-0.02	0.15
6	24	3140	-0.01	0.15	0.15	0.77	0.03	0.04	10	10	0.03	0.64	-0.18	-0.02	0.17
7	1	2607	0.00	0.15	0.15	0.76	0.03	0.04	8	8	0.03	0.67	-0.18	-0.01	0.18
8	2	2927	0.00	0.13	0.13	0.83	0.01	0.02	9	9	0.01	0.73	-0.14	-0.01	0.13
9	3	3165	0.00	0.12	0.12	0.84	0.01	0.02	10	10	0.02	0.74	-0.14	-0.02	0.12
10	4	2591	0.00	0.12	0.12	0.84	0.01	0.02	8	17	0.01	0.74	-0.13	-0.01	0.12
11	5	2887	0.00	0.12	0.12	0.85	0.01	0.02	9	15	0.01	0.74	-0.13	-0.01	0.12
12	6	3169	0.00	0.13	0.13	0.84	0.01	0.02	10	11	0.01	0.71	-0.14	-0.01	0.14
13	7	2602	0.00	0.13	0.13	0.83	0.02	0.02	8	17	0.01	0.72	-0.14	-0.01	0.14
14	8	2891	0.00	0.14	0.14	0.81	0.02	0.03	8	17	0.01	0.71	-0.16	-0.01	0.14
15	9	3167	0.00	0.14	0.14	0.80	0.03	0.03	10	16	0.01	0.72	-0.17	0.00	0.15
16	10	2512	0.00	0.14	0.14	0.80	0.03	0.03	8	16	0.02	0.71	-0.17	-0.01	0.14
17	11	2804	0.00	0.14	0.14	0.80	0.04	0.03	9	12	0.02	0.71	-0.17	0.00	0.14
18	12	3096	0.00	0.14	0.14	0.82	0.03	0.02	10	10	0.01	0.71	-0.16	-0.01	0.13
19	13	2516	0.00	0.14	0.14	0.81	0.03	0.02	8	8	0.01	0.71	-0.16	0.00	0.14
20	14	2806	0.00	0.13	0.13	0.82	0.03	0.01	13	9	0.01	0.74	-0.15	-0.01	0.13
21	15	3132	-0.01	0.13	0.13	0.84	0.03	0.01	19	10	0.01	0.75	-0.15	-0.01	0.12
22	16	2557	-0.01	0.13	0.13	0.83	0.04	0.01	15	8	0.01	0.72	-0.14	-0.02	0.14
23	17	2857	-0.01	0.13	0.13	0.83	0.04	0.01	15	9	0.01	0.70	-0.14	-0.02	0.14
24	18	1461	-0.01	0.13	0.13	0.83	0.03	0.02	9	4	0.01	0.67	-0.14	-0.02	0.15

Astronomical Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1720	0.03	0.17	0.16	0.69	0.02	0.05	10	5	0.00	0.00	-0.16	0.02	0.21
1	19	2637	0.04	0.17	0.17	0.70	0.02	0.06	16	16	0.00	0.00	-0.16	0.03	0.22
2	20	2927	0.04	0.17	0.17	0.68	0.02	0.06	19	16	0.00	0.00	-0.16	0.03	0.22
3	21	3228	0.04	0.17	0.16	0.69	0.01	0.05	18	9	0.00	0.00	-0.17	0.03	0.23
4	22	2628	0.04	0.17	0.16	0.68	0.01	0.06	17	13	0.00	0.00	-0.17	0.04	0.24
5	23	2910	0.04	0.17	0.17	0.69	0.02	0.06	18	10	0.00	0.00	-0.18	0.03	0.23
6	24	3140	0.04	0.18	0.17	0.68	0.02	0.06	20	11	0.00	0.00	-0.17	0.03	0.23
7	1	2607	0.04	0.18	0.17	0.66	0.01	0.06	16	8	0.00	0.00	-0.17	0.04	0.24
8	2	2927	0.04	0.18	0.18	0.66	0.02	0.06	19	9	0.00	0.00	-0.16	0.03	0.25
9	3	3165	0.04	0.19	0.18	0.66	0.02	0.06	21	10	0.00	0.00	-0.17	0.03	0.25
10	4	2591	0.04	0.19	0.18	0.64	0.02	0.06	16	17	0.00	0.00	-0.17	0.03	0.25
11	5	2887	0.04	0.19	0.18	0.65	0.03	0.06	19	15	0.00	0.00	-0.17	0.03	0.25
12	6	3169	0.04	0.19	0.18	0.64	0.03	0.06	21	20	0.00	0.00	-0.18	0.04	0.25
13	7	2602	0.04	0.19	0.19	0.62	0.03	0.06	16	17	0.00	0.00	-0.18	0.04	0.25
14	8	2891	0.04	0.19	0.19	0.62	0.03	0.07	19	19	0.00	0.00	-0.18	0.04	0.24
15	9	3167	0.04	0.19	0.19	0.62	0.02	0.06	25	20	0.00	0.00	-0.18	0.04	0.24
16	10	2512	0.05	0.19	0.18	0.63	0.03	0.06	21	16	0.00	0.00	-0.18	0.05	0.23
17	11	2804	0.04	0.19	0.18	0.63	0.03	0.06	25	18	0.00	0.00	-0.18	0.04	0.24
18	12	3096	0.04	0.19	0.18	0.64	0.03	0.07	29	24	0.00	0.00	-0.18	0.04	0.24
19	13	2516	0.05	0.19	0.18	0.64	0.03	0.07	17	34	0.00	0.00	-0.17	0.05	0.25
20	14	2806	0.04	0.19	0.18	0.63	0.03	0.06	17	28	0.00	0.00	-0.18	0.04	0.25
21	15	3132	0.04	0.19	0.18	0.65	0.03	0.05	21	28	0.00	0.00	-0.19	0.03	0.23
22	16	2557	0.04	0.18	0.18	0.65	0.03	0.05	15	24	0.00	0.00	-0.19	0.03	0.23
23	17	2857	0.03	0.18	0.17	0.66	0.03	0.05	16	22	0.00	0.00	-0.18	0.03	0.22
24	18	1461	0.03	0.17	0.17	0.68	0.02	0.05	9	10	0.00	0.00	-0.18	0.03	0.22

Table 3.19. Bolivar Roads Principal Component Direction Currents Forecast April 2000 -March 2001 Evaluation Statistics. Note the reference level is26 cm/s.

GBM Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1420	0.02	0.19	0.19	0.88	0.00	0.01	0	0	0.01	0.95	-0.21	0.00	0.24
1	19	2119	0.05	0.19	0.19	0.88	0.00	0.01	0	0	0.00	0.96	-0.18	0.03	0.26
2	20	2360	0.07	0.21	0.20	0.83	0.00	0.02	0	0	0.01	0.96	-0.17	0.05	0.31
3	21	2604	0.10	0.24	0.22	0.77	0.00	0.03	5	0	0.02	0.89	-0.15	0.08	0.38
4	22	2115	0.13	0.27	0.23	0.74	0.00	0.05	7	0	0.03	0.90	-0.15	0.11	0.43
5	23	2319	0.15	0.27	0.23	0.71	0.00	0.06	2	0	0.03	0.91	-0.14	0.14	0.43
6	24	2445	0.14	0.27	0.22	0.71	0.00	0.04	0	0	0.03	0.88	-0.13	0.13	0.43
7	1	2070	0.13	0.26	0.23	0.74	0.00	0.05	6	0	0.04	0.87	-0.15	0.10	0.42
8	2	2250	0.10	0.25	0.22	0.77	0.00	0.05	4	0	0.05	0.88	-0.17	0.08	0.37
9	3	2469	0.09	0.25	0.23	0.74	0.00	0.04	1	0	0.03	0.79	-0.19	0.05	0.38
10	4	2000	0.08	0.25	0.24	0.74	0.00	0.03	0	0	0.03	0.77	-0.21	0.05	0.40
11	5	2236	0.07	0.25	0.24	0.75	0.00	0.03	9	0	0.02	0.79	-0.21	0.03	0.37
12	6	2482	0.06	0.25	0.24	0.78	0.00	0.03	10	0	0.02	0.85	-0.21	0.03	0.35
13	7	2045	0.06	0.25	0.24	0.81	0.00	0.04	8	0	0.04	0.83	-0.21	0.04	0.35
14	8	2310	0.05	0.24	0.24	0.82	0.00	0.03	9	0	0.02	0.93	-0.21	0.02	0.32
15	9	2546	0.05	0.23	0.22	0.84	0.00	0.02	10	0	0.01	0.95	-0.21	0.03	0.29
16	10	2036	0.03	0.22	0.22	0.86	0.01	0.01	8	0	0.01	0.97	-0.22	0.01	0.26
17	11	2258	0.02	0.22	0.22	0.83	0.01	0.01	8	0	0.01	0.94	-0.23	0.00	0.25
18	12	2460	0.00	0.20	0.20	0.84	0.01	0.01	0	0	0.01	0.93	-0.24	-0.01	0.24
19	13	2016	-0.02	0.21	0.21	0.80	0.02	0.01	0	0	0.02	0.88	-0.28	-0.02	0.24
20	14	2247	-0.03	0.22	0.22	0.77	0.02	0.01	0	0	0.02	0.89	-0.31	-0.04	0.26
21	15	2558	-0.04	0.22	0.21	0.80	0.02	0.01	0	0	0.02	0.90	-0.29	-0.05	0.23
22	16	2073	-0.04	0.21	0.20	0.84	0.02	0.01	0	0	0.01	0.88	-0.27	-0.04	0.19
23	17	2295	-0.02	0.20	0.20	0.85	0.01	0.01	0	0	0.01	0.88	-0.26	-0.02	0.20
24	18	1168	-0.01	0.20	0.20	0.85	0.01	0.01	0	0	0.01	0.93	-0.25	-0.01	0.22

HSCM Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1404	-0.05	0.28	0.27	0.59	0.03	0.01	0	0	0.01	0.80	-0.42	-0.06	0.31
1	19	2093	-0.02	0.28	0.28	0.57	0.01	0.02	0	0	0.01	0.79	-0.40	-0.03	0.33
2	20	2334	0.01	0.29	0.29	0.55	0.00	0.02	0	0	0.01	0.83	-0.37	0.01	0.37
3	21	2574	0.05	0.31	0.30	0.52	0.01	0.04	0	0	0.02	0.77	-0.36	0.05	0.42
4	22	2088	0.07	0.31	0.31	0.52	0.01	0.05	0	0	0.02	0.79	-0.36	0.11	0.43
5	23	2289	0.08	0.30	0.29	0.57	0.01	0.05	1	0	0.02	0.78	-0.35	0.11	0.43
6	24	2415	0.07	0.29	0.29	0.57	0.01	0.03	5	0	0.03	0.82	-0.34	0.10	0.39
7	1	2051	0.04	0.30	0.29	0.61	0.02	0.03	7	5	0.03	0.85	-0.36	0.06	0.38
8	2	2232	0.01	0.30	0.30	0.61	0.03	0.03	0	9	0.05	0.76	-0.37	0.00	0.38
9	3	2438	-0.01	0.31	0.31	0.57	0.04	0.03	0	7	0.05	0.69	-0.41	0.00	0.38
10	4	1974	-0.01	0.31	0.31	0.59	0.04	0.03	0	1	0.05	0.71	-0.42	0.00	0.37
11	5	2207	-0.02	0.32	0.32	0.55	0.04	0.03	0	0	0.04	0.75	-0.42	-0.05	0.38
12	6	2449	-0.01	0.32	0.32	0.54	0.03	0.03	6	0	0.04	0.76	-0.40	-0.03	0.39
13	7	2017	0.01	0.31	0.31	0.57	0.02	0.04	8	0	0.04	0.78	-0.38	-0.02	0.38
14	8	2280	0.01	0.31	0.31	0.62	0.02	0.03	9	0	0.04	0.84	-0.36	0.00	0.35
15	9	2514	0.02	0.30	0.30	0.65	0.02	0.03	10	0	0.03	0.87	-0.35	0.03	0.34
16	10	2009	0.01	0.29	0.29	0.68	0.02	0.02	8	0	0.03	0.85	-0.37	0.01	0.30
17	11	2228	0.00	0.29	0.29	0.66	0.02	0.02	8	0	0.02	0.81	-0.39	0.01	0.30
18	12	2427	-0.03	0.27	0.27	0.65	0.04	0.02	0	0	0.03	0.81	-0.40	0.00	0.28
19	13	1990	-0.06	0.29	0.28	0.66	0.07	0.01	0	0	0.05	0.76	-0.46	-0.04	0.27
20	14	2217	-0.08	0.30	0.29	0.63	0.07	0.01	0	0	0.05	0.82	-0.47	-0.06	0.26
21	15	2525	-0.09	0.29	0.27	0.62	0.05	0.01	0	0	0.03	0.81	-0.45	-0.10	0.24
22	16	2046	-0.10	0.27	0.26	0.64	0.04	0.01	0	0	0.02	0.72	-0.43	-0.11	0.22
23	17	2265	-0.08	0.27	0.26	0.65	0.03	0.01	0	0	0.03	0.80	-0.44	-0.08	0.24
24	18	1153	-0.07	0.28	0.27	0.62	0.04	0.00	0	0	0.02	0.85	-0.43	-0.08	0.27

Table 3.19. Bolivar Roads Principal Component Direction Currents Forecast April 2000 -March 2001 Evaluation Statistics (Continued). Note the reference level is 26 cm/s

Astronomical plus Persistence Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1421	-0.04	0.35	0.35	0.61	0.09	0.06	5	0	0.12	0.54	-0.50	-0.04	0.37
1	19	2119	-0.05	0.35	0.34	0.62	0.09	0.05	7	1	0.12	0.54	-0.51	-0.05	0.35
2	20	2360	-0.06	0.36	0.36	0.62	0.10	0.06	7	9	0.13	0.50	-0.52	-0.05	0.33
3	21	2604	-0.07	0.36	0.36	0.62	0.10	0.05	5	8	0.14	0.48	-0.53	-0.06	0.33
4	22	2115	-0.06	0.35	0.35	0.61	0.10	0.05	8	0	0.13	0.56	-0.52	-0.06	0.35
5	23	2319	-0.03	0.36	0.36	0.61	0.09	0.07	9	0	0.13	0.52	-0.52	-0.05	0.40
6	24	2445	-0.03	0.37	0.37	0.58	0.10	0.07	6	1	0.14	0.48	-0.53	-0.04	0.44
7	1	2070	-0.01	0.37	0.37	0.57	0.09	0.07	4	2	0.14	0.47	-0.51	0.00	0.46
8	2	2250	0.00	0.31	0.31	0.63	0.05	0.05	2	2	0.08	0.59	-0.40	0.00	0.38
9	3	2469	0.02	0.29	0.29	0.66	0.03	0.04	4	0	0.06	0.67	-0.36	0.02	0.36
10	4	2000	0.02	0.30	0.30	0.68	0.04	0.04	5	0	0.06	0.70	-0.36	0.02	0.38
11	5	2236	0.02	0.30	0.30	0.68	0.04	0.05	3	7	0.07	0.72	-0.35	0.03	0.34
12	6	2482	0.02	0.30	0.30	0.66	0.03	0.05	0	10	0.07	0.65	-0.37	0.01	0.39
13	7	2045	0.01	0.33	0.33	0.62	0.04	0.05	0	8	0.08	0.66	-0.39	0.01	0.43
14	8	2310	-0.02	0.34	0.34	0.62	0.06	0.05	0	9	0.09	0.65	-0.41	-0.02	0.40
15	9	2546	-0.04	0.34	0.33	0.60	0.06	0.04	0	10	0.08	0.66	-0.42	-0.03	0.35
16	10	2036	-0.04	0.33	0.33	0.59	0.06	0.03	0	8	0.08	0.62	-0.45	-0.03	0.35
17	11	2258	-0.04	0.32	0.32	0.63	0.06	0.03	0	8	0.08	0.62	-0.45	-0.02	0.36
18	12	2460	-0.01	0.32	0.32	0.63	0.05	0.04	0	10	0.08	0.64	-0.42	0.00	0.38
19	13	2016	0.00	0.31	0.31	0.63	0.05	0.04	0	8	0.09	0.60	-0.39	0.01	0.37
20	14	2247	0.01	0.31	0.31	0.64	0.05	0.05	0	1	0.08	0.54	-0.37	0.00	0.40
21	15	2558	0.01	0.32	0.32	0.64	0.04	0.06	8	0	0.09	0.52	-0.39	-0.01	0.39
22	16	2073	-0.01	0.34	0.34	0.62	0.06	0.05	8	0	0.10	0.51	-0.42	-0.01	0.37
23	17	2295	-0.03	0.34	0.34	0.61	0.07	0.05	7	0	0.11	0.55	-0.46	-0.03	0.36
24	18	1168	-0.04	0.35	0.35	0.58	0.09	0.06	4	0	0.12	0.54	-0.51	-0.04	0.38

Astronomical Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1421	0.03	0.30	0.30	0.66	0.00	0.08	0	0	0.00	0.00	-0.32	-0.02	0.43
1	19	2119	0.01	0.29	0.29	0.66	0.02	0.07	0	0	0.00	0.00	-0.33	-0.03	0.41
2	20	2360	-0.01	0.31	0.31	0.64	0.03	0.06	0	0	0.00	0.00	-0.40	-0.04	0.39
3	21	2604	-0.03	0.30	0.30	0.63	0.05	0.04	0	0	0.00	0.00	-0.41	-0.03	0.36
4	22	2115	-0.03	0.29	0.29	0.67	0.05	0.04	0	0	0.00	0.00	-0.39	-0.02	0.35
5	23	2319	-0.01	0.28	0.28	0.69	0.04	0.04	0	0	0.00	0.00	-0.35	-0.01	0.34
6	24	2445	0.01	0.27	0.27	0.72	0.02	0.04	0	0	0.00	0.00	-0.32	-0.01	0.32
7	1	2070	0.03	0.27	0.27	0.71	0.02	0.04	0	0	0.00	0.00	-0.30	0.02	0.34
8	2	2250	0.05	0.26	0.26	0.71	0.01	0.03	0	0	0.00	0.00	-0.30	0.05	0.34
9	3	2469	0.07	0.26	0.25	0.69	0.01	0.03	0	0	0.00	0.00	-0.27	0.07	0.37
10	4	2000	0.08	0.27	0.26	0.69	0.01	0.05	0	0	0.00	0.00	-0.25	0.09	0.39
11	5	2236	0.08	0.28	0.26	0.69	0.02	0.05	0	0	0.00	0.00	-0.23	0.07	0.42
12	6	2482	0.08	0.29	0.28	0.68	0.03	0.06	0	0	0.00	0.00	-0.25	0.06	0.45
13	7	2045	0.06	0.30	0.29	0.65	0.03	0.05	0	0	0.00	0.00	-0.31	0.04	0.44
14	8	2310	0.01	0.31	0.31	0.65	0.06	0.05	0	0	0.00	0.00	-0.40	0.00	0.41
15	9	2546	-0.01	0.31	0.31	0.66	0.07	0.03	0	0	0.00	0.00	-0.41	-0.01	0.38
16	10	2036	-0.03	0.31	0.30	0.65	0.07	0.03	0	0	0.00	0.00	-0.43	-0.02	0.34
17	11	2258	-0.01	0.28	0.28	0.68	0.05	0.02	0	0	0.00	0.00	-0.38	0.00	0.35
18	12	2460	0.02	0.26	0.26	0.69	0.02	0.02	0	0	0.00	0.00	-0.32	0.02	0.35
19	13	2016	0.04	0.24	0.24	0.73	0.01	0.01	0	0	0.00	0.00	-0.28	0.04	0.33
20	14	2247	0.06	0.24	0.23	0.73	0.01	0.02	0	0	0.00	0.00	-0.25	0.05	0.34
21	15	2558	0.07	0.25	0.24	0.74	0.00	0.04	0	0	0.00	0.00	-0.23	0.05	0.35
22	16	2073	0.06	0.26	0.25	0.73	0.00	0.05	0	0	0.00	0.00	-0.26	0.02	0.39
23	17	2295	0.04	0.28	0.27	0.70	0.00	0.06	0	0	0.00	0.00	-0.29	0.00	0.41
24	18	1168	0.03	0.29	0.29	0.66	0.01	0.08	0	0	0.00	0.00	-0.32	-0.01	0.44

Table 3.20. Morgans Point Principal Component Direction Currents Forecast April 2000 -March 2001 Evaluation Statistics. Note the reference level is26 cm/s.

GBM Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1309	0.03	0.24	0.24	0.68	0.00	0.00	0	0	0.01	0.59	-0.31	0.03	0.31
1	19	2067	0.04	0.24	0.24	0.65	0.00	0.00	0	0	0.00	0.56	-0.31	0.05	0.34
2	20	2230	0.04	0.25	0.24	0.65	0.00	0.01	0	0	0.01	0.62	-0.29	0.05	0.34
3	21	2465	0.06	0.25	0.24	0.67	0.00	0.01	0	0	0.01	0.57	-0.26	0.06	0.38
4	22	2060	0.09	0.25	0.24	0.66	0.00	0.01	0	0	0.01	0.48	-0.23	0.08	0.40
5	23	2206	0.08	0.25	0.23	0.69	0.00	0.02	0	0	0.02	0.47	-0.23	0.06	0.40
6	24	2258	0.06	0.24	0.23	0.72	0.00	0.02	0	0	0.02	0.49	-0.23	0.04	0.37
7	1	2040	0.06	0.23	0.22	0.74	0.00	0.01	0	0	0.01	0.43	-0.23	0.04	0.36
8	2	2203	0.04	0.22	0.21	0.75	0.00	0.00	0	0	0.01	0.33	-0.25	0.03	0.33
9	3	2405	0.04	0.23	0.22	0.74	0.00	0.01	0	0	0.01	0.30	-0.25	0.02	0.34
10	4	1995	0.03	0.23	0.23	0.73	0.00	0.01	1	0	0.01	0.36	-0.27	0.00	0.32
11	5	2183	0.03	0.23	0.23	0.74	0.00	0.01	0	0	0.01	0.38	-0.27	0.02	0.33
12	6	2389	0.05	0.24	0.23	0.71	0.00	0.01	0	0	0.01	0.50	-0.25	0.04	0.36
13	7	2015	0.06	0.25	0.24	0.69	0.00	0.02	0	0	0.02	0.37	-0.26	0.05	0.38
14	8	2205	0.06	0.25	0.25	0.67	0.00	0.01	0	0	0.02	0.46	-0.26	0.04	0.39
15	9	2421	0.07	0.25	0.24	0.67	0.00	0.02	0	0	0.03	0.53	-0.24	0.05	0.39
16	10	1982	0.09	0.25	0.23	0.68	0.00	0.02	0	0	0.03	0.43	-0.22	0.08	0.39
17	11	2164	0.11	0.25	0.23	0.68	0.00	0.03	0	0	0.03	0.48	-0.20	0.10	0.39
18	12	2397	0.11	0.25	0.23	0.67	0.00	0.02	0	0	0.03	0.49	-0.20	0.12	0.39
19	13	2000	0.10	0.24	0.22	0.69	0.00	0.01	0	0	0.01	0.40	-0.19	0.11	0.38
20	14	2161	0.08	0.23	0.22	0.74	0.01	0.01	0	0	0.02	0.48	-0.20	0.07	0.36
21	15	2412	0.05	0.23	0.22	0.74	0.00	0.00	0	0	0.01	0.49	-0.23	0.02	0.34
22	16	2024	0.03	0.23	0.22	0.72	0.00	0.00	0	0	0.00	0.60	-0.27	0.02	0.33
23	17	2165	0.02	0.24	0.23	0.69	0.00	0.00	0	0	0.00	0.61	-0.30	0.03	0.33
24	18	1122	0.03	0.24	0.24	0.68	0.00	0.00	0	0	0.00	0.67	-0.30	0.05	0.31

HSCM Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1297	0.12	0.24	0.20	0.74	0.00	0.01	0	0	0.01	0.40	-0.14	0.12	0.39
1	19	2049	0.13	0.24	0.21	0.72	0.00	0.02	0	0	0.02	0.37	-0.14	0.12	0.41
2	20	2210	0.14	0.24	0.20	0.71	0.00	0.02	0	0	0.02	0.31	-0.11	0.12	0.41
3	21	2443	0.17	0.26	0.19	0.69	0.00	0.04	0	0	0.04	0.26	-0.08	0.15	0.42
4	22	2042	0.20	0.28	0.19	0.65	0.00	0.04	0	0	0.04	0.26	-0.05	0.18	0.44
5	23	2186	0.18	0.26	0.19	0.67	0.00	0.03	0	0	0.03	0.37	-0.06	0.17	0.43
6	24	2237	0.15	0.25	0.20	0.74	0.00	0.04	0	0	0.04	0.29	-0.11	0.13	0.40
7	1	2022	0.13	0.24	0.20	0.75	0.00	0.03	0	0	0.03	0.30	-0.12	0.11	0.39
8	2	2183	0.11	0.23	0.20	0.77	0.00	0.02	0	0	0.02	0.31	-0.13	0.09	0.37
9	3	2383	0.13	0.24	0.21	0.74	0.00	0.03	0	0	0.03	0.27	-0.13	0.11	0.39
10	4	1977	0.12	0.25	0.22	0.74	0.00	0.02	2	0	0.03	0.32	-0.16	0.11	0.39
11	5	2163	0.12	0.25	0.22	0.71	0.00	0.03	0	0	0.03	0.29	-0.16	0.11	0.39
12	6	2367	0.12	0.25	0.22	0.72	0.01	0.02	0	0	0.02	0.39	-0.16	0.11	0.40
13	7	1997	0.12	0.25	0.22	0.71	0.00	0.03	0	0	0.03	0.42	-0.16	0.11	0.40
14	8	2185	0.11	0.25	0.23	0.72	0.00	0.04	0	0	0.04	0.56	-0.17	0.10	0.40
15	9	2399	0.11	0.24	0.22	0.74	0.00	0.02	0	0	0.02	0.62	-0.16	0.10	0.40
16	10	1964	0.13	0.25	0.22	0.73	0.00	0.03	0	0	0.04	0.51	-0.14	0.12	0.41
17	11	2144	0.16	0.27	0.22	0.67	0.00	0.04	0	0	0.04	0.46	-0.12	0.14	0.41
18	12	2375	0.16	0.27	0.22	0.63	0.00	0.03	0	0	0.03	0.30	-0.13	0.16	0.42
19	13	1982	0.15	0.26	0.21	0.67	0.00	0.02	0	0	0.02	0.33	-0.14	0.17	0.40
20	14	2141	0.13	0.24	0.20	0.72	0.00	0.01	0	0	0.01	0.37	-0.13	0.13	0.37
21	15	2390	0.10	0.22	0.19	0.78	0.00	0.01	0	0	0.01	0.53	-0.16	0.09	0.34
22	16	2006	0.09	0.21	0.19	0.78	0.00	0.00	0	0	0.01	0.62	-0.16	0.07	0.34
23	17	2145	0.09	0.22	0.20	0.79	0.00	0.01	0	0	0.01	0.53	-0.18	0.09	0.36
24	18	1112	0.10	0.22	0.19	0.78	0.00	0.01	0	0	0.01	0.57	-0.16	0.11	0.36

Table 3.20. Morgans Point Principal Component Direction Currents Forecast April 2000 -March 2001 Evaluation Statistics (Continued). Note the reference level is 26 cm/s

Astronomical plus Persistence Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1297	0.04	0.20	0.19	0.85	0.00	0.01	0	0	0.01	0.59	-0.20	0.03	0.27
1	19	2049	0.04	0.20	0.20	0.84	0.00	0.02	0	0	0.02	0.49	-0.20	0.02	0.27
2	20	2210	0.03	0.19	0.19	0.84	0.00	0.01	0	0	0.02	0.54	-0.21	0.02	0.25
3	21	2443	0.03	0.20	0.20	0.83	0.00	0.01	0	0	0.01	0.53	-0.22	0.02	0.26
4	22	2042	0.03	0.20	0.19	0.83	0.01	0.01	0	0	0.01	0.54	-0.20	0.03	0.27
5	23	2186	0.02	0.19	0.19	0.85	0.01	0.01	0	0	0.01	0.62	-0.22	0.01	0.25
6	24	2237	0.01	0.19	0.19	0.86	0.00	0.01	0	0	0.01	0.69	-0.21	0.00	0.23
7	1	2022	0.01	0.18	0.18	0.87	0.00	0.01	0	0	0.01	0.72	-0.21	0.00	0.22
8	2	2183	0.01	0.14	0.14	0.92	0.00	0.00	0	0	0.00	0.79	-0.16	0.00	0.18
9	3	2383	0.02	0.16	0.16	0.92	0.00	0.00	0	0	0.00	0.81	-0.18	0.01	0.22
10	4	1977	0.01	0.17	0.17	0.90	0.00	0.01	0	0	0.00	0.83	-0.19	0.01	0.21
11	5	2163	0.01	0.18	0.18	0.89	0.00	0.00	0	0	0.00	0.76	-0.22	0.01	0.22
12	6	2367	0.01	0.19	0.19	0.88	0.01	0.01	0	0	0.01	0.71	-0.22	0.01	0.22
13	7	1997	0.02	0.19	0.19	0.85	0.00	0.00	0	0	0.01	0.66	-0.22	0.02	0.24
14	8	2185	0.00	0.20	0.20	0.85	0.01	0.00	0	0	0.01	0.63	-0.24	0.00	0.24
15	9	2399	-0.01	0.19	0.19	0.86	0.01	0.01	0	0	0.01	0.61	-0.25	-0.01	0.22
16	10	1964	0.00	0.18	0.18	0.87	0.00	0.00	0	0	0.01	0.67	-0.23	0.00	0.21
17	11	2144	0.01	0.17	0.17	0.88	0.00	0.01	0	0	0.01	0.68	-0.22	0.01	0.21
18	12	2375	0.02	0.18	0.18	0.86	0.01	0.00	0	0	0.01	0.70	-0.22	0.02	0.23
19	13	1982	0.02	0.18	0.18	0.85	0.01	0.00	0	0	0.01	0.79	-0.22	0.03	0.24
20	14	2141	0.02	0.18	0.18	0.84	0.00	0.00	0	0	0.00	0.73	-0.22	0.02	0.24
21	15	2390	0.02	0.19	0.18	0.85	0.00	0.01	0	0	0.01	0.71	-0.23	0.02	0.24
22	16	2006	0.03	0.20	0.19	0.83	0.00	0.01	0	0	0.01	0.59	-0.23	0.02	0.27
23	17	2145	0.03	0.20	0.20	0.83	0.00	0.02	0	0	0.02	0.61	-0.23	0.01	0.27
24	18	1112	0.03	0.20	0.20	0.84	0.00	0.02	0	0	0.02	0.61	-0.23	0.03	0.26

Astronomical Forecast

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	1297	0.10	0.18	0.15	0.88	0.00	0.01	0	0	0.00	0.00	-0.09	0.10	0.28
1	19	2049	0.10	0.18	0.15	0.87	0.00	0.01	0	0	0.00	0.00	-0.08	0.09	0.28
2	20	2210	0.09	0.18	0.15	0.88	0.00	0.01	0	0	0.00	0.00	-0.09	0.08	0.27
3	21	2443	0.09	0.18	0.15	0.89	0.00	0.01	0	0	0.00	0.00	-0.09	0.08	0.27
4	22	2042	0.10	0.18	0.15	0.89	0.00	0.01	0	0	0.00	0.00	-0.08	0.09	0.27
5	23	2186	0.09	0.18	0.15	0.88	0.00	0.01	0	0	0.00	0.00	-0.09	0.07	0.28
6	24	2237	0.08	0.17	0.15	0.89	0.00	0.01	0	0	0.00	0.00	-0.09	0.05	0.27
7	1	2022	0.08	0.17	0.15	0.90	0.00	0.01	0	0	0.00	0.00	-0.10	0.06	0.25
8	2	2183	0.08	0.16	0.14	0.90	0.00	0.00	0	0	0.00	0.00	-0.11	0.07	0.26
9	3	2383	0.09	0.18	0.15	0.87	0.00	0.00	0	0	0.00	0.00	-0.10	0.08	0.28
10	4	1977	0.08	0.18	0.16	0.88	0.00	0.01	0	0	0.00	0.00	-0.11	0.07	0.27
11	5	2163	0.07	0.17	0.16	0.89	0.00	0.01	0	0	0.00	0.00	-0.12	0.06	0.26
12	6	2367	0.08	0.18	0.16	0.91	0.00	0.01	0	0	0.00	0.00	-0.11	0.08	0.25
13	7	1997	0.09	0.18	0.15	0.89	0.00	0.01	0	0	0.00	0.00	-0.11	0.08	0.26
14	8	2185	0.07	0.18	0.16	0.89	0.00	0.01	0	0	0.00	0.00	-0.14	0.07	0.25
15	9	2399	0.06	0.17	0.16	0.91	0.00	0.01	0	0	0.00	0.00	-0.13	0.06	0.23
16	10	1964	0.07	0.16	0.14	0.93	0.00	0.00	0	0	0.00	0.00	-0.10	0.06	0.23
17	11	2144	0.08	0.16	0.13	0.93	0.00	0.01	0	0	0.00	0.00	-0.09	0.08	0.24
18	12	2375	0.09	0.16	0.14	0.91	0.00	0.00	0	0	0.00	0.00	-0.10	0.08	0.25
19	13	1982	0.09	0.17	0.14	0.89	0.00	0.00	0	0	0.00	0.00	-0.10	0.09	0.27
20	14	2141	0.09	0.17	0.15	0.89	0.00	0.00	0	0	0.00	0.00	-0.10	0.09	0.27
21	15	2390	0.09	0.17	0.15	0.87	0.00	0.00	0	0	0.00	0.00	-0.09	0.08	0.28
22	16	2006	0.10	0.18	0.15	0.87	0.00	0.01	0	0	0.00	0.00	-0.09	0.08	0.29
23	17	2145	0.10	0.19	0.16	0.87	0.00	0.01	0	0	0.00	0.00	-0.10	0.08	0.30
24	18	1112	0.10	0.19	0.16	0.87	0.00	0.01	0	0	0.00	0.00	-0.10	0.10	0.30

4. SUPPLEMENTAL EVALUATION

First, we consider supplemental statistics to further evaluate the water level and principal component direction currents responses during the one year evaluation period. Next near surface temperature and near surface salinity evaluation working criteria are presented to evaluate the near surface density response.

