CSDL Informal Technical Note No. 8

COMPARISON OF NOAA WATER LEVEL FORECAST GUIDANCE FROM THE REAL TIME OCEAN FORECAST SYSTEM, EXTRATROPICAL STORM SURGE SYSTEM, AND THE NATIONAL OCEAN SERVICE GULF OF MEXICO SYSTEM: JANUARY–APRIL 2006 MONTHLY ANALYSIS

Silver Spring, Maryland
July 2007

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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July 2007

U.S. Department of Commerce
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NOTICE

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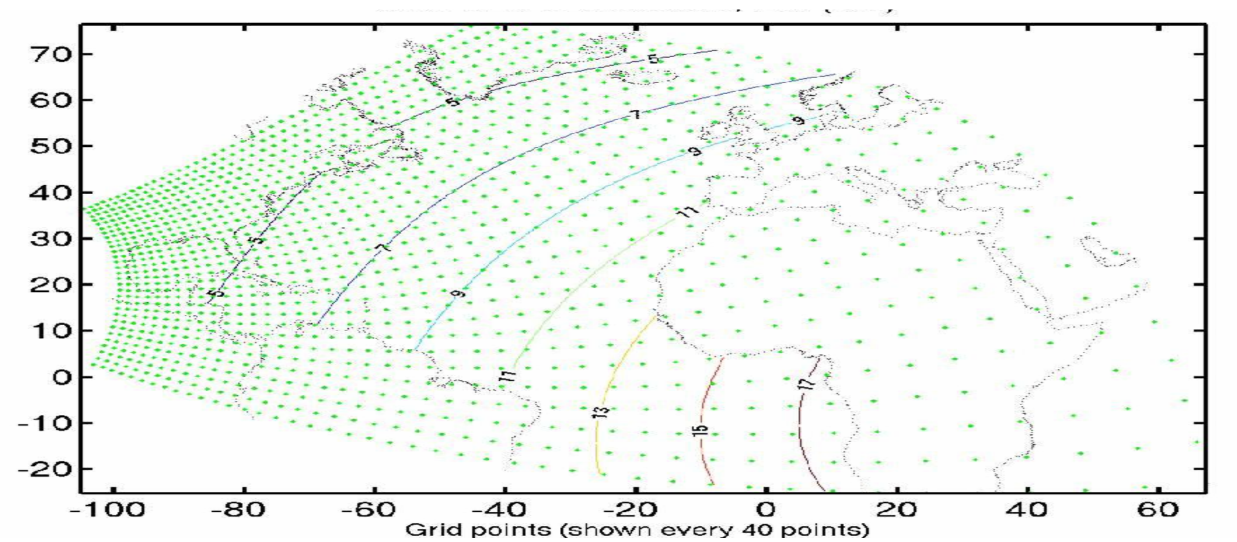

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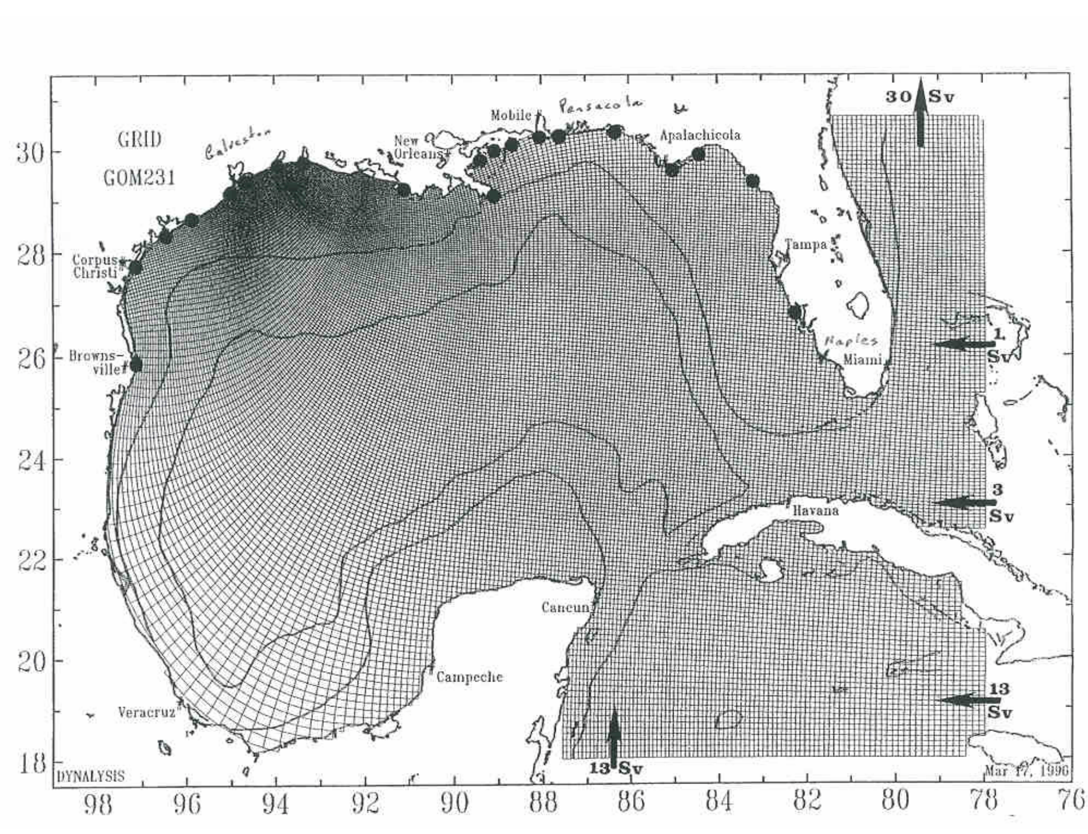

