NOAA Technical Memorandum NOS CS 20

EVALUATION OF NATIONAL WEATHER SERVICE AND EXTRAMURAL WATER LEVEL FORECAST GUIDANCE FROM REAL TIME OCEAN FORECAST SYSTEMS

Silver Spring, Maryland
October 2010

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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ABSTRACT

The water level guidance, both subtidal and total, from National Weather Service (NWS) and extramural real-time oceanographic forecast modeling systems were compared to 24 National Ocean Service (NOS) water level stations on the U.S. East Coast and along the Gulf of Mexico shoreline. The National Weather Service (NWS) Real Time Ocean Forecast System (RTOFS), NWS Extra-Tropical Storm Surge (ETSS) Model, United States Navy (USN) global Navy Coupled Ocean Model (G-NCOM), and University of North Carolina (UNC) Western North Atlantic Forecast System Advanced Circulation (ADCIRC) Model water level forecasts were compared with the observations during November 2008. Because the ETSS model is subtidal, the ETSS forecast water levels were compared with observed subtidal water levels. The observed subtidal water levels were obtained using a 30 hour low pass Fourier filter. Because the RTOFS, ADCIRC, and G-NCOM includes tides, their forecast water levels were compared with the total observed water level. Two new versions of RTOFS were considered and contrasted with the previous RTOFS results documented in Richardson and Schmalz (2007). Using the ADCIRC nowcast water levels, it was possible to perform a harmonic analysis as well as a subtidal comparison with subtidal observed water levels. Since G-NCOM included tides, subtidal results were obtained by subtraction of the NOS predicted astronomic tide from the total nowcast water level (detiding).

The evaluation demonstrates that for total water level forecast guidance, the order of preference in terms of root mean square error (RMSE) is first ADCIRC, next G-NCOM, followed by RTOFS. For subtidal water level forecast guidance, again based on RMSE, the order of preference is ETSS, ADCIRC, RTOFS, and G-NCOM.

An explanation of all cases which were run and a description of all processing steps are presented. Program descriptions are provided in Appendix A with script and program input files provided in Appendix B.

1. INTRODUCTION

Coastal ocean and estuarine nowcast/forecast systems require specification of the offshore boundary conditions for water level, density, and currents. These boundary conditions must be provided from basin scale numerical models, since observation density is insufficient in time and space to meet the necessary requirements. Here we evaluate the ability of both NWS and extramurally run ocean nowcast/forecast models to provide water level boundary conditions.

The Real Time Ocean Forecast System (RTOFS) Atlantic application run at the National Centers for Environmental Prediction (NCEP) uses the Hybrid Coordinate Ocean Model (HYCOM) with1200 x 1684 points in the horizontal as shown in Figure 1.1 and 18 isopyncnal and 7 *z*-levels in the vertical. Surface forcings, in the form of 10-m winds and sea-level atmospheric pressure, are from the 3-hour NCEP Global Forecast System (GFS), a numerical weather prediction modeling system. The open boundaries are relaxed to NCEP climatology. Tides are included in terms of tidal potential and boundary tides, that are specified in terms of the M_2, S_2, N_2, K_2, K_1, P_1, O_1, and Q_1 tidal constituents. River inputs are specified in terms of US Geological Survey (USGS) daily streamflow data and climatology. In the previously analyzed operational version (Richardson and Schmalz, 2007), SST data from the GOES AVHRR are assimilated. In experimental version one, improvements to the tidal dynamics have been made, while in experimental version two, in addition to the tidal improvement SSH data assimilation has been incorporated. Refer to Bleck et al. (2002) for further details regarding the HYCOM model development and computational algorithms.

The University of North Carolina(UNC) ADCIRC western North Atlantic Forecast model is a two-dimensional vertically integrated finite element model. The domain covers the western Atlantic Ocean from 60 degrees West and contains the Gulf of Mexico and spans 7.9 to 45.8 degrees North latitudes as shown in Figure 1.2. Tidal forcings include the M_2, S_2, N_2, K_2, K_1, $2N_2$, O_1, and Q_1 tidal constituents (Blain et al., 2003). See Leuttich et al. (1992) and Kolar et al. (1994) for computational details. The system is run 4 times daily forced by the NWS North American Mesoscale (NAM) 10-meter winds. Each cycle produces a 24 hour nowcast, and an 84 hour forecast forced by the NWS NAM model for the AWIP32 (221) grid.

NOS/Coast Survey Development Laboratory (CSDL) has utilized the subtidal water level forecast guidance produced by the NWS Meteorological Development Laboratory (MDL) Extra-Tropical Storm Surge (ETSS) Model for offshore water level boundary conditions for the NOS New York Harbor /Port of New Jersey, Chesapeake Bay, and Galveston Bay operational forecast systems. Separate domains are run for the East Coast as shown in Figures 1.3 and 1.4, West Coast, Alaskan Coast, and Gulf of Mexico as shown in Figure 1.5. The NWS GFS is used to provide the meteorological forcings at approximately 100 km resolution. The two-dimensional depth averaged shallow water equations are solved in complex variables via finite differences on an elliptical grid. See Chen et al. (1993) for additional model details.

The U.S. Navy (USN) Global Coastal Ocean Model (G-NCOM) system in Region 1 contains the western North Atlantic and Gulf of Mexico and is run on a 1/8 by 1/8 degree grid as shown in Figure 1.6 based on the Princeton Ocean Model (POM) using 41 layers. See Blumberg and Mellor (1987) and Blumberg and Herring (1987) for computational details and Martin (2000) for operational implementation. The daily 00Z forecast cycle has a horizon out 72 hours and is forced by U.S. Navy Operational Global Atmospheric Prediction System (NOGAPS) winds and Multi-Channel Sea Surface Temperature (MCSST). Barotropic tides are added from the Oregon State global ¼ by ¼ degree TPXO6.2 tidal model (Egbert and Erofeeva, 2002) for the above eight RTOFS constituents as well as the two long period constituents (M_f, M_m).

Initially, the two experimental RTOFS versions are contrasted with the operational version during January through April 2006 for hours 1-24. Next ADCIRC nowcast and forecast guidance are evaluated over this same time period and contrasted with the RTOFS results.

For November 2008, we have compared daily forecast/nowcast results of both subtidal (ETSS) and total water level response (RTOFS, G-NCOM, and ADCIRC) along the East coast and throughout the Gulf of Mexico from hours 6-36 for all models. Results are compared and contrasted versus observations and some initial conclusions drawn. A set of programs has been developed to perform the comparisons. The software is outlined in Appendix A and is largely as previously reported by Richardson and Schmalz (2007). Also in Appendix A, a description of each program is provided while complete script and control file listings are given in Appendix B.

Chapter 2 presents a description of all "cases", a total of twelve, one including the ADCIRC harmonic analysis. Instruction on how to run the analysis program set is also provided. In Chapter 3, the two experimental RTOFS versions are compared with the operational RTOFS for the months of January, February, March, and April 2006. In Chapter 4, ADCIRC nowcasts and forecast guidance are evaluated. In addition, water level harmonic analysis results are presented to enumerate the ADCIRC tidal error. Analysis results from the months of January, February, March, and April 2006, involving RTOFS and ETSS are presented in Chapter 4. In Chapter 5, all the forecast model water levels are compared and contrasted to observations in November 2008. Chapter 6 presents some conclusions drawn from the work already completed (see Richardson and Schmalz, 2007) as well as this study, as well as recommendations for future subjects of investigation.

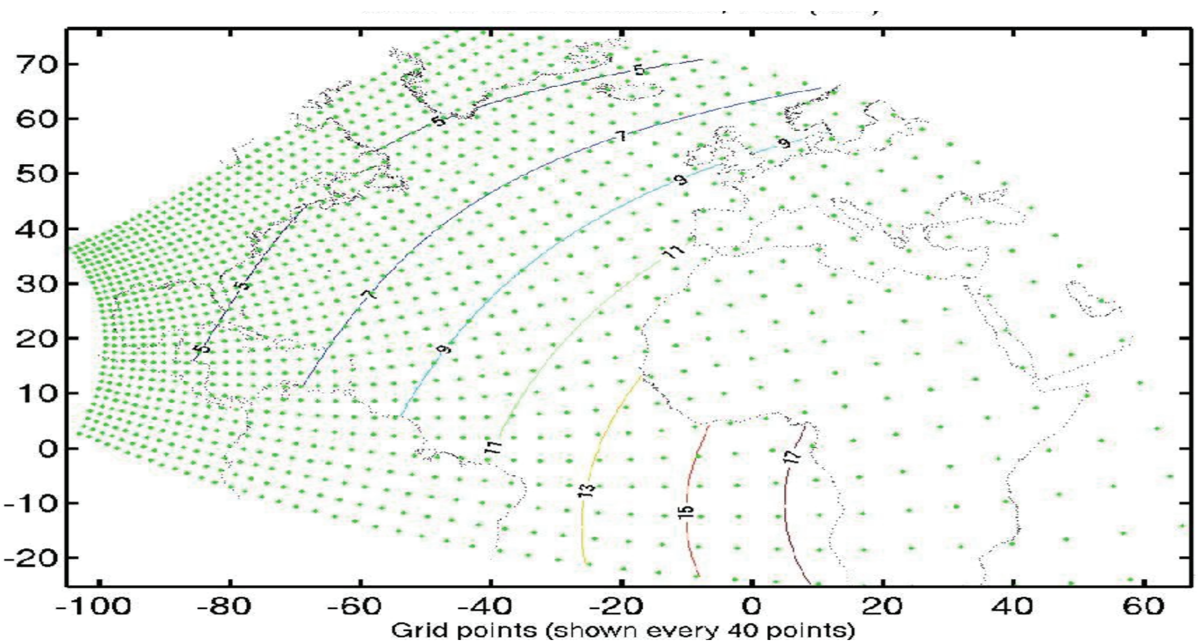


Figure 1.1 RTOFS Grid with spacing from 5 to 17 km

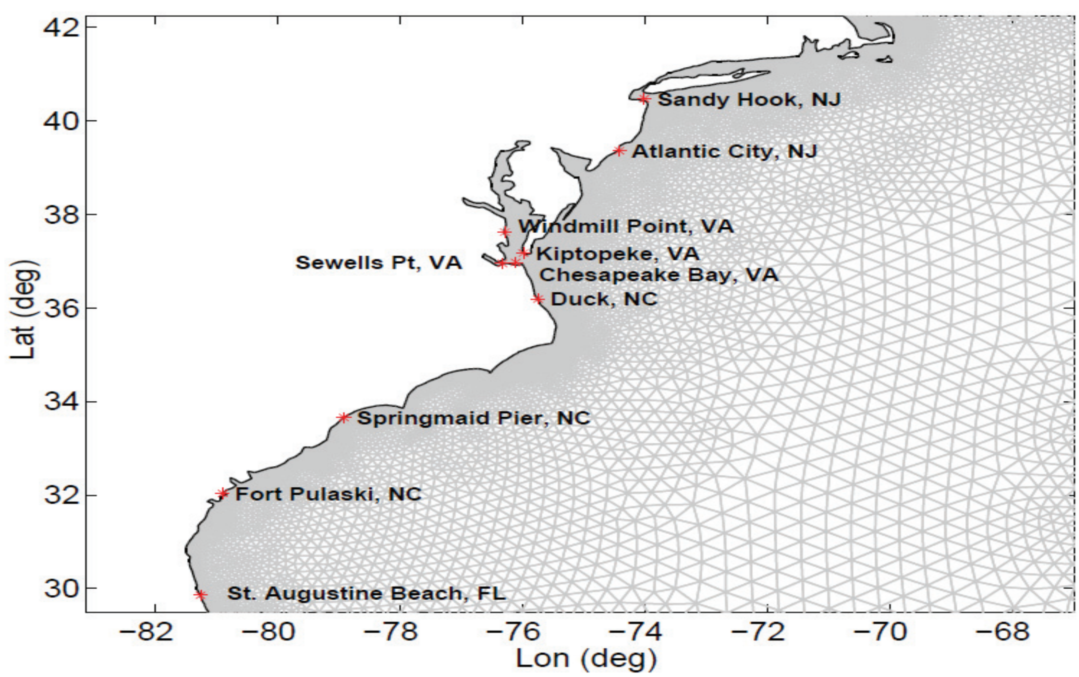


Figure 1.2. ADCIRC Western North Atlantic Grid along the East Coast with resolution ranging from 5.6 to 44.5 km.

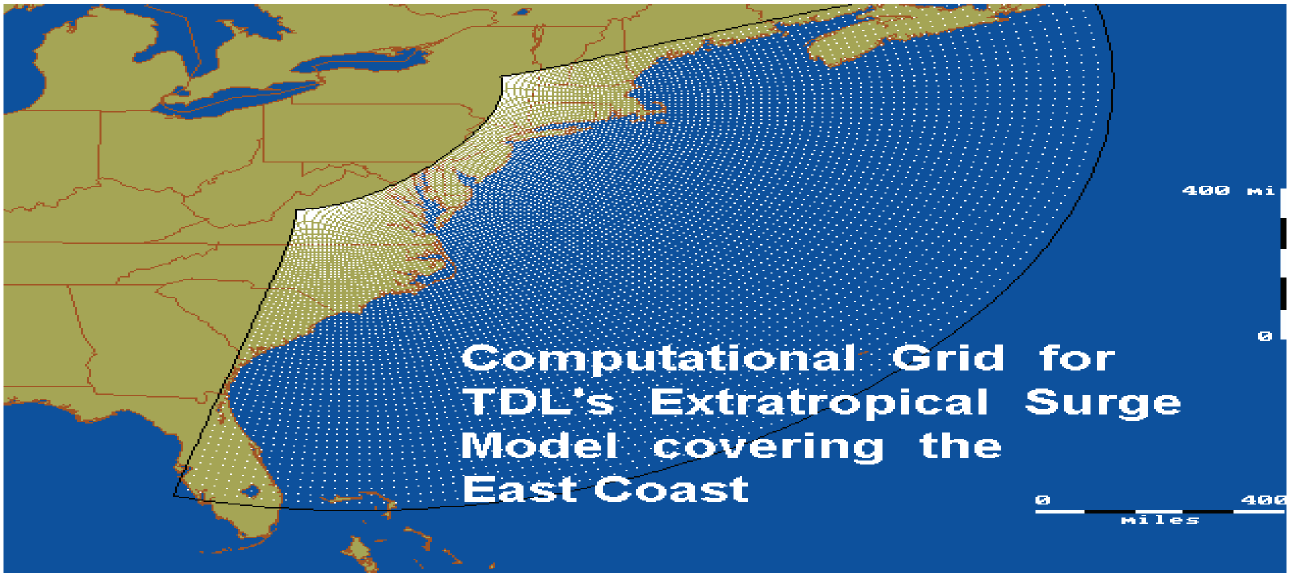


Figure 1.3 ETSS East Coast Grid with order 10 km coastal resolution

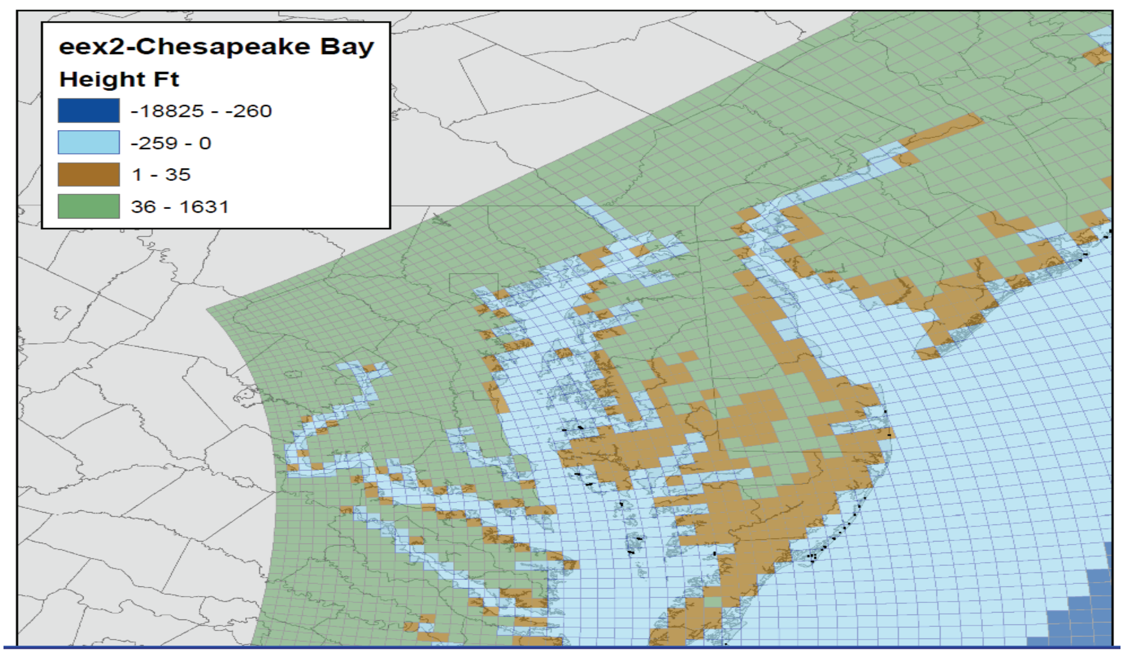


Figure1.4. High Resolution ~6 km ETSS East Coast Grid in the Vicinity of Chesapeake and Delaware Bays.

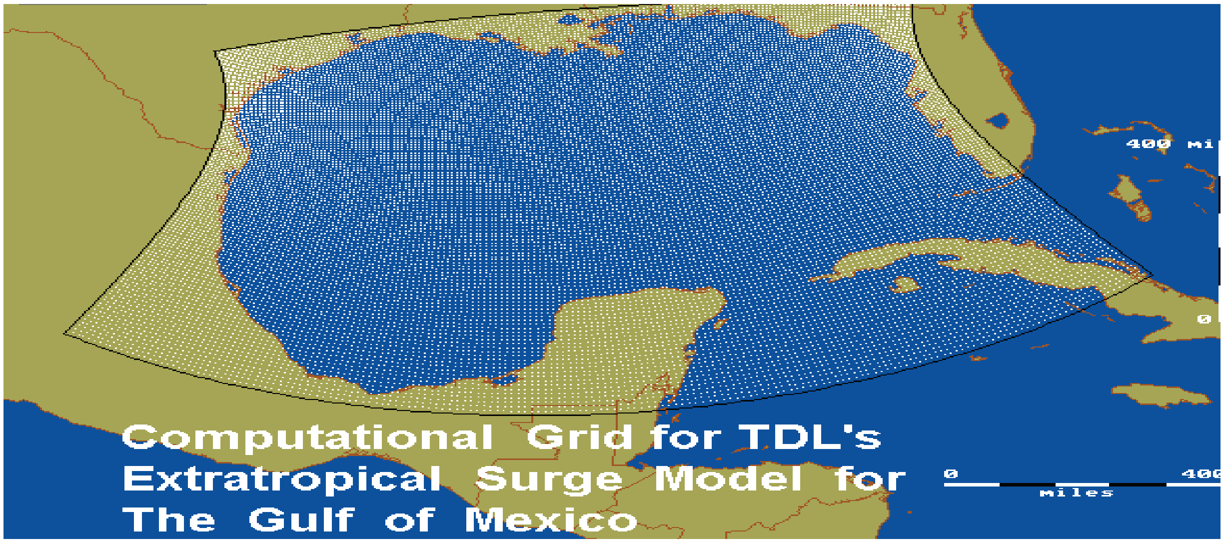


Figure 1.5 ETSS Gulf of Mexico Grid with order 10 km coastal resolution

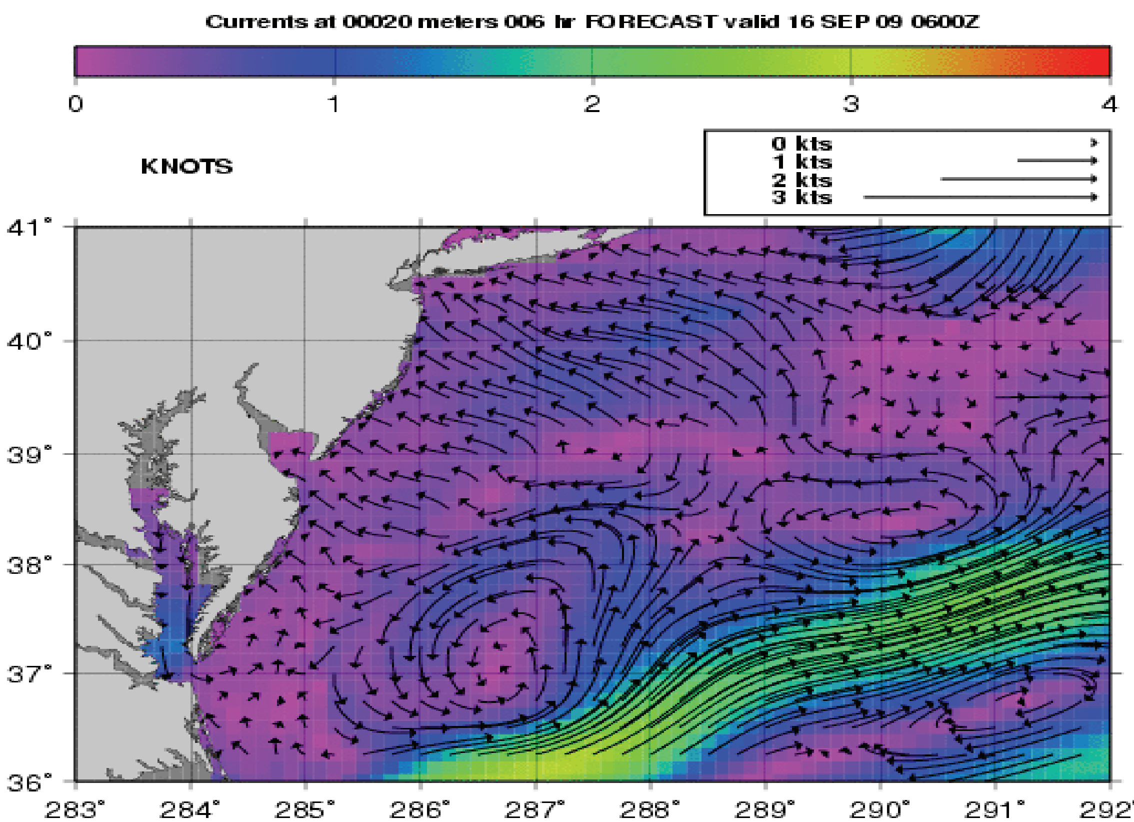


Figure 1.6 G-NCOM Grid in the Mid-Atlantic Region 1/8 degree ~ 10km

2. CASE DESCRIPTIONS

Twelve cases, as shown in Table 2.1, were developed to facilitate the comparison of a subtidal forecast model (ETSS) with three total water level forecast models including RTOFS, ADCIRC, and G-NCOM. As a prerequisite, the observed water level data obtained with respect to MLLW and GMT must be processed. This is performed with the program reform_coops.f described by Richardson and Schmalz (2004). For the subtidal comparison, the observed water level data were 30 hour low pass filtered using program 30hourlp.f, a version of the standard Fourier filter program. Cases 1 through 12 are described in this chapter. Note that all water level processing is in GMT.