4.1. Additional Statistical Measures

The following standard statistics are also considered for near surface temperature and near surface salinity.

SM = Mean error. *Informal working targets for surface temperature and salinity are 1 °C, and 1 PSU, respectively.*
STD = Standard deviation of the error. *Informal working targets for surface temperature and salinity are 1.73 °C, and 1.73 PSU, respectively.*
RMSE = Root mean square error. *Informal working targets for surface temperature and salinity are 2 °C, and 2 PSU, respectively. Note working targets are such that* $RMSE^2 = SM^2 + STD^2$.

Also, the following additional standard statistical measures are presented for water levels and principal component direction currents at prediction depth based on the associated errors defined as model prediction minus observation. Informal working target levels are presented not only for water levels and currents but also for near surface temperature and near surface salinity.

WILLMOTT RE= Willmott dimensionless average relative error in the range (0-1), where 0 corresponds to no error. Refer to Willmott et al. (1985). *The informal working target is to be under 0.05.*
BIAS=Intercept, b, of the linear regression of the model on the observed data, y=mx + b, where y corresponds to the observation and x the model series. *Informal working targets for water levels, prediction depth current strengths, surface salinity, and surface temperature are +/-5cm, +/-10 cm/s, +/-1 PSU, and +/-1 °C, respectively.*
GAIN=Slope, m, of the linear regression of the model on the observed data, y=mx + b, where y corresponds to the observation and x the model series. *The informal working target is to be in the range of 0.9 to 1.1.*
STD ERROR=Standard error of the linear regression assuming a bivariate normal distribution for the observed data and model series. *Informal working targets for water levels, prediction depth current strengths, surface salinity, and surface temperature are 10 cm, 20 cm/s, 2 PSU, and 2 °C, respectively.*
CC=Linear correlation coefficient. *The informal working target is to exceed 0.9.*

The following supplemental statistical measure which contrasts the previously considered worst case outlier frequency, WOF, is also considered for water level and principal component direction currents.

NFUF=Nowcast/Forecast Utility Frequency, conditioned on the observation differing from the tidal prediction by a given reference level (5 cm, 26 cm/s), of occurrence when the model prediction is closer to the observation than the tidal prediction. *The informal working target is to exceed 0.85.*

Water levels are considered in Table 4.1. Note the RMSE are under 10 cm on the nowcast for stations and exceed the 10cm working target level only on the forecast at Morgans Point. The working targets for the remaining statistics are met or nearly met at all stations for both nowcast and forecast. Note the water level response is nearly the same in both models.

Table 4.1. Water Level Analysis April 2000 - March 2001: Supplemental Statistical Measures. Note GPP=Galveston Pleasure Pier, P21= Galveston Pier 21, BR=Bolivar Roads (Port Bolivar), EP=Eagle Point, and MP=Morgans Point. GBM results in line 1 with HSCM results given in line2.

Statistical Measure	Nowcast					Forecast (1-24h)				
Working Target Value	GPP	P21	BR	EP	MP	GPP	P21	BR	EP	MP
Willmott Relative Error *[<0.05]*	0.021 -	0.030 0.031	0.034 0.034	0.024 0.026	0.040 0.040	0.046 -	0.056 0.062	0.061 0.063	0.053 0.054	0.076 0.075
Bias *[+/-5 cm]*	-3.5 -	-3.7 -3.7	-1.1 -0.8	1.3 1.5	-5.7 -5.3	-2.9 -	-3.3 -3.4	-1.2 -0.8	-0.7 -0.4	-7.8 -7.5
Gain *[0.9-1.1]*	0.978 -	1.01 1.00	1.005 1.008	0.979 0.992	1.058 1.057	0.892 -	0.913 0.890	0.908 0.909	0.852 0.864	0.927 0.922
Standard Error *[10cm]*	6.5 -	6.3 6.5	7.5 7.6	5.9 6.1	6.8 7.0	10.2 -	9.3 9.8	10.1 10.3	8.7 8.8	9.7 9.8
Correlation Coefficient *[>0.9]*	0.967 -	0.958 0.955	0.938 0.937	0.955 0.953	0.957 0.954	0.917 -	0.903 0.892	0.885 0.880	0.900 0.898	0.909 0.907
NFUF (5 cm) *[>0.8]*	0.884 -	0.873 0.872	0.912 0.917	0.936 0.940	0.878 0.886	0.786 -	0.797 0.790	0.831 0.829	0.864 0.864	0.752 0.758

Principal comonent direction prediction depth currents are given in Table 4.2. The working targets are met or very nearly met at Bolivar Roads for the GBM. Morgans Point currents in both models do not approach the quality of the Bolivar Roads results.

4.3. Surface Temperature and Salinity

Near surface temperature nowcast/forecast results are presented in Table 4.3. Since a SST specification based on PORTS observations is used in both models, and persistence of the SST is made for the forecast, nowcast and forecast errors tend to be similar in both models. RMSE is order 1.5 °C at Bolivar Roads and 1.0 °C at Morgans Point. While no formal NOS criteria have been adopted for surface temperature, the CF(2 °C) > 0.9 criteria is met. Bottom temperature measurements are available at PORTS current stations only. Due to measurement sparsity no criteria have been established. An assessment of forecast age for surface temperature is given in Appendix B.

Near surface salinity nowcast/forecast results are presented in Table 4.4. Both nowcast and forecast results are similar with an RMSE of order 2.5 PSU at Bolivar Roads and at Morgans Point. The errors at Bolivar Roads are due to the inability of the PORTS station spacings to resolve the strong horizontal salinity gradients through the Bay entrance. No salinity measurements have been available

Table 4.2. Principal Component Direction Prediction Depth Current Analysis April 2000 -March 2001: Supplemental Statistical Measures. Prediction depth equal to 4.7m. BR= Bolivar Roads and MP=Morgans Point.GBM results in line 1 with HSCM results given in line2.

Statistical Measure Working Target Value	Nowcast BR	 MP	Forecast (1-24h) BR	 MP
Willmott Relative Error *[<0.05]*	0.054 0.132	0.464 0.313	0.066 0.144	0.473 0.283
Bias *[+/-10 cm/s]*	-5.7 4.7	-6.8 -16.9	-5.4 2.9	-2.4 -13.0
Gain *[0.9-1.1]*	1.152 1.628	2.443 1.019	1.108 1.576	2.302 0.976
Standard Error *[20 cm/s]*	19.5 22.1	20.8 20.8	22.3 24.6	21.3 20.8
Correlation Coefficient *[>0.9]*	0.924 0.901	0.641 0.644	0.899 0.876	0.621 0.642
NFUF (26 cm/s) *[>0.8]*	0.916 0.809	0.420 0.316	0.893 0.793	0.481 0.394

Table 4.3. Surface Temperature Analysis April 2000 -March 2001: Supplemental Statistical Measures. GPP=GBM results at Galveston Pleasure Pier, BR=GBM results at Bolivar Roads, EP=HSCM results at Eagle Point, and MP=HSCM results at Morgans Point. NOS informal targets italicized .GBM results in line 1 with HSCM results given in line2.

Statistical Measure NOS Target Value	Nowcast GPP	 BR	 EP	 MP	Forecast (1-24h) GPP	 BR	 EP	 MP
SM *[+/- 1.0 °C]*	0.75 -	1.06 1.08	1.30 1.29	0.30 0.51	0.77 -	0.96 0.99	1.13 1.08	0.21 0.43
SD *[1.73 °C]*	0.86 -	0.79 0.82	1.06 1.05	0.78 0.83	0.98 -	0.81 0.85	1.04 1.07	0.84 0.92
RMS *[2 °C]*	1.14 -	1.32 1.36	1.68 1.66	0.837 0.977	1.25 -	1.25 1.30	1.54 1.52	0.863 1.02
Willmott Relative Error *[<0.05]*	0.007 -	0.040 0.041	0.080 0.079	0.020 0.025	0.008 -	0.036 0.037	0.074 0.072	0.022 0.028
Bias *[1 °C]*	-0.963 -	-0.523 -0.046	0.935 0.708	-2.22 -1.17	-1.75 -	-0.235 0.578	0.375 0.180	-2.50 -1.24
Gain *[0.9-1.1]*	1.009 -	0.980 0.962	0.895 0.906	1.068 1.023	1.042 -	0.973 0.942	0.929 0.941	1.081 1.028
Standard Error *[2 °C]*	0.858 -	0.787 0.812	1.01 1.01	0.758 0.824	0.94 -	0.80 0.82	1.02 1.06	0.807 0.92
Correlation Coefficient *[>0.9]*	0.993 -	0.972 0.970	0.935 0.937	0.970 0.965	0.991 -	0.970 0.968	0.931 0.928	0.966 0.958
CF (2 °C) [>0.9]	0.936 -	0.896 0.873	0.783 0.800	0.977 0.972	0.906 -	0.929 0.905	0.866 0.883	0.973 0.962

Table 4.4. Surface Salinity Analysis April 2000 -March 2001: Supplemental Statistical Measures. BR=Bolivar Roads, EP=Eagle Point, and MP=Morgans Point. NOS informal targets italicized. GBM results in line 1 with HSCM results given in line2.

Statistical Measure NOS Target Value	Nowcast BR	 EP	 MP	Forecast (1-24h) BR	 EP	 MP
SM *[+/- 1 PSU]*	0.63 0.31	-0.16 0.52	0.66 0.58	1.00 0.90	0.33 0.70	0.66 0.49
SD *[1.73 PSU]*	2.48 2.64	1.50 1.70	2.55 2.41	2.60 2.80	1.91 1.89	2.82 2.69
RMS *[2 PSU]*	2.56 2.65	1.51 1.78	2.64 2.47	2.78 2.94	1.94 2.02	2.89 2.73
Willmott Relative Error *[<0.05]*	0.043 0.048	0.066 0.083	0.081 0.071	0.052 0.060	0.128 0.140	0.105 0.091
Bias *[1 PSU]*	0.07 0.59	0.916 1.25	-1.22 -1.06	-0.683 -0.041	2.19 1.64	-1.75 -1.50
Gain *[0.9-1.1]*	0.966 0.955	0.918 0.820	1.054 1.047	0.985 0.958	0.738 0.764	1.106 1.102
Standard Error *[2 PSU]*	2.48 2.62	1.48 1.60	2.54 2.40	2.60 2.79	1.75 1.77	2.79 2.66
Correlation Coefficient *[>0.9]*	0.922 0.910	0.877 0.854	0.872 0.885	0.914 0.897	0.776 0.768	0.844 0.861
CF (2 PSU) [>0.9]	0.604 0.625	0.888 0.805	0.817 0.832	0.563 0.519	0.813 0.768	0.734 0.760

since August 2000 and some suspect values appear to have been allowed to pass through the CORMS procedures undetected at Morgans Point. No formal NOS criteria have been adopted for surface salinity. In Galveston Bay, the CF(2 PSU) > 0.9 criterion is not met. No bottom salinity criteria have been established. An assessment of forecast age for surface salinity is also given in Appendix B.

5. WATER LEVEL EVENT EVALUATION

The experimental nowcast/forecast system is evaluated with respect to both high and low water level events over the formal evaluation period April 2000 through March 2001. A high water level event is considered to occur when observed, nowcast, forecast, and astronomical tide predicted water levels exceed MHHW by a certain level. A low water level event is considered to occur when observed, nowcast, forecast, and astronomical tide predicted water levels fall below MLLW by a certain level. A 10 cm level was used for both high and low water events. A success is defined as the joint occurrence of observed and predicted (nowcast, forecast, or astronomical tide) water level events; e.g., the model or tide prediction predicts the event. A failure is defined as the occurrence of an observed water level event which is not present in the nowcast, forecast, or astronomical tide predicted water levels. A false alarm is the opposite condition of a failure; i.e., a predicted event which is not observed. The computer programs used in the analysis have been documented by Richardson and Schmalz (2000).

Prior to assessing the ability of the nowcast/forecast system to predict high and low water events, we consider the distribution by month of the number of observed high and low water events (shown in Table 5.1). Note the variability of high and low water events over the year. Low water events occur usually during the November through March period with high water events more prevalent during May through June and September through November. Within a given month the number of high and low water events changes as one proceeds from Galveston Pleasure Pier up the estuary to Morgans Point. During the winter period, there are more low water events at Morgans Point than observed at Galveston Pleasure Pier. Consider January 2001 in which 19 low water events occur at Galveston Pleasure Pier in contrast to 28 at Morgans Point. For January 2001, 16 events are due to the astronomical tide at Galveston Pleasure Pier in contrast to 17 at Morgans Point. Thus it appear that nontidal effects cause 4 events at Galveston Pleasure Pier (at least 3 low water events) and 14 events at Morgans Point (at least 11 low water events). This indicates the greater influence of the Northers on Morgans Point water levels relative to Galveston Pleasure Pier during January 2001.

5.1. Nowcast Results

In Tables 5.2 and 5.3, the number of successes, failures, and false alarms are contrasted between the nowcast and astronomical tide prediction at Galveston Pleasure Pier and at Morgans Point, respectively. Note that in almost all months, the number of successes in the nowcasts is greater than for the astronomical tide prediction at both stations. The mean success difference is generally lower for the nowcasts relative to the astronomical tide prediction as well. The number of failures and the mean failure are lower for the nowcast then for the astronomical tide prediction. False alarms are usually lower for the tide predictions. This might be anticipated since for tide predictions only during certain extreme conditions would the critical conditions be exceeded. In Tables 5.4 and 5.5, the analysis is shown for high and low water events, respectively, at Galveston Pleasure Pier with similar analyses shown at Morgans Point in Tables 5.6 and 5.7. For most months at both stations for both high and low water events, the nowcast results are improved relative to those obtained by the astronomical tide prediction.

5.2. Forecast and Adjusted Forecast Results

Forecast water level event results are contrasted with those of the adjusted forecasts in Table 5.8 for Galveston Pleasure Pier and in Tables 5.9 for Morgans Point. To adjust the forecasts, the following linear model was used: Y= mX + b, where Y=adjusted forecast, X=base forecast, and (m,b) = (gain, bias). A gain of 1.05 was used at both locations with a bias of -5 cm used at Galveston Pleasure Pier and of -7.5 cm used at Morgans Point. These values were determined by examining the water level event analysis results for the first few months of the evaluation period. We experimented with different sets of bias and gain to seek to increase the number of successes with a reduction in failures and false alarms. Results during July and August 2000 for the adjusted forecast are much improved over the forecast at both stations. During the other months, forecast and adjusted forecast results are very similar. Low and High water event analyses are presented in Tables 5.10 and 5.11 at Galveston Pleasure Pier and in Tables 5.12 and 5.13 at Morgans Point. The adjusted forecast results are superior at both stations for both high and low water events.

5.3. Skill Measures

We desire the number of successes to be greater in the nowcasts and forecasts than in the tidal prediction for each month. In addition, the number of failures and false alarms in the nowcasts and forecasts should be smaller than in the tidal prediction for each month as well. This then becomes the criteria for event based water level nowcast and forecast skill assessment. We seek the ratio of the number of months in which the above conditions are met for each category to the total number of months. This ratio is used to define the first skill measure as presented in Tables 5.14 for all events and in Tables 5.15 and 5.16 for high and low water events, respectively. Note that results for the nowcast, forecast, and adjusted forecasts are superior to the tidal prediction for successes and failures but not for false alarms, which can occur only rarely for the tidal predictions.

In addition, we seek the number of months in the nowcast, forecast, and tide prediction in which the number of successes is greater than the sum of the number of failures and false alarms. We divide by the total number of months to obtain a second overall skill score as given in Table 5.17. Note with respect to this measure as well, the nowcast, forecast, and adjusted forecasts are all superior to the astronomical tide prediction.

5.4. Demonstration of Nowcast/Forecast System Utility

To demonstrate the nowcast/forecast system utility, monthly plots of nowcast versus observations, astronomical tide prediction versus observations, forecast versus observation, and adjusted forecast versus observation were developed. Note the same set of harmonic constants given in Chapter 2 were used in the water level event analysis. Results for each month indicated that the nowcast and forecasts were superior to the astronomical tide predictions. Of particular concern is the months during the winter during which Northers may be expected to occur; e.g., consider January 2001 nowcast results shown in Figure 5.1 and forecast results in Figure 5.2 at Galveston Pleasure Pier and in Figure 5.3 and Figure 5.4 at Morgans Point. The nowcast and forecasts exhibit the ability to predict several significant low water events, which are especially detrimental to marine transport with respect to increased grounding potential. The magnitude of the events is severely underestimated by the astronomical tide prediction at both locations. The occurrence of these winter cold front southerly excursions can be suitably observed and predicted by the NWS/AVN atmospheric model to allow for the hydrodynamic effects to be nowcast and forecast, respectively.

Table 5.1. Observed High/Low Water Level Events: April 2000 - March 2001. Note the critical high and low water event levels (m) are given in parenthesis relative to MLLW. At Eagle Point no data are available after June 2000. For Galveston Pleasure Pier and Morgans Point, the total number of high and low water astronomical tide events is given in parentheses.

Month	Galveston Pleasure Pier (0.749,-0.10)	Galveston Pier 21 (0.530,-0.10)	Port Bolivar (Bolivar Roads) (0.530,-0.10)	Eagle Point (0.436,-0.10)	Morgans Point (0.496,-0.10)
April	3/7 (0)	5/10	7/7	7/8	8/11 (0)
May	14/0 (5)	16/1	15/0	19/0	23/0 (3)
June	13/6 (9)	9/7	10/7	19/4	12/5 (0)
July	6/16 (7)	0/18	0/15	-	1/18 (4)
August	0/6 (1)	0/12	0/10	-	0/11 (1)
September	12/2 (6)	15/4	13/2	-	11/6 (6)
October	20/0 (13)	23/0	25/0	-	23/2 (9)
November	15/10 (5)	14/10	15/10	-	12/11 (8)
December	5/18 (9)	5/17	4/14	-	2/20 (8)
January	1/19 (16)	1/19	1/18	-	3/28 (17)
February	0/14 (10)	0/15	3/15	-	1/16 (14)
March	4/12 (5)	8/12	10/11	-	7/15 (5)

Table 5.2. Galveston Pleasure Pier Nowcast/Tidal Prediction Water Level Event Analysis
April 2000 - March 2001

Month	Number of Successes	Mean (cm) Success Difference	Number of Failures	Mean (cm) Failure Difference	Number of False Alarms	Mean (cm) False Alarm Difference
April	6/0	2.4/-	2/10	6.4/29.1	1/0	10.5/-
May	10/5	3.5/10.0	1/9	36.0/15.8	3/1	23.0/13.2
June	14/9	5.9/3.4	3/10	11.2/19.4	6/3	18.9/6.4
July	11/7	5.3/5.2	10/15	9.3/9.8	5/3	20.1/8.8
August	0/1	-/0.8	7/5	8.7/10.3	2/4	17.4/5.4
September	10/6	3.6/4.5	4/8	18.1/14.7	7/4	26.3/16.9
October	17/13	5.6/5.2	1/7	5.2/9.2	14/12	8.0/14.1
November	12/5	3.5/12.9	4/20	12.8/23.0	5/3	24.9/12.2
December	17/9	3.4/14.7	1/14	5.3/27.6	1/7	6.3/15.5
January	20/16	4.8/19.0	0/4	-/28.1	2/3	15.2/13.2
February	11/10	5.4/12.7	3/4	4.2/8.0	2/2	7.6/10.0
March	14/5	6.2/32.1	1/11	9.5/32.7	5/0	21.6/-

Table 5.3. Morgans Point Nowcast/Tidal Prediction Water Level Event Analysis
April 2000 - March 2001

Month	Number of Successes	Mean (cm) Success Difference	Number of Failures	Mean (cm) Failure Difference	Number of False Alarms	Mean (cm) False Alarm Difference
April	10/0	7.6/-	4/19	11.0/26.9	0/0	-/-
May	13/3	2.1/12.6	3/20	14.0/15.3	6/0	13.1/-
June	10/0	4.1/-	5/17	11.3/18.3	6/3	6.0/6.0
July	4/4	12.0/2.8	14/15	11.8/14.5	3/4	4.0/12.3
August	0/1	-/0.3	11/10	11.1/17.9	0/1	-/6.9
September	11/6	3.6/3.7	6/11	15.0/23.0	6/1	10.7/9.9
October	15/9	4.8/4.1	2/16	6.0/16.8	4/16	6.8/19.7
November	12/8	5.1/11.1	5/15	22.7/28.5	0/5	-/19.4
December	10/8	13.6/22.7	8/14	12.6/26.6	0/5	-/16.6
January	20/17	10.4/17.5	7/14	16.9/22.8	1/6	2.2/19.7
February	13/14	11.4/13.1	6/3	8.9/26.3	1/3	8.0/4.3
March	15/5	7.8/25.6	5/17	14.5/30.7	1/1	2.2/6.2

Table 5.4. Galveston Pleasure Pier Nowcast High/Low Water Level Event Analysis
April 2000 - March 2001

Month	Number of Successes	Mean (cm) Success Difference	Number of Failures	Mean (cm) Failure Difference	Number of False Alarms	Mean (cm) False Alarm Difference
April	1/5	0.7/2.8	0/2	-/6.4	0/1	-/10.5
May	10/0	3.5/10.0	1/0	35.8/-	2/1	18.8/31.6
June	11/3	5.6/6.9	1/2	19.2/7.2	5/1	13.3/46.6
July	6/5	2.3/8.9	0/10	-/9.3	3/2	12.6/31.2
August	0/0	-/-	0/7	-/8.7	1/1	2.9/31.8
September	9/1	3.9/0.9	3/1	16.9/21.7	6/1	22.1/51.6
October	17/0	5.6/-	1/0	5.2/-	14/0	8.0/-
November	11/1	3.6/2.8	1/3	3.1/16.0	4/1	11.6/78.0
December	5/12	2.0/3.9	0/1	-/5.3	1/0	6.3/-
January	1/19	4.6/4.8	0/0	-/-	1/1	1.5/28.9
February	0/11	-/5.4	0/3	-/4.2	2/0	7.6/-
March	3/11	5.8/6.3	0/1	-/9.5	3/2	15.0/31.3

Table 5.5. Galveston Pleasure Pier Tidal Prediction High/Low Water Level Event Analysis
April 2000 - March 2001

Month	Number of Successes	Mean (cm) Success Difference	Number of Failures	Mean (cm) Failure Difference	Number of False Alarms	Mean (cm) False Alarm Difference
April	0/0	-/-	3/7	19.9/33.0	0/0	-/-
May	5/0	10.0/-	9/0	15.8/-	0/1	-/13.2
June	3/6	1.9/4.2	10/0	19.4/-	0/3	-/6.4
July	0/7	-/5.2	6/9	9.5/9.9	1/2	0.4/13.0
August	0/1	-/0.8	0/5	-/10.3	4/0	5.4/-
September	6/0	4.5/-	6/2	8.8/32.3	4/0	16.9/-
October	13/0	5.2/-	7/0	9.2/-	12/0	14.3/-
November	5/0	12.9/-	10/10	17.7/28.4	3/0	12.2/-
December	2/7	5.5/17.4	3/11	24.7/28.3	1/6	7.0/16.9
January	0/16	-/19.0	1/3	41.0/23.8	0/3	-/13.2
February	0/10	-/12.7	0/4	-/8.0	0/2	-/10.0
March	0/5	-/32.1	4/7	30.5/33.9	0/0	-/-

Table 5.6. Morgans Point Nowcast High/Low Water Level Event Analysis
April 2000 - March 2001

Month	Number of Successes	Mean (cm) Success Difference	Number of Failures	Mean (cm) Failure Difference	Number of False Alarms	Mean (cm) False Alarm Difference
April	4/6	1.5/11.6	0/4	-/11.0	0/0	-/-
May	13/0	2.1/-	3/0	14.0/-	5/1	8.7/35.1
June	9/1	2.8/15.9	2/3	7.1/14.1	6/0	6.0/-
July	1/3	5.4/14.3	0/14	-/11.8	2/1	3.9/4.1
August	0/0	-/-	0/11	-/11.1	0/0	-/-
September	9/2	2.6/8.2	1/5	5.4/16.9	6/0	10.7/-
October	15/0	4.8/-	2/0	6.0/-	4/0	6.8/-
November	11/1	3.6/22.0	0/5	-/22.7	0/0	-/-
December	2/8	6.9/15.3	0/8	-/15.3	0/0	-/-
January	1/19	5.9/10.7	1/6	12.2/17.7	1/0	2.2/-
February	1/12	5.3/11.9	0/6	-/8.9	1/0	8.0/-
March	3/12	3.4/9.0	3/2	17.3/10.2	0/1	-/2.2

Table 5.7. Morgans Point Tidal Prediction High/Low Water Level Event Analysis
April 2000 - March 2001

Month	Number of Successes	Mean (cm) Success Difference	Number of Failures	Mean (cm) Failure Difference	Number of False Alarms	Mean (cm) False Alarm Difference
April	0/0	-/-	8/11	17.9/33.5	0/0	-/-
May	3/0	12.6/-	20/0	15.3/-	0/0	-/-
June	0/0	-/-	12/5	20.9/12.1	3/0	6.0/-
July	0/4	-/2.8	1/14	18.1/14.3	0/4	-/12.3
August	0/1	-/0.3	0/10	-/17.9	0/1	-/6.9
September	6/0	3.7/-	5/6	8.6/34.9	1/0	9.9/-
October	9/0	4.1/-	14/2	12.1/49.4	16/0	19.7/-
November	8/0	11.1/12.9	4/11	17.6/32.5	5/0	19.4/-
December	0/8	-/22.7	2/12	22.6/27.3	0/5	-/16.6
January	0/17	-/17.5	3/11	32.9/20.1	0/6	-/19.7
February	0/14	-/13.1	1/2	51.6/13.7	0/3	-/4.3
March	0/5	-/25.6	7/10	34.3/28.1	0/1	-/6.2

Table 5.8. Galveston Pleasure Pier Forecast/Adjusted Forecast Water Level Event Analysis April 2000 - March 2001
Adjusted forecast y = 1.05x - 0.05, where x is the unadjusted forecast.

Month	Number of Successes	Mean (cm) Success Difference	Number of Failures	Mean (cm) Failure Difference	Number of False Alarms	Mean (cm) False Alarm Difference
April	3/5	5.2/3.5	6/3	15.2/19.2	6/8	10.6/12.5
May	10/9	5.7/5.9	1/2	16.5/12.0	4/5	17.4/22.0
June	14/15	5.0/2.6	3/2	11.6/15.9	8/8	20.5/19.9
July	9/16	7.1/4.4	12/5	12.6/8.3	5/3	17.1/20.0
August	0/4	-/0.9	6/2	11.7/10.2	4/9	13.0/10.1
September	12/13	4.4/4.3	1/0	16.2/-	7/6	17.9/19.0
October	18/16	5.4/4.6	1/3	12.7/7.4	5/3	8.6/13.8
November	13/12	6.3/6.9	3/5	11.8/11.6	5/7	8.9/10.2
December	14/14	7.3/8.5	4/3	11.4/12.7	3/5	15.9/16.4
January	19/20	8.0/9.6	1/0	24.5/-	3/2	19.5/19.1
February	10/12	6.3/9.5	4/2	16.1/17.0	4/6	16.2/12.1
March	10/12	5.2/8.7	4/2	11.1/15.3	4/8	11.7/12.7

Table 5.9. Morgans Point Forecast/Adjusted Forecast Water Level Event Analysis April 2000 - March 2001
Adjusted forecast y = 1.05x - 0.075, where x is the unadjusted forecast.