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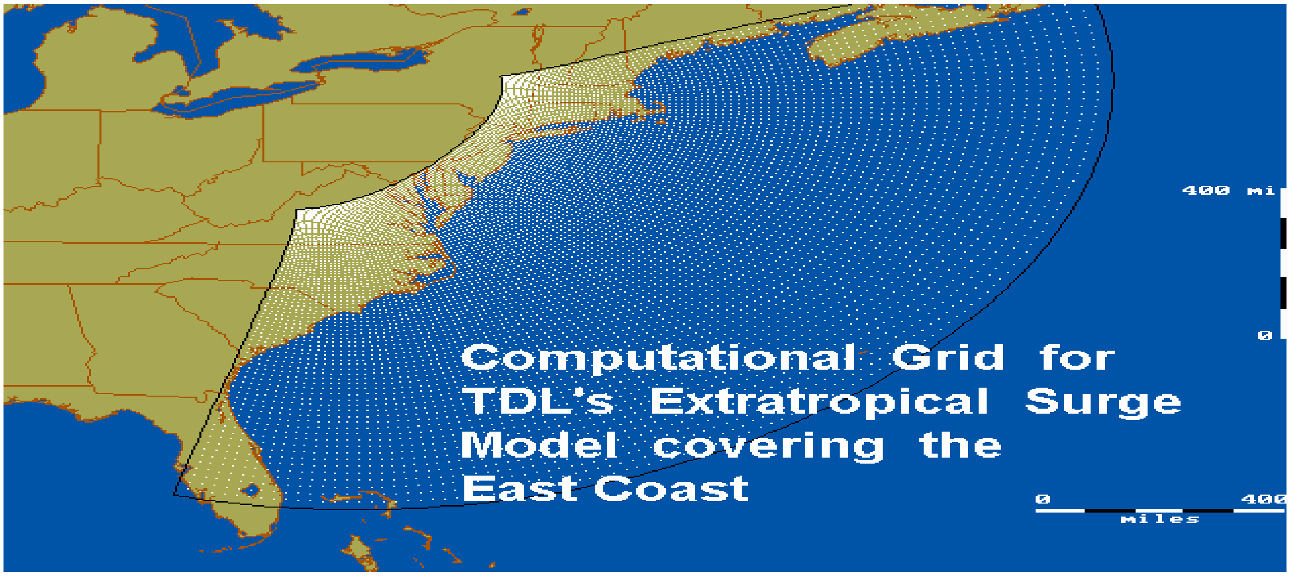