Table 2.1. Inventory of Evaluation Cases

Case No.	Case Descriptions	Period (Hours)	Analysis Month (No, Year)
1	RTOFS forecast guidance (operational, adjusted) vs. observations	1-24	1-4, 2006
2	RTOFS forecast guidance (versions 1 and 2, adjusted) vs. observations	1-24	1-4, 2006
3	ADCIRC forecast guidance (adjusted) vs. observations	6-36	1-4, 2006
4	ADCIRC nowcast (adjusted) vs. observations	1-24	1-4, 2006
5	ADCIRC forecast guidance (adjusted) vs. observations	1-24	1-4, 2006
6	RTOFS forecast guidance (adjusted) vs. observations	6-36	11, 2008
7	ADCIRC forecast guidance (adjusted) vs. observations	6-36	11, 2008
8	G-NCOM forecast guidance (adjusted) vs. observations	6-36	11, 2008
9	ETSS subtidal forecast guidance (adjusted) vs. 30 hr LPF observations	6-36	11, 2008
10	ADCIRC Nowcast Processing and Harmonic Analysis	1-24	1-4. 2006
11	ADCIRC nowcast 30hr LPF (adjusted) vs. 30hr LPF observations	1-24	1-4, 2006
12	G-NCOM forecast guidance (detided, adjusted) vs. 30hr LPF observations	6-36	11, 2008

Case 1: Operational RTOFS Total Water Level Comparison: Adjusted Forecast Guidance vs. Observations Hr 1-24

The processing steps for the RTOFS daily forecast files are given in Table 2.2 and are discussed below. Readhycom.f reads the forecast output for hours 1 through 24. The output format is the standard ETSS format, and the naming convention for output files is hycom.(mn)(dy)(year), where mn is the month, dy is the day, and the year is 2006. Adjust24.f reads these water level values and adds an offset. The offset is determined by subtracting the first forecast value from the first observed value. This offset is added to each forecast value for hours 1 through 24. The naming convention for output files is hycom.(mn)(dy)(year)_adj. The adjusted daily forecast files are fed into the analysis program, wl_sa.ph24.f, for comparison with the observed data. Wl_sa.ph24.f is a revision of wl_sa.ph. The comparison is performed over hours 1 through 24, instead of hours 6 through 36 as had been done previously.

Table 2.2. Case 1: Operational RTOFS Total Water Level Comparison: Adjusted Forecast Guidance vs. Observations Hr 1-24

Script	Source File	Control File
readhy.jcl	readhycom.f	readhy.jan06.n
adjust.jcl	adjust24.f	adj_rtofs.jan06.n
wl_sa.jcl	wl_sa.ph24.f	wl_rtofs.jan06.n

Case 2: RTOFS Versions 1 and 2 Total Water Level Comparison: Adjusted Forecast Guidance vs. Observations Hr 1-24

Read_monrtofs.f reads the (versions 1 and 2) RTOFS model output from netCDF files which were provided in the form of monthly concatenated files. These monthly concatenated files are converted into daily forecast files, for hours 1 through 24, just as we worked with before. Adjust24.f is a revision of adjust_blk.f. Adjust24.f adjusts model values for hours 1 through 24, instead of hours 6 through 36, as had been done previously. The naming convention for output files is rtofs.(mn)(dy)(year)_adj. Wl_sa.ph24.f carries out the comparison with the observed values for hours 1 through 24. All processing steps are shown in Table 2.3.

Table 2.3. Case 2: RTOFS Versions 1 and 2 Total Water Level Comparison: Adjusted Forecast Guidance vs. Observations Hr 1-24

Script	Source File	Control File
month.jcl	read_monrtofs.f	readhy.jan06.n
adjust.jcl	adjust24.f	adj_rtofs.jan06mon.n
wl_sa.jcl	wl_sa.ph24.f	wl_rtofs.jan06mon.n

Case 3: ADCIRC Total Water Level Comparison: Adjusted Forecast Guidance vs. Observations Hr 6-36

Readadcirc.f reads ADCIRC forecast water level output. The naming convention for output files is adcirc.(year)(mn)(dy). The forecast output is adjusted to the observed in the standard way by adjust_blk.f. The naming convention for output files is adcirc.(year)(mn)(dy)_adj. The analysis is performed by wl_sa.ph.f for hours 6 through 36 of the Forecast Guidance cycle. All processing steps are shown in Table 2.4.

Table 2.4. Case 3: ADCIRC Total Water Level Comparison: Adjusted Forecast Guidance vs. Observations Hr 6-36

Script	Source File	Control File
readadc.jcl	read_adcirc.f	adc_jan06.n
adjust.jcl	adjust_blk.f	adj_adcirc.jan06.n
wl_sa.jcl	wl_sa.ph.f	wl_adcirc.jan06.n

Case 4: ADCIRC Total Water Level Comparison: Adjusted Nowcast vs. Observations Hr 1-24

Readadcnew24.f reads ADCIRC nowcast water level values for hours 1 through 24. Adjust24.f reads these water level values and adds the appropriate offset, for hours 1 through 24. The naming convention for output files is rtofs.(mn)(dy)(year)_adj. The analysis is performed by wl_sa.ph24.f for hours 1 through 24 of the cycle. All processing steps are shown in Table 2.5.

Table 2.5. Case 4: ADCIRC Total Water Level Comparison: Adjusted Nowcast vs. Observations Hr 1-24

Script	Source File	Control File
readadcnew24.jcl	read_adcnew24.f	adcnew24_jan06.n
adjust.jcl	adjust24.f	adj_adcnew.jan06.n
wl_sa.jcl	wl_sa.ph24.f	wl_adcnew.jan06.n

Case 5: ADCIRC Total Water level Comparison: Adjusted Forecast Guidance vs. Observations Hr 1-24

Readadcirc24.f reads ADCIRC forecast output for hours 1 through 24 of the forecast cycle. These forecast values are adjusted by adjust24.f. Analysis is performed by wl_sa.ph24.f. All processing steps are shown in Table 2.6.

Table 2.6. Case 5: ADCIRC Total Water Level Comparison: Adjusted Forecast Guidance vs. Observations Hr 1-24

Script	Source File	Control File
readadcirc24.jcl	read_adcirc24.f	adc_jan06.n
adjust.jcl	adjust24.f	adj_adcold.jan06.n
wl_sa.jcl	wl_sa.ph24.f	wl_adcold.jan06.n

Case 6: Operational RTOFS Total Water Level Comparison: Adjusted Forecast Guidance vs. Observations Hr 6-36

Readrtofs.f reads daily RTOFS forecast output, hours 6 through 36, from netCDF. The output files are in standard ETSS block format, and the naming convention is rtofs.(mn)(dy)(year). Adjust_blk.f adjusts the model values in the standard way. The naming convention for output files is rtofs.(mn)(dy)(year)_adj. Wl_sa.ph.f carries out the comparison, hours 6 through 36, with the observed data. All processing steps are shown in Table 2.7.

Table 2.7. Case 6: Operational RTOFS Total Water Level Comparison: Adjusted Forecast Guidance vs. Observations Hr 6-36

Script	Source File	Control File
rtofs.jcl	readrtofs.f	readhy.nov08.n
adjust.jcl	adjust_blk.f	adj_rtofs.nov08.n
wl_sa.jcl	wl_sa.ph.f	wl_rtofs.nov08.n

Case 7: ADCIRC Total Water Level Comparison: Adjusted Forecast Guidance vs. Observations Hr 6-36

Readadcirc.f reads ADCIRC forecast water level output for hours 6 through 36 of each forecast cycle. The naming convention for output files is adcirc.(year)(mn)(dy). Adjust_blk.f adjusts the forecast output in the standard way by adding the appropriate offset. The naming convention for output files is adcirc(year)(mn)(dy)_adj. Wl_sa.ph.f carries out the comparison with observed values, hours 6 through 36, in the standard way. All processing steps are shown in Table 2.8.

Table 2.8. Case 7: ADCIRC Total Water Level Comparison: Adjusted Forecast Guidance vs. Observations Hr 6-36

Script	Source File	Control File
readadc.jcl	read_adcirc.f	adc_nov08.n
adjust.jcl	adjust_blk.f	adj_adcirc.nov08.n
wl_sa.jcl	wl_sa.ph.f	wl_adcirc.nov08.n

Case 8: G-NCOM Total Water Level Comparison: Adjusted Forecast Guidance vs. Observations Hr 6-36

Readncom.f reads G-NCOM forecast water level output from netCDF for hours 1 through 36. These daily netCDF files are converted to an output of daily forecast files in standard block format. However, the G-NCOM forecast output is at 3 hour intervals. Adjust_blk adds the offset (first observed value – the first forecast value) to the model values at 3 hour intervals. The naming convention for the adjusted output files is ncom.(mn)(dy)(year)_adj. Wl_sa.ph.f analyzes these adjusted forecast output vs. the observed water level values for hours 1 through 36 (at 3 hour intervals). All processing steps are shown in Table 2.9.

Table 2.9. Case 8: G-NCOM Total Water Level Comparison: Adjusted Forecast Guidance vs. Observations Hr 6-36

Script	Source File	Control File
readncom.jcl	readncom.f	readncom.nov08.n
adjust.jcl	adjust_blk.f	adj_ncom.nov08.n
wl_sa.jcl	wl_sa.ph.f	wl_ncom.nov08.n

Case 9: ETSS Subtidal Water Level Comparison: Adjusted Forecast Guidance vs. Filtered Observations Hr 6-36

ETSS forecast files were copied to the analysis home directory. The directory structure is divided into ec (East Coast) and gm (Gulf of Mexico). The files are daily forecast files for all stations for that region. The water level forecast output is recorded in tenths of feet. The processing steps itemized in Table 2.10 are discussed in turn below. Read_tdl.f reads the water level data for each station, from hours 6 through 36, and converts the values from tenths of feet to meters. The naming convention of the output file is etss.(mn)(dy)(year) where mn is month, dy is day, and year is 2006. Adjust_blk.f reads these water level values (in meters) and adds an offset. The offset is determined by subtracting the first forecast value from the first observed value. This offset is then added to all of the forecast values through hour 36. The output format from this program is identical to the standard ETSS block format that it read the data from. The naming convention for the output files is etss.(nm)(dy)(year)_adj. Each daily adjusted forecast file is fed into the analysis program, wl_sa.ph.f, for comparison with the observed data. The comparison is performed over hours 6 through 36 of each daily forecast cycle. All processing steps are shown in Table 2.10. Note since the ETTS forecast water levels are subtidal, the observed water levels are 30 hour low pass filtered.

Table 2.10. Case 9: ETSS Subtidal Water Level Comparison: Adjusted Forecast Guidance vs. Filtered Observations Hr 6-36

Script	Source File	Control File
read_tdl.jcl	read_tdl.f	read_nov08.n
adjust.jcl	adjust_blk.f	adj_etss.nov08.n
wl_sa.jcl	wl_sa.ph.f	wl_tdl.nov08.n

Case 10. ADCIRC Nowcast Processing and Harmonic Analysis

The nowcast processing and harmonic analysis steps are given in Table 2.11 and described below.

Table 2.11. Case 10: ADCIRC Nowcast Processing and Harmonic Analysis

Script	Source File	Control File
readadcnew24.jcl	read_adcnew24.f	adcnew24_jan06.n
hycomha.jcl	hycom29.f	hycomha_jan06.n
harm29d.jcl	harm29d.f	-
const.jcl	const2.f	constt.jan06.n

The ADCIRC nowcasts were extracted from the daily forecast files. The forecast output begins on hour 1 of that specified day. The 24 previous hourly values (-23 through 0, column 1), beginning at hour 1 of the previous day and continuing through hour 0 of the present day, are the nowcast data associated with the present nowcast/forecast cycle. Readhyc_nowc.f reads from the nowcast/forecast file, then reformats the nowcasts into the standard ETSS block format. The naming convention for the reformatted daily nowcast files is hycom.(mn)(dy)(year). Dy of the output file will always be one day prior to that of the original nowcast/forecast file.

One purpose for working with the ADCIRC nowcasts was to perform harmonic analysis. Hycom29.f performs two functions necessary to run harm29. The nowcast data are read from the previously created nowcast daily files. The daily nowcast data is written to output files (by station) and concatenated. So for each station file, there is a continuous data string for the entire month (this is a necessary condition for the 30 hour low pass filter process). The naming convention for the output files is *_nowc.jan06. The program also creates the control files necessary to run harm29. The naming convention for these control files is control.*.001. The final step in the processing of nowcasts is to run program hyc_reform.f. This program will read the month long RTOFS nowcast data files (by station) and create from them the daily nowcast files in standard ETSS "block" format.

The harmonic analysis was performed by running a script (harm29d.jcl) using NOS standard procedures as outlined by Zervas (1997). An output file for each station was created with the naming convention *_nowc.jan06.cons. 24 harmonic constituents, amplitude and phase, are written to output using the standard NOS format of 7(f5.3,f4.1). Const2.f was created to display the harmonic constants derived from harm29 along with the accepted harmonic constants from CO-OPS. For each of the 24 constituents, the amplitude and phase (harm29 and accepted) are written to a table. The difference for both amplitude and phase are calculated and written to the table. Using these calculated values of difference for all 24 constituents, const2.f calculates an estimate of the RMS difference using a method discussed by Hess (1994). Also calculated is a NOS constituent weighted gain and phase difference in hours.

Case 11: ADCIRC Subtidal Water Level Comparison: Nowcast vs. Filtered Observations
Hr 1-24

This comparison was done with the filtered and adjusted nowcast values vs. the filtered observed values. Processing steps are shown in Table 2.12. Note that it is necessary to first go from ETSS standard block format to single station file format to do the filtering and then to return to the ETSS block format for the adjustment and analysis steps.

Table 2.12. Case 11. ADCIRC Subtidal Water Level Comparison: Filtered and Adjusted Nowcast vs. Filtered Observations Hr 1-24

Script	Source File	Control File
readadcnew24.jcl	read_adcnew24.f	adcnew24_jan06.n
hycomha.jcl	hycom29.f	hycomha_jan06.n
30hourlp.jcl	30hourlp.f	interactive prompt
hycref.jcl	hyc_reform.f	hycref30.jan06.n
adjust.jcl	adjust_blk.f	adj_hyc.n30.jan06.n
wl_sa.jcl	wl_sa.ph.f	wl_adc.nowc.jan06.n

Case 12: G-NCOM Subtidal Water Level Comparison: Detided and Adjusted Forecast Guidance vs. Filtered Observations Hr 6-36

NOS accepted harmonic constants for the ten tidal constituents used in the OSU tide model (TPXO6.2, Egbert and Erofeeva, 2002) were fed into the standard NOS prediction program (Program Pred) generating a month long prediction for each station (Zervas, 1997). These predicted values were subtracted from the forecast output, resulting in a de-tided series, which was adjusted and compared against the filtered observations as shown in Table 2.13. OSU tide model results at the G-NCOM water level station grid points were not used in the detiding.

Table 2.13. Case 12: G-NCOM Subtidal Water Level Comparison: Detided and Adjusted Forecast Guidance vs. Filtered Observations Hr 6-36

Script	Source File	Control File
readncom.jcl	readncom.f	readncom.nov08.n
readpred.jcl	readpred.f	read_nov08det.n
adjust.jcl	adjust_blk.f	adj_ncomdet.nov08.n
wl_sa.jcl	wl_sa.ph.f	wl_ncomdet.nov08.n

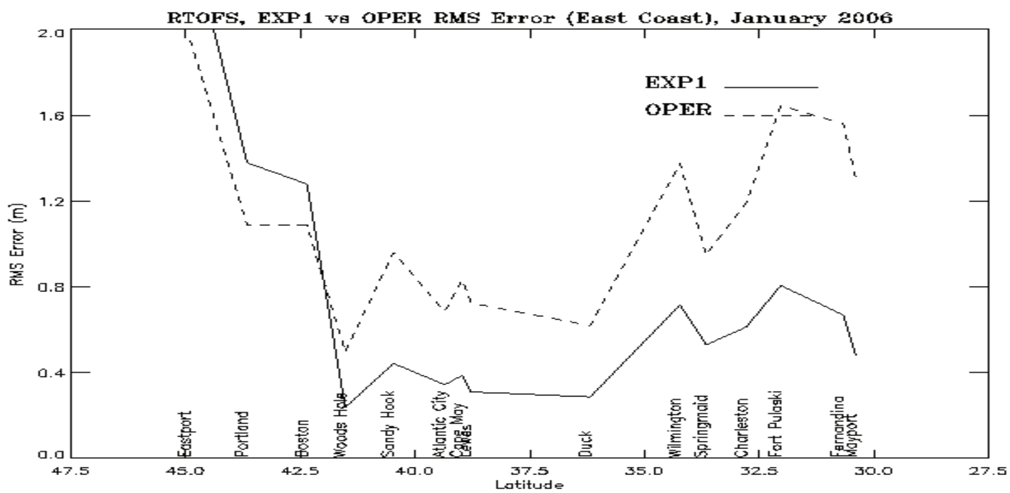
3. RTOFS WATER LEVEL ANALYSIS RESULTS

RTOFS experimental versions 1 and 2 water level forecasts were evaluated for each of the months January-April 2006 for hours 1-24. Next these forecasts were compared to the RTOFS operational water level forecast for each of the months January-April 2006 for hours 1 -24. It was necessary to use this time horizon, since the experimental version results were supplied in concatenated daily form. RMSEs with respect to NOS observations are given in Table 3.1 for each month.

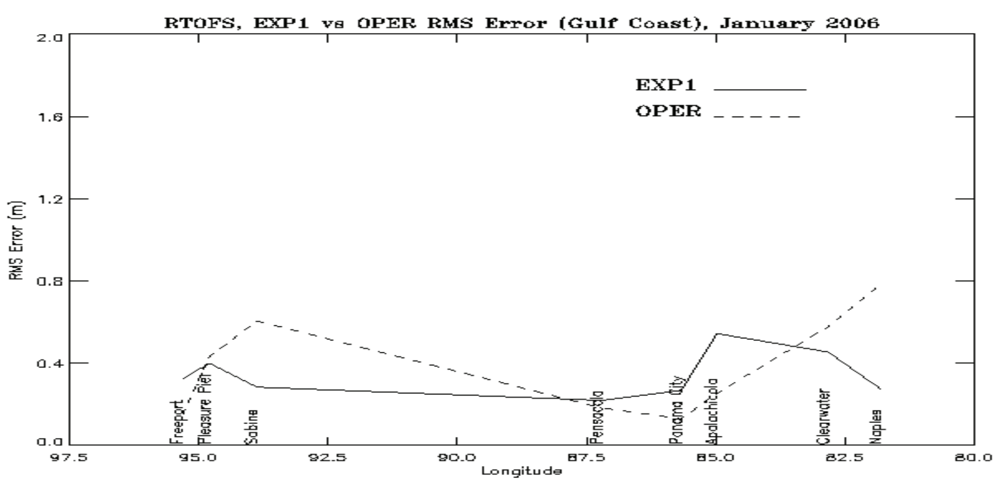
Table 3.1. RTOFS Operational and Experimental Forecast Guidance Monthly Water Level Comparisons to NOS Observations January – April 2006 (RMSE [meters]). Forecast hours 1-24 are used in the comparisons. Table entries are operational forecast guidance/experimental forecast 1 guidance /experimental forecast 2 guidance.

Station	January	February	March	April
Eastport, ME	1.95/2.44/2.42	1.86/2.28/2.25	1.85/2.42/2.41	1.74/2.37/2.35
Portland, ME	1.10/1.38/1.37	1.04/1.25/1.24	1.04/1.37/1.36	0.96/1.32/1.34
Boston, MA	1.09/1.28/1.28	1.03/1.28/1.29	1.05/1.17/1.17	0.97/1.37/1.39
Woods Hole, MA	0.50/0.24/0.24	0.49/0.24/0.26	0.50/0.27/0.29	0.51/0.25/0.27
Sandy Hook, NJ	0.96/0.44/0.45	0.95/0.43/0.44	0.94/0.45/0.48	0.95/0.49/0.50
Atlantic City, NJ	0.68/0.34/0.34	0.68/0.33/0.34	0.66/0.40/0.40	0.67/0.39/0.41
Cape May, NJ	0.83/0.39/0.39	0.81/0.36/0.36	0.76/0.40/0.41	0.80/0.40/0.42
Lewes, DE	0.72/0.31/0.32	0.71/0.30/0.30	0.68/0.34/0.34	0.70/0.32/0.33
Duck, NC	0.62/0.29/0.29	0.65/0.27/0.28	0.68/0.33/0.34	0.72/0.33/0.34
Wilmington, NC	1.37/0.72/0.70	1.40/0.69/0.67	1.37/0.66/0.65	1.36/0.64/0.64
Springmaid Pier, SC	0.95/0.53/0.54	0.96/0.52/0.54	0.94/0.59/0.61	0.93/0.56/0.56
Charleston, SC	1.19/0.61/0.60	1.20/0.58/0.59	1.21/0.65/0.67	1.21/0.63/0.64
Fort Pulaski, GA	1.65/0.81/0.81	1.68/0.78/0.78	1.66/0.88/0.88	1.66/0.84/0.83
Fernandina Beach, FL	1.56/0.67/0.68	1.55/0.66/0.66	1.58/0.70/0.73	1.60/0.68/0.70
Mayport, FL	1.31/0.48/0.49	1.31/0.49/0.47	1.35/0.51/0.52	1.36/0.48/0.49
Naples, FL	0.78/0.27/0.28	0.80/0.32/0.34	0.78/0.23/0.25	0.76/0.26/0.31
Clearwater, FL	0.58/0.45/0.46	0.55/0.31/0.31	0.59/0.32/0.32	0.55/0.36/0.31
Apalachicola, FL	0.25/0.54/0.55	0.25/0.32/0.32	0.23/0.35/0.36	0.22/0.67/0.70
Panama City, FL	0.13/0.27/0.27	0.12/0.16/0.15	0.13/0.18/0.19	0.14/0.28/0.31
Pensacola, FL	0.18/0.22/0.22	0.18/0.23/0.22	0.18/0.24/0.25	0.21/0.28/0.30
Sabine Pass, TX	0.61/0.28/0.28	0.63/0.45/0.45	0.64/0.50/0.51	0.63/0.31/0.32
Galveston Pleasure Pier, TX	0.43/0.40/0.40	0.48/0.35/0.35	0.49/0.39/0.40	0.49/0.47/0.48
Freeport, TX	0.15/0.32/0.33	0.18/0.21/0.22	0.18/0.25/0.27	0.18/0.37/0.38

Results for RTOFS experimental version 2, which includes the sea surface height (SSH) assimilation, are nearly the same as those in RTOFS experimental version 1 without SSH assimilation. This indicates that the SSH assimilation has a minor impact on coastal water levels. RTOFS Experimental versions 1 and 2 include improved tidal dynamics relative to the operational version. In Figure 3.1-3.4, the RMSEs for the operational version are plotted against the RMSEs for experimental version 1, along the Atlantic seaboard in Part (a) and along the Gulf Coast in Part (b), for the months January through April 2006, respectively. Note the consistency of the comparisons from month to month. In Figures 3.5-3.10, the RTOFS experimental version 1 forecast water levels are plotted versus water level observation over the first ten days during January 2006 (which are representative of conditions over the entire month) at Sandy Hook, NJ, Cape May, NJ, Charleston, SC, Mayport, FL, Naples, FL, and Galveston Pleasure Pier, TX, respectively. Note despite the adjustment applied at the start of each daily forecast, the forecast curves are nearly continuous at all stations.