Month	Number of Successes	Mean (cm) Success Difference	Number of Failures	Mean (cm) Failure Difference	Number of False Alarms	Mean (cm) False Alarm Difference
April	10/11	6.6/6.2	6/6	17.2/10.8	5/3	14.9/16.1
May	13/11	4.9/6.4	1/4	16.0/10.7	6/4	12.8/17.1
June	9/10	6.7/5.8	5/7	15.4/8.5	10/4	15.3/21.1
July	3/10	12.4/5.5	15/8	15.7/9.5	7/1	13.2/35.4
August	0/6	-/3.0	11/5	13.9/8.8	1/2	30.8/18.5
September	13/13	9.3/5.3	2/4	25.8/13.0	9/7	16.8/19.5
October	13/14	9.0/5.9	1/4	9.0/10.6	7/5	12.3/16.0
November	11/12	7.0/4.2	4/3	17.8/10.2	3/0	15.1/-
December	11/12	11.6/6.5	7/5	14.7/9.0	0/2	-/8.2
January	18/18	11.7/6.0	9/2	15.2/21.0	1/2	5.9/8.3
February	8/11	8.8/3.9	8/5	21.1/15.9	4/3	20.7/10.8
March	12/12	4.8/6.9	8/6	15.3/21.5	1/5	3.6/13.0

Table 5.10. Galveston Pleasure Pier Forecast High/Low Water Level Event Analysis April 2000 - March 2001

Month	Number of Successes	Mean (cm) Success Difference	Number of Failures	Mean (cm) Failure Difference	Number of False Alarms	Mean (cm) False Alarm Difference
April	1/2	2.1/6.8	1/5	16.3/15.0	4/2	12.3/7.1
May	10/0	5.7/-	1/0	16.5/-	3/1	15.9/21.5
June	10/4	3.7/8.2	2/1	12.5/9.9	8/0	20.5/-
July	6/3	4.5/12.2	0/12	-/12.6	5/0	17.1/-
August	0/0	-/-	0/6	-/11.7	4/0	13.0/-
September	11/1	4.7/0.1	0/1	-/16.2	6/1	19.0/11.1
October	18/0	5.4/-	1/0	12.7/-	4/1	3.6/28.9
November	11/2	6.4/5.7	3/0	11.2/-	4/1	9.6/6.1
December	3/11	3.8/8.3	2/2	10.5/12.3	2/1	15.4/16.9
January	1/18	4.6/8.2	0/1	-/24.5	1/2	32.4/13.0
February	0/10	-/6.3	0/4	-/16.1	4/0	16.2/-
March	2/8	5.5/5.1	2/2	11.8/10.5	3/1	14.9/2.1

Table 5.11. Galveston Pleasure Pier Adjusted Forecast High/Low Water Level Event Analysis April 2000 - March 2001 Adjusted forecast y = 1.05x - 0.05, where x is the unadjusted forecast.

Month	Number of Successes	Mean (cm) Success Difference	Number of Failures	Mean (cm) Failure Difference	Number of False Alarms	Mean (cm) False Alarm Difference
April	1/4	1.0/4.3	1/2	20.0/18.9	3/5	11.8/12.9
May	9/0	5.9/-	2/0	12.0/-	2/3	20.1/23.2
June	10/5	2.7/2.5	2/0	15.9/9.9	7/1	20.5/15.8
July	4/12	3.8/4.5	2/3	6.7/9.4	2/1	25.9/8.2
August	0/4	-/0.1	0/2	-/10.2	3/6	15.3/7.6
September	11/2	4.1/5.7	0/0	-/-	4/2	21.6/13.8
October	16/0	4.6/-	3/0	7.4/-	2/1	2.5/36.3
November	10/2	7.1/5.9	5/0	11.6/-	5/2	8.7/13.9
December	3/11	3.8/9.8	2/1	13.7/10.8	2/3	14.5/17.7
January	1/19	3.2/10.0	0/0	-/-	1/1	29.7/8.4
February	0/12	-/9.5	0/2	-/17.0	3/3	10.2/13.9
March	2/10	8.0/8.8	2/0	15.3/-	2/6	13.4/12.4

Table 5.12. Morgans Point Forecast High/Low Water Level Event Analysis April 2000 - March 2001

Month	Number of Successes	Mean (cm) Success Difference	Number of Failures	Mean (cm) Failure Difference	Number of False Alarms	Mean (cm) False Alarm Difference
April	5/5	3.0/10.3	1/5	12.3/18.1	5/0	14.9/-
May	13/0	4.9/-	1/0	16.0/-	5/1	12.0/17.3
June	8/1	5.3/17.7	1/4	10.5/16.7	10/0	15.3/-
July	1/2	5.4/15.8	0/15	-/15.7	7/0	13.2/-
August	0/0	-/-	0/11	-/13.9	1/0	30.8/-
September	9/4	9.0/10.0	0/2	-/25.8	9/0	16.8/-
October	13/0	9.0/-	1/0	9.0/-	7/0	12.3/-
November	11/0	7.0/-	0/4	-/17.8	3/0	15.1/-
December	2/9	13.6/11.1	0/7	-/14.7	0/0	-/-
January	1/17	5.1/12.1	1/8	22.3/14.4	1/0	5.9/-
February	0/8	-/8.8	0/8	-/21.1	4/0	20.7/-
March	3/9	5.2/4.7	4/4	17.2/13.5	0/1	-/3.6

Table 5.13. Morgans Point Adjusted Forecast High/Low Water Level Event Analysis April 2000 - March 2001
Adjusted forecast $y = 1.05x - 0.075$, where x is the unadjusted forecast.

Month	Number of Successes	Mean (cm) Success Difference	Number of Failures	Mean (cm) Failure Difference	Number of False Alarms	Mean (cm) False Alarm Difference
April	3/8	5.2/6.6	4/2	9.5/13.6	3/0	16.1/-
May	11/0	6.4/-	4/0	10.7/-	3/1	13.8/26.9
June	8/2	5.3/7.8	4/3	8.4/8.6	4/0	21.1/-
July	1/9	0.2/6.1	0/8	-/9.5	1/0	35.4/-
August	0/6	-/3.0	0/5	-/8.8	1/1	26.3/10.8
September	9/4	4.9/6.3	2/2	8.3/17.8	5/2	21.9/13.3
October	14/0	5.9/-	4/0	10.6/-	4/1	10.9/36.0
November	10/2	3.5/7.6	1/2	8.0/11.3	0/0	-/-
December	2/10	8.5/6.1	0/5	-/9.0	0/2	-/8.2
January	1/17	0.2/6.3	1/1	29.3/12.6	0/2	-/8.3
February	0/11	-/3.9	0/5	-/15.9	1/2	23.1/4.7
March	2/10	7.5/6.8	5/1	22.0/19.2	0/5	-/13.0

Table 5.14. Nowcast/Forecast System Skill Measure Set 1 Water Level Event Results: April 2000 - March 2001

Station / Prediction	Success	Failure	False Alarm
Pleasure Pier (GPP)			
Nowcast	11/12	11/12	3/12
Forecast	10/12	10/12	2/12
Adjusted Forecast	12/12	12/12	3/12
Morgans Point (MP)			
Nowcast	9/12	10/12	8/12
Forecast	9/12	9/12	4/12
Adjusted Forecast	11/12	12/12	5/12

Table 5.15. Nowcast/Forecast System Skill Measure Set 1 High Water Event Results: April 2000 - March 2001

Station / Prediction	Success	Failure	False Alarm
Pleasure Pier (GPP)			
Nowcast	10/12	10/12	1/12
Forecast	10/12	10/12	1/12
Adjusted Forecast	10/12	10/12	2/12
Morgans Point (MP)			
Nowcast	11/12	11/12	2/12
Forecast	10/12	11/12	2/12
Adjusted Forecast	10/12	11/12	2/12

Table 5.16. Nowcast/Forecast System Skill Measure Set 1 Low Water Event Results: April 2000 - March 2001

Station / Prediction	Success	Failure	False Alarm
Pleasure Pier (GPP)			
Nowcast	7/12	7/12	4/12
Forecast	6/12	6/12	5/12
Adjusted Forecast	9/12	9/12	4/12
Morgans Point (MP)			
Nowcast	6/12	8/12	1/12
Forecast	5/12	8/12	5/12
Adjusted Forecast	8/12	10/12	4/12

Table 5.17. Nowcast/Forecast System Skill Measure Set 2 Water Level Event Results: April 2000 - March 2001

Station/Analysis	Nowcast	Tide Prediction	Forecast	Adjusted Forecast
Galveston Pleasure Pier:				
Total	9/12	2/12	8/12	9/12
High	7/12	0/12	5/12	4/12
Low	5/12	3/12	6/12	6/12
Morgans Point:				
Total	8/12	1/12	7/12	10/12
High	7/12	0/12	4/12	5/12
Low	4/12	1/12	4/12	6/12

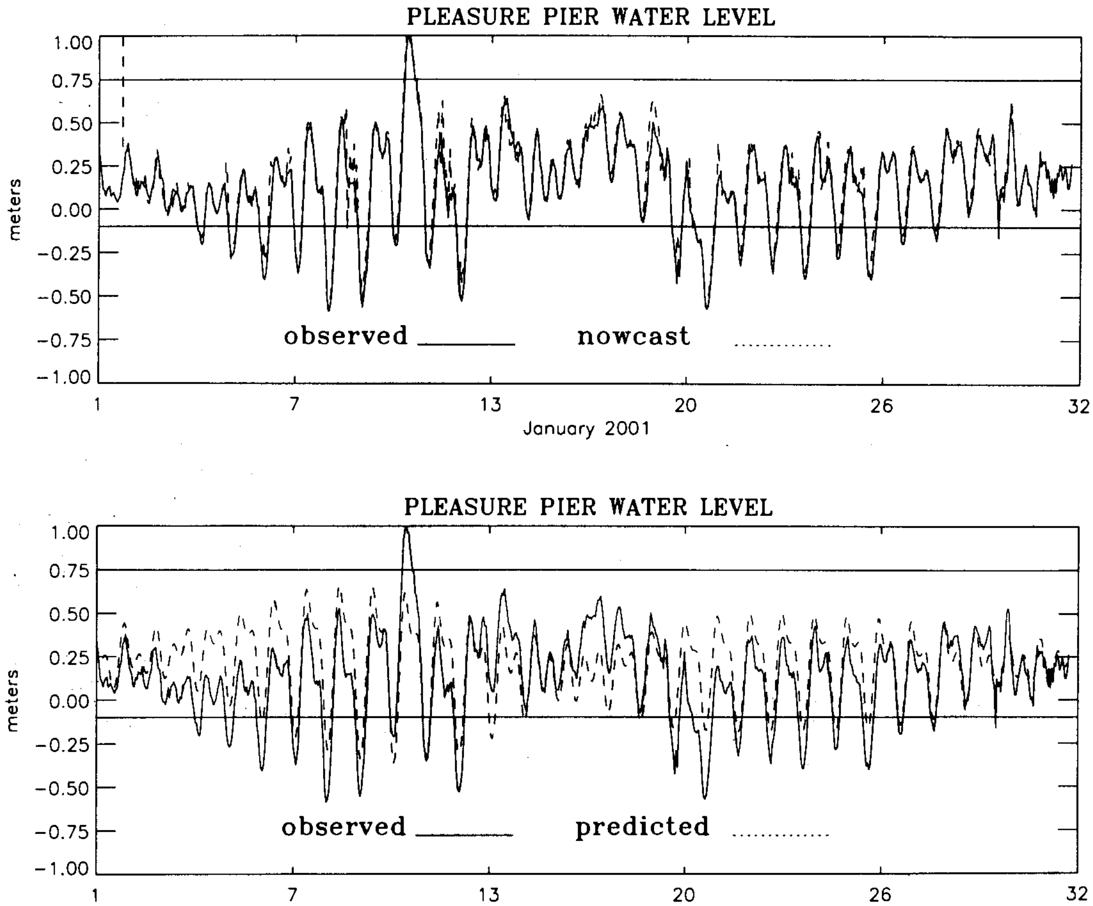


Figure 5.1. Galveston Pleasure Pier Nowcast Results: January 2001

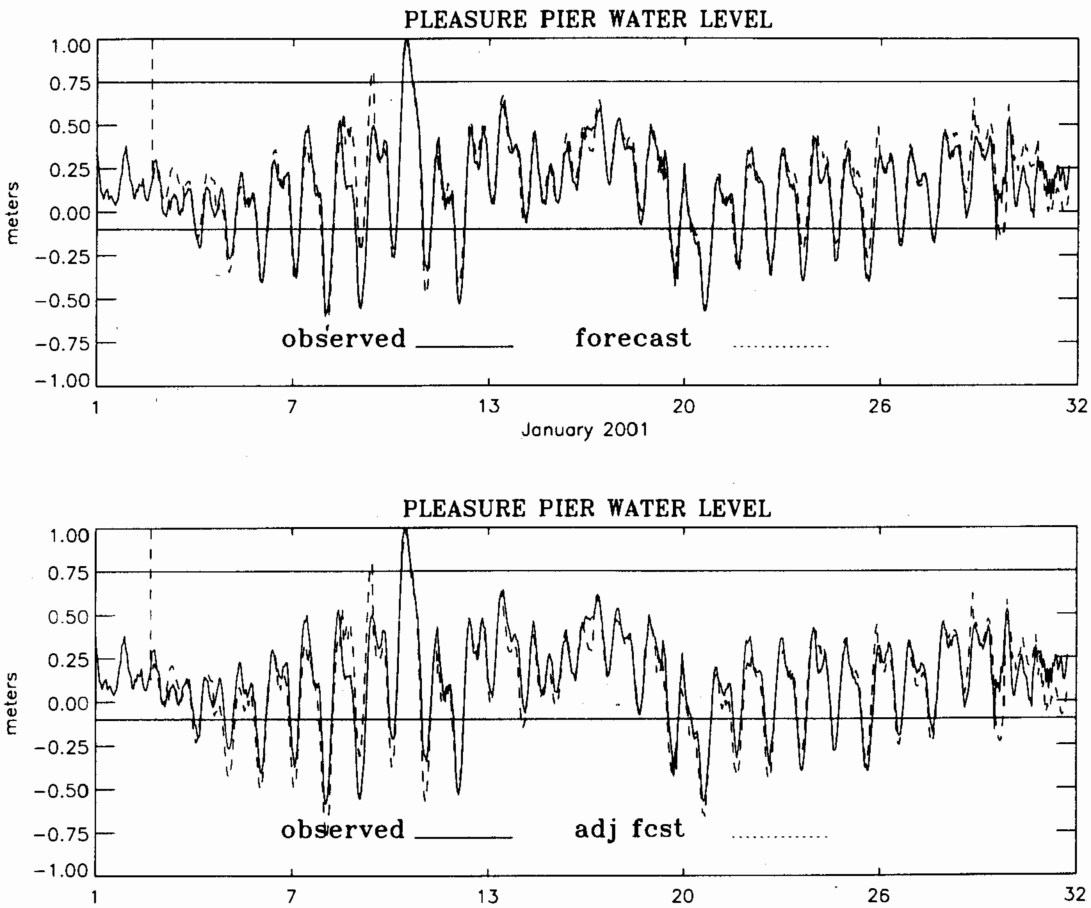


Figure 5.2. Galveston Pleasure Pier Forecast Results: January 2001

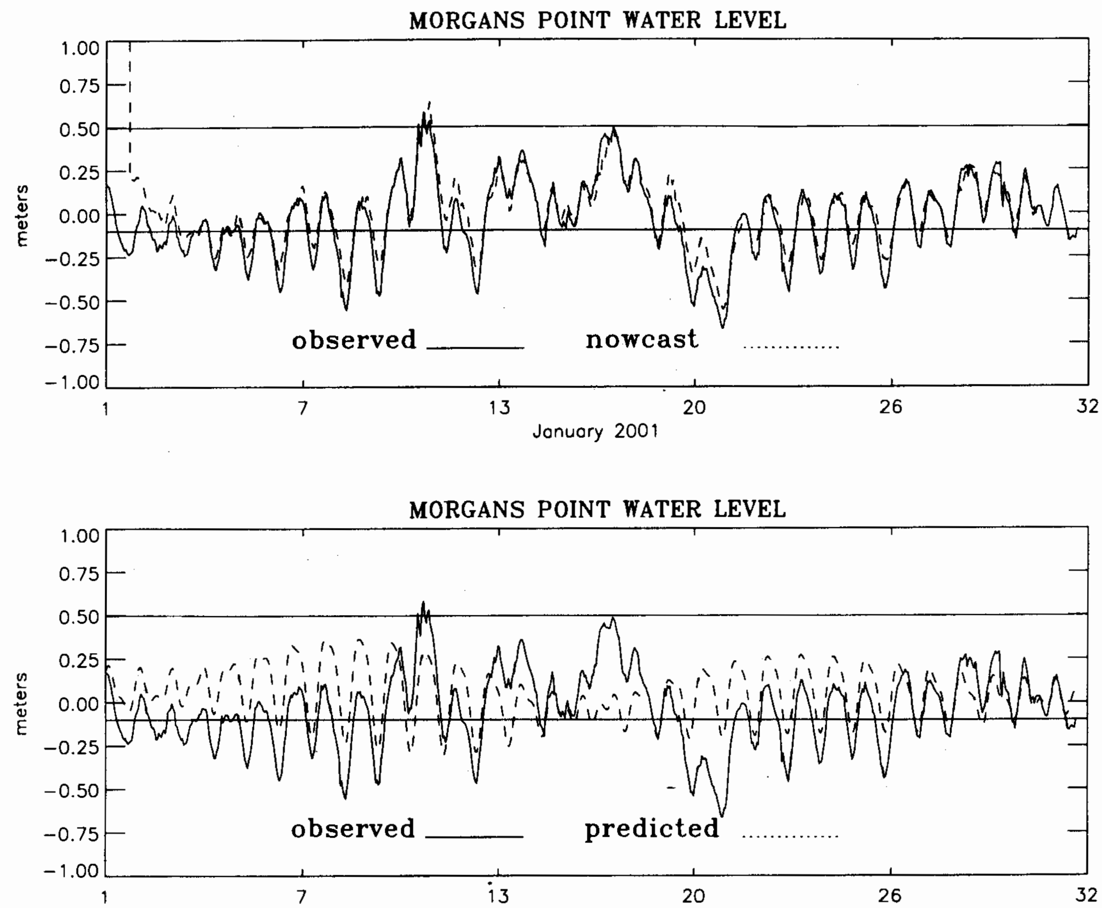
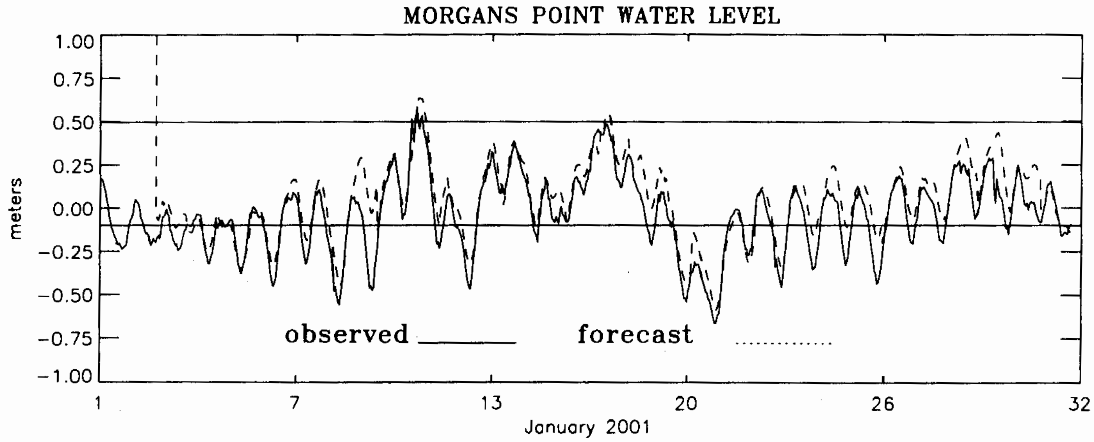


Figure 5.3. Morgans Point Nowcast Results: January 2001



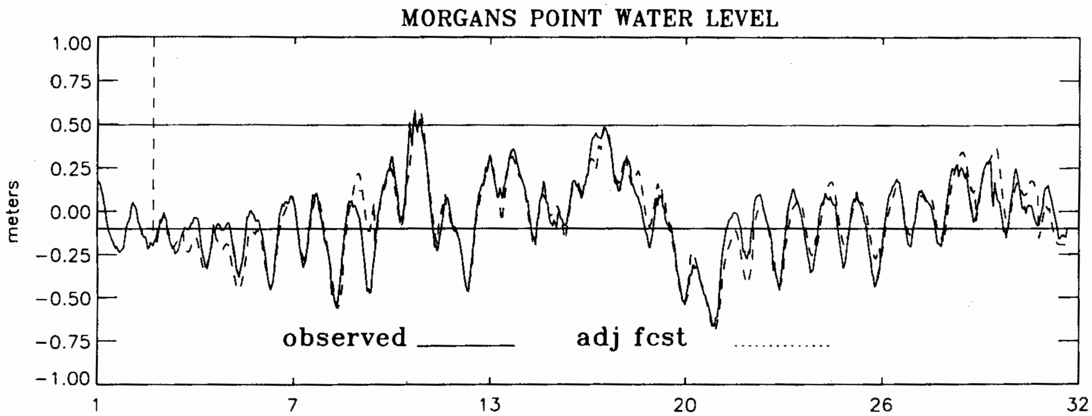


Figure 5.4. Morgans Point Forecast Results: January 2001

6. PRINCIPAL COMPONENT DIRECTION CURRENT EVENT EVALUATION

The experimental nowcast/forecast system is evaluated with respect to both flood and ebb current events over the six month period September 2000 through February 2001. The evaluation is made for prediction depth (4.7m) depth currents along the principal component direction (PCD). This allows one to consider the currents in the same manner as water levels and is possible due to the strong rectilinear nature of the currents (see page 47 of Chapter 3) at both ADCP stations.

Since the Morgans Point station had been removed due to dredging operations in late Spring 2000, removed again for several weeks during August 2000 due to a cabling problem, and then redeployed at a slightly different location, it was decided to begin the analysis during September 2000. In June 2001, CO-OPS completed a least squares harmonic analysis for the redeployed current meter location at Morgans Point. The six month period September 2000 through February 2001 represents the latest period for which observations correspond to the period over which the harmonic analysis was completed at Morgans Point. Note the harmonic constant sets used are slightly different than those given in Chapter 2 at both stations. Note the same principal flood directions given in Table 2.6 were assumed at model level 3 and were adjusted to the values corresponding to the revised harmonic constant sets at model level 1 (305 degrees at Bolivar Roads and 344 degrees at Morgans Point).

A flood current event is considered to occur when observed, nowcast, forecast, and astronomically predicted principal component direction currents exceed a certain reference level. A ebb current event is considered to occur when observed, nowcast, forecast, and astronomically predicted principal component direction currents are less than a certain level. Thus flood currents are considered positive. The selected reference levels were +/- 65cm/s and +/-40cm/s at Bolivar Roads and Morgans Point, respectively. A success is defined as the joint occurrence of observed and nowcast or forecast or astronomically predicted principal component direction currents events; e.g., the model

Table 6.1. Flood/Ebb Monthly Summary at Bolivar Roads. Note the reference level was 65 cm/s.

Month Year	Number of Flood Events	(Min, Max) Flood Currents (cm/s)	Number of Ebb Events	(Min, Max) Ebb Currents (cm/s)
September 2000	21	(68.0,95.0)	14	(65.7,81.8)
October 2000	23	(68.4,89.4)	13	(65.6,76.1)
November 2000	20	(65.1,102.9)	22	(68.2,114.7)
December 2000	20	(66.0,116.4)	19	(67.4,111.8)
January 2001	16	(66.0,104.2)	23	(67.2,127.3)
February 2001	17	(70.6,98.7)	24	(65.1,124.3)

or tidal current prediction predicts the event. A failure is defined as the occurrence of an observed principal component direction current event which is not present in the nowcast or forecast or astronomically predicted principal component direction currents. A false alarm is the opposite condition of a failure. The computer programs used in the analysis have been documented by Richardson and Schmalz (2001). Prior to assessing the ability of the nowcast/forecast system to predict flood and ebb current events, we consider the number of observed flood and ebb current events by month as shown in Table 6.1 at Bolivar Roads and in Table 6.2 at Morgans Point. Note the variability of flood and ebb current events over this six month period. Due to the influence of the freshwater inflows, the number of ebb events is much larger than the number of flood events at Morgans Point. With respect to Bolivar Roads, the number of flood events is significantly reduced, while the number of ebb events is significantly increased at Morgans Point. At Bolivar Roads the number of flood and ebb events are more nearly in balance. Note the strength of the ebb currents is greater than the flood current events in all six months at Morgans Point and for the last four months starting in November 2000 at Bolivar Roads.

Table 6.2. Flood/Ebb Monthly Summary at Morgans Point. Note the reference level was 40 cm/s.

Month Year	Number of Flood Events	(Min, Max) Flood Currents (cm/s)	Number of Ebb Events	(Min, Max) Ebb Currents (cm/s)
September 2000	3	(41.4,44.7)	6	(41.1,49.1)
October 2000	2	(40.4,49.4)	14	(40.4,55.0)
November 2000	13	(40.1,47.0)	38	(40.3,64.3)
December 2000	16	(40.1,51.9)	35	(40.6,61.2)
January 2001	5	(40.4,75.8)	37	(40.5,83.3)
February 2001	14	(42.6,56.4)	34	(40.0,76.1)

6.1. Nowcast Results

In Tables 6.3 and 6.4, the number of successes, failures, and false alarms are contrasted between the nowcast and astronomical tidal current prediction at Bolivar Roads and at Morgans Point, respectively. Note at Bolivar Roads, the number of successes in the nowcasts at level 1 is greater than for the astronomical tidal current prediction for all months except November, when several nowcast cycles were missed. For model level 3, which is nearest the actual prediction depth, the current strengths are reduced from the level 1 values, and the opposite behavior is observed. The mean success difference, which is determined as the average difference between the prediction and the observation, is generally of the same order for both nowcast model levels and nearly equal to the astronomical tidal current prediction. The mean failure difference, which is determined in an analogous manner, is lower in the nowcast than in the astronomical tidal current prediction during the last four months and higher than in the astronomical tidal current prediction during the first two months. The number of false alarms is generally lower for nowcast model level 3 and generally higher for nowcast model level 1 relative to astronomical tidal current predictions. Overall at Bolivar Roads, the nowcast model level 1 results are superior to the astronomical tidal current predictions, while for nowcast model level 3 the results are slightly degraded with respect to the tidal current predictions.

At Morgans Point, the number of successes for astronomical tidal current prediction is larger than in the nowcast at both levels over the last four months. The number of failures is larger in the astronomical tidal current prediction for the first three months and smaller for the last three months than for the nowcasts. The mean failure difference is generally smaller for the astronomical tidal current prediction. The number of false alarms is larger for astronomical tidal current prediction but the mean false alarm difference is generally less than in the nowcast at model level 3 and greater than the nowcast level 1 results. Overall, the astronomical tidal current prediction is slightly superior to the nowcast results at both model levels.

Table 6.3. Bolivar Roads Tidal Prediction versus Nowcast PCD Event Monthly Summary. Note Tide Prediction (shown opposite month and year) and GBM Level 3 employ a flood direction of 322 while GBM Level 1 employs a flood direction of 305.

Month Year	Number of Successes	Mean Success Difference (cm/s)	Number of Failures	Mean Failure Difference (cm/s)	Number of False Alarms	Mean False Alarm Difference (cm/s)
Sep 2000	24	6.8	11	15.4	2	9.0
Level 1	29	9.1	7	16.9	13	32.3
Level 3	16	7.0	17	23.5	1	24.8
Oct 2000	32	5.1	4	10.8	6	11.3
Level 1	35	11.3	4	42.9	15	27.1
Level 3	24	5.5	9	29.5	3	27.1
Nov 2000	30	10.7	12	32.5	6	25.3
Level 1	22	11.6	9	31.8	12	24.4
Level 3	14	10.7	14	29.6	2	37.6
Dec 2000	29	10.6	10	44.8	3	17.3
Level 1	33	10.5	5	14.6	6	16.2
Level 3	26	11.5	13	26.2	0	-
Jan 2001	26	11.4	13	37.2	0	-
Level 1	32	10.8	6	22.4	0	-
Level 3	19	16.6	20	27.5	0	-
Feb 2001	28	9.2	13	35.6	5	38.5
Level 1	35	13.6	5	19.1	2	23.8
Level 3	21	19.9	19	25.7	1	0.9

Table 6.4. Morgans Point Tidal Prediction/Nowcast PCD Event Monthly Summary. Note Tide Prediction (shown opposite month and year) and HSCM Level 3 employ a flood direction of 341 while HSCM Level 1 employs a flood direction of 344.

Month Year	Number of Successes	Mean Success Difference (cm/s)	Number of Failures	Mean Failure Difference (cm/s)	Number of False Alarms	Mean False Alarm Difference (cm/s)
Sep 2000	0	-	9	18.7	1	15.6
Level 1	1	3.2	8	18.2	1	16.5
Level 3	2	0.9	7	32.3	2	24.1
Oct 2000	1	4.9	15	16.4	7	10.0
Level 1	0	-	10	21.1	0	-
Level 3	0	-	10	34.4	0	-
Nov 2000	13	7.9	38	27.3	7	14.4
Level 1	0	-	38	28.6	7	19.8
Level 3	2	2.6	35	42.0	8	25.8
Dec 2000	17	5.6	34	23.0	11	12.5
Level 1	3	5.2	37	23.7	1	9.6
Level 3	4	6.1	35	33.7	8	24.2
Jan 2001	8	9.2	34	27.3	13	12.8
Level 1	1	25.0	43	26.4	3	9.6
Level 3	2	14.9	41	41.2	7	20.3
Feb 2001	16	6.5	32	24.1	5	18.7
Level 1	2	49.0	46	23.1	1	5.3
Level 3	6	15.3	43	36.9	3	23.1

6.2. Forecast and Adjusted Forecast Results

Forecast principal component direction current event results at both Bolivar Roads (given in Table 6.5) and at Morgans Point (given in Table 6.6) were comparable to those achieved during the nowcast. At Bolivar Roads forecast level 1 results were improved over the tidal current predictions, while at Morgans Point both forecast level results were similar and slightly degraded with respect to the tidal current predictions. In an effort to improve the forecast results, the following linear model was used to adjust flood and ebb currents individually: Y= mX + b, where Y=adjusted forecast, X=base forecast, and (m,b) == (gain, bias). As noted in Table 6.5 at Bolivar Roads, the adjusted forecast results are nearly the same as the unadjusted forecast for each model level. For the adjusted forecast at both model levels, the number of successes is slightly increased with a corresponding decrease in the number of failures. The number of false alarms is slightly increased for the adjusted forecast.

Forecast results at Morgans Point are contrasted with those of several adjusted forecasts in Table 6.6. The unadjusted HSCM forecast results are very similar to those presented for the nowcast in Table 6.4. As previously discussed, the nowcast results are not superior to those of the tidal current prediction. Note results obtained from the GBM at Morgans Point were also considered. Several

Table 6.5. Bolivar Roads Forecast/Adjusted Forecast PCD Event Monthly Summary. Note adjusted forecast, GBM0=(m = 1.05,b = -6 cm/s on both ebb and flood)

Month Year	Number of Successes	Mean Success Difference (cm/s)	Number of Failures	Mean Failure Difference (cm/s)	Number of False Alarms	Mean False Alarm Difference (cm/s)
Sep 2000						
Level 1	32/33	10.6/13.9	7/6	16.2/18.7	14/20	27.3/31.9
Level 3	23/23	7.2/8.8	12/13	26.8/24.2	2/5	10.5/22.4
Oct 2000						
Level 1	35/35	11.9/17.4	6/6	13.5/16.5	19/23	28.6/37.2
Level 3	26/29	7.7/10.2	9/6	13.7/19.5	2/8	10.1/15.1
Nov 2000						
Level 1	25/24	8.7/11.7	4/6	31.4/21.3	7/9	24.9/26.2
Level 3	16/18	8.1/10.6	9/7	23.0/22.0	3/3	6.9/17.1
Dec 2000						
Level 1	32/33	11.0/14.0	7/5	30.3/34.7	5/4	31.9/35.9
Level 3	27/27	12.6/12.1	13/13	33.0/28.7	2/3	8.6/15.6
Jan 2001						
Level 1	33/32	11.2/11.6	5/6	35.3/28.7	1/1	56.4/16.7
Level 3	21/27	15.6/13.8	18/11	30.7/32.6	0/0	-/-
Feb 2001						
Level 1	33/35	14.4/14.7	11/7	23.9/26.6	4/6	39.4/32.0
Level 3	19/22	21.1/16.9	22/19	30.2/27.7	1/2	0.9/11.7

adjustments were tried in an attempt to improve the forecasts relative to the astronomical tidal current predictions. In general the HSC1[1] results represented the best approach towards adjusting the HSC results, while the GBM3[1] results were the best for the GBM and are comparable to the HSC1[3] results.