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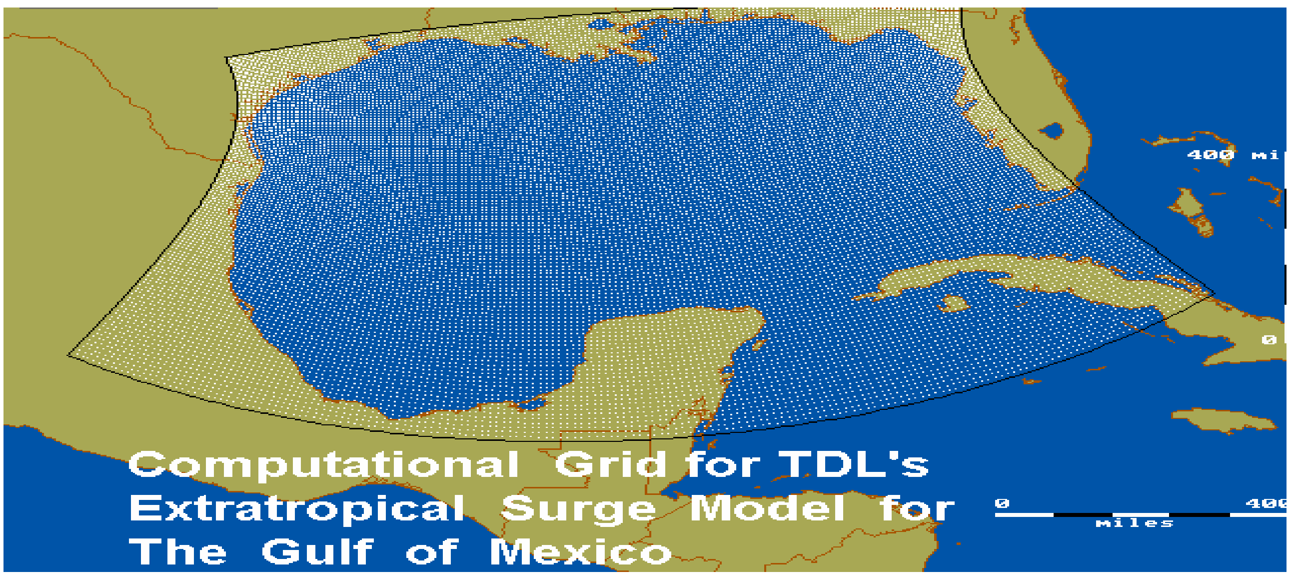

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ABSTRACT

Water level comparisons, both nontidal and complete water level, of forecasts versus observations have been performed at a total of 24 National Ocean Service (NOS) stations on the East Coast and along the Gulf of Mexico shoreline. Both the National Weather Service (NWS) Real Time Ocean Forecast System (RTOFS) water levels and the NWS Extratropical Storm Surge (ETSS) water levels were compared with the observations for the months of January, February, March, and April 2006. Because the ETSS system is nontidal, the ETSS forecast water levels were compared with observed nontidal water levels. The observed nontidal water levels were obtained using a 30 hour low pass filter. A nontidal comparison involving ETSS and NGOM (NOS Gulf of Mexico) forecast systems vs. observed was performed for January 2006. Because the RTOFS includes tides, RTOFS forecast water levels were compared with the total observed water level. Using the RTOFS nowcast water levels, it was possible to perform a nontidal comparison with nontidal observed water levels. Similar results were obtained by subtraction of the NOS predicted astronomic tide from the total nowcast water level (detiding).

Program descriptions are provided along with an explanation of all cases which were run, and a description of all processing steps. Script and program input files are given in Appendix B. The NGOM and ETSS forecast guidance performed well, and were of near equal quality. The nontidal RTOFS nowcast also performed well, and was nearly as accurate as ETSS.

1. INTRODUCTION

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 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) atmospheric model. 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. SST data from the GOES AVHRR are assimilated. Refer to Bleck et al. (2002) for further details regarding the HYCOM model development and computational algorithms.