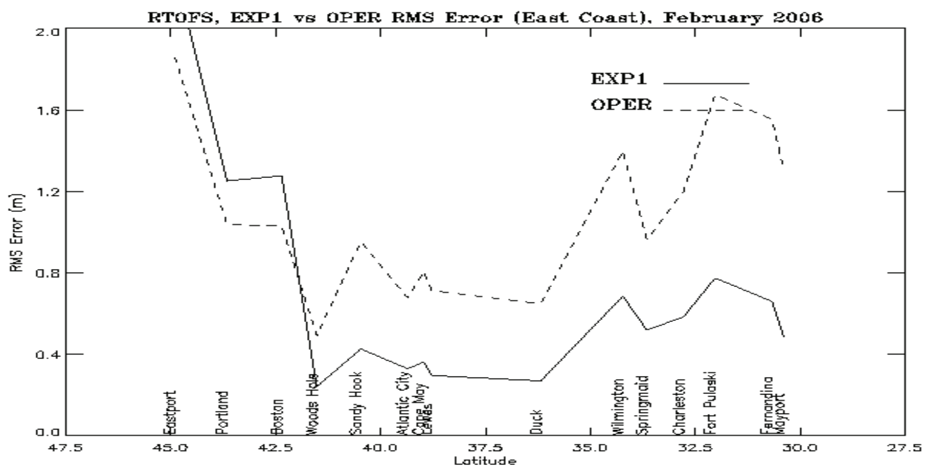


(a)

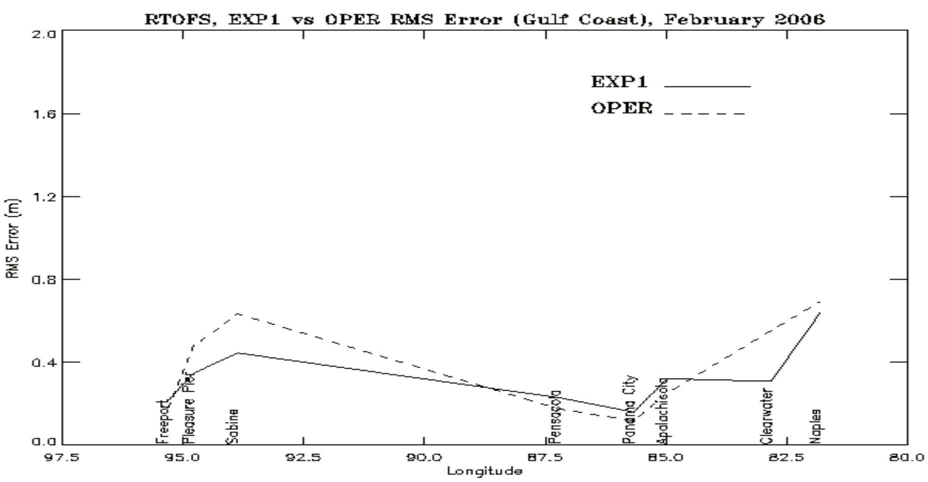


(b)

Figure 3.1. Experimental Version 1 RTOFS vs. Operational Version RTOFS Total Water Level Forecast Guidance RMSE (meters) for East Coast Stations (a) and for Gulf of Mexico Stations (b) for January 2006.

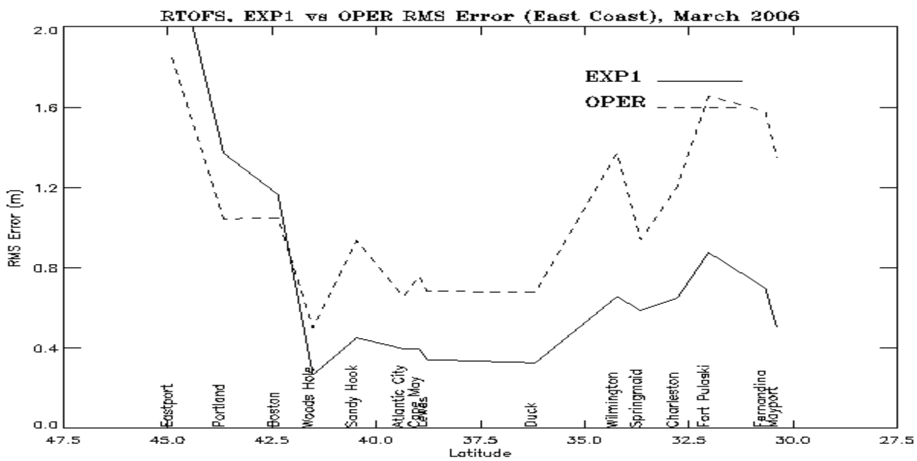


(a)

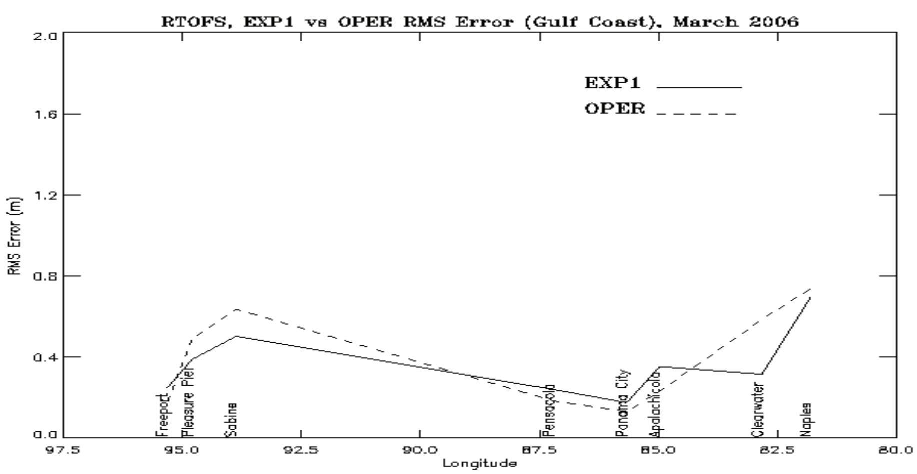


(b)

Figure 3.2. Experimental Version 1 RTOFS vs. Operational Version RTOFS Total Water Level Forecast Guidance RMSE (meters) for East Coast Stations (a) and for Gulf of Mexico Stations (b) for February 2006.

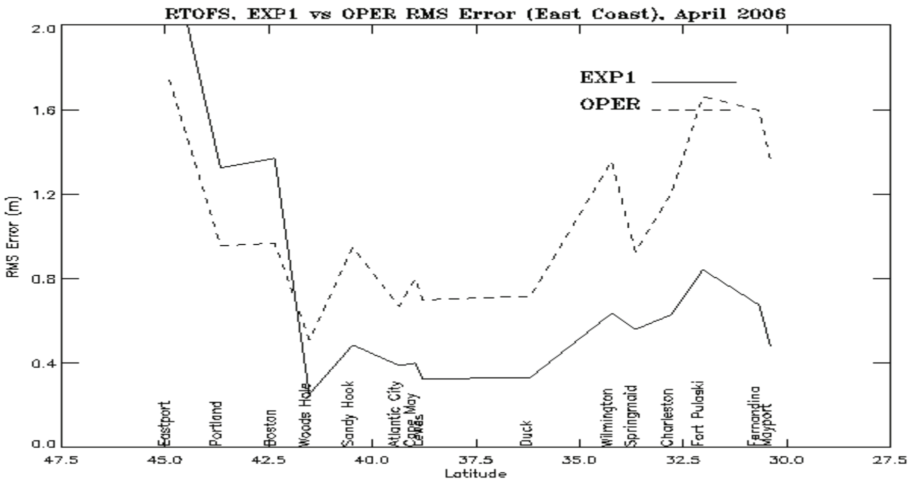


(a)

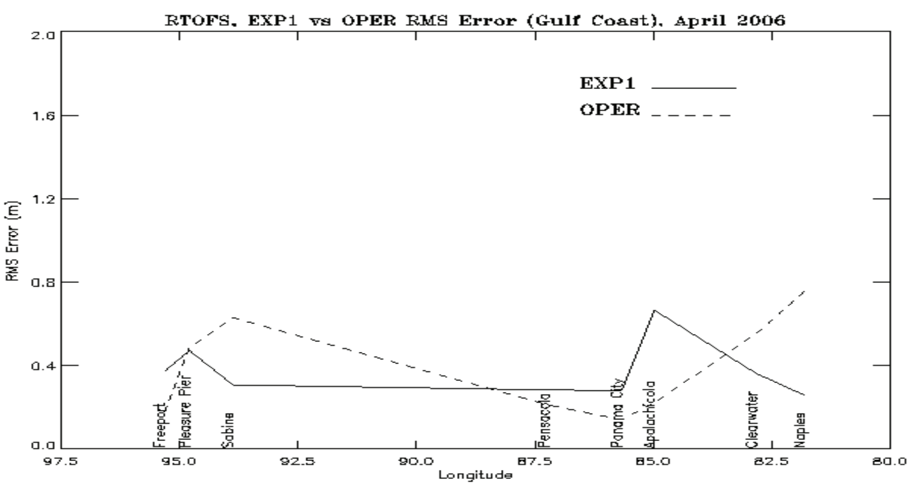


(b)

Figure 3.3. Experimental Version 1 RTOFS vs. Operational Version RTOFS Total Water Level Forecast Guidance RMSE (meters) for East Coast Stations (a) and for Gulf of Mexico Stations and (b) for March 2006.

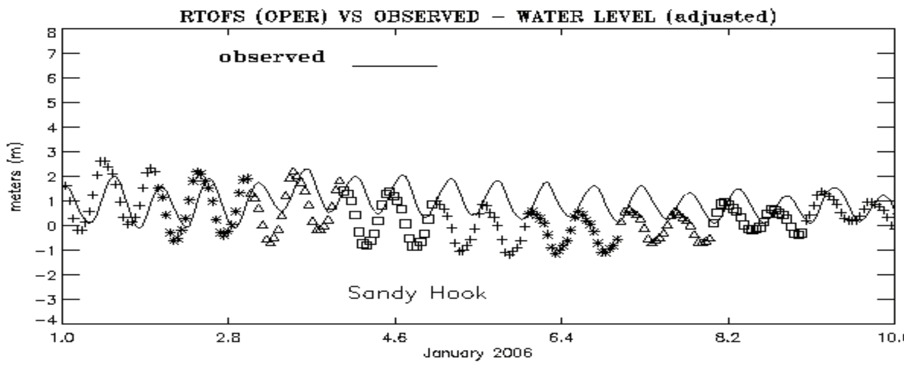


(a)

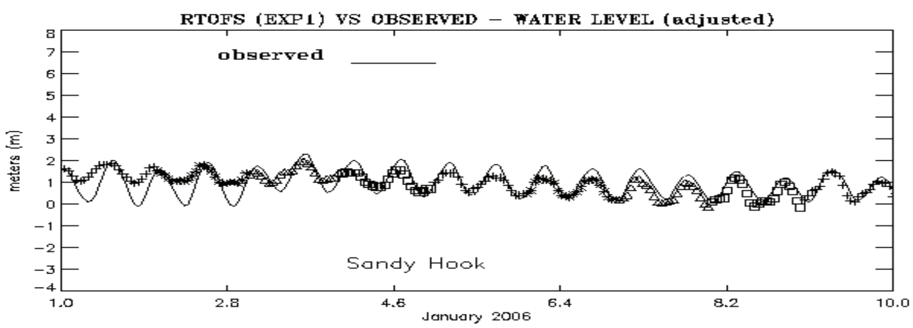


(b)

Figure 3.4. Experimental Version 1 RTOFS vs. Operational Version RTOFS Total Water Level Forecast Guidance RMSE (meters) for East Coast Stations (a) and for Gulf of Mexico Stations and (b) for April 2006.

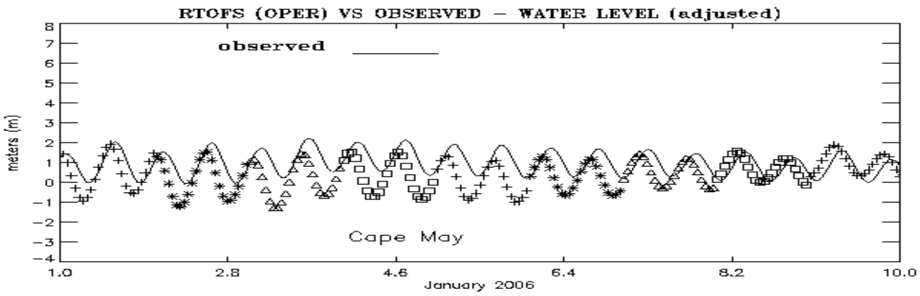


(a)

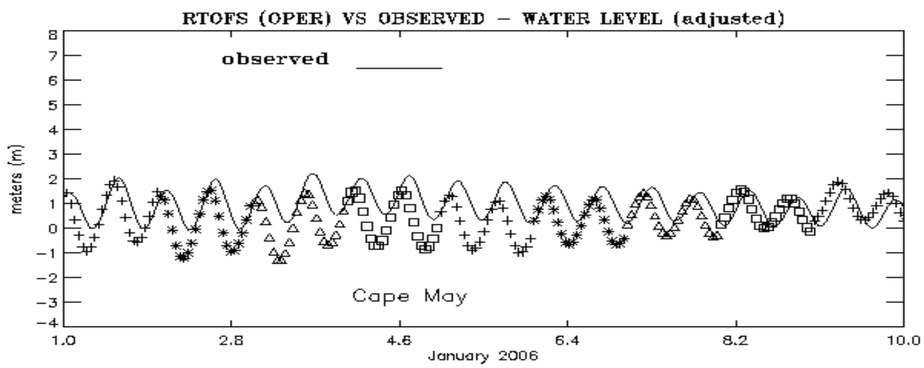


(b)

Figure 3.5. Operational RTOFS vs. Experimental Version 1 RTOFS Total Water Level Forecast Guidance against NOS Water Level Observations at Sandy Hook, NJ for January 2006. Operational RTOFS results are shown in (a), while Experimental Version 1 RTOFS results are shown in (b). Note (+,*,Δ, and □) are used to designate alternate 24 hour forecast values with the first symbol in the forecast series always on the observation curve due to the adjustment process.

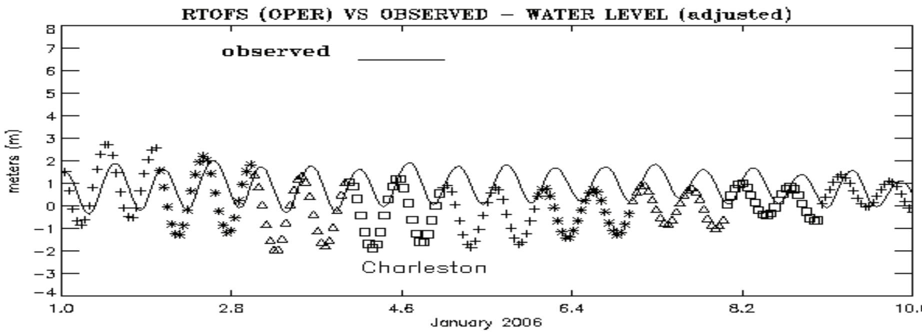


(a)

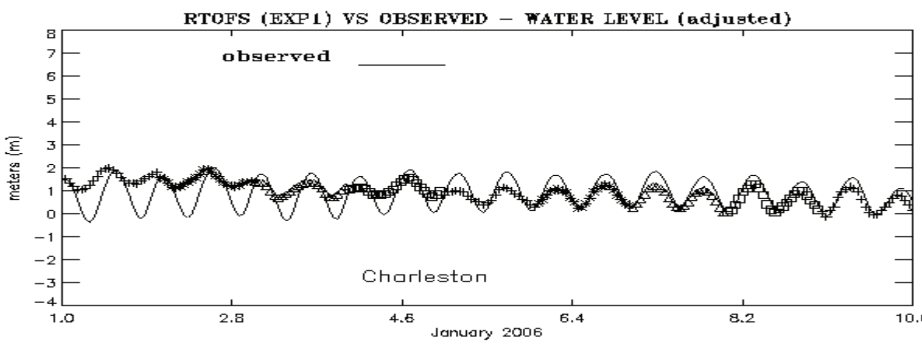


(b)

Figure 3.6. Operational RTOFS vs. Experimental Version 1 RTOFS Total Water Level Forecast Guidance against NOS Water Level Observations at Cape May, NJ for January 2006. Operational RTOFS results are shown in (a), while Experimental Version 1 RTOFS results are shown in b). Note (+,*,Δ, and □) are used to designate alternate 24 hour forecast values with the first symbol in the forecast series always on the observation curve due to the adjustment process.

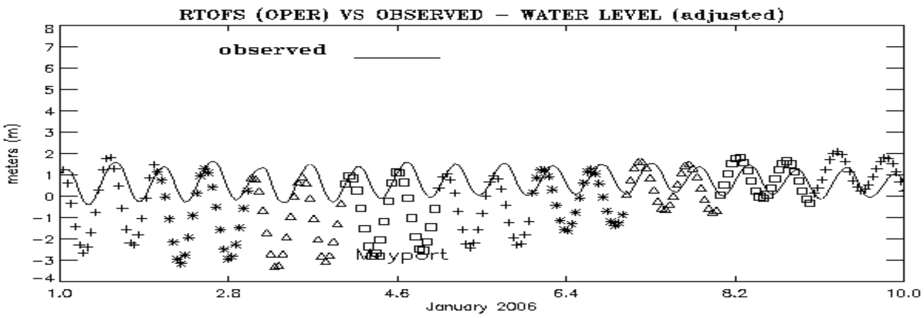


(a)

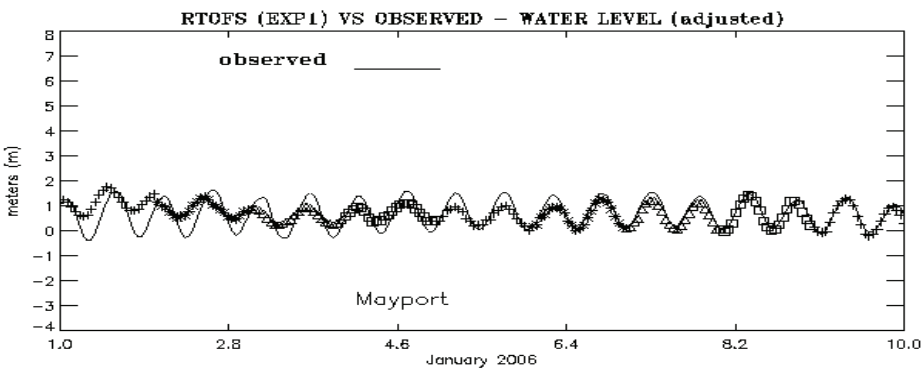


(b)

Figure 3.7. Operational RTOFS vs. Experimental Version 1 RTOFS Total Water Level Forecast Guidance against NOS Water Level Observations at Charleston, SC for January 2006. Operational RTOFS results are shown in (a), while Experimental Version 1 RTOFS results are shown in (b). Note (+,*,Δ, and □) are used to designate alternate 24 hour forecast values with the first symbol in the forecast series always on the observation curve due to the adjustment process.