Table 6.6. Morgans Point Forecast and Adjusted Forecast PCD Event Monthly Summary. Note HSC=unadjusted HSCM forecast, HSC1=(flood: m=1,b=0, ebb: m=2,b=-15 cm/s), HSC2=(flood: m=1,b=0, ebb: m=2,b=0), GBM1=(flood: m=4,b=0, ebb: m=4,b=0), GBM2=(flood: m=4,b=0, ebb:m=3,b=-20 cm/s), and GBM3^1=(flood: m=3.5,b=0, ebb:m=2.5,b=0) ; GBM3^3=(flood: m=4,b=0, ebb:m=3,b=0). Note the superscripts denote model level number. For model level 1 a flood direction of 344 degrees was used, while for model level 3 the flood direction was taken as 341 degrees.

Month Year	Number of Successes	Mean Success Difference (cm/s)	Number of Failures	Mean Failure Difference (cm/s)	Number of False Alarms	Mean False Alarm Difference (cm/s)
Sep 2000						
HSC^1 / HSC^3	0/0	-/-	9/9	17.8/24.2	3/4	19.5/23.9
HSC1^1/HSC1^3	5/4	25.8/11.1	3/4	18.5/20.3	23/11	28.0/18.6
HSC2	2	3.2	6	19.4	6	26.0
GBM1	5	7.0	3	24.0	18	22.0
GBM2	5	12.9	3	18.7	27	23.9
GBM3^1/GBM3^3	4/2	11.9/7.9	5/7	30.6/17.0	11/9	28.6/23.4
Oct 2000						
HSC^1 / HSC^3	0/0	-/-	12/12	23.3/36.4	1/2	8.0/12.7
HSC1^1/HSC1^3	11/7	24.8/13.5	0/5	-/22.0	27/24	33.9/27.7
HSC2	2	6.2	10	26.7	18	20.1
GBM1	6	15.6	9	22.0	48	27.9
GBM2	12	13.4	3	25.8	45	31.3
GBM3^1/GBM3^3	9/4	14.2/4.4	5/11	21.0/25.8	14/28	18.2/23.6
Nov 2000						
HSC^1 / HSC^3	4/2	13.1/5.4	30/32	24.5/34.9	1/6	25.2/21.3
HSC1^1/HSC1^3	21/11	18.2/13.3	7/18	14.5/31.3	12/15	35.7/27.0
HSC2	8	7.8	24	33.8	14	18.8
GBM1	12	18.5	19	31.6	19	25.5
GBM2	14	14.0	17	27.0	18	29.5
GBM3^1/GBM3^3	16/10	10.6/11.9	17/22	24.5/32.9	5/8	33.8/27.1
Dec 2000						
HSC^1 / HSC^3	3/3	30.3/3.6	43/42	37.9/23.6	1/6	19.0/23.6
HSC1^1/HSC1^3	23/17	12.8/13.4	13/22	30.7/25.5	10/9	42.4/23.1
HSC2	12	5.5	31	27.1	8	21.0
GBM1	21	12.4	23	22.6	19	28.5
GBM2	29	10.9	10	20.7	26	28.3
GBM3^1/GBM3^3	16/17	15.0/8.3	23/28	31.8/27.2	11/10	27.1/27.1
Jan 2001						
HSC^1 / HSC^3	2/1	16.0/29.4	42/43	26.9/38.8	3/6	14.9/23.2
HSC1^1/HSC1^3	27/19	22.2/19.8	11/24	27.1/36.3	18/13	35.8/30.4
HSC2	13	10.5	30	39.9	10	25.6
GBM1	19	14.5	22	32.0	26	28.3
GBM2	25	13.5	14	24.8	35	29.2
GBM3^1/GBM3^3	20/11	11.5/10.5	22/30	30.6/31.8	9/19	36.4/24.7
Feb 2001						
HSC^1 / HSC^3	1/5	17.2/7.2	46/43	22.8/33.4	1/4	4.7/20.1
HSC1^1/HSC1^3	24/21	24.6/11.3	13/22	24.8/30.4	10/9	32.2/24.5
HSC2	16	5.9	29	31.5	7	17.1
GBM1	27	10.1	20	34.5	17	29.9
GBM2	22	13.5	21	37.8	18	33.3
GBM3^1/GBM3^3	17/20	14.9/6.0	27/29	31.2/29.6	4/14	22.3/25.3

6.3. Skill Measures

As for water level events, we desire the number of success to be greater in the nowcasts and forecasts than in the tidal current prediction for each month. In addition, the number of failures and false alarms in the nowcasts and forecasts should be smaller than in the tidal prediction for each month as well. As a skill measure, we subtract the number of failures and false alarms from the number of successes for each month and then average these monthly scores. We use this criterion for event based principal component direction current nowcast and forecast skill assessment as shown in Table 6.7. Note even with the adjustments, it is not possible at Morgans Point, to obtain the nowcast/forecast skill results at Bolivar Roads. That is the skill results are negative at Morgans Point indicating a larger number of failures and false alarms than successes. However, the adjusted forecasts are improved over the tidal current predictions at Morgans Point. At Bolivar Roads the skill scores are positive for the nowcast and both forecasts and the level 1 results are better than the astronomical tidal current prediction.

It should be noted that the results obtained are based on the selection of the reference levels. At Bolivar Roads, the selection of a 65 cm/s level produced a near equal number of flood and ebb events. The selection of a higher value would have produced a fewer number of events. If the level is selected at too high a value, only a few events are available for analysis. Note 80 cm/s would seem to be a limiting value based on the maximum ebb currents during September and October 2000 in Table 6.1. The use of a 65 cm/s level would tend to include more strictly tidally induced events. Thus the astronomical tidal current prediction results would appear to be favored since they include zero error for a purely tidally induced event. One hopes that the model current results become more accurate than the astronomical tidal current prediction as the meteorologically induced portion of the currents increases. The degree of improvement is a subtle issue, since the model also includes errors for both the tidal and nontidal portions of the current. Thus for the model to outperform the astronomical tidal current prediction on an event basis with the 65 cm/s reference level, it must outperform the astronomical tidal current prediction over an event set, which represents tidally and meteorologically dominated events. This is a severe test since model results are representative of the grid cell average and are thus not at the precise horizontal and vertical location of the observation.

Similar considerations hold at Morgans Point. However, the 40 cm/s level appears to be near the maximum level based on the peak flood current in September 2000 as given in Table 6.2. Note at this maximum level, ebb events predominate over flood events in both number and in current magnitude. This indicates the strong influence of the freshwater inflows on currents at Morgans Point. During the winter wet season, additional sources of freshwater inflow from the Houston metropolitan area, which are not included in the models, may have significant impact on the current structure at Morgans Point and much less of an impact at Bolivar Roads in the lower Bay. This tends to explain why the nowcast/forecast results at Morgans Point are degraded relative to the results at Bolivar Roads.

6.4. Development of Nowcast/Forecast System Utility

To study the nowcast/forecast system utility, monthly plots of nowcast versus observations, astronomical tide prediction versus observations, forecast versus observation, and adjusted forecast

Table 6.7. Principal Component Direction Current Nowcast and Forecast Skill Assessment: September 2000 - February 2001. Note GBM=unadjusted GBM forecast, GBM0=(m=1.05, b=-6 cm/s). Note HSC=unadjusted HSCM forecast, HSC1=(flood: m=1,b=0, ebb: m=2,b=-15 cm/s), HSC2=(flood: m=1,b=0, ebb: m=2,b=0), GBM1=(flood: m=4,b=0, ebb: m=4,b=0), GBM2=(flood: m=4,b=0, ebb:m=3,b=-20 cm/s), and GBM3=(flood: m=4,b=0, ebb:m=3,b=0). Note for Nowcast, model level 1/model level 3 results are given. For the Forecast, GBM, GBM0, GBM3, HSC, and HSC1 model level 1/model level 3 results are given.

Prediction	Bolivar Roads		Morgans Point	
Principal Flood Direction (Degrees True)	305/322		344/341	
Tidal Current	14.0		-25.2	
Nowcast	17.0/3.5		-31.3/-30.5	
Forecast	GBM	16.7/6.5	HSC	-30.3/-33.0
	GBM0	15.5/9.3	HSC1	-6.0/-16.2
			HSC2	-23.3
			GBM1	-25.5
			GBM2	-21.7
			GBM3	-11.8/-25.2

versus observation were developed for both model level 1 and 3. Results for each month indicate that, during certain time periods, the nowcast and forecasts were superior to the astronomic tidal current prediction while this was not the case during other periods. On many occasions the level 1 and level 3 results bracketed the observations at Bolivar Roads. To illustrate the results, January 2001 is considered. GBM nowcast model level 1 and level 3 results are shown at Bolivar Roads in Figure 6.1 and 6.2, respectively. Note in Figure 6.1 and Figure 6.2 during 5-9 January, flood currents are underestimated in the nowcast at both levels 1 and 3 (level 1 results more closely match the observations than level 1 results) and overestimated by the tidal predictions. During 12-13 January, nowcast results at both level 1 and 3 are improved over those obtained from tidal prediction. During 26-27 January, the opposite is true. GBM forecast results are given in Figure 6.3 and Figure 6.4 at model levels 1 and 3, respectively. Note during 30 January the peak ebb current is better represented in the GBM forecasts than by the astronomical tidal current prediction. In the lower portions of Figures 6.3 and 6.4, the feasibility of trying to adjust the GBM forecast to peak flood and ebb events is demonstrated for the 30 January ebb event.

In Figures 6.5 and 6.6, HSCM nowcast results at model levels 1 and 3 are contrasted with the astronomical tidal current prediction at Morgans Point. Note the astronomical tidal current prediction is clearly superior to the HSCM nowcast at level 3, while the level 1 HSCM nowcast results are very near the quality of the tidal prediction. HSCM level 1 results reflect the greater influence of the freshwater lens relative to level 3 results. The ebb strengths are much more closely reproduced in the level 1 nowcast results. HSCM forecast results are shown in Figures 6.7 and 6.8 at model levels 1 and 3, respectively. HSCM level 1 forecast results are superior to those at level 3. In the lower portions of these figures, the adjusted HSCM forecasts are shown. Note the same adjustments are used for both levels and appear to produce excessive ebb strengths for the level 1 results. Note however, by using the adjusted forecasts, the large ebb events during 28-30 January not shown by the astronomical tidal current predictions were captured. The forecast results at Morgans Point obtained by using the GBM are shown in Figures 6.9 and 6.10, at model levels 1 and 3, respectively. Note the severely damped current response from the unadjusted forecasts at both model level. The GBM adjusted forecasts are shown in the lower portions of these figures. While the HSCM forecast results are clearly superior to those of the GBM through comparison of the bias and gain factors, one notes that by using these adjustments it was possible to obtain results of similar quality to the unadjusted HSCM forecasts results at each level.

Based on the results over the complete six month period, a range of current speeds should be provided to the mariner. At Bolivar Roads, the unadjusted forecasts are so near the observations, that no adjustment appears to be worthwhile. One should then use the GBM results at level 1 and 3 and the tide prediction to define the upper and lower current strength bounds. By definition, the tide prediction is explicitly included in this range and one would determine the frequency of occurrence for the observation to be within the range to provide the mariner with a confidence estimate. A similar approach would be used at Morgans Point. If only the GBM is used due to computational resource constraints, one would define the range based on the adjusted GBM level 1 and 3 forecast results and the tidal current prediction. In principle, the same adjustment factors could be used on the nowcasts. However, it is recommended that the nowcast results not be adjusted, so that an indication of the model's ability to directly replicate the currents is always available.

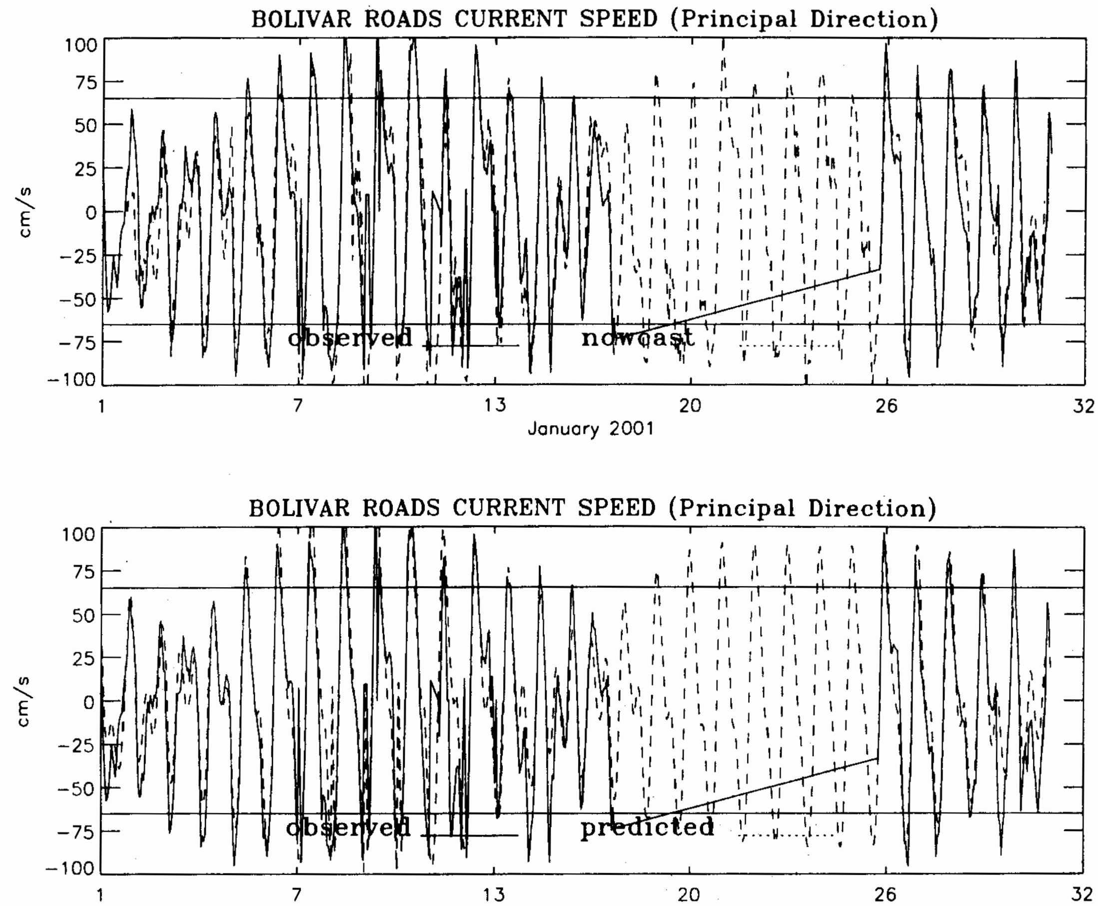
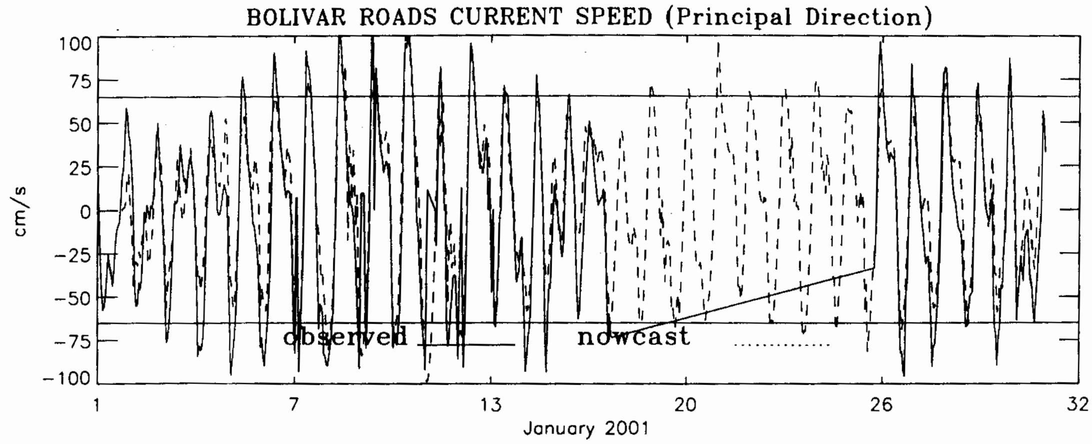


Figure 6.1. Bolivar Roads Principal Component Direction Prediction Depth Current Speed during January 2001: Level 1 Nowcast and Astronomical Tidal Current Prediction. Note observational data gaps are indicated by straight line segments.



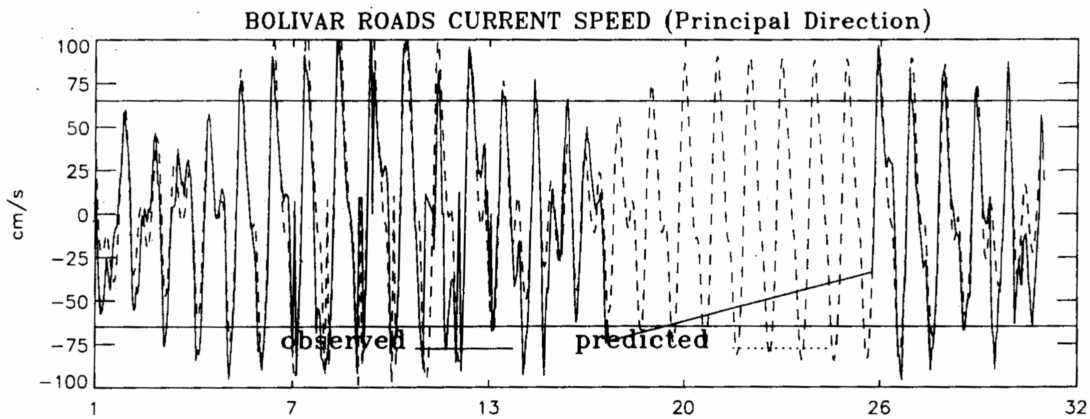


Figure 6.2. Bolivar Roads Principal Component Direction Prediction Depth Current Speed during January 2001: Level 3 Nowcast and Astronomical Tidal Current Prediction. Note observational data gaps are indicated by straight line segments

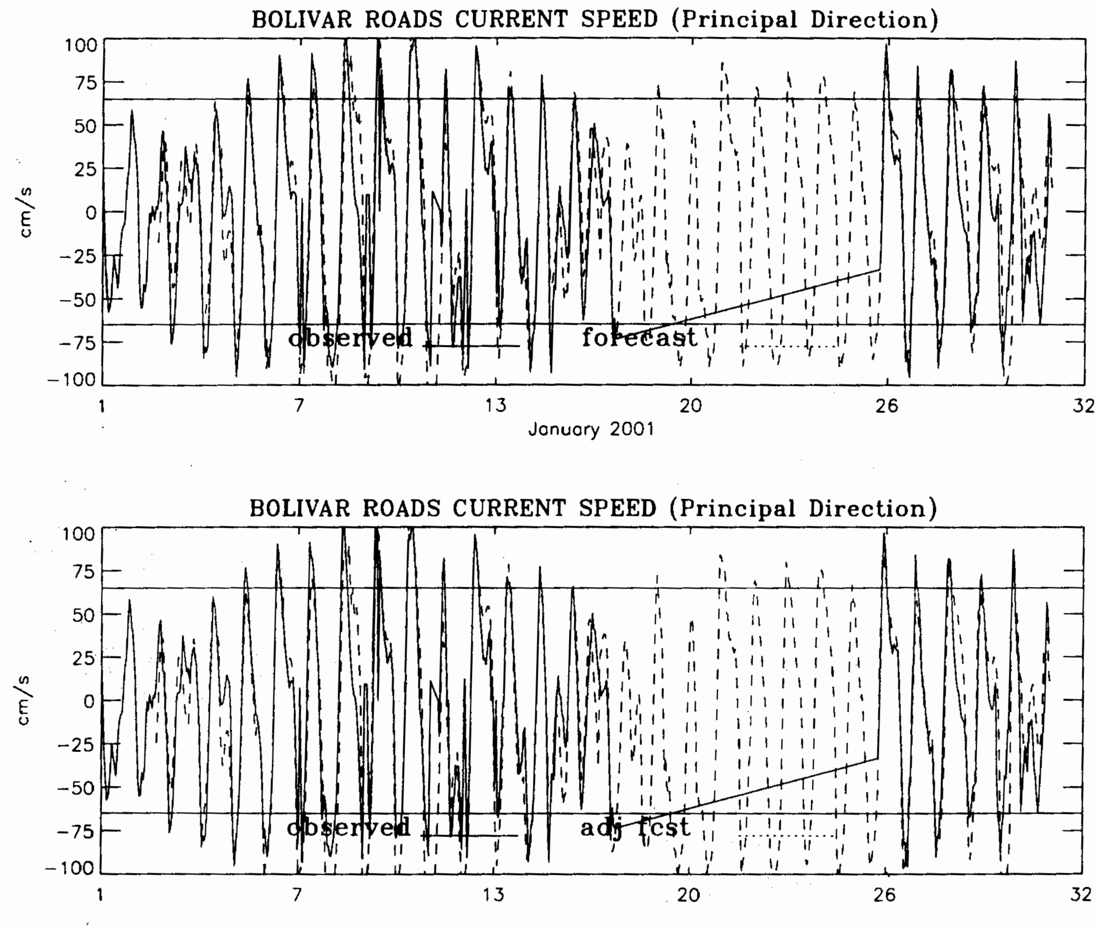


Figure 6.3. Bolivar Roads Principal Component Direction Prediction Depth Current Speed during January 2001: Level 1 Forecast and Adjusted Forecast (GBM0). Note observational data gaps are indicated by straight line segments.

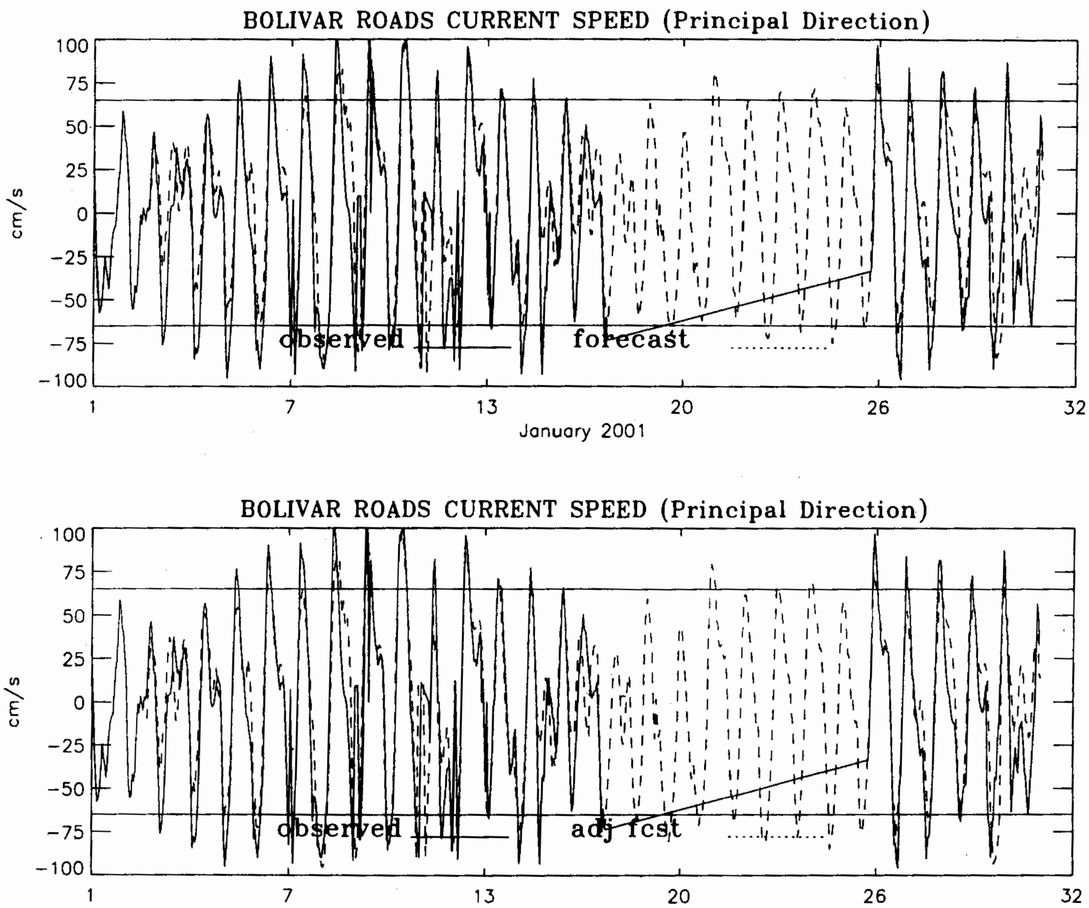


Figure 6.4. Bolivar Roads Principal Component Direction Prediction Depth Current Speed during January 2001: Level 3 Forecast and Adjusted Forecast (GBM0). Note observational data gaps are indicated by straight line segments.

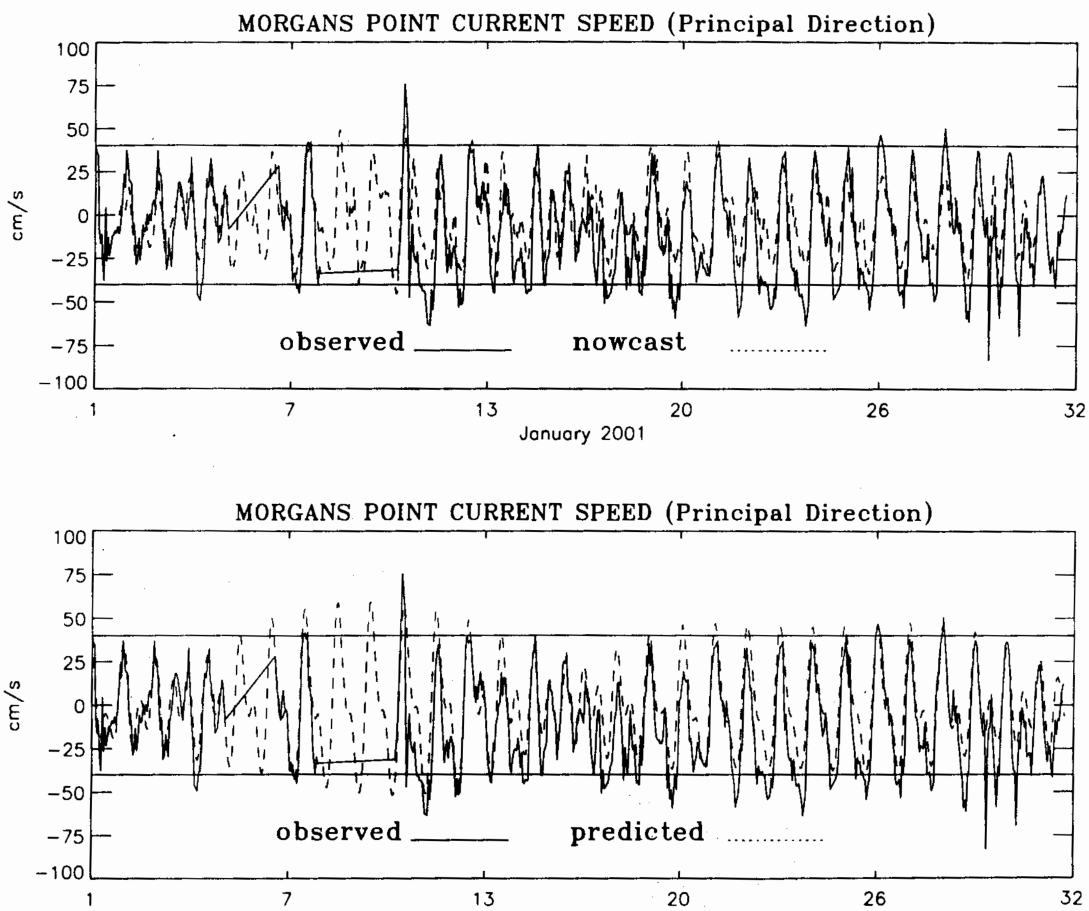


Figure 6.5. Morgans Point Principal Component Direction Prediction Depth Current Speed during January 2001: Level 1 Nowcast and Astronomical Tidal Current Prediction. Note observational data gaps are indicated by straight line segments.