NOS/Coast Survey Development Laboratory (CSDL) has utilized the nontidal water level forecasts produced by the NWS Meteorology Development Laboratory (MDL) Extratropical Storm Surge (ETSS) system for offshore water level boundary conditions for the New York Harbor /Port of New Jersey, Chesapeake Bay, and Galveston Bay forecast systems. Separate domains are run for the East Coast, West Coast, Alaskan Coast, and Gulf of Mexico. 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 NOS Gulf of Mexico (NGOM) system, formerly known as the Dynalysis Gulf of Mexico (DGOM) system, employs a three dimensional split mode finite difference method and makes use of the U.S. Navy Coupled Ocean/Atmospheric Mesoscale Prediction System (COAMPS) wind and sea level atmospheric pressure forcings. The horizontal resolution of these meteorological forcings is approximately 20 km. Additional model details may be found in Patchen et al. (1998; 1999a ; 1999b). The NGOM system has been set-up in a forecast mode by Patchen and Blaha (2002) at the Naval Oceanographic Office (NAVOCEANO) and has been transitioned to quasi-operational status at NOS, where the hourly forecast guidance results over the 48 hour forecast period have been made available for further analysis.

We have compared daily forecast/nowcast results of both nontidal and total water level response along the East coast and throughout the Gulf of Mexico from hours 6-36 for all forecasts. A set of programs has been developed to perform the comparisons. The programs are briefly itemized as follows:

. Read_tdlblk.f was developed to read forecast 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 “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 “block” format, hours 1 - 24.

. Read_dyn.f was used exactly as it was in the earlier DGOM system comparison study as described by Richardson and Schmalz (2004).

. Adjust_blk.f was written to adjust the daily forecast guidance 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_blk.f was revised in order to read nowcast/forecast data in "block" format, and to write the output in the same "block" 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 "block" format.

. Hycom_nowcha.f performs two functions necessary to run the harmonic analysis program (harm29). The nowcast data is read from the previously created daily nowcast files. The daily nowcast data is written to output files (by station) and concatenated. Having a continuous data stream is necessary to run the 30 hour low pass filter program. 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 "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.phblk.f. RMS and standard deviation statistics of the error signal are calculated on a daily forecast basis, and combined for the entire month. The mean and standard deviation for the observed and forecast water levels are also calculated. Wl_sa.phblk.f was revised in order to read forecast/nowcast data from "block" format.

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_wlanblk.pro was revised in order to read forecast/nowcast data from "block" format.

Reform_coops.f, read_tdlblk.f, read_dyn.f, adjust_blk.f, and wl_sa.phblk.f are written in FORTRAN 77, while plot_wlanblk.pro is written in IDL. All programs are run at CSDL on Linux workstations.

Chapter 2 presents a description of all "cases", a total of seven, and a description of how the harmonic analysis was carried out. Instruction on how to run the analysis program set is also provided. In Chapter 3, RTOFS water level harmonic analysis results are presented to enumerate the tidal error. Analysis results from the months of January, February, March, and April 2006, involving RTOFS and ETSS are presented in Chapter 4. The results of the ETSS/NGOM comparison for January of 2006 are provided in Chapter 5. The program wl_sa.ph.f, as described by Richardson and Schmalz (2004), was used for this statistical comparison. Chapter 6 presents some conclusions drawn from the work already completed, as well as recommendations for future subjects of study. In Appendix A, a description of each program is provided. Complete script and control file listings are given in Appendix B.

2. CASE DESCRIPTIONS

Seven cases as shown in Table 2.1 were developed to facilitate the comparison of a nontidal forecast system (ETSS) with a total water level forecast system (RTOFS). As a prerequisite, the observed water level data obtained with respect to MLLW must be processed. This is performed with the program reform_coops.f described by Richardson and Schmalz (2004). For all nontidal comparisons, the observed water level data must be 30 hour low pass filtered. This is performed with the program 30hourlp.f, a version of the standard branch program. Cases 1 through 7 are described in this chapter. Also, a description of the harmonic analysis which was performed on the RTOFS nowcast data is provided.

Table 2.1. Inventory of Evaluation Cases

Case No.	Case Descriptions
1	ETSS and NGOM (adjusted) vs 30hr LPF observations
2	RTOFS (adjusted) vs observations
3	RTOFS nowcast 30 hr LPF (unadjusted) vs 30hr LPF observations
4	RTOFS nowcast (unadjusted) vs observations
5	RTOFS forecast (unadjusted) vs observations
6	RTOFS nowcast 30hr LPF (adjusted) vs 30hr LPF observations
7	RTOFS forecast (detided, adjusted) vs 30hr LPF observations

Case 1: ETSS Nontidal Comparison: Adjusted Forecast vs. Filtered Observations

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 data is recorded in tenths of feet. The processing steps itemized in Table 2.2 are discussed in turn below.

read_tdlblk.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.phblk.f, for comparison with the observed data. The comparison is performed over hours 6 through 36 of each daily forecast cycle.