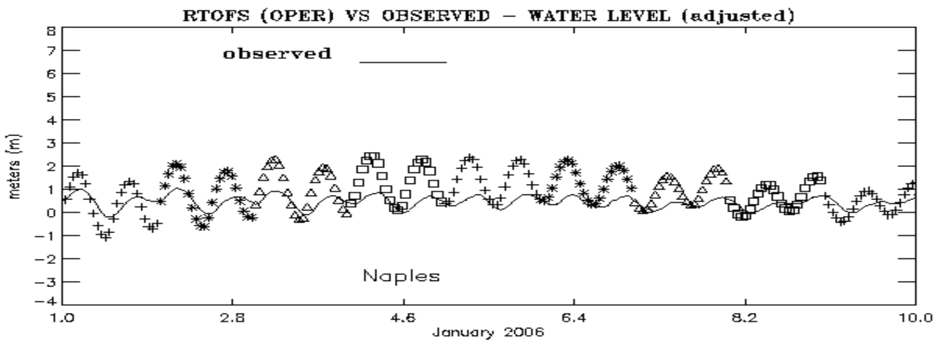


(a)

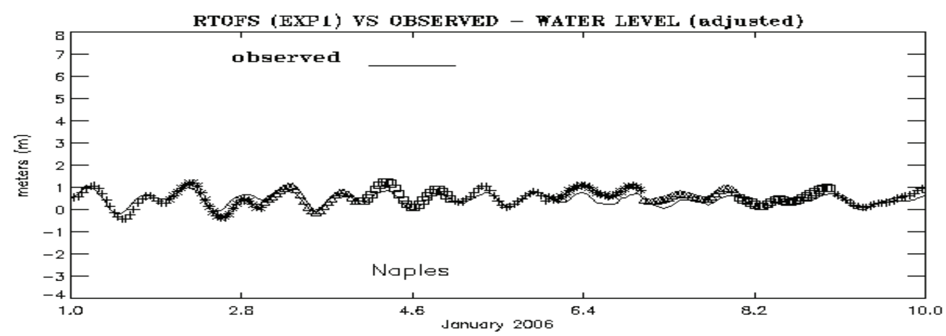


(b)

Figure 3.8. Operational RTOFS vs. Experimental Version 1 RTOFS Total Water Level Forecast Guidance against NOS Water Level Observations at Mayport, FL for January 2006. Operational RTOFS results are shown in (a), while Experimental Version 1 RTOFS results are shown in (b). Note (+,*,Δ, and □) are used to designate alternate 24 hour forecast values with the first symbol in the forecast series always on the observation curve due to the adjustment process

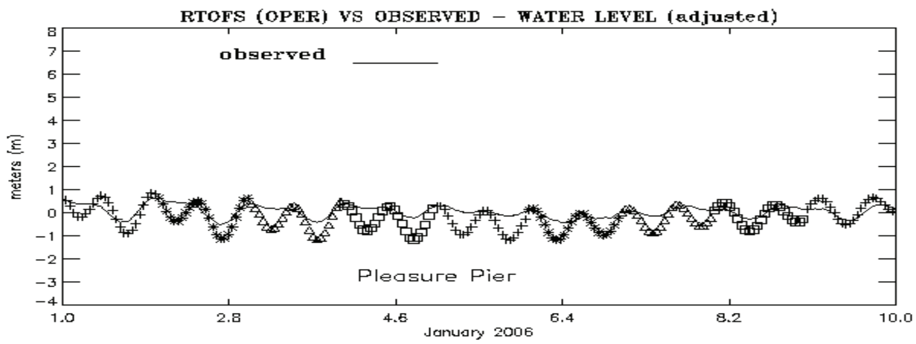


(a)

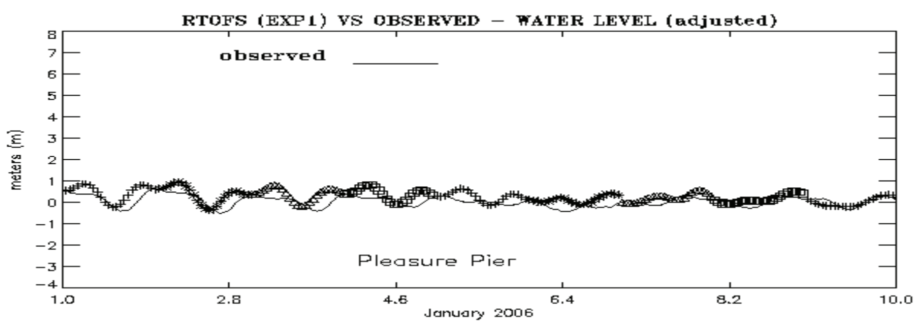


(b)

Figure 3.9. Operational RTOFS vs. Experimental Version 1 RTOFS Total Water Level Forecast Guidance against NOS Water Level Observations at Naples, FL for January 2006. Operational RTOFS results are shown in (a), while Experimental Version 1 RTOFS results are shown in (b). Note (+,*,Δ, and □) are used to designate alternate 24 hour forecast values with the first symbol in the forecast series always on the observation curve due to the adjustment process.



(a)



(b)

Figure 3.10. Operational RTOFS vs. Experimental Version 1 RTOFS Total Water Level Forecast Guidance against NOS Water Level Observations at Galveston Pleasure Pier, TX for January 2006. Operational RTOFS results are shown in (a), while Experimental Version 1 RTOFS results are shown in (b). Note (+,*,Δ, and □) are used to designate alternate 24 hour forecast values with the first symbol in the forecast series always on the observation curve due to the adjustment process.

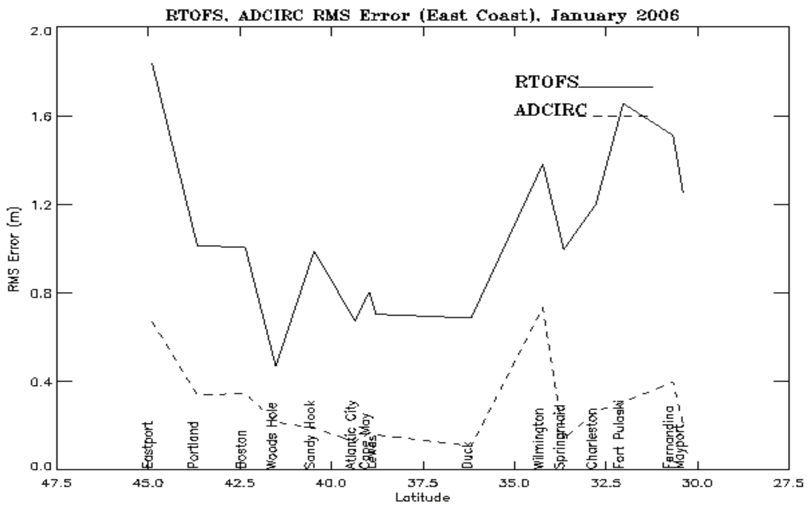
4. ADCIRC WATER LEVEL ANALYSIS RESULTS

ADCIRC vs. RTOFS

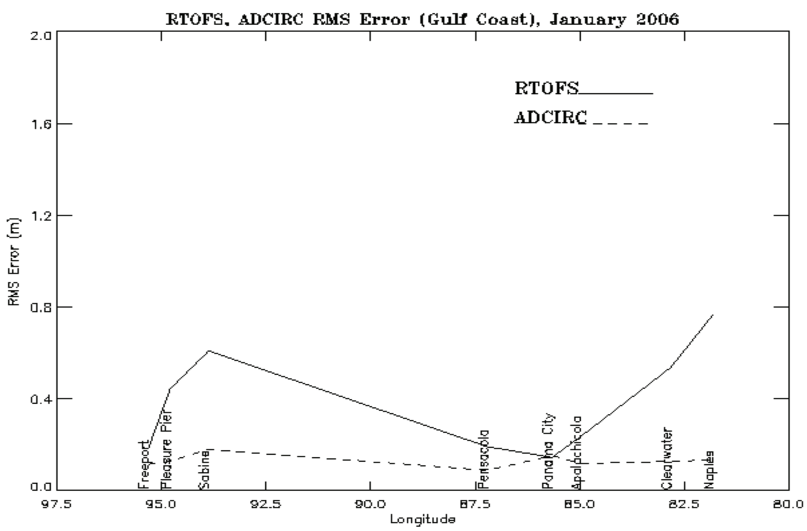
ADCIRC total water level forecast guidance comparisons were made to the operational RTOFS version results previously reported by Richardson and Schmalz (2007) for forecast hours 6-36 for each of the four months January – April 2006 in Table 4.1. ADCIRC forecast guidance is shown versus the operational RTOFS version results in Figures 4.1 for January, in Figure 4.2 for February, in Figure 4.3 for March, and in Figure 4.4 for April, respectively. In each figure RMSE with respect to the NOS observations at the East Coast stations are shown in Part a, while the Gulf stations are given in Part b.

Table 4.1. ADCIRC and RTOFS Operational Forecast Guidance Monthly Water Level Comparisons to NOS Observations January – April 2006 (RMSE [meters]). Forecast hours 6-36 are used in the comparisons. Table entries are ADCIRC forecast/ RTOFS forecast.

Station	January	February	March	April
Eastport, ME	0.67/1.84	0.68/1.80	0.68/1.73	0.66/1.71
Portland, ME	0.34/1.01	0.33/0.97	0.30/0.95	0.28/0.91
Boston, MA	0.35/1.01	0.33/0.97	0.31/0.94	0.30/0.90
Woods Hole, MA	0.22/0.47	0.19/0.47	0.19/0.50	0.19/0.51
Sandy Hook, NJ	0.19/0.99	0.18/0.98	0.13/0.97	0.10/0.98
Atlantic City, NJ	0.13/0.67	0.14/0.67	0.14/0.65	0.10/0.66
Cape May, NJ	0.17/0.81	0.16/0.75	0.18/0.76	0.12/0.80
Lewes, DE	0.16/0.70	0.17/0.66	0.14/0.70	0.10/0.71
Duck, NC	0.11/0.69	0.11/0.65	0.12/0.70	0.12/0.69
Wilmington, NC	0.73/1.38	0.70/1.35	0.73/1.44	0.71/1.37
Springmaid Pier, SC	0.14/1.00	0.12/0.98	0.14/1.01	0.13/1.01
Charleston, SC	0.27/1.20	0.25/1.20	0.26/1.25	0.22/1.25
Fort Pulaski, GA	0.31/1.66	0.29/1.60	0.29/1.71	0.25/1.70
Fernandina Beach, FL	0.40/1.51	0.36/1.41	0.37/1.54	0.35/1.52
Mayport, FL	0.21/1.25	0.20/1.17	0.19/1.27	0.18/1.26
Naples, FL	0.14/0.77	0.12/0.77	0.14/0.80	0.12/0.78
Clearwater, FL	0.13/0.54	0.14/0.52	0.13/0.53	0.12/0.53
Apalachicola, FL	0.12/0.24	0.12/0.22	0.12/0.21	0.10/0.19
Panama City, FL	0.15/0.15	0.16/0.14	0.14/0.14	0.10/0.14
Pensacola, FL	0.09/0.19	0.09/0.20	0.07/0.18	0.07/0.18
Sabine Pass, TX	0.18/0.61	0.21/0.64	0.21/0.67	0.20/0.67
Galveston Pleasure Pier, TX	0.13/0.44	0.13/0.44	0.12/0.45	0.12/0.44
Freeport, TX	0.12/0.19	0.12/0.16	0.11/0.15	0.11/0.14

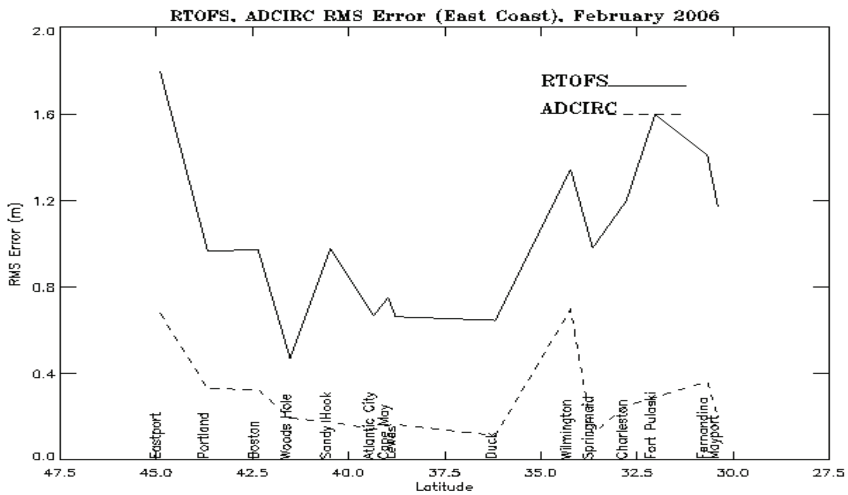


(a)

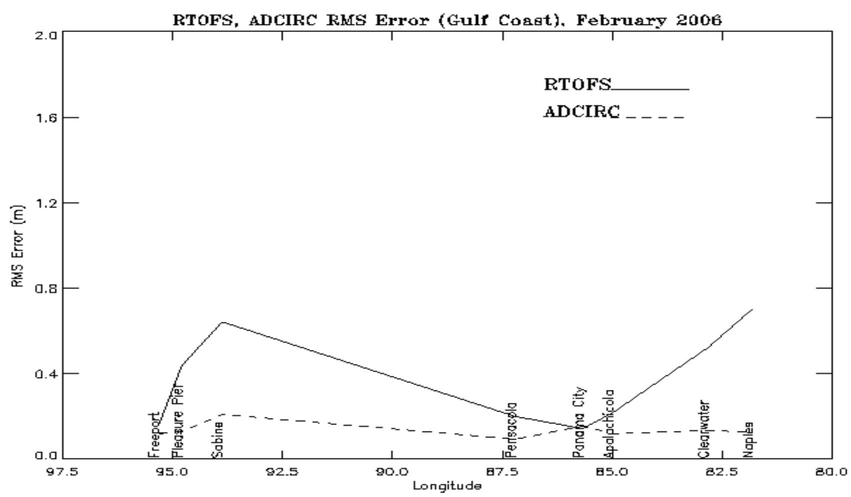


(b)

Figure 4.1. ADCIRC vs. RTOFS Operational Version Total Water Level Forecast Guidance RMSE (meters) for East Coast Stations (a) and for Gulf of Mexico Stations (b) for January 2006.

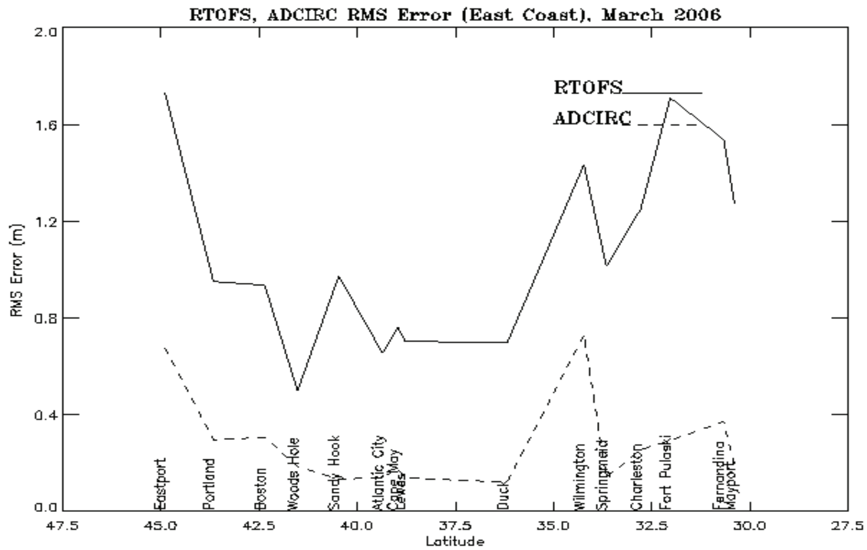


(a)

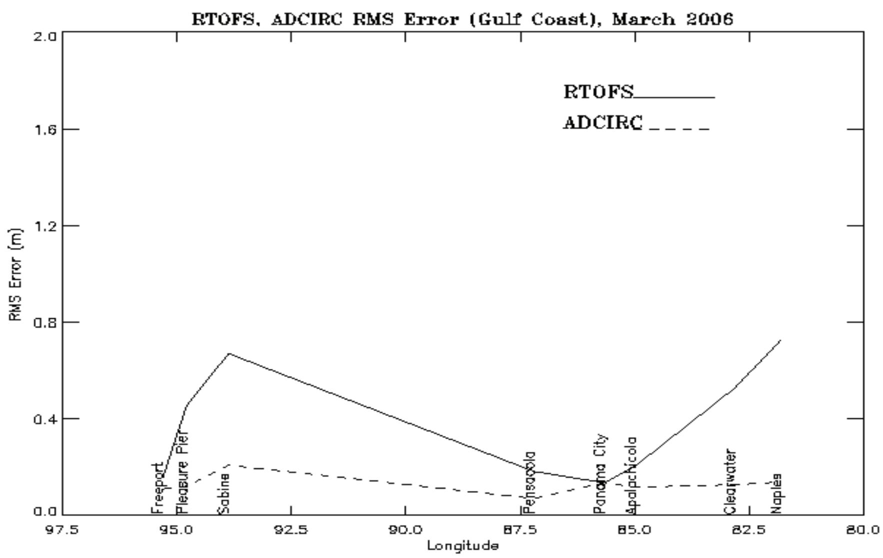


(b)

Figure 4.2. ADCIRC vs. RTOFS Operational Version Total Water Level Forecast Guidance RMSE (meters) for East Coast Stations (a) and for Gulf of Mexico Stations (b) for February 2006.

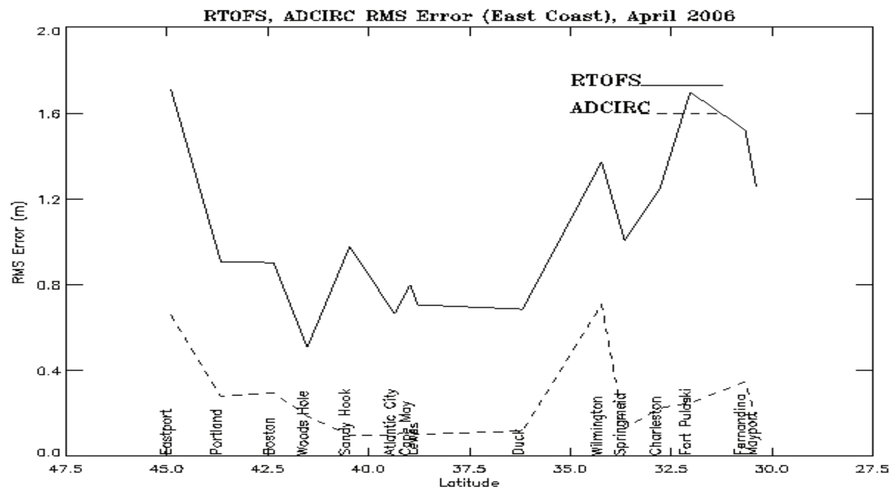


(a)

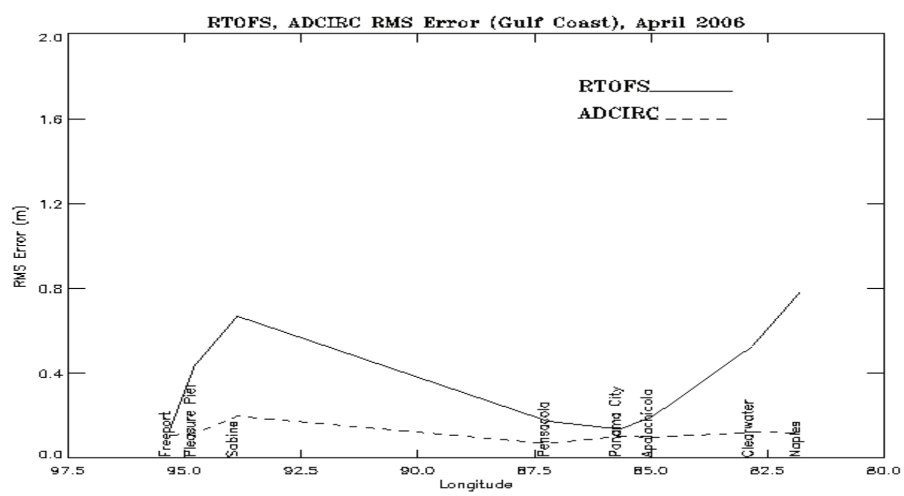


(b)

Figure 4.3. ADCIRC vs. RTOFS Operational Version Total Water Level Forecast Guidance RMSE (meters) for East Coast Stations (a) and for Gulf of Mexico Stations (b) for March 2006.



(a)



(b)

Figure 4.4. ADCIRC vs. RTOFS Operational Version Total Water Level Forecast Guidance RMSE (meters) for East Coast Stations (a) and for Gulf Stations (b) for April 2006.

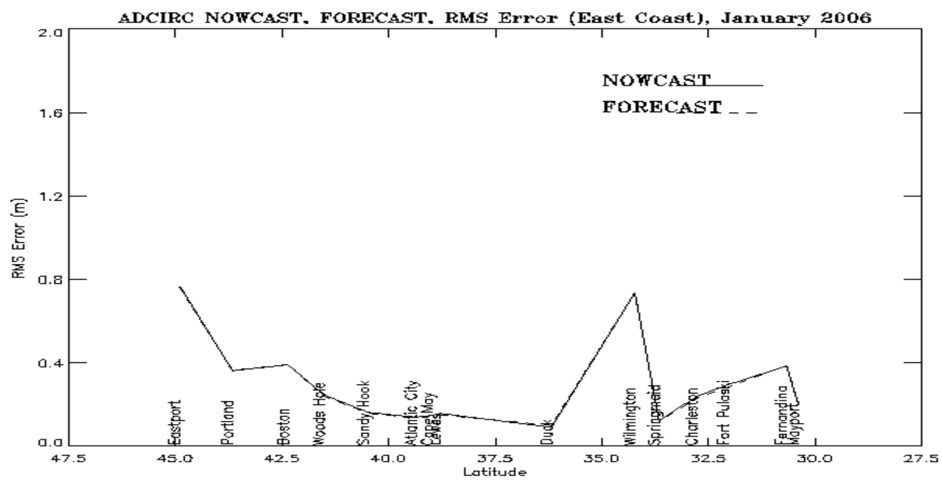
The same procedures for adjustment of the initial forecast hour to the observations were followed for each forecast type. ADCIRC forecast guidance RMSEs are order 1/3 of the RTOFS RMSEs for the East Coast stations and order ½ the RTOFS RMSEs for the Gulf stations.

ADCIRC Nowcast vs. Forecast

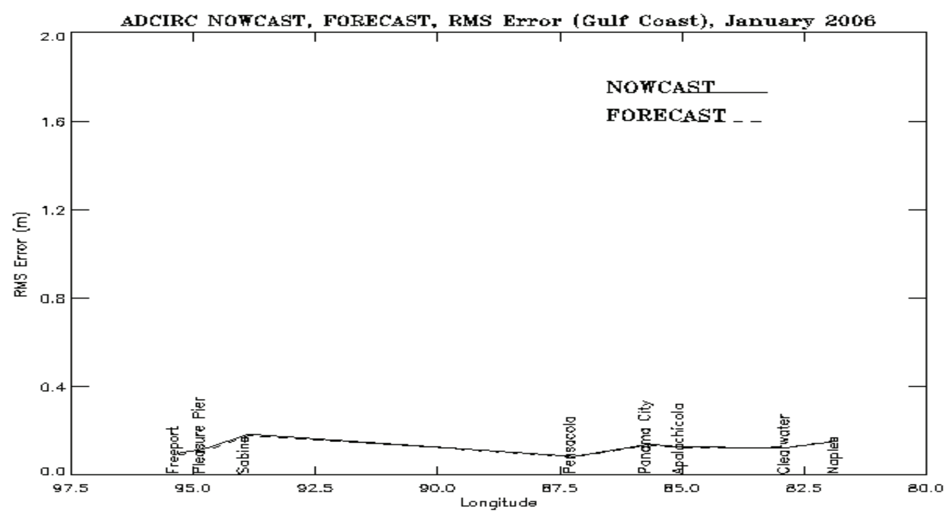
ADCIRC nowcast RMSEs are contrasted with forecast guidance RMSEs for each month for hours 1-24 of the forecast corresponding to the next nowcast period. Water levels were adjusted to match the NOS observations for the first hour with the adjustment used for the remaining 23 hours. Nowcast and forecast errors are nearly identical for all four months and are as shown for February 2006 along the Atlantic coast in Figures 4.6-4.7 and along the Gulf coast in Figures 4.8-4.9. Nowcast and forecast guidance RMSEs are shown in Table 4.2 and in Figure 4.5 for January 2006.