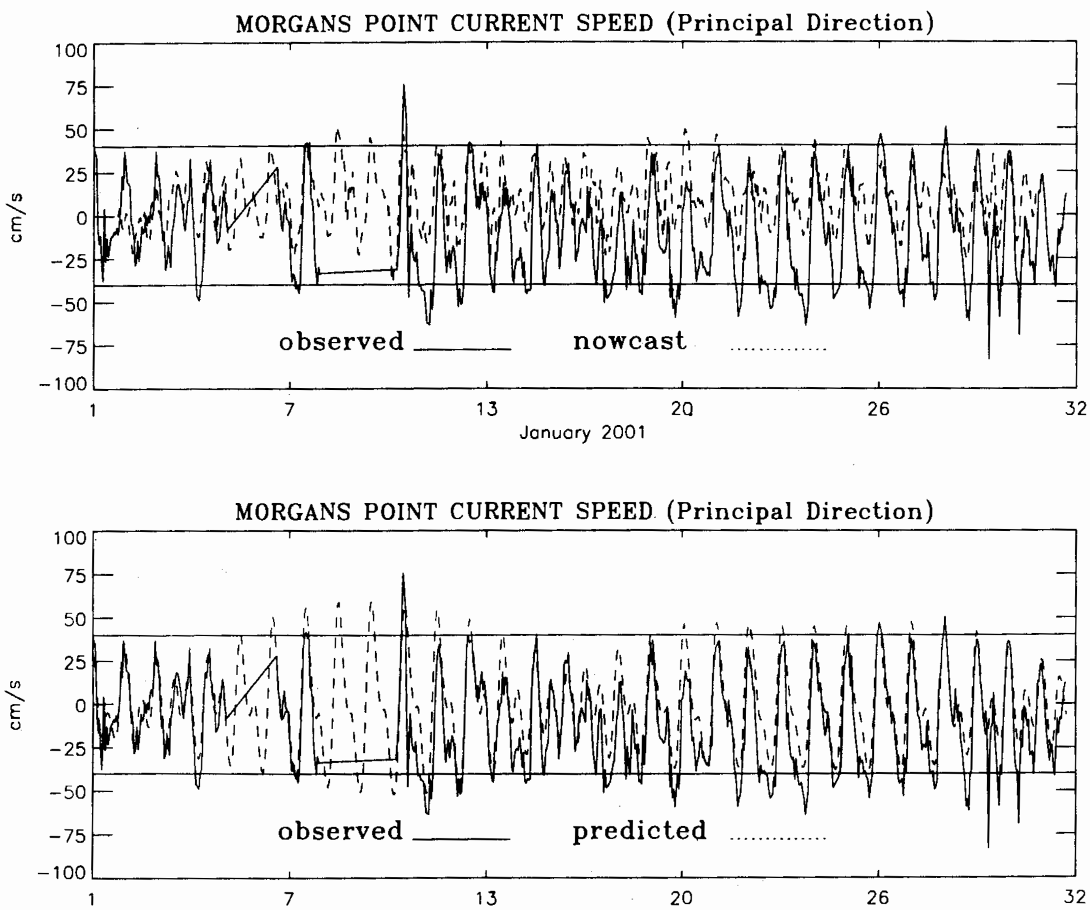


Figure 6.6. Morgans Point Principal Component Direction Prediction Depth Current Speed during January 2001: Level 3 Nowcast and Astronomical Tidal Current Prediction. Note observational data gaps are indicated by straight line segments

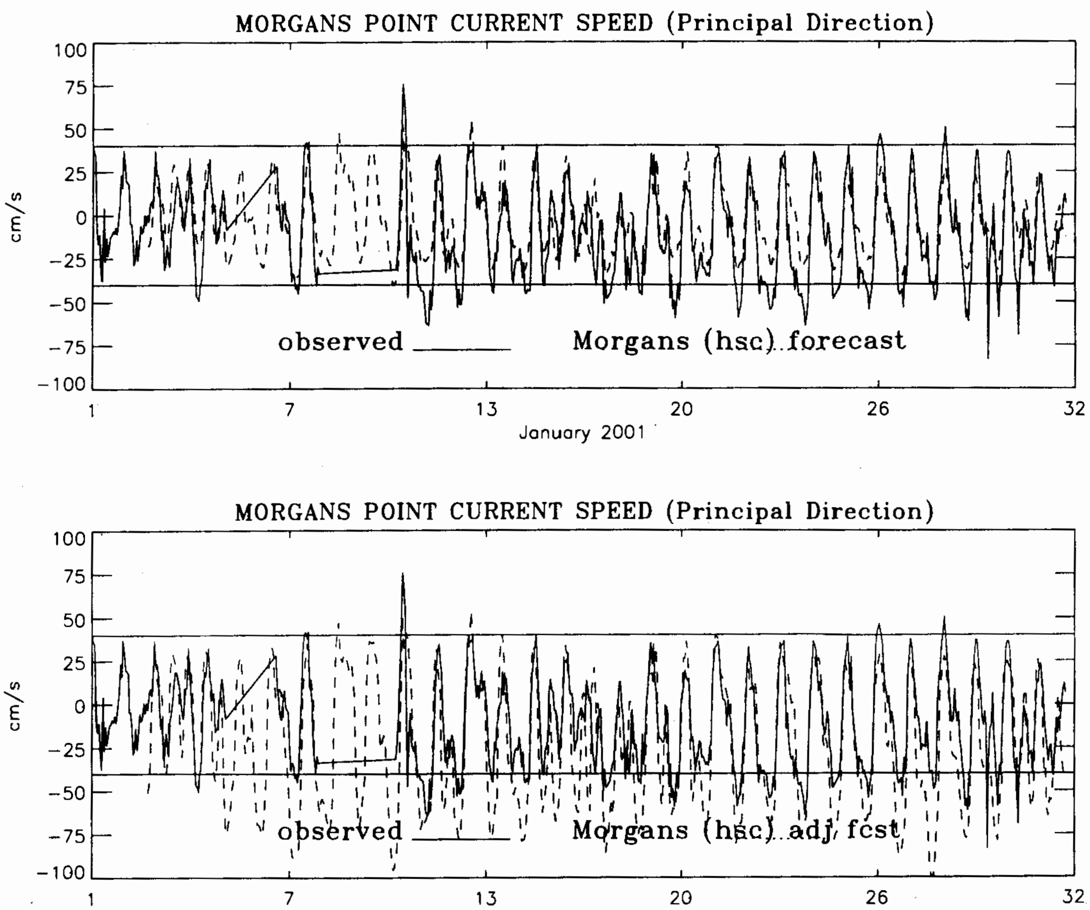


Figure 6.7. Morgans Point Principal Component Direction Prediction Depth Current Speed during January 2001: Level 1 Forecast and Adjusted Forecast (HSC1). Note observational data gaps are indicated by straight line segments.

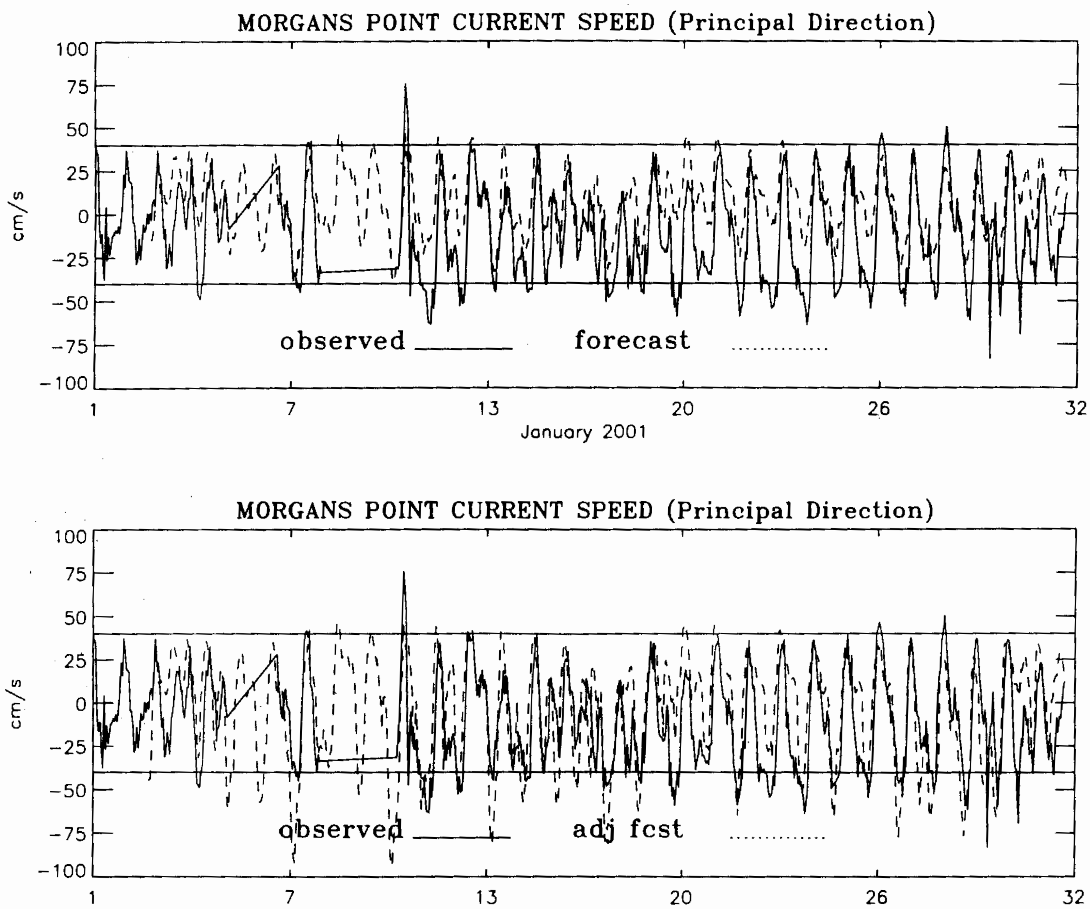
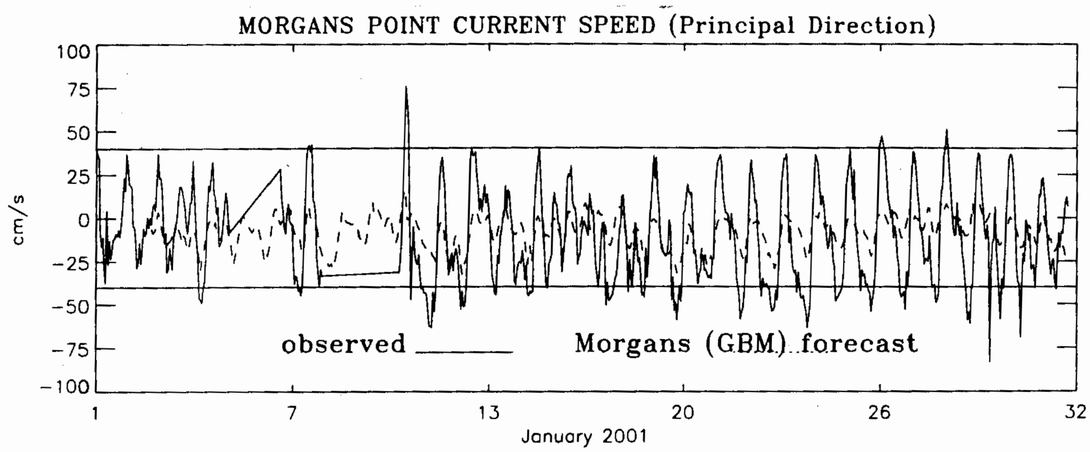


Figure 6.8. Morgans Point Principal Component Direction Prediction Depth Current Speed during January 2001: Level 3 Forecast and Adjusted Forecast (HSC1). Note observational data gaps are indicated by straight line segments



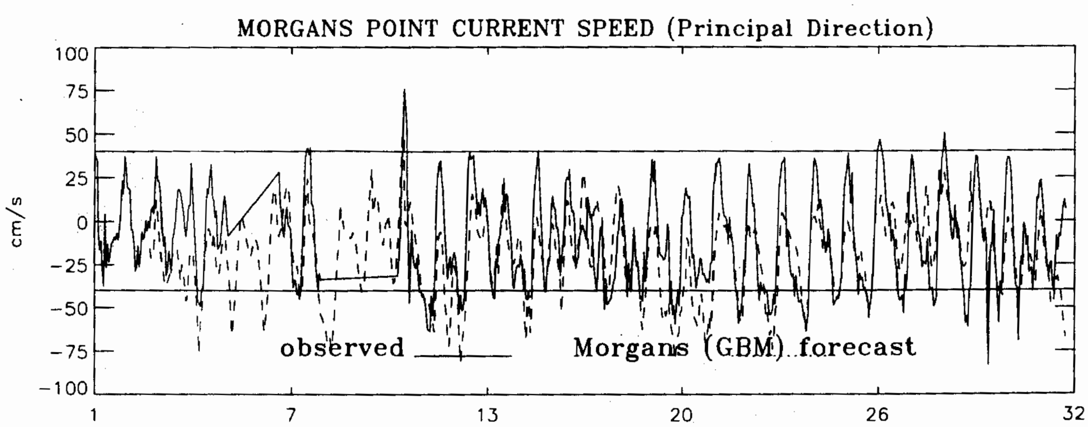


Figure 6.9. Morgans Point Principal Component Direction Prediction Depth Current Speed during January 2001: Level 1 Forecast and Adjusted Forecast (GBM2). Note observational data gaps are indicated by straight line segments.

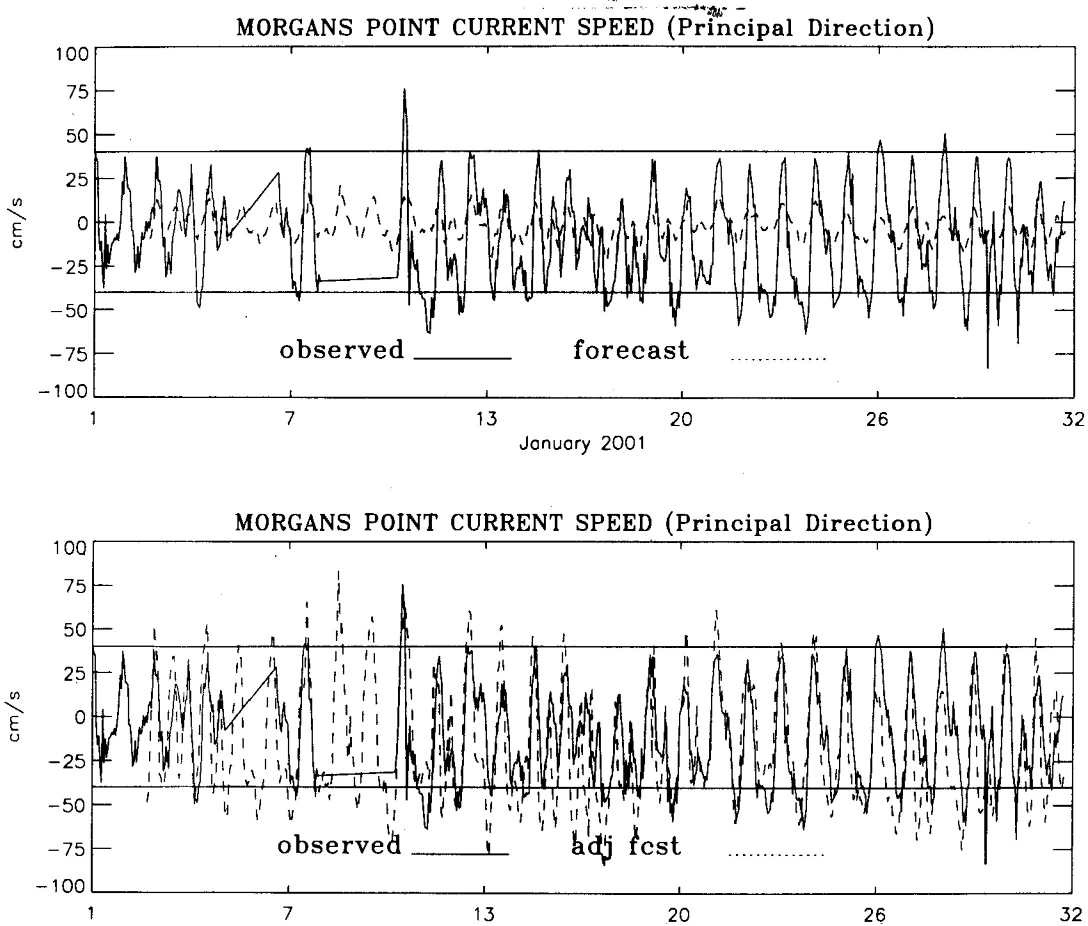


Figure 6.10. Morgans Point Principal Component Direction Prediction Depth Current Speed during January 2001: Level 3 Forecast and Adjusted Forecast (GBM2). Note observational data gaps are indicated by straight line segments.

7. CONCLUSIONS AND RECOMMENDATIONS

An experimental nowcast/forecast system has been developed and evaluated for Galveston Bay and the Houston Ship Channel. The experimental system has been formally evaluated over the one year period April 2000 through March 2001 using the NOS (1999) formal procedures. In general, the water surface elevation nowcast and forecast results meet or exceed the acceptance criteria for statistical measure sets 1 and 2, but do not meet statistical measure set 3 criteria especially for the timings of high and low waters. For principal component direction currents, the acceptance criteria are generally not met for all three statistical measure sets. As for water levels, the criteria for the timings of the zero crossings (slack before ebb and slack before flood), peak ebb, and peak flood currents are not met. However, the current forecast at Bolivar Roads for the GBM is superior to the tidal current prediction. At Morgans Point, the current forecast can be adjusted using linear regression to outperform the tidal current prediction on an event basis. Additional work is required to demonstrate that adjusted nowcast and forecast currents can meet the criteria for the three statistical measures.

Measurement issues include the CTD sensor biofouling and ADCP cabling problems. The biofouling has prevented (S,T) measurements to be made at a number of stations. The ADCP at the Redfish Bar station was removed and continued cable snagging both at Morgans Point and Bolivar Roads persisted. For an operational nowcast/forecast system, these two issues will need to be addressed. One possibility is to develop a statistical nowcasting method to fill in for missing station data. A second option, is to use horizontal ADCP mounted on channel markers and to employ improved antifouling sealants for the CTD sensor package.

Additional measurement requirements have been voiced by several potential operational system users. The Galveston and Texas City Pilots have requested an ADCP in the Texas City turning basin and outside the Galveston Bay Entrance jetties, while the Houston Pilots have requested an ADCP at the Port of Houston turning basin. In addition, water levels measured by the TCOON at Lynchburg Landing and Manchester Dock 2 have been requested to be incorporated within the PORTS.

From a modeling perpective, the following additional measurements are requested. Horizontal ADCPs for measuring velocity cross-sections at different locations along the channel are needed to define the density currents in the channel. Monthly or event triggered CTD surveys along the HSC are needed to locate the movement of the salt wedge.

The ADCP/CTD Houston Ship Channel survey measurements made in September 1999 indicated order 8 PSU stratification within the channel. The sigma coordinate representation of the channel employed in the GBM and HSCM cannot maintain this level of stratification. A generalized vertical coordinate or higher order horizontal differencing schemes may need to be considered to overcome the stratification limitation.

The USCG VTS has indicated a need to predict the lateral current shears produced during high inflow events associated with urban runoff within the Port of Houston. This would require a higher resolution model, which would include rainfall/runoff flows.

The hydrodynamic forecast is dependent on the NWS/AVN atmospheric, NWS/ETSS offshore subtidal water level, and NWS/WGRFC river forecasts. Therefore, it is necessary to monitor the accuracy of these forecast inputs on a continuing basis during operations (Richardson and Schmalz, 1999). Both long term and event based statistics are necessary and may be seasonally dependent and should be computed for the operational system.

During major events, alternate forcings may need to be considered. Higher resolution windfields would be used over the Bay during tropical storms and hurricane events. In addition, hourly flow forecasts would be used for the Trinity and San Jacinto Rivers to more accurately depict flood period hydrographs. In addition, for major rainfall events, a separate rainfall-runoff model for the City of Houston would be used to define the major inflows along the Port of Houston.

Of concern is the availability of current and density measurements to validate the three-dimensional models within the present experimental nowcast/forecast system. One approach towards alleviating this concern would be to broaden the PORTS system philosophy to include nonreal-time measurements. Several mobile instrument packs (Mobile-PORTS) might be incorporated to allow for the acquisition of additional data throughout the system in nonreal time. The basic real time navigational sensors (Navigational-PORTS) would be stationary and could of course be increased, but the mobile sensors would be used to continually obtain additional data and to assess future additional navigational sensor sites. As the model validation and PORTS mature, the Mobile-PORTS sensors would either migrate into the Navigational-PORTS or be discontinued for use elsewhere.

It is difficult to determine a set of statistics and acceptance levels for hydrodynamic model validation within the Experimental Galveston Bay Nowcast/Forecast System. As an alternative, it is useful to consider the NOS (1999) criteria as a set of initial statistical measures based on navigation user requirements used to define target levels for model validation. In this context, the validation of the hydrodynamic model is considered in terms of system performance measures. This allows an initial operational system to be developed with improvements in refined system performance directly assessed. Model validation in this context becomes model refinement/validation and is a continuing process.

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APPENDIX A: WATER LEVEL AND PRINCIPAL COMPONENT DIRECTION CURRENT HARMONIC ANALYSIS

A-1 – A-4: Galveston Bay Model Water Level Results
A-5 – A-6: Houston Ship Channel Model Water Level Results
A-7: Galveston Bay Model Principal Component Direction Current Results
A-8: Houston Ship Channel Model Principal Component Direction Current Results

Notes for the tables:

Refer to Table 2.2 and Table 2.6 for water level and current harmonic analysis periods, respectively. Phases are given in kappa prime. Gain and phases are weighted by observed constituent amplitudes and EST. RMS corresponds to the estimated root mean square error based on techniques used by Hess (1994).

CHRISTMAS BAY
677-2132

HARM29C	ELEVATION-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0420	239.00	0.03	192.60	0.0100	46.40
S(2)	0.0060	230.70	0.01	201.90	-.0007	28.80
N(2)	0.0070	209.30	0.01	181.96	0.0006	27.34
K(1)	0.0780	22.70	0.07	1.25	0.0030	21.45
M(4)	0.0020	218.90	0.00	247.89	-.0004	-28.99
O(1)	0.0810	19.00	0.07	358.04	0.0078	20.96
M(6)	0.0010	244.10	0.00	251.19	0.0007	-7.09
S(4)	0.0010	36.30	0.00	105.00	0.0007	-68.70
NU(2)	0.0010	213.30	0.00	173.02	-.0011	40.28
S(6)	0.0010	58.60	0.00	19.20	0.0010	39.40
MU(2)	0.0000	0.00	0.00	28.89	-.0015	-28.89
2N(2)	0.0010	179.70	0.00	237.83	-.0024	-58.13
OO(1)	0.0030	26.40	0.00	12.57	-.0019	13.83
LMD(2)	0.0000	235.20	0.00	215.87	-.0009	19.33
M(1)	0.0060	20.80	0.01	70.02	0.0002	-49.22
J(1)	0.0060	24.50	0.00	9.69	0.0045	14.81
RHO(1)	0.0030	17.40	0.00	334.87	-.0004	42.53
Q(1)	0.0160	17.10	0.01	342.31	0.0032	34.79
T2	0.0000	231.00	0.00	160.05	-.0006	70.95
2Q(1)	0.0020	15.30	0.00	60.47	-.0004	-45.17
P(1)	0.0260	22.40	0.02	3.25	0.0044	19.15
L(2)	0.0010	202.80	0.00	208.73	-.0020	-5.93
K(2)	0.0020	230.00	0.01	161.91	-.0044	68.09
M(8)	0.0000	280.60	0.00	263.28	0.0000	17.32

GAIN (-): 1.07
PHASE (HR): 1.27
EST. RMS (M): 0.04

ALLIGATOR POINT
877-1801

HARM29C	ELEVATION-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0430	193.20	0.03	192.60	0.0110	0.60
S(2)	0.0070	181.10	0.01	201.90	0.0003	-20.80
N(2)	0.0070	166.50	0.01	181.96	0.0006	-15.46
K(1)	0.0810	6.40	0.07	1.25	0.0060	5.15
M(4)	0.0010	175.20	0.00	247.89	-.0014	-72.69
O(1)	0.0840	359.90	0.07	358.04	0.0108	1.86
M(6)	0.0010	137.70	0.00	251.19	0.0007	-113.49
S(4)	0.0000	179.10	0.00	105.00	-.0003	74.10
NU(2)	0.0010	170.10	0.00	173.02	-.0011	-2.92
S(6)	0.0010	275.40	0.00	19.20	0.0010	-103.80
MU(2)	0.0000	0.00	0.00	28.89	-.0015	-28.89
2N(2)	0.0010	139.80	0.00	237.83	-.0024	-98.03
OO(1)	0.0040	12.90	0.00	12.57	-.0009	0.33
LMD(2)	0.0000	187.60	0.00	215.87	-.0009	-28.27
M(1)	0.0060	3.10	0.01	70.02	0.0002	-66.92
J(1)	0.0070	9.60	0.00	9.69	0.0055	-0.09
RHO(1)	0.0030	357.10	0.00	334.87	-.0004	22.23
Q(1)	0.0160	356.70	0.01	342.31	0.0032	14.39
T2	0.0000	181.60	0.00	160.05	-.0006	21.55
2Q(1)	0.0020	353.50	0.00	60.47	-.0004	-66.97
P(1)	0.0270	5.90	0.02	3.25	0.0054	2.65
L(2)	0.0010	160.00	0.00	208.73	-.0020	-48.73
K(2)	0.0020	180.10	0.01	161.91	-.0044	18.19
M(8)	0.0010	82.90	0.00	263.28	0.0010	179.62

GAIN (-): 1.10
PHASE (HR): -0.02
EST. RMS (M): 0.02

ROLLOVER PASS
877-0971

HARM29C	ELEVATION-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0600	128.20	0.06	204.00	0.0033	-75.80
S(2)	0.0130	105.60	0.02	197.30	-.0025	-91.70
N(2)	0.0130	106.60	0.01	177.36	-.0007	-70.76
K(1)	0.0810	336.30	0.12	3.05	-.0370	-26.75
M(4)	0.0020	253.70	0.01	343.49	-.0041	-89.79
O(1)	0.1000	341.20	0.11	0.34	-.0091	-19.14
M(6)	0.0020	97.00	0.00	46.39	0.0014	50.61
S(4)	0.0020	57.50	0.00	161.80	0.0008	-104.30
NU(2)	0.0030	109.50	0.00	153.62	0.0009	-44.12
S(6)	0.0020	288.70	0.00	68.00	0.0017	-139.30
MU(2)	0.0000	0.00	0.00	125.09	-.0027	-125.09
2N(2)	0.0020	85.10	0.00	10.13	0.0008	74.97
OO(1)	0.0040	331.40	0.01	15.77	-.0082	-44.37
LMD(2)	0.0000	117.70	0.00	36.07	-.0024	81.63
M(1)	0.0070	338.70	0.01	64.42	-.0061	-85.72
J(1)	0.0080	333.80	0.00	277.69	0.0065	56.11
RHO(1)	0.0040	343.30	0.00	37.17	0.0003	-53.87
Q(1)	0.0190	343.60	0.02	345.71	-.0002	-2.11
T2	0.0010	106.50	0.00	9.95	-.0008	96.55
2Q(1)	0.0030	346.10	0.01	125.27	-.0037	-139.17
P(1)	0.0270	336.70	0.04	350.25	-.0096	-13.55
L(2)	0.0020	100.10	0.00	226.73	-.0023	-126.63
K(2)	0.0040	103.80	0.01	241.21	-.0051	-137.41
M(8)	0.0030	61.90	0.00	115.48	0.0024	-53.58

GAIN (-): 0.83
PHASE (HR): -2.03
EST. RMS (M): 0.08

GALVESTON, GPS BUOY
877-1021

HARM29C	ELEVATION-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.1370	93.50	0.14	101.50	0.0020	-8.00
S(2)	0.0320	83.50	0.04	89.90	-.0050	-6.40
N(2)	0.0310	69.40	0.04	88.46	-.0100	-19.06
K(1)	0.1420	299.80	0.18	292.55	-.0350	7.25
M(4)	0.0080	211.20	0.00	234.89	0.0030	-23.69
O(1)	0.1460	302.10	0.17	301.24	-.0270	0.86
M(6)	0.0040	136.60	0.00	148.59	0.0020	-11.99
S(4)	0.0020	85.80	0.00	239.10	-.0010	-153.30
NU(2)	0.0060	72.70	0.01	90.22	-.0020	-17.52
S(6)	0.0040	309.70	0.00	24.20	0.0020	-74.50
MU(2)	0.0000	0.00	0.00	283.89	-.0030	76.11
2N(2)	0.0040	45.40	0.01	75.33	-.0020	-29.93
OO(1)	0.0060	297.60	0.01	283.87	-.0010	13.73
LMD(2)	0.0010	88.90	0.00	96.17	0.0000	-7.27
M(1)	0.0100	300.90	0.01	296.82	-.0020	4.08
J(1)	0.0120	298.70	0.01	288.29	-.0020	10.41
RHO(1)	0.0060	303.00	0.01	304.97	-.0010	-1.97
Q(1)	0.0280	303.20	0.03	305.51	-.0060	-2.31
T2	0.0020	83.90	0.00	90.35	0.0000	-6.45
2Q(1)	0.0040	304.30	0.00	309.77	-.0010	-5.47
P(1)	0.0470	300.00	0.06	293.15	-.0120	6.85
L(2)	0.0040	62.90	0.00	114.63	0.0000	-51.73
K(2)	0.0090	82.70	0.01	89.01	-.0010	-6.31
M(8)	0.0100	33.10	0.00	161.38	0.0080	-128.28

GAIN (-): 0.87
PHASE (HR): 0.04
EST. RMS (M): 0.04

GALVESTON PLEASURE PIER (677)
677-1510

HARM29C	ELEVATION-MODEL AMPL(m)	KPRIME	ACCEPTED VALUES AMPL(m)	KPRIME	DIFFERENCE AMPL(m)	KPRIME
M(2)	0.1410	91.90	0.13	100.90	0.0069	-9.00
S(2)	0.0330	85.50	0.03	93.00	0.0025	-7.50
N(2)	0.0320	68.50	0.03	86.46	-.0003	-17.96
K(1)	0.1400	297.00	0.17	298.45	-.0279	-1.45
M(4)	0.0090	205.10	0.01	212.99	0.0032	-7.89
O(1)	0.1430	298.80	0.15	297.04	-.0115	1.76
M(6)	0.0040	138.70	0.00	71.99	0.0028	66.71
S(4)	0.0020	90.50	0.00	10.40	0.0014	80.10
NU(2)	0.0060	71.70	0.01	80.22	-.0004	-8.52
S(6)	0.0040	305.00	0.00	77.30	0.0034	-132.30
MU(2)	0.0000	0.00	0.00	13.39	-.0046	-13.39
2N(2)	0.0040	45.20	0.01	56.63	-.0036	-11.43
OO(1)	0.0060	295.10	0.01	333.67	-.0013	-38.57
LMD(2)	0.0010	88.90	0.00	161.77	-.0002	-72.87
M(1)	0.0100	297.90	0.01	314.72	-.0031	-16.82
J(1)	0.0110	296.10	0.01	275.59	0.0006	20.51
RHO(1)	0.0050	299.60	0.01	297.17	-.0029	2.43
Q(1)	0.0280	299.70	0.03	284.41	-.0061	15.29
T2	0.0020	85.80	0.00	118.65	-.0023	-32.85
2Q(1)	0.0040	300.60	0.00	326.37	0.0025	-25.77
P(1)	0.0460	297.10	0.05	295.35	-.0034	1.75
L(2)	0.0050	62.00	0.00	141.43	0.0004	-79.43
K(2)	0.0090	85.00	0.00	92.91	0.0044	-7.91
M(8)	0.0100	32.50	0.00	93.68	0.0094	-61.18

GAIN (-): 0.96
PHASE (HR): -0.10
EST. RMS (M): 0.03

HIGH ISLAND
877-0923

HARM29C	ELEVATION-MODEL AMPL(m)	KPRIME	ACCEPTED VALUES AMPL(m)	KPRIME	DIFFERENCE AMPL(m)	KPRIME
M(2)	0.1510	99.80	0.16	98.60	-.0087	1.20
S(2)	0.0390	86.50	0.04	89.10	-.0052	-2.60
N(2)	0.0340	73.80	0.04	78.46	-.0041	-4.66
K(1)	0.1580	304.10	0.17	296.85	-.0130	7.25
M(4)	0.0090	222.20	0.01	231.69	0.0026	-9.49
O(1)	0.1660	305.50	0.16	295.64	0.0084	9.86
M(6)	0.0040	123.80	0.00	70.29	0.0022	53.51
S(4)	0.0020	61.50	0.00	357.10	-.0004	64.40
NU(2)	0.0070	77.30	0.00	75.62	0.0024	1.68
S(6)	0.0030	304.10	0.00	309.30	0.0021	-5.20
MU(2)	0.0000	0.00	0.00	17.99	-.0046	-17.99
2N(2)	0.0050	47.80	0.01	67.43	-.0029	-19.63
OO(1)	0.0070	302.70	0.01	311.37	0.0003	-8.67
LMD(2)	0.0010	93.60	0.00	295.97	-.0005	157.63
M(1)	0.0120	304.80	0.01	328.62	-.0020	-23.82
J(1)	0.0130	303.40	0.01	309.19	0.0060	-5.79
RHO(1)	0.0060	306.10	0.01	327.87	-.0010	-21.77
Q(1)	0.0320	306.20	0.03	285.61	-.0003	20.59
T2	0.0020	87.10	0.00	153.65	-.0026	-66.55
2Q(1)	0.0040	306.90	0.00	128.07	0.0034	178.83
P(1)	0.0520	304.20	0.05	289.55	0.0008	14.65
L(2)	0.0050	67.30	0.01	127.03	-.0029	-59.73
K(2)	0.0110	85.50	0.01	107.11	0.0022	-21.61
M(8)	0.0070	24.90	0.00	286.58	0.0067	98.32