Table 2.2. Case 1: ETSS Nontidal Comparison: Adjusted Forecast vs. Filtered Observations

Script	Source File	Control File
read_tdl.sh	read_tdlblk.f	read_jan06.n
adjust.jcl	adjust_blk.f	adj_etss.jan06.n
wl_sa.jcl	wl_sa.phblk.f	wl_tdl.jan06.n

Case 2: RTOFS Total Water Level Comparison: Adjusted Forecast vs. Observations

The RTOFS daily forecast files are presented in a format dissimilar to the ETSS format. The processing steps are given in Table 2.3 and are discussed in turn below. Readhycom.f reads the forecast values for hours 6 through 36. 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.

Adjust_blk.f is used exactly as it was for the processing of the ETSS forecast data. An offset is added to each forecast value for hours 6 through 36. 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.phblk.f, for comparison with the observed data. The comparison is performed over hours 6 through 36, just as it was done for ETSS.

Table 2.3. Case 2: RTOFS Total Water Level Comparison: Adjusted Forecast vs. Observations

Script	Source File	Control File
readhy.jcl	readhycom.f	readhy.jan06.n
adjust.jcl	adjust_blk.f	adj_hyc.jan06.n
wl_sa.jcl	wl_sa.phblk.f	wl_hyc.jan06.n

RTOFS Nowcast Processing and Harmonic Analysis

The nowcast processing and harmonic analysis steps are given in Table 2.4 and described in turn below.

Table 2.4. RTOFS Nowcast Harmonic Analysis

Script	Source File	Control File
readhy.jcl	readhyd_nowc.f	readhy.jan06.n
hycomha.jcl	hycom_nowcha.f	hycomha.jan06.n
30hourlp.jcl	30hourlp.f	interactive prompt
harm29d.jcl	harm29d.f	-
const.jcl	const2.f	constt.jan06.n

The RTOFS nowcast data were incorporated into the daily forecast files. The forecast data 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 nowcast data into the standard ETSS 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 RTOFS nowcast data was to perform harmonic analysis. hycom_nowcha.f performs two functions necessary to run harm29. The nowcast data is 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 nowcast data 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.

Harmonic Analysis

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).

Analysis of Harmonic Results

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 3 : RTOFS Nontidal Comparison: Filtered Nowcast vs. Filtered Observations

The RTOFS Nowcast data was filtered using the standard 30 hour low pass filter. This attempt to assess the non-tidal portion of the RTOFS error produced very large RMS errors. In fact, the errors calculated for the non-tidal portion of the nowcast exceeded the error produced from the total forecast water level. Note no adjustment and demeaning was performed as shown in the processing inventory given in Table 2.5.

Table 2.5. Case 3: RTOFS Nontidal Comparison: Filtered Nowcast vs. Filtered Observations

Script	Source File	Control File
readhy.jcl	readhyc_nowc.f	readhy_jan06.n
hycomha.jcl	hycom_nowcha.f	hycomha_jan06.n
30hourlp.jcl	30hourlp.f	interactive prompt
hycref.jcl	hyc_reform.f	hycref.jan06.n
wl_sa.jcl	wl_sa.phblk.f	wl_hyc_n30.jan06.n

Case 4: RTOFS Total Water Level Comparison: Nowcast vs. Observations

The RTOFS nowcast data were analyzed and very large RMS errors were determined, especially for the East Coast stations. The processing steps are given in Table 2.6.

Table 2.6. Case 4: RTOFS Total Water Level Comparison: Nowcast vs. Observations

Script	Source File	Control File
readhy.jcl	readhyc_nowc.f	readhy.jan06.n
hycomha.jcl	hycom_nowcha.f	hycomha.jan06.n
hycref.jcl	hyc_reform.f	hycref.jan06.n
wl_sa.jcl	wl_sa.phblk.f	wl_hyc.nowc.jan06.n

Case 5: RTOFS Total Water Level Comparison: Forecast vs. Observations

The RTOFS forecast data was re-analyzed – this time not adjusted. The purpose for this analysis was to demonstrate the near equality of the RTOFS forecast and the RTOFS nowcast (Cases 4 and 5). RTOFS forecast and nowcast generally agree to with 1 cm. The necessary processing steps are given in Table 2.7.