Table 4.2. ADCIRC Forecast Guidance and Nowcast Monthly Water Level Comparisons to NOS Observations January – April 2006 (RMSE [meters]). Nowcast hours 1-24 and corresponding forecast hours 1-24 are used in the comparisons. Table entries are forecast guidance/nowcast.

Station	January	February	March	April
Eastport, ME	0.76/0.77	0.77/0.76	0.71/0.70	0.66/0.66
Portland, ME	0.36/0.36	0.35/0.35	0.32/0.31	0.31/0.31
Boston, MA	0.39/0.39	0.37/0.37	0.32/0.32	0.32/0.32
Woods Hole, MA	0.24/0.25	0.22/0.22	0.21/0.21	0.20/0.20
Sandy Hook, NJ	0.16/0.16	0.16/0.18	0.13/0.14	0.14/0.13
Atlantic City, NJ	0.14/0.14	0.14/0.15	0.11/0.11	0.11/0.11
Cape May, NJ	0.14/0.15	0.15/0.16	0.16/0.17	0.15/0.14
Lewes, DE	0.16/0.16	0.14/0.15	0.13/0.14	0.12/0.11
Duck, NC	0.10/0.09	0.11/0.12	0.11/0.10	0.10/0.10
Wilmington, NC	0.74/0.74	0.72/0.73	0.69/0.69	0.70/0.70
Springmaid Pier, SC	0.12/0.12	0.14/0.15	0.16/0.15	0.15/0.15
Charleston, SC	0.23/0.24	0.25/0.25	0.24/0.24	0.22/0.22
Fort Pulaski, GA	0.29/0.30	0.32/0.31	0.28/0.28	0.25/0.25
Fernandina Beach, FL	0.39/0.38	0.38/0.38	0.36/0.36	0.36/0.36
Mayport, FL	0.21/0.20	0.20/0.20	0.20/0.20	0.20/0.20
Naples, FL	0.16/0.16	0.14/0.14	0.17/0.16	0.13/0.13
Clearwater, FL	0.13/0.13	0.11/0.11	0.11/0.10	0.11/0.11
Apalachicola, FL	0.13/0.13	0.12/0.12	0.13/0.12	0.10/0.10
Panama City, FL	0.14/0.14	0.13/0.13	0.11/0.12	0.10/0.10
Pensacola, FL	0.08/0.08	0.09/0.09	0.09/0.09	0.09/0.08
Sabine Pass, TX	0.18/0.19	0.19/0.20	0.18/0.18	0.18/0.18
Galveston Pleasure Pier, TX	0.11/0.12	0.11/0.11	0.11/0.11	0.12/0.12
Freeport, TX	0.09/0.10	0.10/0.10	0.10/0.10	0.10/0.10

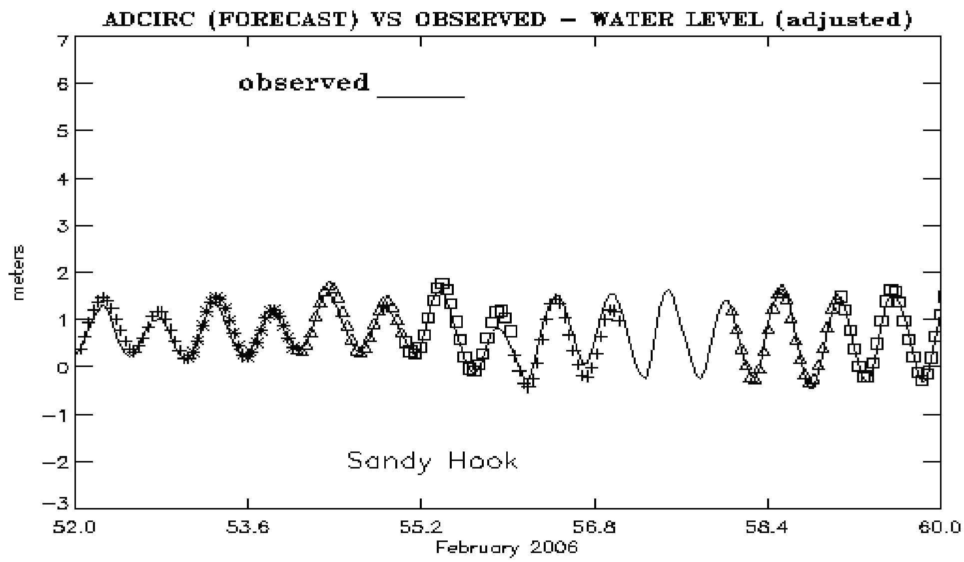


(a)

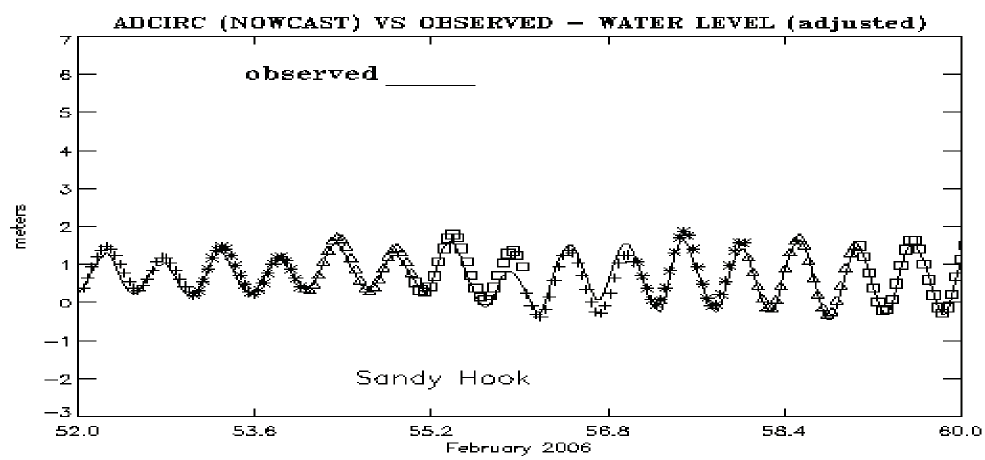


(b)

Figure 4.5. ADCIRC Nowcast vs. ADCIRC Total Water Level Forecast Guidance RMSE (meters) for East Coast Stations (a) and for Gulf of Mexico Stations (b) for January 2006.

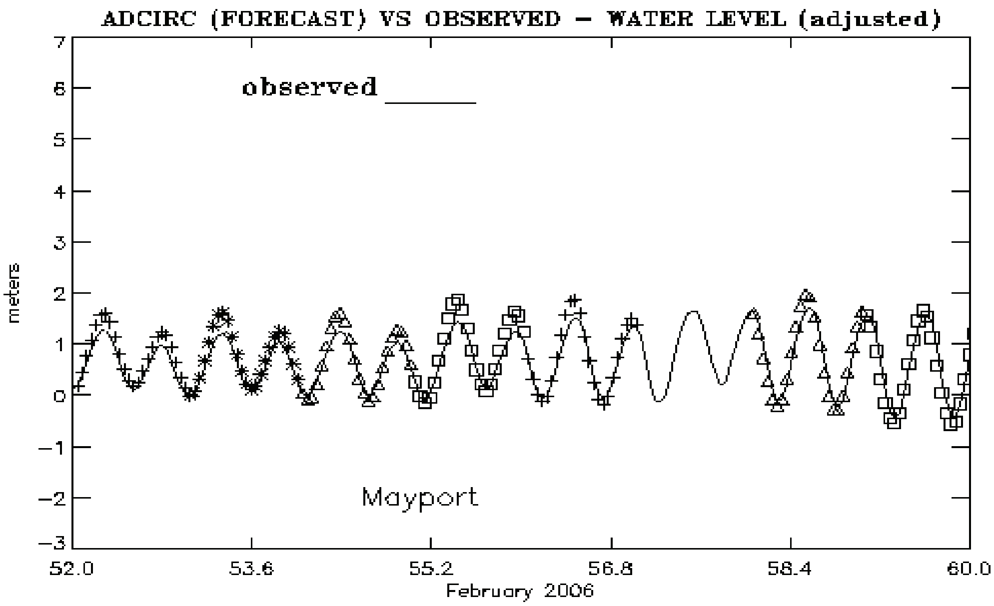


(a)

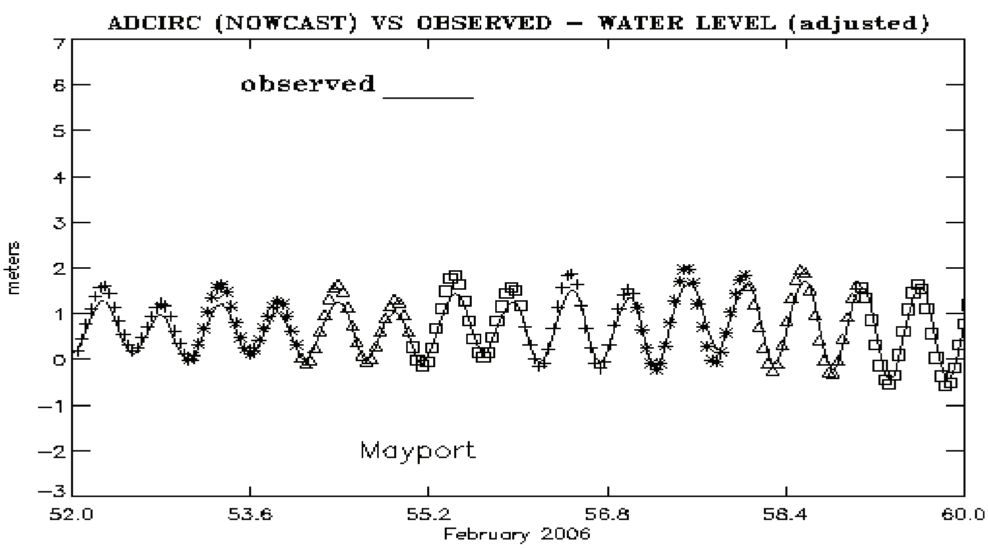


(b)

Figure 4.6. ADCIRC Forecast Guidance (a) vs. ADCIRC Nowcast (b) Total Water Level for Sandy Hook, NJ for February 2006. Note (+,*,Δ, and □) are used to designate alternate 24 hour forecast and nowcast series with the first symbol in the series always on the observation curve due to the adjustment process.

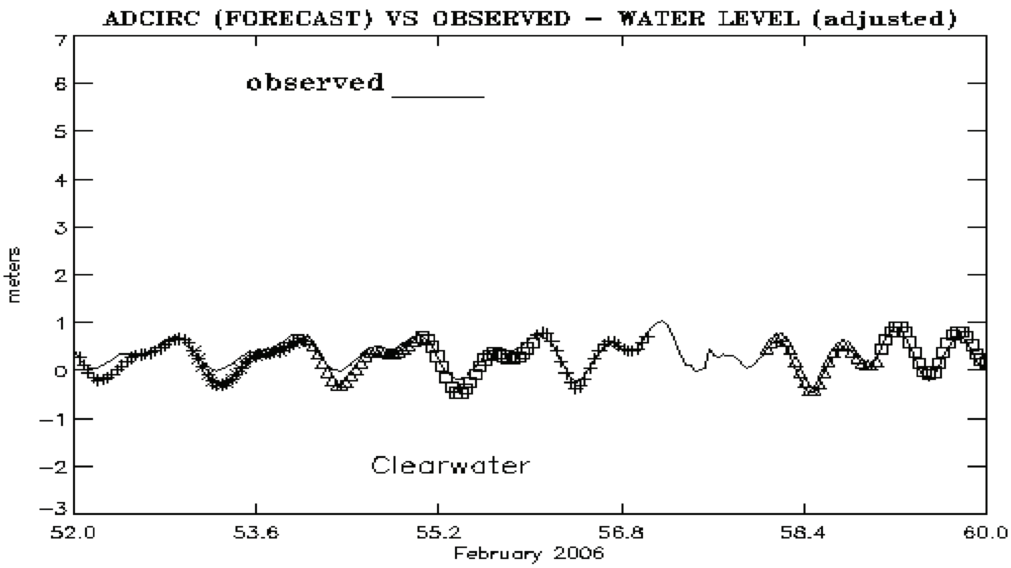


(a)

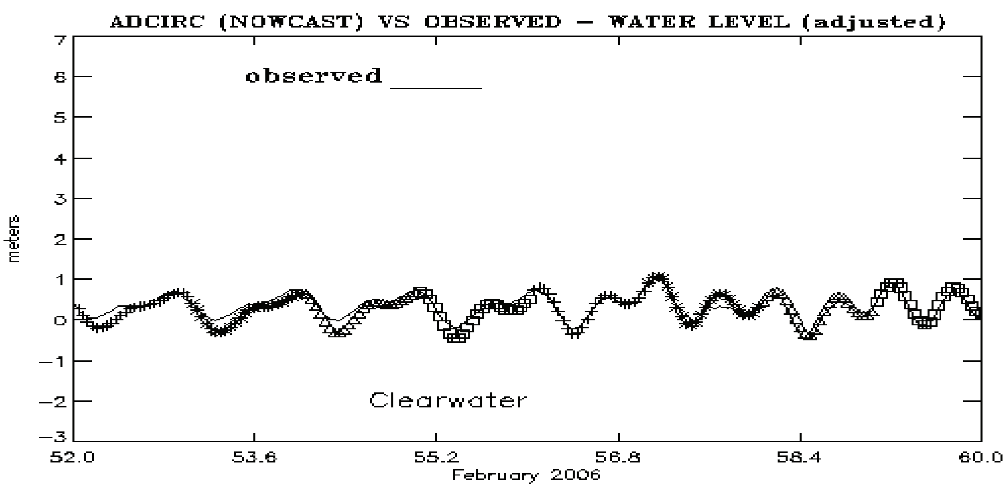


(b)

Figure 4.7. ADCIRC Forecast Guidance (a) vs. ADCIRC Nowcast (b) Total Water Level for Mayport, FL for February 2006. Note (+,*,Δ, and □) are used to designate alternate 24 hour forecast and nowcast series with the first symbol in the series always on the observation curve due to the adjustment process.

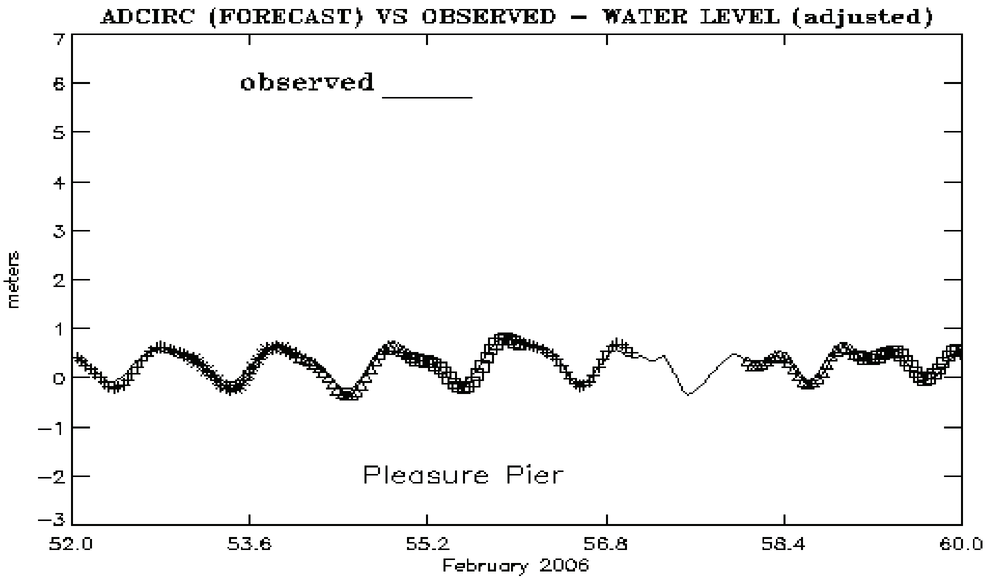


(a)

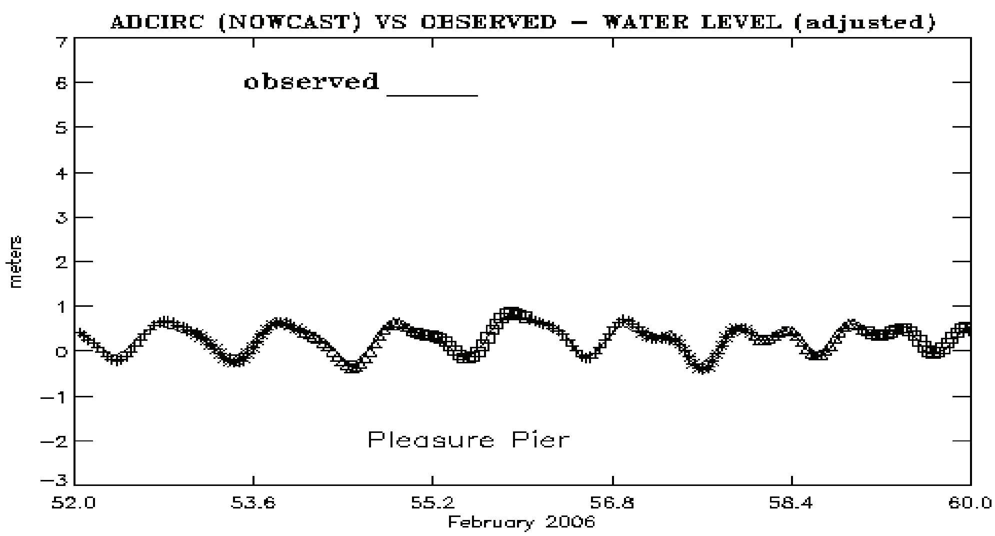


(b)

Figure 4.8. ADCIRC Forecast Guidance (a) vs. ADCIRC Nowcast (b) Total Water Level for Clearwater, FL for February 2006. Note (+,*,Δ, and □) are used to designate alternate 24 hour forecast and nowcast series with the first symbol in the series always on the observation curve due to the adjustment process.



(a)



(b)

Figure 4.9. ADCIRC Forecast Guidance (a) vs. ADCIRC Nowcast (b) Total Water Level for Galveston Pleasure Pier, TX for February 2006. Note (+,*,Δ, and □) are used to designate alternate 24 hour forecast and nowcast series with the first symbol in the series always on the observation curve due to the adjustment process.

ADCIRC Nowcast Harmonic Analysis

To assess the error in the tidal portion of the ADCIRC water level forecast, it was necessary to use the following methodology. The daily water level forecasts could not be directly concatenated to produce the requisite monthly (29 day) series, since they may be discontinuous at the start and end of each 24 hour period. As a result, it was necessary to concatenate each 24 hour nowcast to avoid the discontinuities. Since the same tidal forcing is used during both the nowcast and forecast, this procedure should be valid. 29 day harmonic analyses were performed for each month, January through April, to produce 24 tidal constituents. NOS accepted harmonic constants are based on a least squares analysis of a minimum of one year record for the short term constituents, which are then increased by order 2-3% to enable a more favorable comparison to observations. For the long term constituents, Sa and Ssa, usually several year analyses are averaged.

In Table 4.3, we consider the two major tidal constituents M_2 and S_2 and compare the ADCIRC harmonic analysis results with the NOS accepted harmonic constants. The amplitude and phase differences (ADCIRC – NOS) are given at selected locations where NOS nowcast/forecast systems have been developed or are planned in the near future. It is noted that ADCIRC under predicts the M_2 and over predicts S_2 tidal amplitudes at the majority of stations. ADCIRC leads in phase at most stations with respect to the NOS values for both constituents.

Table 4.3. M_2/S_2 ADCIRC vs. NOS Harmonic Analysis Results at Nowcast/Forecast System Boundary Locations for January 2006

NOS Station	ADCIRC Amp(m)	NOS Amp(m)	Difference (m)	ADCIRC Phase (o)	NOS Phase (o)	Difference (o)
Sandy Hook, NJ NYOFS	0.680 0.154	0.688 0.134	-0.008 0.020	2.7 6.2	6.0 32.6	-3.3 -26.4
Cape May, NJ DBOFS	0.661 0.123	0.714 0.125	-0.053 -0.002	30.4 37.1	28.6 55.3	1.8 -18.2
Charleston, SC CHOFS	0.682 0.137	0.783 0.119	-0.101 0.018	353.3 351.2	10.4 36.1	-17.1 -44.9
Mayport, FL SJOFS	0.794 0.154	0.676 0.105	0.118 0.049	13.5 13.8	25.3 48.3	-11.8 -34.5
Naples, FL TBOFS	0.250 0.125	0.286 0.096	-0.036 0.029	126.4 114.3	144.2 156.1	-17.8 -41.8
Galveston, TX GBOFS	0.128 0.073	0.139 0.034	-0.011 0.039	272.0 255.7	276.1 267.9	-4.10 -12.2

In Tables 4.4-4.8, detailed constituent comparisons are presented at Boston, MA, Sandy Hook, NJ, Cape May, NJ, Charleston, SC, and Mayport, FL, respectively, for the East Coast. In Tables 4.9-4.12 results are presented in the same format at Naples, FL, Panama City, FL, Sabine Pass, TX, and Galveston Pleasure Pier, TX, for the Gulf Coast. As noted above for ADCIRC only 24 constituents are derived. The remainder of the 37 constituents not derived are indicated by ******. Note at the bottom of each table gain, phase, and an estimated RMS error are given. The gain of each constituent, ADCIRC/NOS, is first computed. The gain given is a weighted gain of each of the 24 constituent gains, with the weights determined by the NOS accepted constituent amplitudes. A similar procedure is used to determine the phase, which is expressed in hours. An estimated RMS error is computed based on the individual constituent amplitude and phase differences following a method given by Hess (1994). Note a negative phase indicates that ADCIRC leads the NOS prediction. Best results along the East Coast are obtained at Duck, NC where the gain is 0.99, the phase difference is -0.16 hour, and the estimated RMS error is 4 cm, while along the Gulf Coast best results are achieved at Panama City, FL where the gain is 1.04, phase difference is -0.16 hour, and the estimated RMS error is 3 cm.

To examine the consistency of the ADCIRC 29 day harmonic analysis, additional 29-day analyses were performed for February, March, and April 2006. The results at all 24 coastal stations are summarized in terms of NOS harmonic constituent weighted gain and phase in Table 4.13 and in terms of estimated RMS error in Table 4.14. In general, one notes very similar values of gain, phase, and estimated RMS error at each station for all four months.