GAIN (-): 0.98
PHASE (HR): 0.31
EST. RMS (M): 0.03

PORT BOLIVAR
677-1328

HARM29C	ELEVATION-MODEL AMPL(m)	KPRIME	ACCEPTED VALUES AMPL(m)	KPRIME	DIFFERENCE AMPL(m)	KPRIME
M(2)	0.0730	118.60	0.07	119.50	0.0062	-0.90
S(2)	0.0200	120.30	0.01	152.00	0.0102	-31.70
N(2)	0.0160	95.00	0.02	93.46	-.0032	1.54
K(1)	0.0920	332.20	0.11	333.75	-.0183	-1.55
M(4)	0.0050	218.40	0.00	89.49	0.0026	128.91
O(1)	0.1070	333.00	0.12	335.24	-.0100	-2.24
M(6)	0.0020	180.50	0.00	135.89	-.0001	44.61
S(4)	0.0020	90.10	0.00	102.70	0.0014	-12.60
NU(2)	0.0030	98.10	0.01	66.92	-.0022	31.18
S(6)	0.0030	357.40	0.00	120.30	0.0027	-122.90
MU(2)	0.0000	0.00	0.00	51.89	-.0015	-51.89
2N(2)	0.0020	71.30	0.00	22.83	-.0029	48.47
OO(1)	0.0050	331.50	0.02	9.57	-.0105	-38.07
LMD(2)	0.0010	119.40	0.01	270.57	-.0045	-151.17
M(1)	0.0080	332.60	0.01	341.82	-.0030	-9.22
J(1)	0.0080	331.90	0.00	349.09	0.0031	-17.19
RHO(1)	0.0040	333.30	0.01	312.37	-.0070	20.93
Q(1)	0.0210	333.40	0.03	317.61	-.0046	15.79
T2	0.0010	120.20	0.01	93.55	-.0048	26.65
2Q(1)	0.0030	333.70	0.00	115.77	-.0010	-142.07
P(1)	0.0300	332.30	0.04	356.05	-.0075	-23.75
L(2)	0.0020	88.40	0.00	220.73	-.0017	-132.33
K(2)	0.0050	120.40	0.02	176.21	-.0176	-55.81
M(8)	0.0040	108.10	0.00	213.58	0.0037	-105.48

GAIN (-): 0.86
PHASE (HR): -0.43
EST. RMS (M): 0.03

GALVESTON PIER 21 (677)
677-1450

HARM29C	ELEVATION-MODEL AMPL(m)	KPRIME	ACCEPTED VALUES AMPL(m)	KPRIME	DIFFERENCE AMPL(m)	KPRIME
M(2)	0.0800	117.70	0.08	122.40	-.0038	-4.70
S(2)	0.0200	117.80	0.02	117.70	-.0029	0.10
N(2)	0.0170	93.30	0.02	107.26	-.0043	-13.96
K(1)	0.0940	326.50	0.13	324.85	-.0346	1.65
M(4)	0.0060	227.80	0.00	268.99	0.0023	-41.19
O(1)	0.1070	329.40	0.12	322.64	-.0125	6.76
M(6)	0.0020	187.40	0.00	101.49	0.0011	85.91
S(4)	0.0020	130.70	0.00	20.00	0.0008	110.70
NU(2)	0.0030	96.50	0.00	100.12	-.0004	-3.62
S(6)	0.0030	4.10	0.00	105.20	0.0024	-101.10
MU(2)	0.0000	0.00	0.00	51.29	-.0037	-51.29
2N(2)	0.0020	68.90	0.01	41.83	-.0038	27.07
OO(1)	0.0050	323.70	0.01	1.07	-.0054	-37.37
LMD(2)	0.0010	117.70	0.00	112.87	0.0001	4.83
M(1)	0.0080	327.90	0.01	347.12	0.0004	-19.22
J(1)	0.0080	325.10	0.01	295.89	-.0011	29.21
RHO(1)	0.0040	330.60	0.01	334.77	-.0030	-4.17
Q(1)	0.0210	330.80	0.02	306.71	-.0034	24.09
T2	0.0010	117.80	0.00	111.85	-.0020	5.95
2Q(1)	0.0030	332.20	0.00	42.67	0.0012	-70.47
P(1)	0.0310	326.70	0.04	318.45	-.0083	8.25
L(2)	0.0020	86.70	0.00	234.73	0.0005	-148.03
K(2)	0.0050	117.80	0.00	192.41	0.0013	-74.61
M(8)	0.0060	110.10	0.00	193.88	0.0057	-83.78

GAIN (-): 0.85
PHASE (HR): 0.13
EST. RMS (M): 0.03

EAGLE POINT
677-1013

HARM29C	ELEVATION-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0410	224.70	0.03	204.60	0.0087	20.10
S(2)	0.0140	200.60	0.01	200.60	0.0036	0.00
N(2)	0.0070	202.00	0.01	183.26	-.0006	18.74
K(1)	0.0880	32.10	0.11	10.05	-.0214	22.05
M(4)	0.0010	306.40	0.00	220.89	-.0005	85.51
O(1)	0.0980	18.80	0.10	3.64	-.0038	15.16
M(6)	0.0010	252.60	0.00	243.09	0.0004	9.51
S(4)	0.0000	57.00	0.00	332.40	-.0003	84.60
NU(2)	0.0010	205.10	0.00	174.92	-.0002	30.18
S(6)	0.0010	136.90	0.00	208.90	0.0007	-72.00
MU(2)	0.0000	0.00	0.00	97.59	-.0024	-97.59
2N(2)	0.0010	179.40	0.00	7.43	-.0017	171.97
OO(1)	0.0040	45.40	0.01	15.37	-.0058	30.03
LMD(2)	0.0000	213.50	0.00	240.27	-.0006	-26.77
M(1)	0.0070	25.40	0.01	67.62	-.0031	-42.22
J(1)	0.0080	38.70	0.00	317.89	0.0040	80.81
RHO(1)	0.0040	13.10	0.01	1.47	-.0018	11.63
Q(1)	0.0190	12.30	0.02	354.41	-.0008	17.89
T2	0.0010	201.50	0.00	247.95	0.0004	-46.45
2Q(1)	0.0030	5.70	0.00	69.97	-.0010	-64.27
P(1)	0.0290	31.10	0.03	8.75	-.0024	22.35
L(2)	0.0010	195.50	0.00	280.13	-.0020	-84.63
K(2)	0.0040	198.60	0.01	259.41	-.0012	-60.81
M(8)	0.0010	245.60	0.00	15.28	0.0007	-129.68

GAIN (-): 0.91
PHASE (HR): 0.98
EST. RMS (M): 0.04

SMITH POINT
877-0931

HARM29C	ELEVATION-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0420	195.00	0.04	188.70	0.0012	6.30
S(2)	0.0120	179.00	0.01	163.50	0.0010	15.50
N(2)	0.0080	173.30	0.01	162.86	-.0045	10.44
K(1)	0.0840	20.80	0.10	353.85	-.0209	26.95
M(4)	0.0020	268.50	0.00	213.19	-.0007	55.31
O(1)	0.0970	9.50	0.12	359.44	-.0246	10.06
M(6)	0.0010	253.70	0.00	290.29	-.0027	-36.59
S(4)	0.0010	57.20	0.00	286.10	0.0007	131.10
NU(2)	0.0020	176.20	0.00	166.32	-.0004	9.88
S(6)	0.0010	90.30	0.00	73.40	-.0002	16.90
MU(2)	0.0000	0.00	0.00	24.39	-.0009	-24.39
2N(2)	0.0010	151.60	0.00	137.03	-.0005	14.57
OO(1)	0.0040	32.10	0.01	348.27	-.0012	43.83
LMD(2)	0.0000	187.50	0.00	177.07	-.0003	10.43
M(1)	0.0070	15.10	0.01	356.62	-.0015	18.48
J(1)	0.0080	26.40	0.01	351.09	-.0018	35.31
RHO(1)	0.0040	4.70	0.00	1.87	-.0006	2.83
Q(1)	0.0190	3.90	0.02	2.31	-.0048	1.59
T2	0.0010	179.60	0.00	164.55	0.0004	15.05
2Q(1)	0.0030	358.30	0.00	5.07	0.0000	-6.77
P(1)	0.0280	19.90	0.03	354.25	-.0067	25.65
L(2)	0.0010	166.80	0.00	214.63	-.0002	-47.83
K(2)	0.0030	177.70	0.00	161.51	0.0000	16.19
M(8)	0.0020	234.40	0.00	311.08	0.0002	-76.68

GAIN (-): 0.83
PHASE (HR): 1.01
EST. RMS (M): 0.04

TRINITY RIVER CH. PLT.
877-1021

HARM29C	ELEVATION-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0390	208.10	0.04	216.60	0.0040	-8.50
S(2)	0.0130	188.40	0.01	214.20	0.0030	-25.80
N(2)	0.0070	185.00	0.01	192.36	-.0020	-7.36
K(1)	0.0850	25.70	0.10	4.25	-.0160	21.45
M(4)	0.0010	266.70	0.00	257.49	-.0010	9.21
O(1)	0.0960	13.50	0.12	4.84	-.0200	8.66
M(6)	0.0010	248.00	0.00	282.79	0.0000	-34.79
S(4)	0.0000	62.00	0.00	187.50	-.0010	-125.50
NU(2)	0.0010	188.10	0.00	195.62	-.0010	-7.52
S(6)	0.0010	91.00	0.00	237.40	0.0000	-146.40
MU(2)	0.0000	0.00	0.00	29.29	-.0010	-29.29
2N(2)	0.0010	162.00	0.00	168.13	0.0000	-6.13
OO(1)	0.0040	37.80	0.00	3.77	-.0010	34.03
LMD(2)	0.0000	199.00	0.00	215.47	0.0000	-16.47
M(1)	0.0070	19.60	0.01	4.62	-.0010	14.98
J(1)	0.0080	31.70	0.01	3.99	-.0010	27.71
RHO(1)	0.0040	8.40	0.00	5.07	0.0000	3.33
Q(1)	0.0190	7.50	0.02	5.11	-.0040	2.39
T2	0.0010	189.20	0.00	214.25	0.0000	-25.05
2Q(1)	0.0030	1.50	0.00	5.37	0.0000	-3.87
P(1)	0.0280	24.70	0.03	4.35	-.0050	20.35
L(2)	0.0010	178.50	0.00	240.73	0.0000	-62.23
K(2)	0.0030	186.80	0.00	214.01	0.0000	-27.21
M(8)	0.0010	220.20	0.00	0.48	0.0000	-140.28

GAIN (-): 0.87
PHASE (HR): 0.72
EST. RMS (M): 0.03

ROUND POINT
877-0559

HARM29C	ELEVATION-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0550	227.00	0.06	238.00	-.0041	-11.00
S(2)	0.0120	217.90	0.01	222.60	-.0020	-4.70
N(2)	0.0100	207.20	0.01	232.26	-.0016	-25.06
K(1)	0.1000	36.80	0.14	25.25	-.0393	11.55
M(4)	0.0030	339.60	0.00	356.79	-.0013	-17.19
O(1)	0.1020	20.90	0.12	4.84	-.0138	16.06
M(6)	0.0020	32.50	0.00	197.19	0.0011	-164.69
S(4)	0.0000	49.50	0.00	231.90	-.0037	177.60
NU(2)	0.0020	209.80	0.00	233.02	-.0001	-23.22
S(6)	0.0010	21.40	0.00	38.00	-.0002	-16.60
MU(2)	0.0000	0.00	0.00	63.99	-.0015	-63.99
2N(2)	0.0010	187.40	0.00	226.53	-.0005	-39.13
OO(1)	0.0040	52.70	0.00	45.77	-.0009	6.93
LMD(2)	0.0000	222.80	0.00	230.87	-.0003	-8.07
M(1)	0.0070	28.80	0.01	15.12	-.0012	13.68
J(1)	0.0080	44.70	0.01	35.39	-.0011	9.31
RHO(1)	0.0040	14.00	0.00	355.97	-.0003	18.03
Q(1)	0.0200	13.00	0.02	354.61	-.0026	18.39
T2	0.0010	218.30	0.00	223.15	0.0001	-4.85
2Q(1)	0.0030	5.10	0.00	344.47	0.0000	20.63
P(1)	0.0330	35.60	0.05	23.75	-.0130	11.85
L(2)	0.0010	200.60	0.00	243.73	-.0005	-43.13
K(2)	0.0030	217.20	0.00	221.31	-.0010	-4.11
M(8)	0.0010	26.90	0.00	183.38	-.0005	-156.48

GAIN (-): 0.81
PHASE (HR): 0.64
EST. RMS (M): 0.04

MORGANS POINT
677-0613

HARM29C	ELEVATION-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0510	237.00	0.05	252.80	-.0029	-15.80
S(2)	0.0150	211.20	0.01	233.30	0.0016	-22.10
N(2)	0.0090	216.10	0.01	237.06	-.0029	-20.96
K(1)	0.1130	35.90	0.12	24.55	-.0101	11.35
M(4)	0.0010	330.60	0.00	3.69	0.0004	-33.09
O(1)	0.1030	21.10	0.11	17.34	-.0110	3.76
M(6)	0.0010	268.80	0.00	244.09	0.0007	24.71
S(4)	0.0000	51.20	0.00	356.80	-.0006	54.40
NU(2)	0.0020	218.90	0.00	247.42	-.0007	-28.52
S(6)	0.0010	202.50	0.00	78.20	0.0007	124.30
MU(2)	0.0000	0.00	0.00	115.09	-.0034	-115.09
2N(2)	0.0010	195.10	0.00	334.63	-.0033	-139.53
OO(1)	0.0040	50.70	0.01	24.27	-.0070	26.43
LMD(2)	0.0000	225.00	0.00	292.47	-.0006	-67.47
M(1)	0.0070	28.50	0.01	76.22	-.0058	-47.72
J(1)	0.0080	43.30	0.00	313.49	0.0046	89.81
RHO(1)	0.0040	14.70	0.01	359.87	-.0036	14.83
Q(1)	0.0200	13.70	0.02	7.41	-.0029	6.29
T2	0.0010	212.20	0.00	276.85	-.0008	-64.65
2Q(1)	0.0030	6.40	0.01	74.87	-.0025	-68.47
P(1)	0.0380	34.80	0.04	24.45	0.0026	10.35
L(2)	0.0010	209.60	0.01	288.93	-.0048	-79.33
K(2)	0.0040	209.10	0.01	270.81	-.0067	-61.71
M(8)	0.0020	355.30	0.00	129.98	0.0017	-134.68

GAIN (-): 0.87
PHASE (HR): 0.01
EST. RMS (M): 0.03

UMBRELLA POINT
877-0625

HARM29C	ELEVATION-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0700	258.10	0.05	252.80	0.0161	5.30
S(2)	0.0210	234.20	0.01	233.30	0.0076	0.90
N(2)	0.0120	238.50	0.01	237.06	0.0001	1.44
K(1)	0.1330	42.70	0.12	24.55	0.0092	18.15
M(4)	0.0010	78.40	0.00	3.69	0.0004	74.71
O(1)	0.1100	27.00	0.11	17.34	-.0040	9.66
M(6)	0.0000	275.00	0.00	244.09	-.0003	30.91
S(4)	0.0010	140.70	0.00	356.80	0.0004	143.90
NU(2)	0.0020	241.10	0.00	247.42	-.0007	-6.32
S(6)	0.0000	85.00	0.00	78.20	-.0003	6.80
MU(2)	0.0000	0.00	0.00	115.09	-.0034	-115.09
2N(2)	0.0020	218.90	0.00	334.63	-.0023	-115.73
OO(1)	0.0050	58.50	0.01	24.27	-.0060	34.23
LMD(2)	0.0000	247.00	0.00	292.47	-.0006	-45.47
M(1)	0.0080	34.80	0.01	76.22	-.0048	-41.42
J(1)	0.0090	50.60	0.00	313.49	0.0056	97.11
RHO(1)	0.0040	20.20	0.01	359.87	-.0036	20.33
Q(1)	0.0210	19.10	0.02	7.41	-.0019	11.69
T2	0.0010	235.20	0.00	276.85	-.0008	-41.65
2Q(1)	0.0030	11.30	0.01	74.87	-.0025	-63.57
P(1)	0.0440	41.60	0.04	24.45	0.0086	17.15
L(2)	0.0020	232.00	0.01	288.93	-.0038	-56.93
K(2)	0.0060	232.30	0.01	270.81	-.0047	-38.51
M(8)	0.0010	15.80	0.00	129.98	0.0007	-114.18

GAIN (-): 1.02
PHASE (HR): 0.52
EST. RMS (M): 0.04

LYNCHBURG LANDING
877-0733

HARM29C	ELEVATION-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0820	261.30	0.08	273.70	0.0040	-12.40
S(2)	0.0270	237.50	0.03	254.40	0.0020	-16.90
N(2)	0.0130	241.50	0.01	251.60	0.0020	-10.10
K(1)	0.1410	44.10	0.16	44.30	-.0190	-0.20
M(4)	0.0030	69.10	0.00	265.00	0.0020	164.10
O(1)	0.1150	27.10	0.13	23.60	-.0110	3.50
M(6)	0.0010	82.80	0.00	175.10	0.0000	-92.30
S(4)	0.0020	133.00	0.00	52.50	0.0010	80.50
NU(2)	0.0030	244.10	0.00	254.60	0.0010	-10.50
S(6)	0.0010	29.30	0.00	304.80	0.0000	84.50
MU(2)	0.0000	0.00	0.00	0.00	0.0000	0.00
2N(2)	0.0020	221.60	0.00	229.60	0.0010	-8.00
OO(1)	0.0050	61.00	0.00	65.00	0.0000	-4.00
LMD(2)	0.0010	250.30	0.00	264.70	0.0000	-14.40
M(1)	0.0080	35.60	0.01	33.90	-.0010	1.70
J(1)	0.0090	52.50	0.01	54.50	-.0010	-2.00
RHO(1)	0.0040	19.80	0.00	14.70	-.0010	5.10
Q(1)	0.0220	18.70	0.03	13.40	-.0030	5.30
T2	0.0020	238.50	0.00	255.20	0.0010	-16.70
2Q(1)	0.0030	10.30	0.00	3.10	0.0000	7.20
P(1)	0.0470	42.80	0.05	42.70	-.0060	0.10
L(2)	0.0020	234.90	0.00	245.10	0.0000	-10.20
K(2)	0.0070	235.60	0.01	252.80	0.0000	-17.20
M(8)	0.0010	208.60	0.00	58.40	0.0000	150.20

GAIN (-): 0.95
PHASE (HR): -0.02
EST. RMS (M): 0.02

MANCHESTER HOUSTON
877-0777

HARM29C	ELEVATION-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0510	228.40	0.09	273.90	-.0410	-45.50
S(2)	0.0130	203.20	0.02	278.60	-.0040	-75.40
N(2)	0.0090	209.00	0.03	260.10	-.0160	-51.10
K(1)	0.1050	36.00	0.17	34.60	-.0610	1.40
M(4)	0.0020	331.60	0.01	79.40	-.0040	-107.80
O(1)	0.1020	20.50	0.12	31.40	-.0230	-10.90
M(6)	0.0010	16.30	0.00	241.20	-.0010	135.10
S(4)	0.0010	40.10	0.00	103.40	-.0010	-63.30
NU(2)	0.0020	211.60	0.00	262.00	-.0030	-50.40
S(6)	0.0000	172.30	0.00	96.90	-.0040	75.40
MU(2)	0.0000	0.00	0.00	0.00	0.0000	0.00
2N(2)	0.0010	189.70	0.00	246.40	-.0020	-56.70
OO(1)	0.0040	51.50	0.00	37.80	-.0010	13.70
LMD(2)	0.0000	216.70	0.00	276.00	-.0010	-59.30
M(1)	0.0070	28.30	0.01	32.90	-.0020	-4.60
J(1)	0.0080	43.70	0.01	36.20	-.0020	7.50
RHO(1)	0.0040	13.90	0.00	30.00	-.0010	-16.10
Q(1)	0.0200	12.90	0.02	29.70	-.0040	-16.80
T2	0.0010	204.20	0.00	278.40	0.0000	-74.20
2Q(1)	0.0030	5.20	0.00	28.10	0.0000	-22.90
P(1)	0.0350	34.90	0.05	34.30	-.0200	0.60
L(2)	0.0010	202.50	0.00	253.60	-.0030	-51.10
K(2)	0.0040	201.20	0.00	278.90	-.0010	-77.70
M(8)	0.0010	322.50	0.00	23.20	-.0010	-60.70

GAIN (-): 0.66
PHASE (HR): -0.69
EST. RMS (M): 0.07

GALVESTON PIER 21 (677)
677-1450

HARM29C	ELEVATION-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0830	115.50	0.08	122.40	-.0008	-6.90
S(2)	0.0210	116.40	0.02	117.70	-.0019	-1.30
N(2)	0.0180	91.20	0.02	107.26	-.0033	-16.06
K(1)	0.0980	325.30	0.13	324.85	-.0306	0.45
M(4)	0.0070	223.40	0.00	268.99	0.0033	-45.59
O(1)	0.1090	327.80	0.12	322.64	-.0105	5.16
M(6)	0.0020	190.40	0.00	101.49	0.0011	88.91
S(4)	0.0020	120.60	0.00	20.00	0.0008	100.60
NU(2)	0.0030	94.50	0.00	100.12	-.0004	-5.62
S(6)	0.0030	3.80	0.00	105.20	0.0024	-101.40
MU(2)	0.0000	0.00	0.00	51.29	-.0037	-51.29
2N(2)	0.0020	67.00	0.01	41.83	-.0038	25.17
OO(1)	0.0050	322.80	0.01	1.07	-.0054	-38.27
LMD(2)	0.0010	115.90	0.00	112.87	0.0001	3.03
M(1)	0.0080	326.50	0.01	347.12	0.0004	-20.62
J(1)	0.0090	324.00	0.01	295.89	-.0001	28.11
RHO(1)	0.0040	328.80	0.01	334.77	-.0030	-5.97
Q(1)	0.0210	329.00	0.02	306.71	-.0034	22.29
T2	0.0010	116.30	0.00	111.85	-.0020	4.45
2Q(1)	0.0030	330.20	0.00	42.67	0.0012	-72.47
P(1)	0.0320	325.50	0.04	318.45	-.0073	7.05
L(2)	0.0030	84.70	0.00	234.73	0.0015	-150.03
K(2)	0.0060	116.40	0.00	192.41	0.0023	-76.01
M(8)	0.0050	103.10	0.00	193.88	0.0047	-90.78

GAIN (-): 0.88
PHASE (HR): 0.04
EST. RMS (M): 0.03

PORT BOLIVAR
677-1328

HARM29C	ELEVATION-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0780	113.90	0.07	119.50	0.0112	-5.60
S(2)	0.0210	116.80	0.01	152.00	0.0112	-35.20
N(2)	0.0170	90.50	0.02	93.46	-.0022	-2.96
K(1)	0.0960	328.00	0.11	333.75	-.0143	-5.75
M(4)	0.0050	223.40	0.00	89.49	0.0026	133.91
O(1)	0.1100	329.50	0.12	335.24	-.0070	-5.74
M(6)	0.0030	184.00	0.00	135.89	0.0009	48.11
S(4)	0.0020	92.60	0.00	102.70	0.0014	-10.10
NU(2)	0.0030	93.70	0.01	66.92	-.0022	26.78
S(6)	0.0030	351.70	0.00	120.30	0.0027	-128.60
MU(2)	0.0000	0.00	0.00	51.89	-.0015	-51.89
2N(2)	0.0020	67.20	0.00	22.83	-.0029	44.37
OO(1)	0.0050	326.60	0.02	9.57	-.0105	-42.97
LMD(2)	0.0010	115.20	0.01	270.57	-.0045	-155.37
M(1)	0.0080	328.70	0.01	341.82	-.0030	-13.12
J(1)	0.0090	327.30	0.00	349.09	0.0041	-21.79
RHO(1)	0.0040	330.10	0.01	312.37	-.0070	17.73
Q(1)	0.0210	330.20	0.03	317.61	-.0046	12.59
T2	0.0010	116.70	0.01	93.55	-.0048	23.15
2Q(1)	0.0030	330.90	0.00	115.77	-.0010	-144.87
P(1)	0.0320	328.10	0.04	356.05	-.0055	-27.95
L(2)	0.0020	84.00	0.00	220.73	-.0017	-136.73
K(2)	0.0060	117.10	0.02	176.21	-.0166	-59.11
M(8)	0.0050	90.70	0.00	213.58	0.0047	-122.88

GAIN (-): 0.90
PHASE (HR): -0.66
EST. RMS (M): 0.03

EAGLE POINT
677-1013

HARM29C	ELEVATION-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0370	218.20	0.03	204.60	0.0047	13.60
S(2)	0.0130	194.90	0.01	200.60	0.0026	-5.70
N(2)	0.0070	190.40	0.01	183.26	-.0006	7.14
K(1)	0.0870	29.50	0.11	10.05	-.0224	19.45
M(4)	0.0000	317.70	0.00	220.89	-.0015	96.81
O(1)	0.0980	16.30	0.10	3.64	-.0038	12.66
M(6)	0.0010	243.80	0.00	243.09	0.0004	0.71
S(4)	0.0010	56.10	0.00	332.40	0.0007	83.70
NU(2)	0.0010	194.20	0.00	174.92	-.0002	19.28
S(6)	0.0010	106.30	0.00	208.90	0.0007	-102.60
MU(2)	0.0000	0.00	0.00	97.59	-.0024	-97.59
2N(2)	0.0010	162.60	0.00	7.43	-.0017	155.17
OO(1)	0.0040	42.70	0.01	15.37	-.0058	27.33
LMD(2)	0.0000	207.40	0.00	240.27	-.0006	-32.87
M(1)	0.0070	22.80	0.01	67.62	-.0031	-44.82
J(1)	0.0080	36.00	0.00	317.89	0.0040	78.11
RHO(1)	0.0040	10.60	0.01	1.47	-.0018	9.13
Q(1)	0.0190	9.70	0.02	354.41	-.0008	15.29
T2	0.0010	195.80	0.00	247.95	0.0004	-52.15
2Q(1)	0.0030	3.20	0.00	69.97	-.0010	-66.77
P(1)	0.0290	28.50	0.03	8.75	-.0024	19.75
L(2)	0.0010	183.90	0.00	280.13	-.0020	-96.23
K(2)	0.0040	193.00	0.01	259.41	-.0012	-66.41
M(8)	0.0010	226.10	0.00	15.28	0.0007	-149.18

GAIN (-): 0.90
PHASE (HR): 0.79
EST. RMS (M): 0.04

MORGANS POINT
677-0613

HARM29C	ELEVATION-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0510	237.60	0.05	252.80	-.0029	-15.20
S(2)	0.0150	209.80	0.01	233.30	0.0016	-23.50
N(2)	0.0090	217.90	0.01	237.06	-.0029	-19.16
K(1)	0.1140	37.30	0.12	24.55	-.0091	12.75
M(4)	0.0010	347.70	0.00	3.69	0.0004	-15.99
O(1)	0.1030	22.10	0.11	17.34	-.0110	4.76
M(6)	0.0010	275.20	0.00	244.09	0.0007	31.11
S(4)	0.0010	65.40	0.00	356.80	0.0004	68.60
NU(2)	0.0020	220.50	0.00	247.42	-.0007	-26.92
S(6)	0.0010	207.00	0.00	78.20	0.0007	128.80
MU(2)	0.0000	0.00	0.00	115.09	-.0034	-115.09
2N(2)	0.0010	198.20	0.00	334.63	-.0033	-136.43
OO(1)	0.0040	52.60	0.01	24.27	-.0070	28.33
LMD(2)	0.0000	224.70	0.00	292.47	-.0006	-67.77
M(1)	0.0070	29.70	0.01	76.22	-.0058	-46.52
J(1)	0.0080	44.90	0.00	313.49	0.0046	91.41
RHO(1)	0.0040	15.60	0.01	359.87	-.0036	15.73
Q(1)	0.0200	14.60	0.02	7.41	-.0029	7.19
T2	0.0010	210.90	0.00	276.85	-.0008	-65.95
2Q(1)	0.0030	7.00	0.01	74.87	-.0025	-67.87
P(1)	0.0380	36.20	0.04	24.45	0.0026	11.75
L(2)	0.0010	211.40	0.01	288.93	-.0048	-77.53
K(2)	0.0040	207.50	0.01	270.81	-.0067	-63.31
M(8)	0.0010	359.90	0.00	129.98	0.0007	-130.08

GAIN (-): 0.87
PHASE (HR): 0.08
EST. RMS (M): 0.03

MANCHESTER HOUSTON
877-0777

HARM29C	ELEVATION-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0700	251.00	0.09	273.90	-.0220	-22.90
S(2)	0.0220	225.10	0.02	278.60	0.0050	-53.50
N(2)	0.0130	229.60	0.03	260.10	-.0120	-30.50
K(1)	0.1350	42.10	0.17	34.60	-.0310	7.50
M(4)	0.0040	51.90	0.01	79.40	-.0020	-27.50
O(1)	0.1120	25.70	0.12	31.40	-.0130	-5.70
M(6)	0.0020	83.30	0.00	241.20	0.0000	-157.90
S(4)	0.0030	94.50	0.00	103.40	0.0010	-8.90
NU(2)	0.0020	232.40	0.00	262.00	-.0030	-29.60
S(6)	0.0030	31.00	0.00	96.90	-.0010	-65.90
MU(2)	0.0000	0.00	0.00	0.00	0.0000	0.00
2N(2)	0.0020	208.10	0.00	246.40	-.0010	-38.30
OO(1)	0.0050	58.50	0.00	37.80	0.0000	20.70
LMD(2)	0.0000	239.00	0.00	276.00	-.0010	-37.00
M(1)	0.0080	33.90	0.01	32.90	-.0010	1.00
J(1)	0.0090	50.30	0.01	36.20	-.0010	14.10
RHO(1)	0.0040	18.70	0.00	30.00	-.0010	-11.30
Q(1)	0.0220	17.60	0.02	29.70	-.0020	-12.10
T2	0.0010	226.20	0.00	278.40	0.0000	-52.20
2Q(1)	0.0030	9.50	0.00	28.10	0.0000	-18.60
P(1)	0.0450	40.90	0.05	34.30	-.0100	6.60
L(2)	0.0020	223.00	0.00	253.60	-.0020	-30.60
K(2)	0.0060	223.00	0.00	278.90	0.0010	-55.90
M(8)	0.0020	279.30	0.00	23.20	0.0000	-103.90