Table 2.7. Case 5: RTOFS Total Water Level Comparison: Forecast vs. Observations

Script	Source File	Control File
readhy.jcl	readhycom.f	readhy.jan06.n
wl_sa.jcl	wl_sa.phblk.f	wl_hycnadj.jan06.n

Case 6: RTOFS Nontidal Comparison: Nowcast vs. Filtered Observations

This comparison was done with the filtered and adjusted nowcast values vs. the filtered observed values. The RMS errors were much smaller than those of Case 3, and the results are comparable with those of Case 1 (ETSS). Processing steps are shown in Table 2.8.

Table 2.8. Case 6: RTOFS Nontidal Comparison: Filtered and Adjusted Nowcast vs. Filtered Observations

Script	Source File	Control File
readhy.jcl	readhyc_nowc.f	readhy.jan06.n
hycomha.jcl	hycom_nowcha.f	hycomha.jan06.n
30hourlp.jcl	30hourlp.f	interactive prompt
hycref.jcl	hyc_reform.f	hycref.jan06.n
adjust.jcl	adjust_blk.f	adj_hyc.n30.jan06.n
wl_sa.jcl	wl_sa.phblk.f	wl_hyc_n30adj.jan06.n

Case 7: RTOFS Nontidal Comparison: Detided and Adjusted Forecast vs. Filtered Observations

Harmonic constants were calculated from the RTOFS nowcast data using Program Harm29. These constituent values 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 values, resulting in a de-tided series, which was adjusted and compared against the filtered observations as shown in Table 2.9.

The analysis results from the detided forecast were not as good as the results from the filtered, adjusted nowcast (Case 6). The RMS error was about 10 cm worse at Eastport, and more than 20 cm worse at St Petersburg and Clearwater. It is not completely clear why the detided forecast (Case 7) did not do as well as expected. A contributing factor may be a tidal signal in the residual.

Table 2.9. Case 7: RTOFS Nontidal Comparison: Detided and Adjusted Nowcast vs. Filtered Observations

Script	Source File	Control File
readhy.jcl	readhyc_nowc.f	readhy.jan06.n
hycomha.jcl	hycom_nowcha.f	hycomha.jan06.n
harm29d.jcl	harm29d.f	control.(station name).001
readpred.jcl	readpred.f	read.n
adjust.jcl	adjust_blk.f	adj_hyc.fdet.jan06.n
wl_sa.jcl	wl_sa.phblk.f	wl.hyc_det.jan06.n

3. RTOFS WATER LEVEL HARMONIC ANALYSIS RESULTS

To assess the error in the tidal portion of the RTOFS 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%. For the long term constituents, Sa and Ssa, usually several year analyses are averaged.

In Table 3.1, we consider the two dominant tidal constituents M_2 and S_2 and compare the RTOFS harmonic analysis results with the NOS accepted harmonic constants. The amplitude and phase differences (RTOFS – 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 RTOFS over predicts the

Table 3.1. M2/S2 RTOFS vs. NOS Harmonic Analysis Results
at Nowcast/Forecast System Boundary Locations for January 2006

Station	RTOFS Amp(m)	NOS Amp(m)	Difference (m)	RTOFS Phase (o)	NOS Phase (o)	Difference (o)
Sandy Hook, NJ NYOFS	0.857 0.380	0.688 0.134	0.169 0.246	294.1 329.2	6.0 32.6	-71.9 -63.4
Cape May, NJ DBOFS	0.947 0.348	0.714 0.125	0.233 0.223	335.0 17.0	28.6 55.3	-53.6 -38.3
Charleston, SC CHOFS	1.125 0.500	0.783 0.119	0.342 0.381	295.2 334.5	10.4 36.1	-75.2 -61.6
Mayport, FL SJOFS	1.449 0.635	0.676 0.105	0.773 0.530	328.3 13.2	25.3 48.3	-57.0 -35.1
St. Petersburg, FL TBOFS	0.874 0.232	0.175 0.057	0.699 0.175	179.9 217.1	197.0 211.7	-17.1 5.4
Galveston, TX GBOFS	0.531 0.167	0.139 0.034	0.392 0.133	276.7 346.2	276.1 267.9	0.60 78.3

tidal amplitudes at all stations for both M_2 and S_2. RTOFS leads in phase at all stations except at Galveston, TX with respect to the NOS values. This would suggest that the bottom roughness over the Atlantic continental shelf should be increased.