Table 4.4. ADCIRC vs. NOS Harmonic Analysis Results at Boston, MA for January 2006

	HARM29		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	1.5950	101.80	1.3980	109.40	0.1970	-7.60
S(2)	0.2840	131.30	0.2130	146.20	0.0710	-14.90
N(2)	0.3290	68.60	0.3090	78.90	0.0200	-10.30
K(1)	0.0960	200.70	0.1430	205.20	-.0470	-4.50
M(4)	0.0680	31.80	0.0230	25.90	0.0450	5.90
O(1)	0.1030	183.10	0.1190	186.70	-.0160	-3.60
M(6)	0.0220	86.80	0.0340	282.10	-.0120	164.70
MK(3)	******	******	0.0050	232.50	******	*******
S(4)	0.0010	204.00	0.0000	0.00	0.0010	-156.00
MN(4)	******	******	0.0110	14.60	******	*******
NU(2)	0.0640	73.10	0.0670	85.50	-.0030	-12.40
S(6)	0.0010	316.10	0.0000	0.00	0.0010	-43.90
MU(2)	******	******	0.0100	69.00	******	*******
2N(2)	0.0440	35.40	0.0390	55.00	0.0050	-19.60
OO(1)	0.0040	218.30	0.0050	227.00	-.0010	-8.70
LAMBD	0.0110	115.50	0.0220	143.20	-.0110	-27.70
S1	******	******	0.0040	122.80	******	*******
M(1)	0.0070	191.90	0.0070	214.40	0.0000	-22.50
J(1)	0.0080	209.50	0.0100	213.50	-.0020	-4.00
MM	******	******	0.0000	0.00	******	*******
SSA	******	******	0.0180	89.80	******	*******
SA	******	******	0.0320	126.30	******	*******
MSF	******	******	0.0000	0.00	******	*******
MF	******	******	0.0000	0.00	******	*******
RHO(1	0.0040	175.50	0.0030	152.80	0.0010	22.70
Q(1)	0.0200	174.40	0.0210	171.10	-.0010	3.30
T2	0.0170	130.10	0.0190	123.90	-.0020	6.20
R2	0.0020	132.50	0.0050	8.20	-.0030	124.30
2Q(1)	0.0030	165.60	0.0030	168.30	0.0000	-2.70
P(1)	0.0320	199.40	0.0470	202.10	-.0150	-2.70
2SM(2	******	******	0.0000	0.00	******	*******
M(3)	******	******	0.0000	0.00	******	*******
L(2)	0.0470	68.60	0.0550	156.20	-.0080	-87.60
2MK(3	******	******	0.0070	207.90	******	*******
K(2)	0.0770	133.70	0.0590	144.50	0.0180	-10.80
M(8)	0.0050	262.80	0.0060	237.10	-.0010	25.70
MS(4)	******	******	0.0090	68.70	******	*******

GAIN (-): 1.09
PHASE (HR): -0.33
EST. RMS (M): 0.23

Table 4.5. ADCIRC vs. NOS Harmonic Analysis Results at Sandy Hook, NJ for January 2006

	HARM29		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.6800	2.70	0.6880	6.00	-.0080	-3.30
S(2)	0.1540	6.20	0.1340	32.60	0.0200	-26.40
N(2)	0.1510	336.00	0.1580	348.60	-.0070	-12.60
K(1)	0.0790	170.40	0.1030	175.70	-.0240	-5.30
M(4)	0.0200	299.40	0.0160	269.70	0.0040	29.70
O(1)	0.0570	180.20	0.0540	172.50	0.0030	7.70
M(6)	0.0100	27.70	0.0170	83.80	-.0070	-56.10
MK(3)	******	******	0.0050	52.40	******	*******
S(4)	0.0010	228.70	0.0100	11.40	-.0090	-142.70
MN(4)	******	******	0.0080	275.80	******	*******
NU(2)	0.0290	339.60	0.0290	345.70	0.0000	-6.10
S(6)	0.0000	111.50	0.0000	0.00	0.0000	111.50
MU(2)	******	******	0.0240	14.50	******	*******
2N(2)	0.0200	309.30	0.0210	336.80	-.0010	-27.50
OO(1)	0.0020	160.60	0.0050	218.70	-.0030	-58.10
LAMBD	0.0050	4.30	0.0080	359.70	-.0030	4.60
S1	******	******	0.0100	124.90	******	*******
M(1)	0.0040	175.30	0.0040	220.80	0.0000	-45.50
J(1)	0.0040	165.60	0.0050	209.20	-.0010	-43.60
MM	******	******	0.0000	0.00	******	*******
SSA	******	******	0.0280	42.90	******	*******
SA	******	******	0.0670	129.10	******	*******
MSF	******	******	0.0000	0.00	******	*******
MF	******	******	0.0000	0.00	******	*******
RHO(1	0.0020	184.40	0.0020	171.10	0.0000	13.30
Q(1)	0.0110	185.10	0.0110	183.10	0.0000	2.00
T2	0.0090	6.00	0.0100	17.40	-.0010	-11.40
R2	0.0010	6.30	0.0010	33.80	0.0000	-27.50
2Q(1)	0.0010	189.90	0.0020	169.20	-.0010	20.70
P(1)	0.0260	171.20	0.0310	180.20	-.0050	-9.00
2SM(2	******	******	0.0000	0.00	******	*******
M(3)	******	******	0.0110	56.40	******	*******
L(2)	0.0220	336.00	0.0270	359.80	-.0050	-23.80
2MK(3	******	******	0.0080	33.80	******	*******
K(2)	0.0420	6.50	0.0380	31.50	0.0040	-25.00
M(8)	0.0030	178.00	0.0000	0.00	0.0030	178.00
MS(4)	******	******	0.0120	224.30	******	*******

GAIN (-): 0.97
PHASE (HR): -0.32
EST. RMS (M): 0.07

Table 4.6. ADCIRC vs. NOS Harmonic Analysis Results at Cape May, NJ for January 2006

	HARM29		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.6610	30.40	0.7140	28.60	-.0530	1.80
S(2)	0.1230	37.10	0.1250	55.30	-.0020	-18.20
N(2)	0.1370	4.00	0.1590	9.70	-.0220	-5.70
K(1)	0.0800	183.20	0.1050	200.40	-.0250	-17.20
M(4)	0.0250	202.30	0.0100	101.00	0.0150	101.30
O(1)	0.0650	200.10	0.0840	185.60	-.0190	14.50
M(6)	0.0080	338.90	0.0080	20.80	0.0000	-41.90
MK(3)	******	******	0.0000	0.00	******	*******
S(4)	0.0010	256.30	0.0000	0.00	0.0010	-103.70
MN(4)	******	******	0.0030	115.30	******	*******
NU(2)	0.0270	7.50	0.0320	7.40	-.0050	0.10
S(6)	0.0010	161.30	0.0000	0.00	0.0010	161.30
MU(2)	******	******	0.0120	40.50	******	*******
2N(2)	0.0180	337.50	0.0210	352.30	-.0030	-14.80
OO(1)	0.0030	166.30	0.0040	215.00	-.0010	-48.70
LAMBD	0.0050	33.50	0.0100	41.60	-.0050	-8.10
S1	******	******	0.0090	134.70	******	*******
M(1)	0.0050	191.60	0.0040	243.40	0.0010	-51.80
J(1)	0.0050	174.80	0.0060	197.10	-.0010	-22.30
MM	******	******	0.0000	0.00	******	*******
SSA	******	******	0.0320	40.30	******	*******
SA	******	******	0.0580	147.70	******	*******
MSF	******	******	0.0000	0.00	******	*******
MF	******	******	0.0000	0.00	******	*******
RHO(1	0.0020	207.30	0.0030	179.30	-.0010	28.00
Q(1)	0.0130	208.40	0.0130	184.10	0.0000	24.30
T2	0.0070	36.80	0.0120	33.70	-.0050	3.10
R2	0.0010	37.40	0.0010	56.50	0.0000	-19.10
2Q(1)	0.0020	216.80	0.0020	171.00	0.0000	45.80
P(1)	0.0260	184.50	0.0360	199.20	-.0100	-14.70
2SM(2	******	******	0.0000	0.00	******	*******
M(3)	******	******	0.0050	94.10	******	*******
L(2)	0.0200	4.00	0.0370	43.90	-.0170	-39.90
2MK(3	******	******	0.0040	110.50	******	*******
K(2)	0.0330	37.60	0.0330	54.50	0.0000	-16.90
M(8)	0.0030	309.70	0.0000	0.00	0.0030	-50.30
MS(4)	******	******	0.0050	128.10	******	*******

GAIN (-): 0.89
PHASE (HR): -0.14
EST. RMS (M): 0.07

Table 4.7. ADCIRC vs. NOS Harmonic Analysis Results at Charleston, SC for January 2006

	HARM29		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.6820	353.30	0.7830	10.40	-.1010	-17.10
S(2)	0.1370	351.20	0.1190	36.10	0.0180	-44.90
N(2)	0.1560	326.60	0.1720	354.90	-.0160	-28.30
K(1)	0.0730	178.70	0.1050	199.70	-.0320	-21.00
M(4)	0.0030	323.80	0.0330	209.60	-.0300	114.20
O(1)	0.0720	198.20	0.0790	203.40	-.0070	-5.20
M(6)	0.0060	31.00	0.0060	135.30	0.0000	-104.30
MK(3)	******	******	0.0080	4.40	******	*******
S(4)	0.0010	4.30	0.0000	0.00	0.0010	4.30
MN(4)	******	******	0.0140	201.40	******	*******
NU(2)	0.0300	330.20	0.0350	351.40	-.0050	-21.20
S(6)	0.0010	292.00	0.0000	0.00	0.0010	-68.00
MU(2)	******	******	0.0250	40.00	******	*******
2N(2)	0.0210	300.00	0.0220	343.30	-.0010	-43.30
OO(1)	0.0030	159.20	0.0050	217.30	-.0020	-58.10
LAMBD	0.0050	352.30	0.0130	356.10	-.0080	-3.80
S1	******	******	0.0180	173.90	******	*******
M(1)	0.0050	188.50	0.0050	243.30	0.0000	-54.80
J(1)	0.0060	169.00	0.0050	213.50	0.0010	-44.50
MM	******	******	0.0000	0.00	******	*******
SSA	******	******	0.0530	50.50	******	*******
SA	******	******	0.0780	176.30	******	*******
MSF	******	******	0.0000	0.00	******	*******
MF	******	******	0.0000	0.00	******	*******
RHO(1	0.0030	206.60	0.0040	198.00	-.0010	8.60
Q(1)	0.0140	207.90	0.0170	198.90	-.0030	9.00
T2	0.0080	351.30	0.0150	19.90	-.0070	-28.60
R2	0.0010	351.10	0.0050	263.80	-.0040	87.30
2Q(1)	0.0020	217.60	0.0020	207.10	0.0000	10.50
P(1)	0.0240	180.20	0.0360	198.30	-.0120	-18.10
2SM(2	******	******	0.0000	0.00	******	*******
M(3)	******	******	0.0170	114.80	******	*******
L(2)	0.0220	326.60	0.0340	5.00	-.0120	-38.40
2MK(3	******	******	0.0050	30.60	******	*******
K(2)	0.0370	351.10	0.0300	37.10	0.0070	-46.00
M(8)	0.0030	296.90	0.0000	0.00	0.0030	-63.10
MS(4)	******	******	0.0100	237.70	******	*******

GAIN (-): 0.86
PHASE (HR): -0.77
EST. RMS (M): 0.20

Table 4.8. ADCIRC vs. NOS Harmonic Analysis Results at Mayport, FL for January 2006

	HARM29		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.7940	13.50	0.6760	25.30	0.1180	-11.80
S(2)	0.1540	13.80	0.1050	48.30	0.0490	-34.50
N(2)	0.1800	347.30	0.1570	7.30	0.0230	-20.00
K(1)	0.0820	191.90	0.0840	202.50	-.0020	-10.60
M(4)	0.0120	105.20	0.0330	159.40	-.0210	-54.20
O(1)	0.0790	203.10	0.0580	210.90	0.0210	-7.80
M(6)	0.0170	98.50	0.0090	196.00	0.0080	-97.50
MK(3)	******	******	0.0080	20.40	******	*******
S(4)	0.0010	268.30	0.0050	290.70	-.0040	-22.40
MN(4)	******	******	0.0130	156.00	******	*******
NU(2)	0.0350	350.80	0.0320	2.70	0.0030	-11.90
S(6)	0.0010	297.30	0.0000	0.00	0.0010	-62.70
MU(2)	******	******	0.0120	31.20	******	*******
2N(2)	0.0240	321.00	0.0190	354.60	0.0050	-33.60
OO(1)	0.0030	180.60	0.0040	212.60	-.0010	-32.00
LAMBD	0.0060	13.70	0.0090	47.80	-.0030	-34.10
S1	******	******	0.0110	158.30	******	*******
M(1)	0.0060	197.50	0.0030	221.20	0.0030	-23.70
J(1)	0.0060	186.30	0.0050	210.20	0.0010	-23.90
MM	******	******	0.0250	230.40	******	*******
SSA	******	******	0.0770	55.40	******	*******
SA	******	******	0.1150	190.20	******	*******
MSF	******	******	0.0390	202.70	******	*******
MF	******	******	0.0000	0.00	******	*******
RHO(1	0.0030	207.90	0.0020	214.50	0.0010	-6.60
Q(1)	0.0150	208.70	0.0110	209.50	0.0040	-0.80
T2	0.0090	13.80	0.0100	22.10	-.0010	-8.30
R2	0.0010	13.80	0.0050	291.80	-.0040	82.00
2Q(1)	0.0020	214.30	0.0020	219.20	0.0000	-4.90
P(1)	0.0270	192.70	0.0290	202.20	-.0020	-9.50
2SM(2	******	******	0.0030	60.10	******	*******
M(3)	******	******	0.0060	186.40	******	*******
L(2)	0.0260	347.30	0.0410	31.40	-.0150	-44.10
2MK(3	******	******	0.0080	44.00	******	*******
K(2)	0.0420	13.90	0.0280	48.20	0.0140	-34.30
M(8)	0.0020	349.00	0.0030	4.20	-.0010	-15.20
MS(4)	******	******	0.0130	175.80	******	*******

GAIN (-): 1.15
PHASE (HR): -0.62
EST. RMS (M): 0.16

Table 4.9. ADCIRC vs. NOS Harmonic Analysis Results at Naples, FL for January 2006

	HARM29		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.2500	126.40	0.2860	144.20	-.0360	-17.80
S(2)	0.1250	114.30	0.0960	156.10	0.0290	-41.80
N(2)	0.0460	104.90	0.0570	130.60	-.0110	-25.70
K(1)	0.1420	3.90	0.1580	9.90	-.0160	-6.00
M(4)	0.0090	165.80	0.0170	123.50	-.0080	42.30
O(1)	0.1650	8.10	0.1430	2.80	0.0220	5.30
M(6)	0.0060	153.40	0.0080	124.80	-.0020	28.60
MK(3)	******	******	0.0090	322.00	******	*******
S(4)	0.0020	191.80	0.0040	235.20	-.0020	-43.40
MN(4)	******	******	0.0080	88.40	******	*******
NU(2)	0.0090	107.80	0.0130	142.30	-.0040	-34.50
S(6)	0.0000	60.10	0.0000	0.00	0.0000	60.10
MU(2)	******	******	0.0090	55.20	******	*******
2N(2)	0.0060	83.40	0.0080	109.40	-.0020	-26.00
OO(1)	0.0070	359.60	0.0050	22.30	0.0020	-22.70
LAMBD	0.0020	120.80	0.0020	149.70	0.0000	-28.90
S1	******	******	0.0170	104.00	******	*******
M(1)	0.0120	6.00	0.0080	34.00	0.0040	-28.00
J(1)	0.0130	1.80	0.0100	7.90	0.0030	-6.10
MM	******	******	0.0000	0.00	******	*******
SSA	******	******	0.0300	66.70	******	*******
SA	******	******	0.0750	167.90	******	*******
MSF	******	******	0.0000	0.00	******	*******
MF	******	******	0.0000	0.00	******	*******
RHO(1	0.0060	9.90	0.0060	359.50	0.0000	10.40
Q(1)	0.0320	10.20	0.0300	349.40	0.0020	20.80
T2	0.0070	114.80	0.0050	147.70	0.0020	-32.90
R2	0.0010	113.80	0.0010	156.70	0.0000	-42.90
2Q(1)	0.0040	12.30	0.0040	327.60	0.0000	44.70
P(1)	0.0470	4.20	0.0520	8.80	-.0050	-4.60
2SM(2	******	******	0.0000	0.00	******	*******
M(3)	******	******	0.0000	0.00	******	*******
L(2)	0.0070	104.90	0.0080	186.80	-.0010	-81.90
2MK(3	******	******	0.0090	301.60	******	*******
K(2)	0.0340	113.30	0.0270	149.40	0.0070	-36.10
M(8)	0.0020	268.40	0.0000	0.00	0.0020	-91.60
MS(4)	******	******	0.0080	152.20	******	*******

GAIN (-): 0.98
PHASE (HR): -0.44
EST. RMS (M): 0.09

Table 4.10. ADCIRC vs. NOS Harmonic Analysis Results at Panama City, FL for January 2006

	HARM29		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0350	98.20	0.0340	91.10	0.0010	7.10
S(2)	0.0240	79.20	0.0200	94.50	0.0040	-15.30
N(2)	0.0060	96.00	0.0070	102.00	-.0010	-6.00
K(1)	0.1350	6.70	0.1450	17.00	-.0100	-10.30
M(4)	0.0010	60.20	0.0110	315.10	-.0100	105.10
O(1)	0.1630	10.40	0.1410	8.50	0.0220	1.90
M(6)	0.0050	46.80	0.0030	77.00	0.0020	-30.20
MK(3)	******	******	0.0000	0.00	******	*******
S(4)	0.0010	7.40	0.0030	77.50	-.0020	-70.10
MN(4)	******	******	0.0050	281.20	******	*******
NU(2)	0.0010	96.30	0.0010	100.50	0.0000	-4.20
S(6)	0.0010	282.40	0.0000	0.00	0.0010	-77.60
MU(2)	******	******	0.0000	0.00	******	*******
2N(2)	0.0010	93.80	0.0010	113.00	0.0000	-19.20
OO(1)	0.0070	3.10	0.0040	24.60	0.0030	-21.50
LAMBD	0.0000	89.40	0.0000	0.00	0.0000	89.40
S1	******	******	0.0050	46.30	******	*******
M(1)	0.0120	8.50	0.0060	62.90	0.0060	-54.40
J(1)	0.0130	4.90	0.0080	20.30	0.0050	-15.40
MM	******	******	0.0000	0.00	******	*******
SSA	******	******	0.0460	39.80	******	*******
SA	******	******	0.1130	152.00	******	*******
MSF	******	******	0.0000	0.00	******	*******
MF	******	******	0.0000	0.00	******	*******
RHO(1	0.0060	11.90	0.0050	353.40	0.0010	18.50
Q(1)	0.0320	12.20	0.0310	353.80	0.0010	18.40
T2	0.0010	79.90	0.0010	94.30	0.0000	-14.40
R2	0.0000	78.40	0.0000	0.00	0.0000	78.40
2Q(1)	0.0040	14.00	0.0040	327.40	0.0000	46.60
P(1)	0.0450	7.00	0.0490	17.60	-.0040	-10.60
2SM(2	******	******	0.0000	0.00	******	*******
M(3)	******	******	0.0000	0.00	******	*******
L(2)	0.0010	96.00	0.0010	80.00	0.0000	16.00
2MK(3	******	******	0.0000	0.00	******	*******
K(2)	0.0060	77.60	0.0050	75.10	0.0010	2.50
M(8)	0.0010	314.50	0.0000	0.00	0.0010	-45.50
MS(4)	******	******	0.0050	325.50	******	*******

GAIN (-): 1.04
PHASE (HR): -0.16
EST. RMS (M): 0.03

Table 4.11. ADCIRC vs. NOS Harmonic Analysis Results at Sabine Pass, TX for January 2006

	HARM29		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.1780	260.90	0.1230	275.50	0.0550	-14.60
S(2)	0.1110	244.00	0.0390	271.50	0.0720	-27.50
N(2)	0.0320	238.30	0.0330	254.40	-.0010	-16.10
K(1)	0.1730	19.40	0.1320	40.70	0.0410	-21.30
M(4)	0.0030	34.50	0.0050	318.90	-.0020	75.60
O(1)	0.2040	21.00	0.1230	34.60	0.0810	-13.60
M(6)	0.0010	296.80	0.0000	0.00	0.0010	-63.20
MK(3)	******	******	0.0070	141.20	******	*******
S(4)	0.0010	87.30	0.0000	0.00	0.0010	87.30
MN(4)	******	******	0.0000	0.00	******	*******
NU(2)	0.0060	241.30	0.0070	269.50	-.0010	-28.20
S(6)	0.0010	151.30	0.0000	0.00	0.0010	151.30
MU(2)	******	******	0.0050	210.30	******	*******
2N(2)	0.0040	215.70	0.0050	220.40	-.0010	-4.70
OO(1)	0.0090	17.80	0.0060	61.40	0.0030	-43.60
LAMBD	0.0010	253.00	0.0010	273.60	0.0000	-20.60
S1	******	******	0.0120	306.30	******	*******
M(1)	0.0150	20.20	0.0060	36.90	0.0090	-16.70
J(1)	0.0160	18.60	0.0070	47.10	0.0090	-28.50
MM	******	******	0.0000	0.00	******	*******
SSA	******	******	0.0770	52.00	******	*******
SA	******	******	0.0650	135.70	******	*******
MSF	******	******	0.0000	0.00	******	*******
MF	******	******	0.0000	0.00	******	*******
RHO(1	0.0080	21.70	0.0060	23.80	0.0020	-2.10
Q(1)	0.0400	21.80	0.0260	21.80	0.0140	0.00
T2	0.0070	244.70	0.0020	271.70	0.0050	-27.00
R2	0.0010	243.30	0.0000	271.30	0.0010	-28.00
2Q(1)	0.0050	22.60	0.0030	28.50	0.0020	-5.90
P(1)	0.0570	19.50	0.0400	33.10	0.0170	-13.60
2SM(2	******	******	0.0000	0.00	******	*******
M(3)	******	******	0.0000	0.00	******	*******
L(2)	0.0050	238.30	0.0040	5.10	0.0010	-126.80
2MK(3	******	******	0.0060	132.80	******	*******
K(2)	0.0300	242.60	0.0080	338.50	0.0220	-95.90
M(8)	0.0000	352.20	0.0000	0.00	0.0000	-7.80
MS(4)	******	******	0.0000	0.00	******	*******

GAIN (-): 1.57
PHASE (HR): -0.94
EST. RMS (M): 0.11

Table 4.12. ADCIRC vs. NOS Harmonic Analysis Results at Galveston Pleasure Pier, TX for January 2006

	HARM29		ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.1280	272.00	0.1390	276.10	-.0110	-4.10
S(2)	0.0730	255.70	0.0340	267.90	0.0390	-12.20
N(2)	0.0240	244.70	0.0360	254.60	-.0120	-9.90
K(1)	0.1590	21.60	0.1710	28.00	-.0120	-6.40
M(4)	0.0020	315.90	0.0060	203.30	-.0040	112.60
O(1)	0.1920	22.10	0.1610	20.30	0.0310	1.80
M(6)	0.0020	355.80	0.0000	0.00	0.0020	-4.20
MK(3)	******	******	0.0000	0.00	******	*******
S(4)	0.0000	249.20	0.0000	0.00	0.0000	-110.80
MN(4)	******	******	0.0000	0.00	******	*******
NU(2)	0.0050	248.30	0.0080	270.90	-.0030	-22.60
S(6)	0.0000	148.50	0.0000	0.00	0.0000	148.50
MU(2)	******	******	0.0050	197.10	******	*******
2N(2)	0.0030	217.30	0.0060	228.80	-.0030	-11.50
OO(1)	0.0080	21.10	0.0060	46.20	0.0020	-25.10
LAMBD	0.0010	264.40	0.0010	272.20	0.0000	-7.80
S1	******	******	0.0140	327.00	******	*******
M(1)	0.0140	21.90	0.0080	24.20	0.0060	-2.30
J(1)	0.0150	21.30	0.0100	34.50	0.0050	-13.20
MM	******	******	0.0000	0.00	******	*******
SSA	******	******	0.0900	55.20	******	*******
SA	******	******	0.0770	157.40	******	*******
MSF	******	******	0.0000	0.00	******	*******
MF	******	******	0.0000	0.00	******	*******
RHO(1	0.0070	22.30	0.0070	4.00	0.0000	18.30
Q(1)	0.0370	22.40	0.0360	7.00	0.0010	15.40
T2	0.0040	256.30	0.0020	268.10	0.0020	-11.80
R2	0.0010	255.00	0.0000	267.50	0.0010	-12.50
2Q(1)	0.0050	22.60	0.0040	349.50	0.0010	33.10
P(1)	0.0530	21.60	0.0510	24.30	0.0020	-2.70
2SM(2	******	******	0.0000	0.00	******	*******
M(3)	******	******	0.0000	0.00	******	*******
L(2)	0.0030	244.70	0.0040	352.10	-.0010	-107.40
2MK(3	******	******	0.0000	0.00	******	*******
K(2)	0.0200	254.40	0.0060	275.60	0.0140	-21.20
M(8)	0.0010	356.20	0.0000	0.00	0.0010	-3.80
MS(4)	******	******	0.0040	224.70	******	*******

GAIN (-): 1.08
PHASE (HR): -0.12
EST. RMS (M): 0.04

Table 4.13. ADCIRC vs. NOS Harmonic Constituent Weighted Gain and Phase Results For January-April 2006.