GAIN (-): 0.83
PHASE (HR): -0.22
EST. RMS (M): 0.04

LYNCHBURG LANDING
877-0733

HARM29C	ELEVATION-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0620	248.00	0.08	273.70	-.0160	-25.70
S(2)	0.0180	222.30	0.03	254.40	-.0070	-32.10
N(2)	0.0110	227.00	0.01	251.60	0.0000	-24.60
K(1)	0.1290	41.10	0.16	44.30	-.0310	-3.20
M(4)	0.0020	44.50	0.00	265.00	0.0010	139.50
O(1)	0.1080	25.00	0.13	23.60	-.0180	1.40
M(6)	0.0000	342.60	0.00	175.10	-.0010	167.50
S(4)	0.0020	98.30	0.00	52.50	0.0010	45.80
NU(2)	0.0020	229.80	0.00	254.60	0.0000	-24.80
S(6)	0.0000	333.90	0.00	304.80	-.0010	29.10
MU(2)	0.0000	0.00	0.00	0.00	0.0000	0.00
2N(2)	0.0010	206.10	0.00	229.60	0.0000	-23.50
OO(1)	0.0050	57.10	0.00	65.00	0.0000	-7.90
LMD(2)	0.0000	236.10	0.00	264.70	-.0010	-28.60
M(1)	0.0080	33.00	0.01	33.90	-.0010	-0.90
J(1)	0.0080	49.00	0.01	54.50	-.0020	-5.50
RHO(1)	0.0040	18.20	0.00	14.70	-.0010	3.50
Q(1)	0.0210	17.10	0.03	13.40	-.0040	3.70
T2	0.0010	223.30	0.00	255.20	0.0000	-31.90
2Q(1)	0.0030	9.10	0.00	3.10	0.0000	6.00
P(1)	0.0430	39.90	0.05	42.70	-.0100	-2.80
L(2)	0.0020	220.50	0.00	245.10	0.0000	-24.60
K(2)	0.0050	220.20	0.01	252.80	-.0020	-32.60
M(8)	0.0010	96.20	0.00	58.40	0.0000	37.80

GAIN (-): 0.82
PHASE (HR): -0.27
EST. RMS (M): 0.04

HSC SECNDRY (GB-M)
HSC SECO

HARM29C PD	CURRENT-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(cm/s)	KPRIME	AMPL(cm/s)	KPRIME	AMPL(cm/s)	KPRIME
M(2)	31.43	128.00	26.70	135.30	4.73	-7.30
S(2)	9.57	126.50	11.47	116.70	-1.90	9.80
N(2)	5.86	102.30	7.77	85.50	-1.90	16.80
K(1)	39.97	304.60	45.47	288.10	-5.50	16.50
M(4)	2.83	227.60	3.76	220.70	-0.93	6.90
O(1)	39.09	295.70	43.78	280.80	-4.68	14.90
M(6)	0.57	203.10	0.87	256.20	-0.31	-53.10
S(4)	0.26	200.20	1.29	287.30	-1.03	-87.10
NU(2)	1.13	105.80	1.49	92.20	-0.36	13.60
S(6)	0.77	26.20	0.57	178.80	0.21	-152.60
MU(2)	0.00	0.00	0.00	0.00	0.00	0.00
2N(2)	0.77	76.70	1.03	35.70	-0.26	41.00
OO(1)	1.70	313.40	1.90	295.50	-0.21	17.90
LMD(2)	0.21	127.30	0.21	126.70	0.00	0.60
M(1)	2.78	300.10	3.09	284.40	-0.31	15.70
J(1)	3.09	309.00	3.45	291.80	-0.36	17.20
RHO(1)	1.49	291.90	1.65	277.60	-0.15	14.30
Q(1)	7.61	291.30	8.49	277.10	-0.87	14.20
T2	0.57	126.60	0.67	117.40	-0.10	9.20
2Q(1)	1.03	286.90	1.13	273.50	-0.10	13.40
P(1)	13.22	303.90	15.02	287.60	-1.80	16.30
L(2)	0.82	95.80	1.13	79.00	-0.31	16.80
K(2)	2.62	126.40	3.14	115.20	-0.51	11.20
M(8)	1.08	101.50	0.72	328.80	0.36	132.70

GAIN (-): 0.91
PHASE (HR): 0.75
EST. RMS (CMS): 14.19

BOLIVAR ROADS -- (GB-M)
BOLIVAR

HARM29C PD	CURRENT-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(cm/s)	KPRIME	AMPL(cm/s)	KPRIME	AMPL(cm/s)	KPRIME
M(2)	32.61	131.20	38.73	136.20	-6.12	-5.00
S(2)	10.44	121.80	12.96	119.70	-2.52	2.10
N(2)	5.14	103.60	7.72	102.30	-2.57	1.30
K(1)	41.92	304.90	58.69	299.00	-16.77	5.90
M(4)	2.37	228.30	3.34	233.60	-0.98	-5.30
O(1)	40.59	293.40	50.26	282.90	-9.67	10.50
M(6)	0.62	196.10	0.51	213.30	0.10	-17.20
S(4)	0.21	161.30	0.62	33.80	-0.41	127.50
NU(2)	0.98	107.30	1.49	106.90	-0.51	0.40
S(6)	0.82	15.50	0.36	280.50	0.46	95.00
MU(2)	0.00	0.00	0.00	0.00	0.00	0.00
2N(2)	0.67	76.00	1.03	68.50	-0.36	7.50
OO(1)	1.75	316.40	2.16	315.00	-0.41	1.40
LMD(2)	0.21	126.80	0.26	128.60	-0.05	-1.80
M(1)	2.88	299.10	3.55	290.90	-0.67	8.20
J(1)	3.19	310.60	3.96	306.90	-0.77	3.70
RHO(1)	1.54	288.40	1.90	276.00	-0.36	12.40
Q(1)	7.87	287.60	9.72	274.90	-1.85	12.70
T2	0.62	122.20	0.77	120.40	-0.15	1.80
2Q(1)	1.08	281.90	1.29	267.00	-0.21	14.90
P(1)	13.89	304.00	19.44	297.80	-5.56	6.20
L(2)	0.72	97.10	1.08	95.80	-0.36	1.30
K(2)	2.83	121.10	3.55	118.40	-0.72	2.70
M(8)	0.82	127.60	0.41	15.50	0.41	112.10

GAIN (-): 0.78
PHASE (HR): 0.36
EST. RMS (CMS): 16.99

REDFISH BAR -- (GB-M)
REDFISH

HARM29C PD	CURRENT-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(cm/s)	KPRIME	AMPL(cm/s)	KPRIME	AMPL(cm/s)	KPRIME
M(2)	19.24	156.50	24.85	172.90	-5.61	-16.40
S(2)	5.35	149.80	7.66	197.60	-2.31	-47.80
N(2)	3.81	127.80	5.86	145.20	-2.06	-17.40
K(1)	24.33	309.30	38.63	304.60	-14.30	4.70
M(4)	1.39	281.20	0.98	287.90	0.41	-6.70
O(1)	21.81	304.70	29.89	305.70	-8.08	-1.00
M(6)	0.15	328.80	0.36	352.80	-0.21	-24.00
S(4)	0.05	323.90	0.72	71.60	-0.67	-107.70
NU(2)	0.72	131.60	1.13	148.90	-0.41	-17.30
S(6)	0.51	102.70	0.41	129.00	0.10	-26.30
MU(2)	0.00	0.00	0.00	0.00	0.00	0.00
2N(2)	0.51	99.00	0.77	117.40	-0.26	-18.40
OO(1)	0.93	314.00	1.29	303.60	-0.36	10.40
LMD(2)	0.15	153.40	0.15	184.40	0.00	-31.00
M(1)	1.54	307.00	2.11	305.10	-0.57	1.90
J(1)	1.70	311.60	2.37	304.10	-0.67	7.50
RHO(1)	0.82	302.70	1.13	306.10	-0.31	-3.40
Q(1)	4.22	302.40	5.81	306.20	-1.59	-3.80
T2	0.31	150.10	0.46	196.60	-0.15	-46.50
2Q(1)	0.57	300.00	0.77	306.70	-0.21	-6.70
P(1)	8.08	309.00	12.76	304.70	-4.68	4.30
L(2)	0.57	121.30	0.82	138.60	-0.26	-17.30
K(2)	1.44	149.30	2.06	199.60	-0.62	-50.30
M(8)	0.46	239.40	0.31	114.60	0.15	124.80

GAIN (-): 0.70
PHASE (HR): -0.17
EST. RMS (CMS): 14.42

MORGANS POINT -- (GB-M)
MORGANS

HARM29C PD	CURRENT-MODEL		ACCEPTED VALUES		DIFFERENCE	
	AMPL(cm/s)	KPRIME	AMPL(cm/s)	KPRIME	AMPL(cm/s)	KPRIME
M(2)	6.43	169.40	16.56	185.40	-10.13	-16.00
S(2)	2.52	137.20	4.99	167.00	-2.47	-29.80
N(2)	0.93	142.90	2.21	155.70	-1.29	-12.80
K(1)	7.15	285.20	18.93	306.20	-11.78	-21.00
M(4)	0.41	359.00	0.21	190.30	0.21	168.70
O(1)	5.45	290.00	12.04	290.70	-6.58	-0.70
M(6)	0.05	12.70	0.26	33.50	-0.21	-20.80
S(4)	0.15	59.00	0.21	217.10	-0.05	-158.10
NU(2)	0.15	146.50	0.41	159.70	-0.26	-13.20
S(6)	0.15	240.70	0.36	295.20	-0.21	-54.50
MU(2)	0.00	0.00	0.00	0.00	0.00	0.00
2N(2)	0.10	116.50	0.31	125.90	-0.21	-9.40
OO(1)	0.26	280.40	0.51	321.60	-0.26	-41.20
LMD(2)	0.05	154.40	0.10	176.90	-0.05	-22.50
M(1)	0.41	287.60	0.87	298.40	-0.46	-10.80
J(1)	0.41	282.80	0.98	313.80	-0.57	-31.00
RHO(1)	0.21	292.10	0.46	284.10	-0.26	8.00
Q(1)	1.03	292.40	2.31	283.00	-1.29	9.40
T2	0.15	138.50	0.31	167.70	-0.15	-29.20
2Q(1)	0.15	294.80	0.31	275.40	-0.15	19.40
P(1)	2.37	285.60	6.28	305.00	-3.91	-19.40
L(2)	0.15	136.40	0.31	149.10	-0.15	-12.70
K(2)	0.67	134.60	1.34	165.50	-0.67	-30.90
M(8)	0.10	310.90	0.21	309.60	-0.10	1.30

GAIN (-): 0.42
PHASE (HR): -0.77
EST. RMS (CMS): 13.10

HSC SECNDY (HSC-M)
HSC SECO

HARM29C PD	CURRENT-MODEL AMPL(cm/s)	CURRENT-MODEL KPRIME	ACCEPTED VALUES AMPL(cm/s)	ACCEPTED VALUES KPRIME	DIFFERENCE AMPL(cm/s)	DIFFERENCE KPRIME
M(2)	27.06	120.20	26.70	135.30	0.36	-15.10
S(2)	8.18	106.40	11.47	116.70	-3.29	-10.30
N(2)	4.73	87.60	7.77	85.50	-3.03	2.10
K(1)	31.74	295.20	45.47	288.10	-13.73	7.10
M(4)	2.31	220.30	3.76	220.70	-1.44	-0.40
O(1)	30.50	281.30	43.78	280.80	-13.27	0.50
M(6)	0.87	184.20	0.87	256.20	0.00	-72.00
S(4)	0.72	281.70	1.29	287.30	-0.57	-5.60
NU(2)	0.93	91.90	1.49	92.20	-0.57	-0.30
S(6)	0.77	343.40	0.57	178.80	0.21	164.60
MU(2)	0.00	0.00	0.00	0.00	0.00	0.00
2N(2)	0.62	54.90	1.03	35.70	-0.41	19.20
OO(1)	1.34	309.20	1.90	295.50	-0.57	13.70
LMD(2)	0.21	113.80	0.21	126.70	0.00	-12.90
M(1)	2.16	288.20	3.09	284.40	-0.93	3.80
J(1)	2.42	302.20	3.45	291.80	-1.03	10.40
RHO(1)	1.18	275.30	1.65	277.60	-0.46	-2.30
Q(1)	5.92	274.40	8.49	277.10	-2.57	-2.70
T2	0.46	106.90	0.67	117.40	-0.21	-10.50
2Q(1)	0.77	267.50	1.13	273.50	-0.36	-6.00
P(1)	10.49	294.20	15.02	287.60	-4.53	6.60
L(2)	0.67	81.00	1.13	79.00	-0.46	2.00
K(2)	2.21	105.30	3.14	115.20	-0.93	-9.90
M(8)	1.54	98.30	0.72	328.80	0.82	129.50

GAIN (-): 0.75
PHASE (HR): 0.08
EST. RMS (CMS): 15.87

BOLIVAR ROADS -- (HSC-M)
BOLIVAR

HARM29C PD	CURRENT-MODEL AMPL(cm/s)	CURRENT-MODEL KPRIME	ACCEPTED VALUES AMPL(cm/s)	ACCEPTED VALUES KPRIME	DIFFERENCE AMPL(cm/s)	DIFFERENCE KPRIME
M(2)	28.45	117.90	38.73	136.20	-10.29	-18.30
S(2)	8.69	103.60	12.96	119.70	-4.27	-16.10
N(2)	4.63	91.40	7.72	102.30	-3.09	-10.90
K(1)	31.74	295.00	58.69	299.00	-26.95	-4.00
M(4)	2.37	208.10	3.34	233.60	-0.98	-25.50
O(1)	31.84	283.00	50.26	282.90	-18.42	0.10
M(6)	0.82	185.40	0.51	213.30	0.31	-27.90
S(4)	0.21	255.80	0.62	33.80	-0.41	-138.00
NU(2)	0.87	94.90	1.49	106.90	-0.62	-12.00
S(6)	0.72	354.30	0.36	280.50	0.36	73.80
MU(2)	0.00	0.00	0.00	0.00	0.00	0.00
2N(2)	0.62	64.90	1.03	68.50	-0.41	-3.60
OO(1)	1.39	307.00	2.16	315.00	-0.77	-8.00
LMD(2)	0.21	111.20	0.26	128.60	-0.05	-17.40
M(1)	2.26	289.00	3.55	290.90	-1.29	-1.90
J(1)	2.52	301.00	3.96	306.90	-1.44	-5.90
RHO(1)	1.23	277.80	1.90	276.00	-0.67	1.80
Q(1)	6.17	277.00	9.72	274.90	-3.55	2.10
T2	0.51	104.20	0.77	120.40	-0.26	-16.20
2Q(1)	0.82	271.10	1.29	267.00	-0.46	4.10
P(1)	10.49	294.10	19.44	297.80	-8.95	-3.70
L(2)	0.67	84.80	1.08	95.80	-0.41	-11.00
K(2)	2.37	102.40	3.55	118.40	-1.18	-16.00
M(8)	1.03	91.20	0.41	15.50	0.62	75.70

GAIN (-): 0.63
PHASE (HR): -0.27
EST. RMS (CMS): 26.80

REDFISH BAR -- (HSC-M)
REDFISH

HARM29C PD	CURRENT-MODEL AMPL(cm/s)	CURRENT-MODEL KPRIME	ACCEPTED VALUES AMPL(cm/s)	ACCEPTED VALUES KPRIME	DIFFERENCE AMPL(cm/s)	DIFFERENCE KPRIME
M(2)	20.16	148.10	24.85	172.90	-4.68	-24.80
S(2)	5.66	129.70	7.66	197.60	-2.01	-67.90
N(2)	4.17	123.30	5.86	145.20	-1.70	-21.90
K(1)	24.13	302.40	38.63	304.60	-14.51	-2.20
M(4)	1.75	270.20	0.98	287.90	0.77	-17.70
O(1)	20.01	293.50	29.89	305.70	-9.88	-12.20
M(6)	0.41	335.00	0.36	352.80	0.05	-17.80
S(4)	0.26	251.00	0.72	71.60	-0.46	179.40
NU(2)	0.82	126.60	1.13	148.90	-0.31	-22.30
S(6)	0.62	121.70	0.41	129.00	0.21	-7.30
MU(2)	0.00	0.00	0.00	0.00	0.00	0.00
2N(2)	0.57	98.40	0.77	117.40	-0.21	-19.00
OO(1)	0.87	311.30	1.29	303.60	-0.41	7.70
LMD(2)	0.15	139.60	0.15	184.40	0.00	-44.80
M(1)	1.44	298.00	2.11	305.10	-0.67	-7.10
J(1)	1.59	306.80	2.37	304.10	-0.77	2.70
RHO(1)	0.77	289.70	1.13	306.10	-0.36	-16.40
Q(1)	3.86	289.10	5.81	306.20	-1.95	-17.10
T2	0.31	130.50	0.46	196.60	-0.15	-66.10
2Q(1)	0.51	284.70	0.77	306.70	-0.26	-22.00
P(1)	7.97	301.70	12.76	304.70	-4.78	-3.00
L(2)	0.62	116.70	0.82	138.60	-0.21	-21.90
K(2)	1.54	128.30	2.06	199.60	-0.51	-71.30
M(8)	0.31	221.80	0.31	114.60	0.00	107.20

GAIN (-): 0.70
PHASE (HR): -0.66
EST. RMS (CMS): 16.63

MORGANS POINT -- (HSC-M)
MORGANS

HARM29C PD	CURRENT-MODEL AMPL(cm/s)	CURRENT-MODEL KPRIME	ACCEPTED VALUES AMPL(cm/s)	ACCEPTED VALUES KPRIME	DIFFERENCE AMPL(cm/s)	DIFFERENCE KPRIME
M(2)	10.03	165.30	16.56	185.40	-6.53	-20.10
S(2)	2.88	149.30	4.99	167.00	-2.11	-17.70
N(2)	2.11	146.20	2.21	155.70	-0.10	-9.50
K(1)	12.29	292.40	18.93	306.20	-6.64	-13.80
M(4)	0.77	339.50	0.21	190.30	0.57	149.20
O(1)	8.74	294.40	12.04	290.70	-3.29	3.70
M(6)	0.15	313.40	0.26	33.50	-0.10	-80.10
S(4)	0.26	350.70	0.21	217.10	0.05	133.60
NU(2)	0.41	148.80	0.41	159.70	0.00	-10.90
S(6)	0.36	276.50	0.36	295.20	0.00	-18.70
MU(2)	0.00	0.00	0.00	0.00	0.00	0.00
2N(2)	0.26	127.10	0.31	125.90	-0.05	1.20
OO(1)	0.36	290.50	0.51	321.60	-0.15	-31.10
LMD(2)	0.05	157.90	0.10	176.90	-0.05	-19.00
M(1)	0.62	293.40	0.87	298.40	-0.26	-5.00
J(1)	0.67	291.50	0.98	313.80	-0.31	-22.30
RHO(1)	0.31	295.20	0.46	284.10	-0.15	11.10
Q(1)	1.70	295.30	2.31	283.00	-0.62	12.30
T2	0.15	149.90	0.31	167.70	-0.15	-17.80
2Q(1)	0.21	296.30	0.31	275.40	-0.10	20.90
P(1)	4.06	292.60	6.28	305.00	-2.21	-12.40
L(2)	0.31	139.70	0.31	149.10	0.00	-9.40
K(2)	0.77	148.00	1.34	165.50	-0.57	-17.50
M(8)	0.36	48.50	0.21	309.60	0.15	98.90

GAIN (-): 0.68
PHASE (HR): -0.49
EST. RMS (CMS): 8.56

APPENDIX B: SURFACE TEMPERATURE AND SURFACE SALINITY FORECAST AGE ANALYSIS

B-1 – B-3: Galveston Bay Model Statistics
B-4 – B-6: Houston Ship Channel Model Statistics

Notes for the tables:

The error is equal to model minus observation.
N == the total number of samples with a maximum of 3560 possible. Note for each hour 10 six-minute samples are possible for 365 days.
SM == mean error
RMS == root mean square error
STD == standard deviation of the error
CF == central frequency associated with a reference level of 1 PSU for salinity and 1 °C for temperature.
NOF == negative outlier frequency associated with twice the CF reference levels.
POF == positive outlier frequency associated with twice the CF reference levels.
MDPO == Maximum duration of positive outliers associated with the POF reference level. In the tables the number of six-minute samples is given. To convert to duration in hours, one divides the number of six-minute samples by 10 and multiplies by the forecast hour interval 24; e.g., multiply tabulated values by 2.4.
MDNO == Maximum duration of negative outliers associated with the NOF reference level. To convert to duration in hours, one divides the number of six-minute samples by 10 and multiplies by the forecast hour interval 24; e.g., mulitiply tabulated values by 2.4.
WOF == worst case outlier frequency is set to zero and is not applicable.
BOF == best case outlier frequency is set to zero and is not applicable.
The five (5), fifty (50) , and ninety five (95) percentile error levels are also included.

BOLIVAR ROADS
SURFACE SALINITY (PSU) MODEL FORECAST: 91.75 - 455.75

FREQUENCY LEVEL 1.00 (PSU)

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	562	0.33	1.66	1.63	0.55	0.07	0.14	3	3	0.00	0.00	-1.40	0.20	2.40
1	19	862	0.22	1.62	1.60	0.58	0.06	0.10	3	8	0.00	0.00	-1.50	0.10	2.20
2	20	963	0.13	1.59	1.59	0.55	0.07	0.08	0	9	0.00	0.00	-1.70	0.10	1.90
3	21	1053	0.06	1.72	1.72	0.54	0.10	0.09	5	10	0.00	0.00	-2.10	0.10	1.90
4	22	858	0.16	1.94	1.93	0.50	0.13	0.12	5	8	0.00	0.00	-2.50	0.30	2.20
5	23	962	0.16	2.19	2.19	0.44	0.16	0.15	17	9	0.00	0.00	-2.90	0.40	2.40
6	24	1004	0.31	2.46	2.44	0.36	0.16	0.22	28	21	0.00	0.00	-3.10	0.60	2.80
7	1	860	0.57	2.83	2.77	0.31	0.16	0.30	25	17	0.00	0.00	-3.00	0.80	3.60
8	2	940	0.79	3.07	2.97	0.27	0.14	0.35	28	19	0.00	0.00	-3.00	1.00	4.40
9	3	1042	1.10	3.27	3.09	0.28	0.13	0.40	41	21	0.00	0.00	-2.80	1.20	4.70
10	4	843	1.42	3.37	3.06	0.27	0.11	0.42	33	17	0.00	0.00	-2.40	1.50	5.00
11	5	962	1.66	3.45	3.03	0.26	0.09	0.46	58	19	0.00	0.00	-1.90	1.70	5.50
12	6	1052	1.65	3.54	3.13	0.24	0.10	0.49	64	20	0.00	0.00	-2.00	1.90	5.50
13	7	840	1.78	3.56	3.09	0.24	0.08	0.48	54	17	0.00	0.00	-1.70	1.80	5.60
14	8	934	1.87	3.58	3.05	0.26	0.08	0.52	66	18	0.00	0.00	-1.60	2.30	5.40
15	9	1006	1.94	3.56	2.99	0.22	0.07	0.54	63	32	0.00	0.00	-1.60	2.40	5.20
16	10	801	1.86	3.37	2.82	0.20	0.08	0.53	68	17	0.00	0.00	-1.80	2.30	4.90
17	11	910	1.82	3.12	2.54	0.20	0.09	0.51	75	9	0.00	0.00	-1.90	2.20	4.80
18	12	986	1.56	2.99	2.55	0.23	0.11	0.48	27	7	0.00	0.00	-2.20	2.00	4.50
19	13	809	1.14	2.68	2.43	0.26	0.10	0.41	17	7	0.00	0.00	-2.30	1.60	3.60
20	14	907	0.97	2.52	2.33	0.32	0.11	0.36	9	9	0.00	0.00	-2.20	1.10	3.50
21	15	1006	0.84	2.30	2.15	0.32	0.10	0.32	9	10	0.00	0.00	-2.10	1.00	3.30
22	16	810	0.82	2.11	1.95	0.35	0.08	0.26	15	8	0.00	0.00	-1.90	0.90	3.10
23	17	915	0.78	2.08	1.93	0.41	0.08	0.23	19	9	0.00	0.00	-2.00	0.80	3.20
24	18	450	0.72	2.07	1.94	0.41	0.08	0.25	4	4	0.00	0.00	-2.00	0.70	3.00

EAGLE POINT
SURFACE SALINITY (PSU) MODEL FORECAST: 91.75 - 455.75

FREQUENCY LEVEL 1.00 (PSU)

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	339	0.39	1.91	1.87	0.62	0.06	0.10	5	5	0.00	0.00	-1.10	0.30	2.00
1	19	514	0.17	1.88	1.87	0.60	0.06	0.07	8	8	0.00	0.00	-1.50	0.20	1.90
2	20	568	0.08	1.91	1.91	0.60	0.08	0.07	9	10	0.00	0.00	-1.90	0.00	1.90
3	21	625	-0.02	1.87	1.87	0.62	0.08	0.07	9	14	0.00	0.00	-1.80	-0.20	1.50
4	22	511	-0.10	1.84	1.84	0.60	0.08	0.07	7	12	0.00	0.00	-1.80	-0.20	1.40
5	23	573	-0.12	1.93	1.93	0.61	0.08	0.07	9	17	0.00	0.00	-1.90	-0.20	1.70
6	24	592	-0.10	1.92	1.92	0.61	0.09	0.07	10	14	0.00	0.00	-1.80	-0.20	1.80
7	1	499	-0.19	1.89	1.88	0.64	0.08	0.06	8	15	0.00	0.00	-1.90	-0.30	1.10
8	2	553	-0.14	1.85	1.84	0.65	0.09	0.10	9	17	0.00	0.00	-1.80	-0.20	1.90
9	3	626	-0.11	1.86	1.85	0.61	0.09	0.10	10	21	0.00	0.00	-1.60	-0.20	2.10
10	4	512	-0.04	1.86	1.86	0.58	0.08	0.11	8	15	0.00	0.00	-1.80	-0.20	2.10
11	5	548	-0.01	1.82	1.82	0.57	0.08	0.10	8	14	0.00	0.00	-1.70	-0.30	2.10
12	6	614	0.13	1.96	1.96	0.50	0.08	0.12	10	20	0.00	0.00	-1.60	-0.10	2.40
13	7	506	0.30	2.01	1.99	0.50	0.07	0.15	12	15	0.00	0.00	-1.60	0.00	2.70
14	8	531	0.47	1.95	1.89	0.51	0.04	0.14	19	8	0.00	0.00	-1.60	0.30	2.90
15	9	586	0.56	1.97	1.89	0.48	0.04	0.16	19	10	0.00	0.00	-1.60	0.30	2.90
16	10	483	0.71	2.07	1.94	0.47	0.04	0.18	17	8	0.00	0.00	-1.60	0.40	3.20
17	11	539	0.78	2.08	1.93	0.50	0.04	0.19	19	9	0.00	0.00	-1.40	0.50	3.30
18	12	595	0.82	2.09	1.93	0.49	0.02	0.21	20	10	0.00	0.00	-1.10	0.50	3.30
19	13	498	0.87	2.04	1.85	0.52	0.01	0.21	17	5	0.00	0.00	-1.10	0.50	3.20
20	14	542	0.86	1.96	1.77	0.50	0.01	0.20	18	2	0.00	0.00	-1.00	0.60	2.90
21	15	593	0.82	1.98	1.80	0.52	0.01	0.20	19	5	0.00	0.00	-1.00	0.50	2.70
22	16	479	0.89	1.95	1.74	0.53	0.00	0.20	16	0	0.00	0.00	-1.00	0.60	2.70
23	17	525	0.87	1.99	1.79	0.57	0.01	0.21	19	0	0.00	0.00	-0.90	0.50	2.60
24	18	256	0.82	1.93	1.75	0.57	0.01	0.20	8	0	0.00	0.00	-1.00	0.50	2.50

MORGANS POINT
SURFACE SALINITY (PSU) MODEL FORECAST: 91.75 - 455.75

FREQUENCY LEVEL 1.00 (PSU)

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	901	0.51	2.75	2.71	0.57	0.06	0.15	49	4	0.00	0.00	-1.60	-0.30	4.10
1	19	1377	0.52	2.65	2.60	0.61	0.04	0.15	75	7	0.00	0.00	-1.40	-0.30	3.80
2	20	1522	0.42	2.73	2.69	0.52	0.07	0.16	85	4	0.00	0.00	-1.80	-0.40	3.80
3	21	1681	0.49	2.73	2.69	0.53	0.06	0.16	99	10	0.00	0.00	-1.80	-0.30	4.30
4	22	1360	0.55	2.67	2.61	0.54	0.06	0.15	73	8	0.00	0.00	-1.80	-0.10	4.30
5	23	1532	0.73	2.77	2.68	0.54	0.06	0.17	84	9	0.00	0.00	-1.60	0.10	4.40
6	24	1646	0.74	2.75	2.65	0.51	0.07	0.18	89	9	0.00	0.00	-1.70	0.10	4.30
7	1	1370	0.85	2.80	2.67	0.50	0.06	0.20	80	6	0.00	0.00	-1.70	0.10	4.60
8	2	1530	0.89	2.84	2.70	0.48	0.06	0.19	89	9	0.00	0.00	-1.70	0.10	4.40
9	3	1650	0.86	2.83	2.70	0.46	0.06	0.19	91	9	0.00	0.00	-1.60	0.20	4.80
10	4	1349	0.96	2.87	2.71	0.45	0.05	0.21	73	8	0.00	0.00	-1.60	0.30	5.10
11	5	1493	0.93	2.85	2.69	0.45	0.04	0.20	79	9	0.00	0.00	-1.50	0.20	4.10
12	6	1640	0.89	2.76	2.61	0.45	0.04	0.21	77	6	0.00	0.00	-1.60	0.20	4.00
13	7	1321	0.87	2.79	2.65	0.44	0.04	0.20	62	7	0.00	0.00	-1.60	0.20	4.70
14	8	1456	0.71	2.78	2.68	0.44	0.06	0.19	69	9	0.00	0.00	-1.70	0.00	4.30
15	9	1612	0.69	2.81	2.73	0.41	0.08	0.19	67	10	0.00	0.00	-1.90	0.00	4.70
16	10	1305	0.72	2.87	2.77	0.39	0.08	0.20	59	7	0.00	0.00	-1.90	0.10	4.70
17	11	1445	0.61	2.89	2.82	0.42	0.11	0.18	63	9	0.00	0.00	-2.10	0.00	4.60
18	12	1570	0.61	2.98	2.92	0.40	0.12	0.18	74	9	0.00	0.00	-2.20	0.00	5.00
19	13	1262	0.52	3.02	2.98	0.38	0.14	0.18	58	8	0.00	0.00	-2.30	-0.20	5.00
20	14	1431	0.50	3.10	3.06	0.38	0.15	0.18	79	9	0.00	0.00	-2.40	-0.10	5.00
21	15	1605	0.44	3.18	3.15	0.38	0.16	0.18	95	10	0.00	0.00	-2.50	-0.40	5.70
22	16	1312	0.42	3.30	3.28	0.34	0.18	0.18	82	8	0.00	0.00	-2.70	-0.40	6.40
23	17	1471	0.46	3.34	3.31	0.34	0.16	0.18	98	7	0.00	0.00	-2.60	-0.40	6.50
24	18	742	0.61	3.39	3.34	0.33	0.16	0.21	57	4	0.00	0.00	-2.40	-0.40	6.50

BOLIVAR ROADS
SURFACE TEMPERATURE (C) MODEL FORECAST: 91.75 - 455.75

FREQUENCY LEVEL 1.00 (DEG C)