In Tables 3.2-3.6, 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 3.7-3.10 results are presented in the same format at St. Petersburg, FL, Panama City, FL, Sabine Pass, TX, and Galveston Pleasure Pier, TX, for the Gulf Coast. As noted above for RTOFS 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, RTOFS/NOS, is first computed. The gain given is 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 may be computed based on the individual constituent amplitude and phase differences following a method given by Hess (1994). Note a negative phase indicates that RTOFS leads the NOS prediction. Best results are achieved at Panama City, FL where the gain is 1.09, phase difference is 0., and the estimated RMS error is 6 cm.

To examine the consistency of the RTOFS 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 3.11 and in terms of estimated RMS error in Table 3.12. In general, one notes very similar values of gain and phase at each station for all four months. Note at St. Petersburg, FL, RTOFS water level forecast results were not processed during April. One notes at Duck, NC, the gain of 0.31 and phase lag of 3.0 hours. These are in sharp contrast to the values at the two surrounding stations. This phenomena may be due to the influence of the RTOFS Gulf Stream separation. One notes, however from Table 3.12, that the estimated RMS error at Duck, NC is of the same order as at the two surrounding stations.

Table 3.2. RTOFS vs. NOS Harmonic Analysis Results at Boston, MA for January 2006

	RTOFS		NOS ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	1.5140	69.10	1.3980	109.40	0.1160	-40.30
S(2)	0.4750	109.30	0.2130	146.20	0.2620	-36.90
N(2)	0.3270	52.80	0.3090	78.90	0.0180	-26.10
K(1)	0.1080	216.40	0.1430	205.20	-.0350	11.20
M(4)	0.0400	311.90	0.0230	25.90	0.0170	-74.00
O(1)	0.0920	216.40	0.1190	186.70	-.0270	29.70
M(6)	0.0130	337.60	0.0340	282.10	-.0210	55.50
MK(3)	******	******	0.0050	232.50	******	*******
S(4)	0.0050	47.60	0.0000	0.00	0.0050	47.60
MN(4)	******	******	0.0110	14.60	******	*******
NU(2)	0.0630	55.00	0.0670	85.50	-.0040	-30.50
S(6)	0.0000	109.70	0.0000	0.00	0.0000	109.70
MU(2)	******	******	0.0100	69.00	******	*******
2N(2)	0.0430	36.40	0.0390	55.00	0.0040	-18.60
OO(1)	0.0040	216.50	0.0050	227.00	-.0010	-10.50
LAMBD	0.0110	87.80	0.0220	143.20	-.0110	-55.40
S1	******	******	0.0040	122.80	******	*******
M(1)	0.0060	216.40	0.0070	214.40	-.0010	2.00
J(1)	0.0070	216.50	0.0100	213.50	-.0030	3.00
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	0.0030	216.40	0.0030	152.80	0.0000	63.60
Q(1)	0.0180	216.40	0.0210	171.10	-.0030	45.30
T2	0.0280	107.70	0.0190	123.90	0.0090	-16.20
R2	0.0040	110.90	0.0050	8.20	-.0010	102.70
2Q(1)	0.0020	216.40	0.0030	168.30	-.0010	48.10
P(1)	0.0360	216.40	0.0470	202.10	-.0110	14.30
2SM(2	******	******	0.0000	0.00	******	*******
M(3)	******	******	0.0000	0.00	******	*******
L(2)	0.0470	52.80	0.0550	156.20	-.0080	-103.40
2MK(3	******	******	0.0070	207.90	******	*******
K(2)	0.1290	112.60	0.0590	144.50	0.0700	-31.90
M(8)	0.0020	272.30	0.0060	237.10	-.0040	35.20
MS(4)	******	******	0.0090	68.70	******	*******

GAIN (-): 1.14
PHASE (HR): -0.92
EST. RMS (M): 0.77

Table 3.3. RTOFS vs. NOS Harmonic Analysis Results at Sandy Hook, NJ for January 2006