Gain is ADCIRC/NOS amplitude and Phase Difference is ADCIRC – NOS.
Thus a negative sign indicates a lead in phase.

Station	Gain (-)				Phase Difference (Hrs)			
	Jan	Feb	Mar	Apr	Jan	Feb	Mar	Apr
Eastport, ME	0.92	0.86	0.86	0.90	-0.59	-0.57	-0.45	-0.32
Portland, ME	1.11	1.05	1.05	1.09	-0.36	-0.35	-0.21	-0.06
Boston, MA	1.09	1.03	1.03	1.07	-0.33	-0.32	-0.17	0.00
Woods Hole, MA	1.25	1.17	1.24	1.28	-0.86	-0.70	-0.63	-0.35
Sandy Hook, NJ	0.97	0.91	0.94	0.97	-0.32	-0.27	-0.09	0.08
Atlantic City, NJ	0.95	0.90	0.92	0.96	-0.16	-0.15	0.05	0.20
Cape May, NJ	0.89	0.85	0.87	0.91	-0.14	-0.14	0.00	0.15
Lewes, DE	0.92	0.88	0.91	0.94	-0.38	-0.39	-0.23	-0.08
Duck, NC	0.99	0.94	0.97	1.01	-0.13	-0.11	0.04	0.22
Wilmington, NC	0.94	0.89	0.92	0.94	-2.59	-2.54	-2.41	-2.26
Springmaid Pier, SC	0.94	0.89	0.92	0.94	-0.17	-0.11	0.01	0.23
Charleston, SC	0.86	0.82	0.85	0.87	-0.77	-0.74	-0.59	-0.42
Fort Pulaski, GA	0.92	0.87	0.88	0.91	-0.69	-0.67	-0.50	-0.33
Fernandina Beach, FL	0.95	0.90	0.92	0.95	-1.03	-1.01	-0.83	-0.67
Mayport, FL	1.15	1.09	1.11	1.14	-0.62	-0.59	-0.41	-0.25
Naples, FL	0.98	0.96	1.04	1.02	-0.44	-0.52	-0.28	0.04
Clearwater Beach, FL	1.12	1.09	1.18	1.16	-0.04	-0.11	0.19	0.52
Apalachicola, FL	1.26	1.30	1.47	1.40	-0.50	-0.57	-0.41	0.02
Panama City, FL	1.04	1.13	1.28	1.21	-0.16	-0.36	-0.02	0.45
Pensacola, FL	0.84	0.96	1.11	1.04	0.35	0.24	0.56	1.15
Sabine Pass, TX	1.57	1.60	1.72	1.68	-0.94	-1.10	-0.76	-0.35
Galveston Pleasure Pier, TX	1.08	1.11	1.20	1.18	-0.12	-0.24	0.06	0.43
Freeport, TX	1.12	1.16	1.26	1.23	-0.15	-0.27	0.02	0.45

Table 4.14. ADCIRC vs. NOS Harmonic Constituent Estimated RMS Error (meters) for January-April 2006.

Station	Estimated RMS Error (m)			
	Jan	Feb	Mar	Apr
Eastport, ME	0.54	0.53	0.53	0.49
Portland, ME	0.23	0.22	0.22	0.21
Boston, MA	0.23	0.21	0.21	0.21
Woods Hole, MA	0.14	0.13	0.13	0.12
Sandy Hook, NJ	0.07	0.06	0.06	0.05
Atlantic City, NJ	0.05	0.05	0.05	0.04
Cape May, NJ	0.07	0.08	0.07	0.07
Lewes, DE	0.08	0.08	0.07	0.06
Duck, NC	0.04	0.04	0.04	0.05
Wilmington, NC	0.53	0.52	0.52	0.51
Springmaid Pier, SC	0.06	0.06	0.06	0.06
Charleston, SC	0.20	0.19	0.18	0.17
Fort Pulaski, GA	0.23	0.22	0.21	0.19
Fernandina Beach, FL	0.30	0.29	0.29	0.27
Mayport, FL	0.16	0.15	0.15	0.14
Naples, FL	0.09	0.09	0.09	0.09
Clearwater Beach, FL	0.06	0.06	0.08	0.07
Apalachicola, FL	0.06	0.07	0.10	0.09
Panama City, FL	0.03	0.04	0.06	0.06
Pensacola, FL	0.04	0.02	0.04	0.06
Sabine Pass, TX	0.11	0.13	0.15	0.12
Galveston Pleasure Pier, TX	0.04	0.05	0.07	0.07
Freeport, TX	0.04	0.05	0.07	0.07

5. MODEL COMPARISON WATER LEVEL ANALYSIS RESULTS

Here we utilize the procedures outlined in Chapter 2, to compare all four forecast models over November 2008. In Table 5.1 the total water level forecast guidance RMSEs are presented at East Coast and Gulf of Mexico stations for each the three total water level models, ADCIRC, G-NCOM, and RTOFS. In general the order of performance is ADCIRC, G-NCOM, and RTOFS. The operational RTOFS does not appear to include the tidal improvements.

In Table 5.2 the subtidal water level forecast guidance RMSEs are presented at East Coast and Gulf of Mexico stations for ETSS and each of the three total water level models, ADCIRC, G-NCOM, and RTOFS. In general, the order of performance is ETSS, ADCIRC, RTOFS, and G-NCOM. The ADCIRC and RTOFS subtidal water levels are determined by 30 hour low pass filtering the concatenated nowcasts over January 2006. The G-NCOM subtidal water level determination is somewhat problematical. First, the water levels are available only at 3 hour intervals, and the tide has been included in the USN distributed product based on a reconstruction from the OSU tide model TPXO6.2 (Egbert and Erofeeva, 2002) results. The approach followed in Table 5.2, is to use the NOS accepted harmonic constants to predict the tide used in the detiding. As a result, any mismatch between the tide model results and the NOS accepted predictions will be included within the subtidal water level error. To examine the consistency of the subtidal errors from month to month, ADCIRC subtidal water levels are given in Table 5.3 for January, February, March, and April of 2006. These results are consistent with results obtained for RTOFS and indicate that there is a relatively small variability in the RMSEs from month to month.

All models with the exception of ETSS are degraded from north of Boston, MA. ETSS which does not contain the tides, exhibits the lowest errors. Of the three other models, which include the tides, ADCIRC, G-NCOM, and RTOFS range from the best to worst performance in RMSE. To aid in the intercomparison of the models, comparisons of ADCIRC and G-NCOM are shown in Figure 5.1, with ADCIRC showing superior results in the mid-Atlantic region. Next G-NCOM (total water level) is compared with ETSS (subtidal water level) in Figure 5.2. Note ETSS is presently used to provide subtidal water level boundary conditions to the near-shore OFS models and NOS tide gauge data are used to provide the tidal water level. Thus the tidal error is near zero and ETSS subtidal error approximates the total water level error. The two-dimensional ETSS model with higher resolution shows the superior RMSE profiles in Figure 5.2. Finally, in Figure 5.3 the operational version of RTOFS replaces G-NCOM in the comparison with ADCIRC, indicating that additional improvements in the tidal dynamics are necessary in RTOFS.

Table 5.1. ADCIRC, G-NCOM, and RTOFS Forecast Guidance Monthly Total Water Level Comparisons to NOS Observations November 2008 (RMSE [meters]). Forecast hours 6-36 are used in the comparisons. All three forecasts include tides. Eastport, ME not included in North Atlantic Coast statistics. ** Wilmington, NC not included in Mid Atlantic Coast statistics.

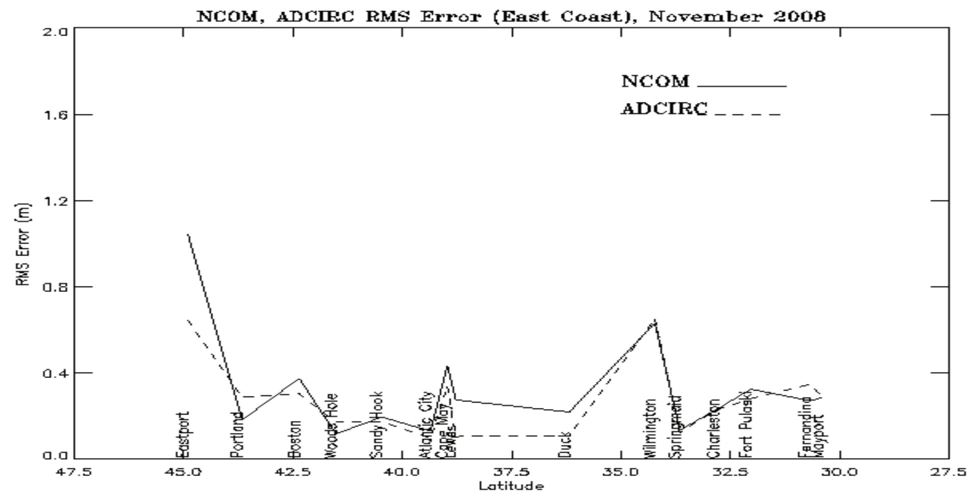
Station	ADCIRC	G-NCOM	RTOFS
Eastport, ME *	0.64	1.04	3.48
Portland, ME	0.29	0.18	1.87
Boston, MA	0.30	0.38	1.89
Woods Hole, MA	0.17	0.12	0.32
North Atlantic Coast	0.20	0.19	1.36
Sandy Hook, NJ	0.17	0.20	0.97
Atlantic City, NJ	0.10	0.13	0.77
Cape May, NJ	0.34	0.44	1.04
Lewes, DE	0.11	0.28	0.87
Duck, NC	0.11	0.22	0.62
Wilmington, NC**	0.65	0.63	1.10
Mid Atlantic Coast	0.17	0.25	0.85
Springmaid Pier, SC	0.12	0.14	1.04
Charleston, SC	0.23	0.24	1.19
Fort Pulaski, GA	0.28	0.33	1.64
Fernandina Beach, FL	0.35	0.27	1.55
Mayport, FL	0.29	0.29	1.46
South Atlantic Coast	0.25	0.25	1.33
Naples, FL	0.16	0.13	0.64
Clearwater, FL	0.18	0.24	0.48
Apalachicola, FL	0.12	0.17	0.21
Panama City, FL	0.12	0.10	0.14
Pensacola, FL	0.09	0.15	0.21
Sabine Pass, TX	0.18	0.12	0.62
Galveston Pleasure Pier, TX	0.12	0.08	0.47
Freeport, TX	0.13	0.10	0.22
Gulf of Mexico	0.14	0.14	0.37

Table 5.2. ETSS, ADCIRC, G-NCOM, and RTOFS Forecast Guidance Monthly Subtidal Water Level Comparisons to NOS Observations (RMSE [meters]). Forecast hours 6-36 are used in the comparisons. Note ETSS water levels are subtidal, while the other three forecasts include tides.

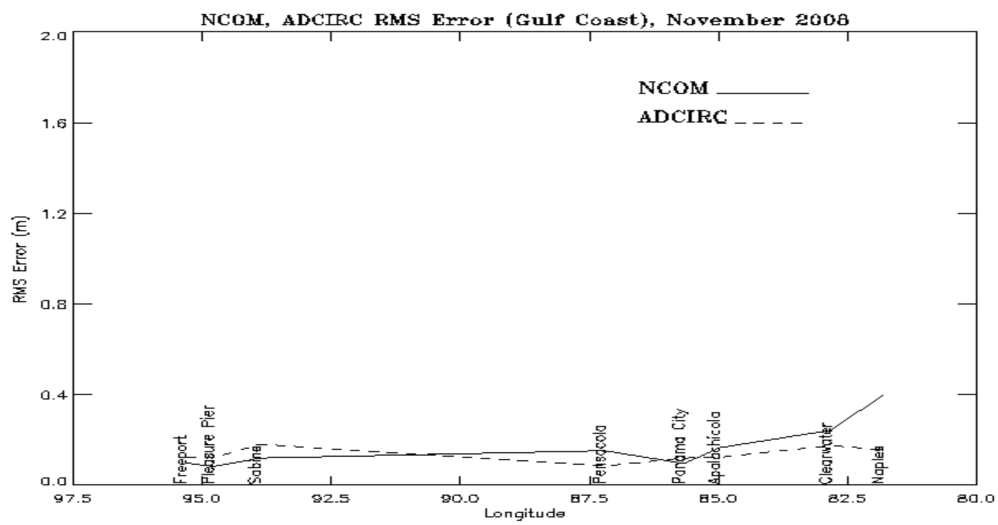
Station	ETSS (11/2008)	ADCIRC (1/2006)	G-NCOM (11/2008)	RTOFS (1/2006)
Eastport, ME	0.08	0.11	0.97	0.12
Portland, ME	0.08	0.11	0.14	0.10
Boston, MA	0.07	0.12	0.35	0.11
Woods Hole, MA	0.06	0.10	0.10	0.10
North Atlantic Coast	0.07	0.11	0.20	0.11
Sandy Hook, NJ	0.09	0.11	0.17	0.10
Atlantic City, NJ	0.08	0.11	0.12	0.10
Cape May, NJ	0.23	0.10	0.40	0.10
Lewes, DE	0.07	0.10	0.27	0.10
Duck, NC	0.06	0.07	0.22	0.21
Wilmington, NC	0.06	0.09	0.61	0.14
Mid Atlantic Coast	0.11	0.10	0.24	0.12
Springmaid Pier, SC	0.05	0.05	0.12	0.10
Charleston, SC	0.05	0.06	0.21	0.09
Fort Pulaski, GA	0.05	0.07	0.27	0.09
Fernandina Beach, FL	0.06	0.06	0.24	0.08
Mayport, FL	0.06	0.04	0.16	0.08
South Atlantic Coast	0.05	0.06	0.20	0.09
Naples, FL	0.04	0.06	0.11	0.07
Clearwater, FL	0.05	0.06	0.26	0.07
Apalachicola, FL	0.10	0.07	0.15	0.08
Panama City, FL	0.04	0.07	0.04	0.06
Pensacola, FL	0.03	0.06	0.15	0.07
Sabine Pass, TX	0.08	0.06	0.10	0.09
Galveston Pleasure Pier, TX	0.07	0.07	0.06	0.07
Freeport, TX	0.06	0.06	0.06	0.06
Gulf of Mexico	0.06	0.06	0.12	0.07

Table 5.3. ADCIRC Nowcast Subtidal Water Level Comparisons to NOS Observations January – April 2006 (RMSE [meters]). Nowcast hours 1-24 are used in the comparisons.

Station	January	February	March	April
Eastport, ME	0.11	0.13	0.11	0.06
Portland, ME	0.11	0.09	0.12	0.06
Boston, MA	0.12	0.10	0.08	0.06
Woods Hole, MA	0.10	0.09	0.06	0.05
Sandy Hook, NJ	0.11	0.12	0.07	0.04
Atlantic City, NJ	0.11	0.10	0.06	0.04
Cape May, NJ	0.10	0.09	0.06	0.05
Lewes, DE	0.10	0.10	0.07	0.05
Duck, NC	0.07	0.08	0.05	0.05
Wilmington, NC	0.09	0.08	0.06	0.09
Springmaid Pier, SC	0.05	0.06	0.04	0.05
Charleston, SC	0.06	0.06	0.04	0.03
Fort Pulaski, GA	0.07	0.06	0.05	0.04
Fernandina Beach, FL	0.06	0.06	0.05	0.04
Mayport, FL	0.04	0.04	0.04	0.03
Naples, FL	0.06	0.03	0.03	0.03
Clearwater, FL	0.06	0.04	0.03	0.03
Apalachicola, FL	0.07	0.05	0.03	0.02
Panama City, FL	0.07	0.05	0.04	0.03
Pensacola, FL	0.06	0.05	0.03	0.03
Sabine Pass, TX	0.06	0.06	0.05	0.03
Galveston Pleasure Pier, TX	0.07	0.06	0.04	0.04
Freeport, TX	0.06	0.05	0.04	0.03

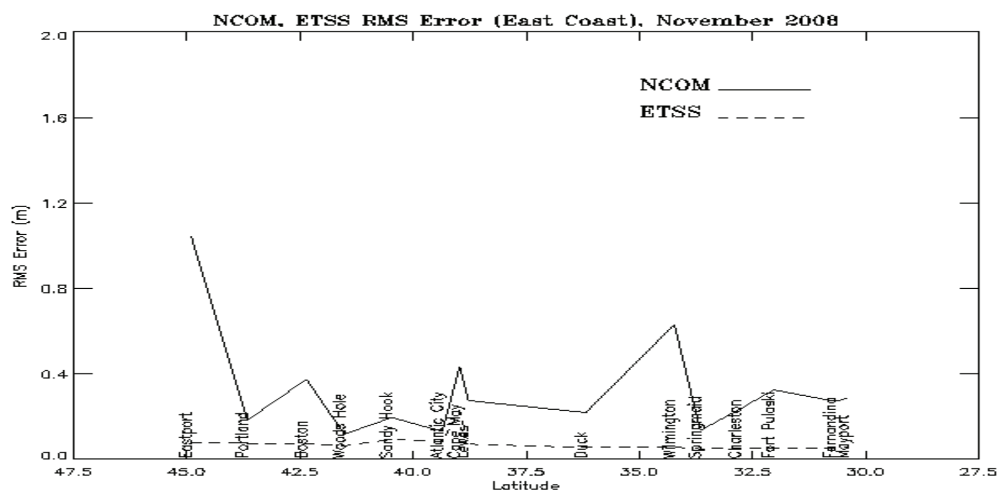


(a)

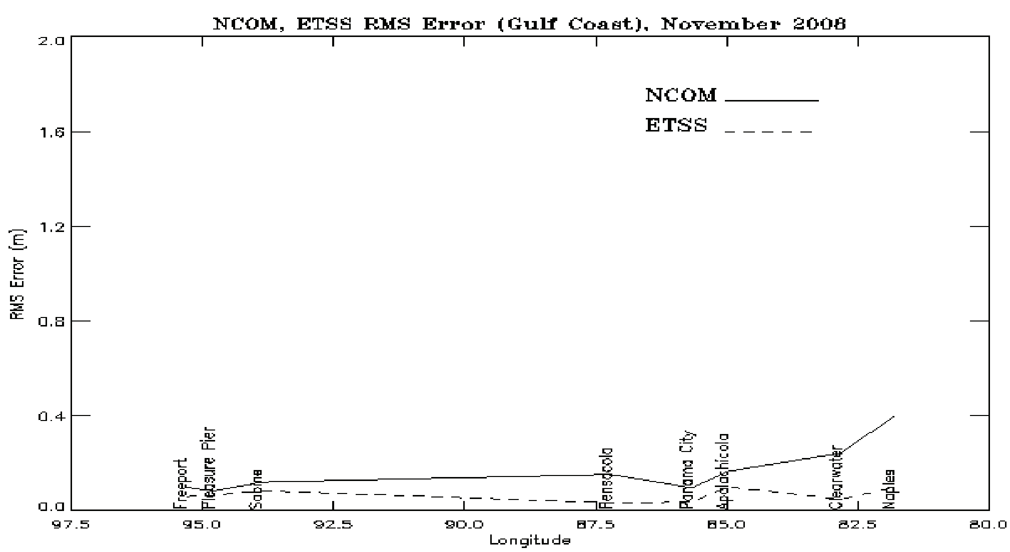


(b)

Figure 5.1. G-NCOM vs. ADCIRC Total Water Level Forecast Guidance RMSE (meters) for East Coast Stations (a) and for Gulf of Mexico Stations (b) for November 2008.