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	562	0.35	0.60	0.49	0.94	0.00	0.01	0	0	0.00	0.00	-0.20	0.30	0.70
1	19	862	0.46	0.62	0.42	0.96	0.00	0.01	0	0	0.00	0.00	0.10	0.40	0.80
2	20	963	0.57	0.73	0.46	0.94	0.00	0.01	0	0	0.00	0.00	0.10	0.50	1.00
3	21	1053	0.71	0.85	0.47	0.86	0.00	0.01	0	0	0.00	0.00	0.30	0.60	1.10
4	22	858	0.87	1.01	0.51	0.74	0.00	0.03	0	0	0.00	0.00	0.40	0.80	1.40
5	23	962	1.06	1.21	0.58	0.59	0.00	0.06	0	0	0.00	0.00	0.40	1.00	1.70
6	24	1004	1.21	1.35	0.61	0.45	0.00	0.08	0	0	0.00	0.00	0.50	1.10	2.00
7	1	860	1.28	1.42	0.61	0.40	0.00	0.08	0	0	0.00	0.00	0.60	1.20	2.00
8	2	940	1.36	1.50	0.64	0.36	0.00	0.10	0	0	0.00	0.00	0.60	1.20	2.10
9	3	1042	1.41	1.55	0.66	0.32	0.00	0.11	7	0	0.00	0.00	0.60	1.30	2.10
10	4	843	1.48	1.62	0.65	0.27	0.00	0.13	8	0	0.00	0.00	0.70	1.40	2.20
11	5	962	1.53	1.66	0.65	0.25	0.00	0.16	9	0	0.00	0.00	0.80	1.40	2.20
12	6	1048	1.56	1.69	0.65	0.25	0.00	0.18	6	0	0.00	0.00	0.80	1.50	2.20
13	7	831	1.55	1.67	0.62	0.26	0.00	0.19	0	0	0.00	0.00	0.80	1.50	2.40
14	8	924	1.49	1.60	0.61	0.30	0.00	0.17	0	0	0.00	0.00	0.70	1.40	2.30
15	9	996	1.35	1.50	0.64	0.37	0.00	0.12	0	0	0.00	0.00	0.50	1.30	2.10
16	10	800	1.16	1.35	0.69	0.49	0.00	0.05	0	0	0.00	0.00	0.30	1.10	1.90
17	11	928	0.98	1.32	0.89	0.58	0.01	0.05	9	0	0.00	0.00	0.10	0.90	1.80
18	12	989	0.81	1.14	0.81	0.67	0.00	0.04	7	0	0.00	0.00	-0.10	0.70	1.70
19	13	811	0.63	0.98	0.75	0.73	0.00	0.03	0	0	0.00	0.00	-0.30	0.50	1.50
20	14	907	0.45	0.88	0.76	0.79	0.00	0.03	0	0	0.00	0.00	-0.50	0.40	1.30
21	15	1006	0.31	0.85	0.79	0.82	0.00	0.02	0	0	0.00	0.00	-0.80	0.30	1.20
22	16	810	0.24	0.82	0.78	0.82	0.00	0.02	0	0	0.00	0.00	-0.80	0.20	1.20
23	17	915	0.22	0.82	0.79	0.80	0.00	0.02	0	0	0.00	0.00	-0.80	0.10	1.20
24	18	450	0.25	0.83	0.80	0.80	0.00	0.03	0	0	0.00	0.00	-0.70	0.20	1.30

EAGLE POINT
SURFACE TEMPERATURE (C) MODEL FORECAST: 91.75 - 455.75

FREQUENCY LEVEL 1.00 (DEG C)

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	330	0.51	1.06	0.93	0.86	0.00	0.05	4	0	0.00	0.00	-0.10	0.40	1.10
1	19	503	0.64	1.05	0.83	0.91	0.00	0.05	12	0	0.00	0.00	0.30	0.50	0.80
2	20	557	0.80	1.16	0.85	0.87	0.00	0.05	19	0	0.00	0.00	0.40	0.70	1.10
3	21	610	0.98	1.31	0.87	0.79	0.00	0.05	25	0	0.00	0.00	0.50	0.80	1.30
4	22	496	1.13	1.45	0.90	0.58	0.00	0.05	24	0	0.00	0.00	0.60	1.00	1.50
5	23	538	1.16	1.34	0.67	0.43	0.00	0.04	11	0	0.00	0.00	0.60	1.10	1.60
6	24	555	1.28	1.43	0.65	0.32	0.00	0.05	7	0	0.00	0.00	0.70	1.20	1.80
7	1	463	1.35	1.49	0.62	0.30	0.00	0.08	2	0	0.00	0.00	0.70	1.30	2.00
8	2	516	1.34	1.51	0.70	0.28	0.00	0.10	0	0	0.00	0.00	0.60	1.40	2.00
9	3	582	1.41	1.71	0.96	0.20	0.01	0.12	6	0	0.00	0.00	0.60	1.50	2.20
10	4	477	1.52	1.85	1.05	0.17	0.01	0.15	8	4	0.00	0.00	0.80	1.60	2.40
11	5	504	1.70	1.87	0.78	0.12	0.00	0.24	9	0	0.00	0.00	1.00	1.60	2.40
12	6	561	1.79	1.96	0.79	0.11	0.00	0.30	10	0	0.00	0.00	1.00	1.70	2.60
13	7	465	1.87	2.02	0.78	0.12	0.00	0.35	6	0	0.00	0.00	1.00	1.80	2.80
14	8	492	1.82	1.95	0.72	0.11	0.00	0.36	0	0	0.00	0.00	1.00	1.80	2.60
15	9	544	1.71	1.86	0.72	0.16	0.00	0.28	0	0	0.00	0.00	0.80	1.70	2.60
16	10	456	1.55	1.77	0.86	0.28	0.00	0.19	7	0	0.00	0.00	0.40	1.50	2.60
17	11	512	1.33	1.60	0.90	0.36	0.00	0.18	7	0	0.00	0.00	0.10	1.30	2.40
18	12	581	1.13	1.60	1.14	0.48	0.00	0.13	18	0	0.00	0.00	-0.30	1.10	2.40
19	13	492	0.85	1.45	1.18	0.57	0.00	0.10	17	0	0.00	0.00	-0.50	0.80	2.00
20	14	539	0.60	1.32	1.18	0.66	0.00	0.09	18	0	0.00	0.00	-0.70	0.50	1.90
21	15	587	0.44	1.22	1.14	0.75	0.00	0.07	6	0	0.00	0.00	-0.80	0.40	1.70
22	16	479	0.31	1.19	1.15	0.72	0.01	0.06	0	0	0.00	0.00	-1.20	0.30	1.40
23	17	524	0.32	1.24	1.20	0.69	0.00	0.08	0	0	0.00	0.00	-1.10	0.30	1.60
24	18	256	0.34	1.26	1.21	0.68	0.01	0.07	0	0	0.00	0.00	-1.10	0.40	1.60

MORGANS POINT
SURFACE TEMPERATURE (C) MODEL FORECAST: 91.75 - 455.75

FREQUENCY LEVEL 1.00 (DEG C)

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	763	0.13	0.78	0.77	0.92	0.02	0.01	0	2	0.00	0.00	-0.60	0.30	0.60
1	19	1173	0.14	0.76	0.74	0.93	0.02	0.01	0	5	0.00	0.00	-0.50	0.30	0.60
2	20	1283	0.17	0.78	0.77	0.92	0.02	0.01	0	9	0.00	0.00	-0.60	0.30	0.70
3	21	1436	0.16	0.79	0.77	0.91	0.01	0.01	0	7	0.00	0.00	-0.70	0.20	0.70
4	22	1172	0.14	0.83	0.82	0.89	0.02	0.01	0	0	0.00	0.00	-0.80	0.20	0.80
5	23	1306	0.20	0.86	0.84	0.87	0.01	0.01	0	0	0.00	0.00	-0.80	0.30	0.90
6	24	1399	0.19	0.85	0.83	0.85	0.01	0.01	1	0	0.00	0.00	-0.70	0.30	1.00
7	1	1169	0.23	0.88	0.85	0.84	0.02	0.01	0	0	0.00	0.00	-0.70	0.30	1.00
8	2	1296	0.23	0.86	0.83	0.82	0.02	0.01	0	0	0.00	0.00	-0.70	0.30	1.10
9	3	1412	0.22	0.84	0.81	0.82	0.02	0.00	0	0	0.00	0.00	-0.70	0.30	1.10
10	4	1146	0.27	0.88	0.83	0.81	0.02	0.01	0	0	0.00	0.00	-0.60	0.30	1.20
11	5	1277	0.27	0.92	0.88	0.79	0.02	0.01	0	2	0.00	0.00	-0.80	0.30	1.20
12	6	1416	0.30	0.98	0.93	0.81	0.03	0.01	0	6	0.00	0.00	-0.70	0.40	1.20
13	7	1143	0.34	0.99	0.93	0.80	0.03	0.01	0	6	0.00	0.00	-0.70	0.40	1.20
14	8	1248	0.33	0.93	0.87	0.83	0.02	0.01	0	5	0.00	0.00	-0.60	0.40	1.10
15	9	1380	0.35	0.83	0.75	0.84	0.01	0.01	0	0	0.00	0.00	-0.50	0.40	1.10
16	10	1110	0.31	0.84	0.79	0.85	0.02	0.01	0	0	0.00	0.00	-0.50	0.30	1.00
17	11	1227	0.24	0.81	0.77	0.85	0.02	0.01	0	0	0.00	0.00	-0.60	0.30	1.00
18	12	1332	0.18	0.78	0.76	0.85	0.01	0.00	0	0	0.00	0.00	-0.70	0.20	1.00
19	13	1074	0.15	0.89	0.88	0.86	0.03	0.01	0	1	0.00	0.00	-0.80	0.20	0.90
20	14	1213	0.17	0.82	0.81	0.85	0.01	0.01	0	0	0.00	0.00	-0.80	0.20	1.00
21	15	1358	0.13	0.88	0.87	0.84	0.01	0.01	0	2	0.00	0.00	-0.80	0.10	0.90
22	16	1121	0.10	0.93	0.92	0.84	0.02	0.02	0	4	0.00	0.00	-0.80	0.10	1.00
23	17	1235	0.10	0.91	0.90	0.85	0.02	0.02	0	4	0.00	0.00	-0.80	0.00	0.90
24	18	610	0.16	0.93	0.92	0.84	0.01	0.02	0	3	0.00	0.00	-0.80	0.10	1.00

BOLIVAR ROADS
SURFACE SALINITY (PSU) MODEL FORECAST: 91.75 - 455.75

FREQUENCY LEVEL 1.00 (PSU)

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	557	0.64	1.84	1.72	0.45	0.07	0.17	0	3	0.00	0.00	-1.20	0.80	2.50
1	19	857	0.42	1.82	1.77	0.46	0.07	0.13	0	8	0.00	0.00	-1.60	0.60	2.30
2	20	955	0.19	1.92	1.92	0.40	0.10	0.11	0	9	0.00	0.00	-1.90	0.40	2.10
3	21	1044	0.02	2.04	2.04	0.41	0.15	0.07	0	10	0.00	0.00	-3.00	0.30	1.90
4	22	851	-0.07	2.32	2.32	0.37	0.16	0.10	3	9	0.00	0.00	-3.90	0.50	2.10
5	23	955	-0.11	2.68	2.68	0.34	0.20	0.16	9	27	0.00	0.00	-4.80	0.50	2.70
6	24	998	-0.07	3.00	3.00	0.30	0.22	0.19	14	23	0.00	0.00	-5.10	0.50	3.10
7	1	859	0.14	3.28	3.28	0.26	0.21	0.26	16	33	0.00	0.00	-5.10	0.70	3.60
8	2	940	0.32	3.42	3.41	0.24	0.18	0.32	15	19	0.00	0.00	-5.60	1.00	3.90
9	3	1040	0.55	3.53	3.48	0.22	0.17	0.38	27	21	0.00	0.00	-5.20	1.20	4.00
10	4	838	0.82	3.52	3.42	0.23	0.16	0.39	19	15	0.00	0.00	-4.30	1.30	4.30
11	5	950	1.27	3.46	3.22	0.20	0.14	0.46	44	14	0.00	0.00	-3.30	1.80	4.60
12	6	1028	1.37	3.52	3.24	0.18	0.13	0.49	54	24	0.00	0.00	-2.90	2.00	4.90
13	7	817	1.59	3.47	3.08	0.24	0.12	0.52	44	20	0.00	0.00	-2.30	2.20	4.90
14	8	912	1.61	3.50	3.10	0.25	0.11	0.51	38	26	0.00	0.00	-2.20	2.20	5.00
15	9	987	1.66	3.40	2.96	0.18	0.10	0.50	83	32	0.00	0.00	-2.10	2.00	5.00
16	10	788	1.59	3.20	2.78	0.17	0.13	0.50	36	17	0.00	0.00	-2.20	2.00	4.70
17	11	900	1.57	3.02	2.58	0.17	0.10	0.50	19	9	0.00	0.00	-2.10	2.10	4.30
18	12	969	1.49	2.87	2.45	0.17	0.10	0.47	26	10	0.00	0.00	-2.10	2.00	4.00
19	13	795	1.37	2.84	2.49	0.19	0.11	0.45	29	17	0.00	0.00	-2.30	1.90	4.00
20	14	898	1.35	2.89	2.56	0.19	0.10	0.45	24	9	0.00	0.00	-2.10	1.90	3.80
21	15	995	1.37	2.74	2.37	0.16	0.09	0.45	16	10	0.00	0.00	-1.90	1.80	3.70
22	16	805	1.31	2.52	2.15	0.17	0.07	0.42	11	8	0.00	0.00	-1.90	1.80	3.50
23	17	908	1.23	2.41	2.07	0.20	0.09	0.38	9	9	0.00	0.00	-2.00	1.60	3.40
24	18	446	1.12	2.30	2.01	0.24	0.10	0.35	4	4	0.00	0.00	-2.10	1.50	3.30

EAGLE POINT
SURFACE SALINITY (PSU) MODEL FORECAST: 91.75 - 455.75

FREQUENCY LEVEL 1.00 (PSU)

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	333	0.73	1.90	1.75	0.56	0.03	0.17	6	4	0.00	0.00	-0.80	0.50	2.60
1	19	506	0.49	1.82	1.75	0.57	0.05	0.16	8	8	0.00	0.00	-1.20	0.30	2.40
2	20	558	0.24	1.74	1.73	0.55	0.08	0.11	9	9	0.00	0.00	-1.70	0.20	2.20
3	21	613	0.10	1.72	1.72	0.58	0.07	0.07	9	10	0.00	0.00	-1.90	0.00	1.70
4	22	503	0.03	1.73	1.73	0.61	0.06	0.08	8	8	0.00	0.00	-1.70	-0.20	1.80
5	23	565	0.06	1.77	1.77	0.62	0.08	0.09	9	8	0.00	0.00	-1.90	-0.20	1.90
6	24	583	0.11	1.80	1.80	0.60	0.08	0.10	10	9	0.00	0.00	-1.60	-0.20	2.00
7	1	499	0.13	1.83	1.82	0.59	0.06	0.12	8	15	0.00	0.00	-1.90	-0.10	2.30
8	2	547	0.22	1.82	1.80	0.61	0.06	0.14	9	17	0.00	0.00	-1.80	-0.10	2.50
9	3	615	0.20	1.76	1.75	0.61	0.08	0.10	10	21	0.00	0.00	-1.90	0.10	2.10
10	4	503	0.25	1.78	1.77	0.55	0.10	0.13	8	14	0.00	0.00	-1.90	0.10	2.40
11	5	539	0.27	1.82	1.80	0.54	0.07	0.14	8	9	0.00	0.00	-1.70	0.20	2.60
12	6	605	0.53	2.06	1.99	0.48	0.06	0.19	20	10	0.00	0.00	-1.50	0.30	2.90
13	7	496	0.77	2.13	1.98	0.45	0.05	0.22	14	3	0.00	0.00	-1.50	0.60	3.30
14	8	523	0.93	2.07	1.85	0.46	0.03	0.24	18	0	0.00	0.00	-1.40	0.70	3.30
15	9	575	1.13	2.14	1.82	0.41	0.02	0.30	21	0	0.00	0.00	-1.20	0.90	3.40
16	10	472	1.24	2.26	1.90	0.38	0.03	0.27	16	0	0.00	0.00	-1.20	1.10	4.00
17	11	531	1.31	2.33	1.93	0.41	0.02	0.30	19	0	0.00	0.00	-0.90	1.00	3.70
18	12	584	1.38	2.42	1.99	0.41	0.02	0.29	20	0	0.00	0.00	-0.80	1.10	3.40
19	13	489	1.42	2.43	1.97	0.44	0.01	0.29	17	0	0.00	0.00	-0.70	1.00	3.30
20	14	533	1.47	2.40	1.90	0.41	0.01	0.30	19	0	0.00	0.00	-0.50	1.20	2.90
21	15	581	1.38	2.27	1.80	0.40	0.03	0.28	19	4	0.00	0.00	-0.40	1.30	2.80
22	16	470	1.30	2.11	1.67	0.44	0.00	0.22	16	0	0.00	0.00	-0.40	1.10	2.70
23	17	515	1.15	2.03	1.67	0.51	0.00	0.21	16	0	0.00	0.00	-0.40	0.90	2.50
24	18	251	1.04	1.94	1.64	0.52	0.00	0.16	8	0	0.00	0.00	-0.50	0.70	2.40

MORGANS POINT 1
SURFACE SALINITY (PSU) MODEL FORECAST: 91.75 - 455.75

FREQUENCY LEVEL 1.00 (PSU)

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	909	0.19	2.55	2.54	0.57	0.08	0.11	59	4	0.00	0.00	-1.90	-0.40	2.40
1	19	1380	0.14	2.39	2.38	0.61	0.05	0.10	85	7	0.00	0.00	-1.80	-0.40	2.00
2	20	1520	0.05	2.48	2.48	0.51	0.08	0.11	94	4	0.00	0.00	-2.00	-0.60	2.50
3	21	1675	0.11	2.41	2.41	0.53	0.07	0.11	100	10	0.00	0.00	-1.90	-0.50	2.80
4	22	1362	0.26	2.43	2.42	0.54	0.05	0.11	81	8	0.00	0.00	-1.70	-0.30	2.60
5	23	1528	0.44	2.51	2.47	0.57	0.06	0.12	90	9	0.00	0.00	-1.60	-0.10	2.90
6	24	1624	0.33	2.31	2.29	0.55	0.07	0.11	76	9	0.00	0.00	-1.70	-0.20	2.20
7	1	1358	0.45	2.41	2.36	0.56	0.06	0.14	71	6	0.00	0.00	-1.70	-0.10	2.50
8	2	1511	0.49	2.41	2.36	0.52	0.06	0.16	73	9	0.00	0.00	-1.70	-0.10	2.50
9	3	1629	0.50	2.42	2.37	0.50	0.06	0.17	75	10	0.00	0.00	-1.80	0.00	2.60
10	4	1339	0.73	2.60	2.50	0.50	0.07	0.18	71	8	0.00	0.00	-1.60	0.20	3.00
11	5	1485	0.77	2.68	2.57	0.51	0.07	0.19	78	9	0.00	0.00	-1.50	0.20	3.10
12	6	1620	0.73	2.44	2.32	0.50	0.07	0.18	66	10	0.00	0.00	-1.40	0.30	2.90
13	7	1316	0.84	2.59	2.45	0.51	0.06	0.17	65	8	0.00	0.00	-1.40	0.40	3.40
14	8	1466	0.80	2.76	2.64	0.52	0.06	0.16	88	8	0.00	0.00	-1.60	0.30	3.60
15	9	1630	0.80	2.80	2.69	0.48	0.06	0.16	95	10	0.00	0.00	-1.70	0.30	4.20
16	10	1311	0.70	2.72	2.63	0.46	0.08	0.15	71	7	0.00	0.00	-1.90	0.30	3.80
17	11	1463	0.62	2.93	2.86	0.47	0.09	0.15	91	9	0.00	0.00	-1.90	0.10	4.10
18	12	1617	0.71	3.20	3.12	0.45	0.11	0.18	131	10	0.00	0.00	-2.10	0.10	5.50
19	13	1308	0.66	3.28	3.21	0.44	0.12	0.19	112	8	0.00	0.00	-2.20	0.00	5.90
20	14	1465	0.51	3.18	3.14	0.42	0.13	0.18	122	9	0.00	0.00	-2.40	-0.10	5.20
21	15	1644	0.42	3.23	3.21	0.41	0.17	0.16	143	10	0.00	0.00	-2.50	-0.30	5.40
22	16	1323	0.27	3.18	3.17	0.41	0.19	0.15	104	8	0.00	0.00	-2.60	-0.50	4.90
23	17	1482	0.23	3.13	3.13	0.41	0.19	0.16	113	9	0.00	0.00	-2.60	-0.50	4.00
24	18	740	0.28	3.03	3.02	0.39	0.17	0.16	57	4	0.00	0.00	-2.50	-0.50	3.90

BOLIVAR ROADS
SURFACE TEMPERATURE (C) MODEL FORECAST: 91.75 - 455.75

FREQUENCY LEVEL 1.00 (DEG C)

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	557	0.34	0.59	0.48	0.93	0.00	0.01	0	0	0.00	0.00	-0.20	0.30	0.60
1	19	857	0.46	0.63	0.43	0.94	0.00	0.01	0	0	0.00	0.00	0.10	0.40	0.70
2	20	955	0.58	0.76	0.49	0.92	0.00	0.01	0	0	0.00	0.00	0.10	0.50	1.00
3	21	1044	0.73	0.90	0.53	0.85	0.00	0.02	0	0	0.00	0.00	0.30	0.60	1.20
4	22	851	0.89	1.06	0.58	0.72	0.00	0.06	0	0	0.00	0.00	0.30	0.70	1.60
5	23	955	1.07	1.24	0.64	0.59	0.00	0.09	0	0	0.00	0.00	0.50	0.90	1.90
6	24	998	1.22	1.39	0.67	0.47	0.00	0.11	0	0	0.00	0.00	0.50	1.10	2.10
7	1	859	1.30	1.46	0.68	0.42	0.00	0.12	0	0	0.00	0.00	0.60	1.20	2.20
8	2	940	1.37	1.54	0.70	0.37	0.00	0.15	0	0	0.00	0.00	0.60	1.20	2.30
9	3	1040	1.43	1.62	0.74	0.31	0.00	0.16	7	0	0.00	0.00	0.70	1.30	2.30
10	4	840	1.52	1.69	0.74	0.26	0.00	0.16	8	0	0.00	0.00	0.70	1.40	2.30
11	5	958	1.57	1.73	0.73	0.21	0.00	0.20	9	0	0.00	0.00	0.70	1.40	2.40
12	6	1037	1.61	1.76	0.73	0.23	0.00	0.23	6	0	0.00	0.00	0.70	1.50	2.50
13	7	823	1.61	1.75	0.68	0.22	0.00	0.24	0	0	0.00	0.00	0.80	1.50	2.50
14	8	914	1.55	1.68	0.65	0.22	0.00	0.19	0	0	0.00	0.00	0.70	1.40	2.40
15	9	987	1.41	1.56	0.66	0.29	0.00	0.12	0	0	0.00	0.00	0.50	1.30	2.20
16	10	792	1.22	1.41	0.72	0.43	0.00	0.09	0	0	0.00	0.00	0.40	1.10	1.90
17	11	918	1.04	1.37	0.90	0.52	0.01	0.09	9	0	0.00	0.00	0.20	1.00	1.90
18	12	980	0.84	1.17	0.81	0.64	0.00	0.06	7	0	0.00	0.00	-0.10	0.80	1.70
19	13	803	0.65	1.01	0.77	0.74	0.00	0.04	0	0	0.00	0.00	-0.30	0.60	1.60
20	14	899	0.46	0.91	0.79	0.79	0.00	0.03	0	0	0.00	0.00	-0.50	0.40	1.40
21	15	995	0.31	0.84	0.79	0.83	0.00	0.02	0	0	0.00	0.00	-0.70	0.30	1.20
22	16	805	0.23	0.80	0.77	0.85	0.00	0.01	0	0	0.00	0.00	-0.80	0.30	1.10
23	17	908	0.20	0.80	0.77	0.85	0.00	0.02	0	0	0.00	0.00	-0.80	0.20	1.20
24	18	446	0.23	0.81	0.77	0.83	0.00	0.03	0	0	0.00	0.00	-0.70	0.20	1.10

EAGLE POINT
SURFACE TEMPERATURE (C) MODEL FORECAST: 91.75 - 455.75

FREQUENCY LEVEL 1.00 (DEG C)

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	324	0.48	1.09	0.98	0.85	0.00	0.07	4	0	0.00	0.00	-0.30	0.30	1.00
1	19	495	0.62	1.09	0.89	0.89	0.00	0.07	12	0	0.00	0.00	0.20	0.40	0.70
2	20	547	0.77	1.19	0.90	0.88	0.00	0.07	19	0	0.00	0.00	0.30	0.60	1.00
3	21	598	0.96	1.33	0.92	0.83	0.00	0.07	25	0	0.00	0.00	0.50	0.70	1.20
4	22	489	1.12	1.47	0.96	0.70	0.00	0.08	25	0	0.00	0.00	0.50	0.90	1.50
5	23	530	1.13	1.34	0.71	0.59	0.00	0.06	11	0	0.00	0.00	0.60	1.00	1.60
6	24	546	1.24	1.42	0.70	0.47	0.00	0.06	7	0	0.00	0.00	0.60	1.10	1.80
7	1	463	1.31	1.47	0.66	0.37	0.00	0.08	1	0	0.00	0.00	0.60	1.20	2.00
8	2	510	1.30	1.50	0.75	0.34	0.00	0.10	0	0	0.00	0.00	0.50	1.30	2.00
9	3	571	1.37	1.69	0.99	0.24	0.02	0.13	6	1	0.00	0.00	0.50	1.40	2.20
10	4	468	1.48	1.83	1.08	0.21	0.01	0.15	8	4	0.00	0.00	0.80	1.50	2.50
11	5	495	1.66	1.84	0.81	0.19	0.00	0.15	9	0	0.00	0.00	0.90	1.50	2.70
12	6	552	1.75	1.93	0.82	0.14	0.00	0.21	10	0	0.00	0.00	0.90	1.60	2.80
13	7	455	1.82	1.99	0.80	0.11	0.00	0.32	6	0	0.00	0.00	0.90	1.60	2.90
14	8	484	1.77	1.91	0.73	0.11	0.00	0.29	0	0	0.00	0.00	1.00	1.70	2.90
15	9	533	1.66	1.82	0.74	0.20	0.00	0.19	0	0	0.00	0.00	0.80	1.60	2.80
16	10	445	1.50	1.73	0.87	0.31	0.00	0.16	7	0	0.00	0.00	0.30	1.40	2.60
17	11	504	1.28	1.57	0.92	0.39	0.00	0.14	7	0	0.00	0.00	-0.10	1.20	2.30
18	12	570	1.06	1.56	1.15	0.52	0.00	0.11	18	0	0.00	0.00	-0.40	1.00	2.10
19	13	483	0.76	1.40	1.18	0.66	0.00	0.08	17	0	0.00	0.00	-0.60	0.70	1.80
20	14	530	0.50	1.27	1.16	0.73	0.00	0.07	18	0	0.00	0.00	-0.80	0.40	1.50
21	15	575	0.33	1.17	1.12	0.75	0.01	0.06	6	0	0.00	0.00	-1.00	0.30	1.30
22	16	470	0.20	1.14	1.13	0.73	0.02	0.04	0	0	0.00	0.00	-1.30	0.30	1.20
23	17	514	0.21	1.19	1.18	0.71	0.02	0.06	0	0	0.00	0.00	-1.30	0.20	1.40
24	18	251	0.23	1.21	1.19	0.69	0.01	0.06	0	0	0.00	0.00	-1.30	0.20	1.40

MORGANS POINT 1
SURFACE TEMPERATURE (C) MODEL FORECAST: 91.75 - 455.75

FREQUENCY LEVEL 1.00 (DEG C)

HR-F	HR	N	SM	RMS	STD	CF	NOF	POF	MDPO	MDNO	WOF	BOF	5	50	95
0	18	764	0.36	0.84	0.76	0.91	0.02	0.01	0	2	0.00	0.00	-0.10	0.50	0.70
1	19	1169	0.38	0.82	0.73	0.93	0.02	0.01	0	3	0.00	0.00	0.00	0.50	0.70
2	20	1280	0.39	0.90	0.81	0.92	0.02	0.01	0	7	0.00	0.00	-0.10	0.50	0.80
3	21	1436	0.39	0.88	0.78	0.90	0.02	0.02	0	5	0.00	0.00	-0.20	0.40	0.90
4	22	1169	0.39	0.89	0.80	0.89	0.02	0.01	0	2	0.00	0.00	-0.40	0.50	0.90
5	23	1300	0.45	0.94	0.82	0.85	0.02	0.01	0	3	0.00	0.00	-0.40	0.50	1.10
6	24	1389	0.46	0.87	0.74	0.85	0.01	0.01	0	0	0.00	0.00	-0.50	0.50	1.10
7	1	1171	0.48	0.96	0.83	0.82	0.02	0.01	0	4	0.00	0.00	-0.40	0.50	1.10
8	2	1303	0.46	0.98	0.86	0.80	0.02	0.01	0	10	0.00	0.00	-0.30	0.50	1.20
9	3	1427	0.43	1.02	0.93	0.79	0.02	0.00	0	20	0.00	0.00	-0.30	0.50	1.20
10	4	1150	0.49	1.02	0.90	0.78	0.02	0.01	0	11	0.00	0.00	-0.40	0.50	1.30
11	5	1291	0.47	1.11	1.00	0.77	0.03	0.01	0	22	0.00	0.00	-0.50	0.60	1.30
12	6	1431	0.50	1.17	1.05	0.75	0.04	0.01	0	29	0.00	0.00	-0.40	0.60	1.30
13	7	1152	0.55	1.14	1.01	0.75	0.04	0.01	0	13	0.00	0.00	-0.30	0.60	1.40
14	8	1265	0.52	1.17	1.05	0.75	0.04	0.01	0	16	0.00	0.00	-0.30	0.60	1.30
15	9	1392	0.57	1.09	0.93	0.77	0.02	0.01	0	21	0.00	0.00	-0.20	0.60	1.30
16	10	1126	0.50	1.13	1.01	0.79	0.03	0.01	0	21	0.00	0.00	-0.20	0.60	1.30
17	11	1239	0.44	1.06	0.96	0.80	0.03	0.01	0	22	0.00	0.00	-0.30	0.50	1.20
18	12	1342	0.38	0.98	0.90	0.84	0.03	0.00	0	19	0.00	0.00	-0.30	0.50	1.10
19	13	1080	0.36	1.05	0.98	0.85	0.03	0.01	0	14	0.00	0.00	-0.40	0.50	1.10
20	14	1220	0.36	1.02	0.95	0.84	0.02	0.02	0	18	0.00	0.00	-0.50	0.40	1.10
21	15	1369	0.34	1.08	1.03	0.85	0.03	0.02	0	19	0.00	0.00	-0.50	0.40	1.10
22	16	1123	0.32	1.07	1.02	0.84	0.03	0.02	1	11	0.00	0.00	-0.40	0.40	1.10
23	17	1250	0.31	1.08	1.04	0.85	0.03	0.02	0	18	0.00	0.00	-0.40	0.30	1.10
24	18	614	0.40	1.05	0.98	0.84	0.02	0.03	0	5	0.00	0.00	-0.30	0.40	1.10