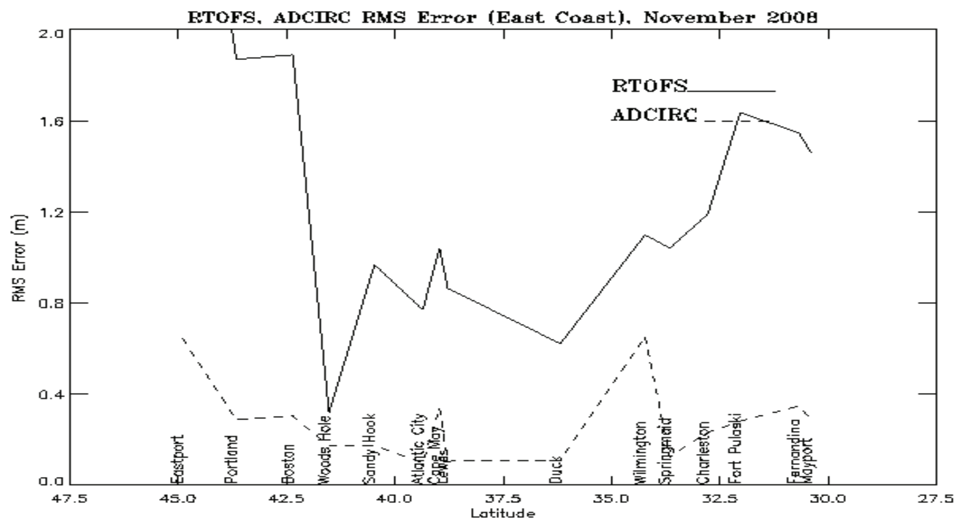


(a)

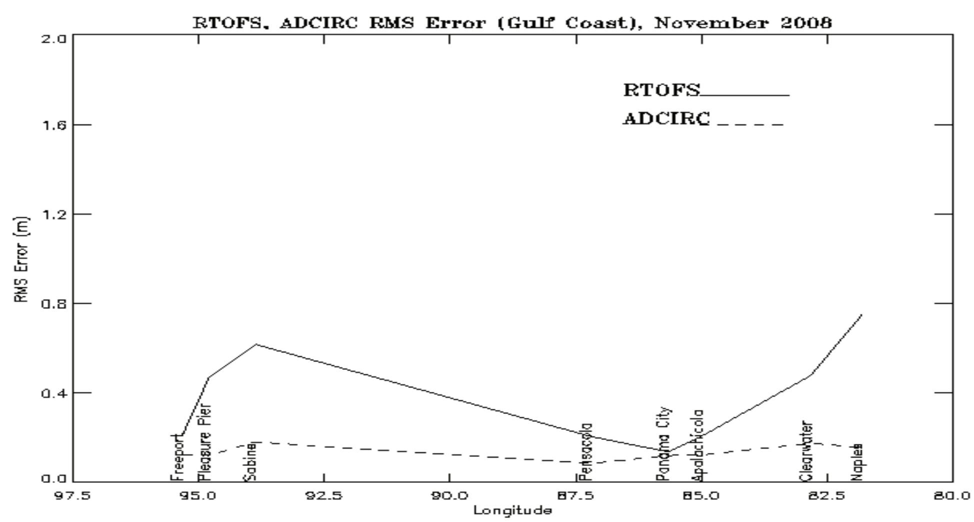


(b)

Figure 5.2. G-NCOM Total Water Level vs. ETSS Subtidal Water Level Forecast Guidance RMSE (meters) for East Coast Stations (a) and for Gulf of Mexico Stations (b) for November 2008.



(a)



(b)

Figure 5.3.RTOFS vs. ADCIRC Total Water Level Forecast Guidance RMSE (meters) for East Coast Stations (a) and for Gulf of Mexico Stations (b) for November 2008.

6. CONCLUSIONS

Total Water Level

Two experimental versions of RTOFS have been compared with the original operational version assessed by Richardson and Schmalz (2007), in which they noted that the major source of the tidal error is in the M_2 and S_2 tidal constituents as determined by 29 day harmonic analysis of concatenated RTOFS nowcasts for each of the four months January – April 2006. Experimental RTOFS version 1 exhibits significant improvement in the tidal dynamics with a reduction in total water level error of nearly 40 cm in the middle Atlantic region, with almost no improvement in the Gulf of Mexico. Even with the improvements, RTOFS total water level RMSEs are significantly larger than either G-NCOM or ETSS.

RTOFS experimental version 2 includes the tidal improvements as well as SSH assimilation, which slightly improves total water level RMSE with respect to RTOFS experimental version 1. Additional improvements in tidal dynamics are necessary to make RTOFS competitive with G-NCOM. However, G-NCOM water level predictions are at three hour intervals and include the OSU tide model (TPXO6.2 Egbert and Erofeeva, 2002) results added after the fact; e.g., this separate modeling of the tidal contribution is added to the G-NCOM simulation result.

ADCIRC and ETSS are two-dimensional vertically integrated models, with ADCIRC including the tides. ADCIRC total water level results are superior to both of the three-dimensional models RTOFS and G-NCOM.

Subtidal Water Level

ADCIRC subtidal results are comparable to ETSS and RTOFS subtidal water level results previously reported by Richardson and Schmalz (2007). With respect to RTOFS subtidal water levels, one notes that the preceeding 30 day nowcasts and the latest forecast guidance could be concatenated and then 30 hr low pass filtered to obtain the subtidal forecast guidance signal, which could then be adjusted over the 6-36 hour forecast guidance horizon and used as the subtidal forecast guidance.

Summary

With respect to both total and subtidal water levels, the cause of the differences is in part due to the use of different wind and sea level atmospheric forcings. G-NCOM uses the U.S. Navy NOGAPS, while RTOFS and ETSS use the NWS GFS forcings and ADCIRC uses NWS NAM. Note prior to the water level comparisons, surface wind forecasts could be compared using the methods in Richardson and Schmalz (2005).

The analysis procedures developed here are sufficiently general to compare both subtidal water level models and total water level models. Additional comparison with the total and subtidal water level forecasts could be performed on a routine monthly basis using a more standardized analysis software package. While the present study focuses on water levels, salinity and temperature structures should be compared with XBT and CTD casts to further assess the ability of the RTOFS and G-NCOM to predict shelf density patterns.

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APPENDIX A : SOFTWARE OVERVIEW AND PROGRAM DESCRIPTIONS

Software Overview

Read_tdl.f was developed to read forecast guidance water level output from ETSS. The program reads water level results from either 00Z or 12Z forecast files. The program writes the output for all stations; e.g. in standard ETSS block format (8f7.4) rather than single station format.

Readhycom.f was developed to read RTOFS water level forecast guidance. The program reads water level results from 00Z forecast files. The program writes the output in standard ETSS block format, hours 1-24. Readrtofs.f is used to consider hours 6-36. Read_monrtofs.f is used to process monthly netCDF RTOFS concatenated daily (1-24 hr) forecast files.

Read_adcirc.f and readncom.f are used to read and reformat as above for ADCIRC and G-NCOM for hours 6-36. Read_adcnew24.f is used to read and reformat ADCIRC files for hours 1-24.

Adjust_blk.f was written to adjust the daily forecast by adding or subtracting, to each forecast point, the offset obtained from the difference of the initial observed point and the initial forecast point. Adjust_blk24.f was used to adjust 1-24 hr forecast data in standard ETSS block format, and to write the output in the same format.

A subset of programs was developed to carry out the harmonic analysis of and the processing of the nowcast data.

Readhyc_nowc.f reads the nowcast water levels from the nowcast/forecast files and writes the output in standard ETSS block format.

Hycom29.f performs two functions necessary to run the harmonic analysis program (harm29). The nowcast data are read from the previously created daily nowcast files. The daily nowcast data are written to output files (by station) and concatenated. Having a continuous data stream is necessary to perform either the 30 hour low pass filtering or the harmonic analysis. For the harmonic analysis, the program also creates the necessary control files.

Hyc_reform.f was created to read nowcast data from these month long (by station) data files and create from them the daily nowcast files in standard ETSS block format, hours 6 – 36.

The harmonic analysis was performed by running a script, harm29.jcl. The script incorporates the standard harmonic analysis program, harm29. Const2.f was created to display the harmonic constants derived from harm29 along with the "accepted" harmonic constants from CO-OPS.

The statistical analysis is performed by wl_sa.ph.f for forecast guidance hrs 6-36. RMSE and standard deviation statistics of the error signal are calculated on a daily forecast basis, and combined for the entire month. Note the program was modified to incorporate the G-NCOM three hour data interval. The mean and standard deviation for the observed and model water levels are also calculated. Wl_sa.ph24.f was used to analyze forecast data from standard ETSS block format over hrs 1-24.

Plot_wlanblk.pro is written in the IDL programming language. The program will plot the observed water level along with points representing the high, low, start and end points for each daily forecast or nowcast. Symbols used to represent these points are plus, square, triangle, and asterisk. Plot.wlanal.pro generates one plot per page. Plot_wlanforc.pro is used to plot all forecast points from standard ETSS block format.

All *.f program files are written in FORTRAN 95, while *.pro files are written in IDL. All programs are run at CSDL on Linux workstations and are discussed in turn below.

A.1. Program Readhycom.f

Program readhycom.f was created to read water level values from the daily RTOFS combined nowcast/forecast files.

Variables read from the control file include *idebug*, *filehyc*, *nsta*, *stat_nam(ns)*, and *fileout*. *Idebug* controls the debug option, *filehyc* is the name of the RTOFS nowcast/forecast file, *nsta* is the number of stations, *stat_nam(ns)* are the station names, and *fileout* gives the forecast guidance output filename.

After the RTOFS 00Z forecast data file is opened, the program reads the station name from the first line of data. Only data from the desired stations are read. The program skips over 24 hours of nowcast data, then skips over the first five hours of forecast output. Starting with hour six, the next 31 values are stored in array *wl_hyc*(). The forecast guidance water level values are then written to output in standard "block" format (8f7.4).

A.2 Program Adjust24.f

A revision of adjust_blk.f was set up to adjust points 1 through 24 of the forecast cycle instead of the 6 through 36 which had been done previously.

A.3. Program Wl_sa.ph24.f

Wl_sa.ph24.f is a revision of wl_sa.phblk.f. Wl_sa.ph24.f was set up to analyze hours 1 through 24, instead of hours 6 through 36 which had been done previously.

A.4. Program Read_monrtofs.f

Read_monrtofs.f was created to read and convert into standard ETSS block format the RTOFS daily forecast data from netCDF format. The "new" RTOFS data were provided in the form of monthly, concatenated, files. Read_monrtofs will read from the control file *idebug*, *ndays*, *filehyc*, *nsta*, and *statnam*. *Idebug* controls the debug function, *ndays* is the number of concatenated daily files, and *filehyc* is the name of the RTOFS file to be read from. *Nsta* is the number of stations and *stat_nam* gives the station names. The program calls subroutine readwl_mo which actually reads the netCDF data. After the call to readwl_mo, the program writes the forecast guidance output in standard ETSS block format.

A.5. Program Read_adcirc.f

Read_adcirc.f was created to read water level values from daily ADCIRC forecast files.Variables read from the control file include *idebug* and *adcfile*. *Idebug* controls the debug option, while *adcfile* is the ADCIRC forecast file to be read from. The program first reads 3 header lines from the ADCIRC forecast file. The program then skips through the appropriate number of hours (5) in order to begin reading water level values at hour 6. A total of 8053 lines of data are skipped over to begin reading the forecast output at hour 6 and continuing through hour 36. Read_adcirc.f writes the forecast output into standard ETSS block format.

A.6. Program Adjust_blk.f

The purpose for Adjust_blk.f is to adjust each data point of the daily forecast guidance by adding the offset obtained from the difference between the initial observed point and the initial forecast point. While other adjustment methods are possible (based on longer term observations and associated ramping), these more elaborate techniques have not been used here. The program is generally run for all stations at once, then run for each day of the comparison period. The adjusted forecast guidance files are used for all analysis work. Adjust_blk.f reads the forecast guidance or nowcast data in standard ETSS block format, and writes the output in the same format.

A.7. Program Readadcnew24.f

Readadcnew24.f is a revision of read_adcirc.f. Read_adcnew24.f was created to read ADCIRC nowcast water level values for hours 1 through 24.

A.8. Program Readadcirc24.f

A revision of read_adcirc.f. Readadcirc24.f skips the appropriate number of lines (1153) to get to hour 1 of the forecast guidance. This version of the program reads values for hours 1 through 24, instead of hours 6 through 36 as had been done previously.

A.9. Program Readrtofs.f

Readrtofs.f was created to read and convert into standard ETSS block format the RTOFS daily forecast guidance data from netCDF. The program reads from a control file *idebug*, *filehyc*, *nsta*, and *stat_nam*. *Idebug* controls the debug function, *filehyc* is the name of the RTOFS file to be read from. *Nsta* is the number of stations and *stat_nam* gives the station names. The program calls subroutine readwl which actually reads the water level data from netCDF files. After the call is made to readwl, the program writes the forecast guidance model output in standard ETSS block format.

A.10. Program Readncom.f

Readncom.f was created to read and convert into standard ETSS block format the G-NCOM daily forecast guidance data from netCDF files. The program reads from a control file *idebug*, *path*, *fname* and *stat_nam*. *Idebug* controls the debug function, while *path* and *fname* give the name of the G-NCOM netCDF forecast guidance file to be read. *Stat_nam(ns)* gives the station names. The program makes a call to subroutine readwl. Readwl actually reads the netCDF data including the variable *zeta*, which contains all water level data.

A.11. Program Read_tdl.f

Program read_tdl.f first reads *nstn_r*, the number of stations to read. There are forecast data for 61 stations in an East Coast ETSS file. There are data for 22 stations in a Gulf Coast ETSS file. Next read is *nstn_wr*, the number of stations to write forecast output for. For this comparison, *nstn_wr(1)* will equal 15 for the East Coast. *Nstn_wr(2)* will equal 9 for the Gulf Coast. The program then reads *tdl_file(1)* and *tdl_file(2)*, the ETSS forecast guidance files for the East Coast and the Gulf Coast, respectively. For each of stations 1 through *nstn_wr*, a station number is read, a logical unit number, and the forecast guidance output filename. Read_tdlblk.f is a very straight forward program. The ETSS forecast guidance data file (00Z or 12Z) is opened, and the output files are opened for stations 1 through *nstn_wr*. Read_tdl.f will read water level values for hours 1 through 24, storing the values in the array *iwl*. The next line is read for hours 25 through 48. If the forecast guidance file is 12Z, the output file for a given station will begin at 0.75 of that Julian day, and will proceed from 0.0 to 1.00 of the following day. If the file is 00Z, the output file will begin at 0.25 of that day, and proceed through 1.50 of the following day. Basically, one skips 6 hours into the forecast guidance file (either 00Z or 12Z) and uses the next 30 hours. This condition simulates the use of the forecast guidance within a nowcast/forecast system mode; e.g., there is a 6 hour meteorological forecast processing time. The output is written in the standard ETSS block format (8f7.4).

A.12. Program Wl_sa.ph.f

Following the parameter and dimension statements, and after the character variables are declared, wl_sa.ph.f will read necessary information from the control file. Variables read from the control file include *idebug*, *istat*, *statnam*, *fout*, *rjd_start*, *rjd_stop*, and *tdmax*. *Idebug* controls the debug function. *Istat* is the number of stations. *Statnam* is the station name. *Fout* is the output file name. *Rjd_start* is the start time, and *rjd_stop* is the stop time. *Tdmax* is the maximum allowable time difference between two data points. The 600 loop is the day loop, beginning with *nd* = 1, and finishing with *nd* = *ndays*. The forecast model file is opened, along with the observed data file. Wl_sa.ph.f calculates the variance and mean for the model water level values, and for the observed data. Subroutine compare is called to calculate the rms difference between the model values and the observed. The daily statistics are written to output in the 850 loop, which begins with *nd* = 1 and ends with *nd* = *ndays*. The statistics for the entire month are calculated in the 1000 loop, and the results are written to the monthly summary table.

A.13. Program Plot_wlanblk.pro

Plot_wlanblk.pro is an IDL program used to plot a month of observed water level data, along with points from each of the daily forecast. From each daily forecast guidance, four points are plotted: the start, the end, the max, and the min. The symbols used to represent forecast guidance values include pluses, triangles, squares, and asterisks. From the control file is read *ptype*, *idebug*, *stat_name*, *titlnam*, *strttime*, and *endtime*. *Ptype* is for plot type, in this case postscript. *Idebug* controls the debug function. *Stat_name* is the station name, *titlnam* is the plot title. *Strttime* and *endtime* specify start and end times. Plot_wlanblk.pro is a conventional IDL program in which the plot command is used to plot the observed curve, while oplot is used to plot the forecast guidance points. The plots are annotated with a title, station name, and a legend.

A.14. Program Plot_wlforc.pro

Plot_wlforc.pro is identical to Plot_wlanblk.pro with one exception. There is an option to plot only the four points from the forecast guidance (start, end, max, and min) or to plot all the forecast guidance points from each cycle.

A.15. Program Hycom29.f

Hycom29.f was created to perform two steps necessary to run harm29, the harmonic analysis program. The nowcast data are read from the daily nowcast files created from Readhyc_nowc.f. Hycom29.f will create, for each station, a concatenated, continuous, month long stream of data. The program will also create the control files necessary to run harm29. A continuous stream of values is also necessary for the 30 hour low pass filter. The daily nowcast files are opened in the 50 loop. The nowcast data are read in the 100 loop (day loop) and the 150 loop (station loop). The 100 day loop begins with a read statement. The read statement reads the time and date information from the daily nowcast data file. The water level data are read in the station loop (150). For each station, the water level values are read from standard ETSS block format (8f7.4) for hours 1 through 24. The concatenated nowcast values, by station, are written to output in the 200 loop.

A.16. Program Readpred.f

Readpred.f was created to de-tide RTOFS forecast data. Readpred will read from a control file all necessary parameters including *idebug*, *nsta*, *filecons, iyear*, *tconv*, *cdfout*, *nday*, and *hycfile*. *Idebug* is the debug switch. *Nsta* is the number of stations. *Filecons* is the file containing values for the model harmonic constituents, output from harm29. *Cdfout* is the output file for the calculated astronomic tide, by station. *Tconv* is the time meridian for which the kappa primes in the harmonic constants were derived. *Nday* is the number of days (number of daily forecasts). *Hycfile(nd)* are the daily RTOFS forecast guidance files. The program first opens *filecons*. It then reads from this file the constituent amplitudes and phase angles. Readpred.f will call subroutine predk to calculate the astronomic tide. We converted the tidal prediction program pred to a subroutine for this usage and called it predk. Predk will calculate the astronomic tide based on the constituent values calculated from harm29. The tidal prediction values are stored in array *hyc_pred(ns,np)*, by station. Daily RTOFS forecast output is read, then stored in array *wl_mod(nd,ns,nhr)*, where *nd* is the day, *ns* is the station number, and *nhr* is the forecast hour. The detided values are obtained by first looping through by day, then looping through by station and by hour, subtracting *hyc_pred(ns,nprhr)* from *wl_mod(nd,ns,nhr)*. The detided output is written in standard ETSS block format for hours 6 through 36 of each forecast cycle.

A.17. Program Hyc_reform.f

Hyc_reform was created to read nowcast water level data, either filtered or non-filtered, from the concatenated, station data files. From this, the program will create the daily nowcast water level data file in standard ETSS block format for hours 6 through 36. The nowcast data are read in the 175 loop (day) and the 100 loop (station). The water level values are stored in *wl_hyc(nd,ns,l*) where *nd* is the day, ns is the station, and *l* is the hour. The water level values are written to output in the 250 (day) loop and the 200 (station) loop. The output is written in standard ETSS block format for *idat* = 1 through 31. *Idat* = 1 through 31 corresponds to hours 6 through 36 of that day's nowcast.

A.18. Program Const2.f

Const2.f was created to compare tidal constituents obtained from the harmonic analysis program, harm29, with the "accepted" harmonic constants from CO-OPS. The program reads both the amplitude and phase angle from the file containing the accepted CO-OPS constants, and from the file containing the calculated (harm29) constants. The file containing the calculated constants is in standard "NOS" format (7(f5.3,f4.1)). The output includes not only the amplitude and phase angle for both the calculated constants and the accepted constants, but the amplitude difference and phase angle difference, Harm29 – accepted, as well. Gain, phase, and an estimated RMS error are computed.

APPENDIX B. SCRIPT AND CONTROL FILES

Table B.1 presents an inventory of all programs used in this analysis. Also listed are an appropriate script file and control file. ~ designates the users home area, and 3model is the project directory.

~/3model/observed/reform_coops.f
~/3model/model/RTOFS/readhycom.f
~/3model/comp/adjust/24hour/adjust24.f
~/3model/comp/wl_sa.ph24.f
~/3model/model/RTOFS/monthly/read_monrtofs.f
~/3model/model/ADCIRC/read_adcirc.f
~/3model/comp/adjust/adjust_blk.f
~/3model/model/ADCIRC/new/read_adcnew24.f
~/3model/model/ADCIRC/old/read_adcirc24.f
~/3model/model/RTOFS/readrtofs.f
~/3model/model/NCOM/readncom.f
~/3model/model/read_tdl.f
~/3model/plot/anal/1plot/24hr/plot_wlforc.pro

Table B.1. Script, Source File, and Control File Inventory

Script	**Source File**	**Example Control File**
readhy.jcl	readhycom.f	readhy_jan06.n
adjust24.jcl	adjust24.f	adj_rtofs.jan06.n
wl_sa.jcl	wl_sa.ph24.f	wl_rtofs.jan06.n
month.jcl	read_monrtofs.f	readhy_jan06.n
readadc.jcl	read_adcirc.f	adc_jan06.n
adjust.jcl	adjust_blk.f	adj_adcirc.jan06.n
readadcnew24.jcl	read_adcnew24.f	adcnew24_jan06.n
readadcirc24.jcl	read_adcirc24.f	adc24_jan06.n
rtofs.jcl	readrtofs.f	readhy.nov08.n
readncom.jcl	readncom.f	readncom.nov08.n
read_tdl.jcl	read_tdl.f	read_nov08.n
	plot_wlforc.pro	cnt.rtofs_new.jan06.n

Script and control files are similar to those in Appendix B of Richardson and Schmalz (2007). The IDL plot program does not have a script file. To run the IDL program, type idl <return>, then type .r plot_wlforc.pro <return>.