	RTOFS		NOS ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.8570	294.10	0.6880	6.00	0.1690	-71.90
S(2)	0.3800	329.20	0.1340	32.60	0.2460	-63.40
N(2)	0.1420	284.80	0.1580	348.60	-.0160	-63.80
K(1)	0.0930	167.40	0.1030	175.70	-.0100	-8.30
M(4)	0.0340	111.20	0.0160	269.70	0.0180	-158.50
O(1)	0.0680	160.00	0.0540	172.50	0.0140	-12.50
M(6)	0.0530	46.00	0.0170	83.80	0.0360	-37.80
MK(3)	******	******	0.0050	52.40	******	*******
S(4)	0.0040	44.80	0.0100	11.40	-.0060	33.40
MN(4)	******	******	0.0080	275.80	******	*******
NU(2)	0.0280	286.10	0.0290	345.70	-.0010	-59.60
S(6)	0.0040	194.40	0.0000	0.00	0.0040	-165.60
MU(2)	******	******	0.0240	14.50	******	*******
2N(2)	0.0190	275.50	0.0210	336.80	-.0020	-61.30
OO(1)	0.0030	174.80	0.0050	218.70	-.0020	-43.90
LAMBD	0.0060	310.40	0.0080	359.70	-.0020	-49.30
S1	******	******	0.0100	124.90	******	*******
M(1)	0.0050	163.70	0.0040	220.80	0.0010	-57.10
J(1)	0.0050	171.10	0.0050	209.20	0.0000	-38.10
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	0.0030	156.80	0.0020	171.10	0.0010	-14.30
Q(1)	0.0130	156.30	0.0110	183.10	0.0020	-26.80
T2	0.0220	327.80	0.0100	17.40	0.0120	-49.60
R2	0.0030	330.60	0.0010	33.80	0.0020	-63.20
2Q(1)	0.0020	152.70	0.0020	169.20	0.0000	-16.50
P(1)	0.0310	166.80	0.0310	180.20	0.0000	-13.40
2SM(2	******	******	0.0000	0.00	******	*******
M(3)	******	******	0.0110	56.40	******	*******
L(2)	0.0200	284.80	0.0270	359.80	-.0070	-75.00
2MK(3	******	******	0.0080	33.80	******	*******
K(2)	0.1030	332.10	0.0380	31.50	0.0650	-59.40
M(8)	0.0020	355.90	0.0000	0.00	0.0020	-4.10
MS(4)	******	******	0.0120	224.30	******	*******

GAIN (-): 1.38
PHASE (HR): -2.09
EST. RMS (M): 0.71

Table 3.4. RTOFS vs. NOS Harmonic Analysis Results at Cape May, NJ for January 2006

	RTOFS		NOS ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.9470	335.00	0.7140	28.60	0.2330	-53.60
S(2)	0.3480	17.00	0.1250	55.30	0.2230	-38.30
N(2)	0.1590	324.30	0.1590	9.70	0.0000	-45.40
K(1)	0.0880	191.60	0.1050	200.40	-.0170	-8.80
M(4)	0.0520	357.40	0.0100	101.00	0.0420	-103.60
O(1)	0.0950	217.80	0.0840	185.60	0.0110	32.20
M(6)	0.0040	299.10	0.0080	20.80	-.0040	-81.70
MK(3)	******	******	0.0000	0.00	******	*******
S(4)	0.0010	345.20	0.0000	0.00	0.0010	-14.80
MN(4)	******	******	0.0030	115.30	******	*******
NU(2)	0.0310	325.70	0.0320	7.40	-.0010	-41.70
S(6)	0.0010	227.60	0.0000	0.00	0.0010	-132.40
MU(2)	******	******	0.0120	40.50	******	*******
2N(2)	0.0210	313.50	0.0210	352.30	0.0000	-38.80
OO(1)	0.0040	165.30	0.0040	215.00	0.0000	-49.70
LAMBD	0.0070	354.50	0.0100	41.60	-.0030	-47.10
S1	******	******	0.0090	134.70	******	*******
M(1)	0.0070	204.70	0.0040	243.40	0.0030	-38.70
J(1)	0.0080	178.50	0.0060	197.10	0.0020	-18.60
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	0.0040	229.10	0.0030	179.30	0.0010	49.80
Q(1)	0.0180	230.90	0.0130	184.10	0.0050	46.80
T2	0.0210	15.30	0.0120	33.70	0.0090	-18.40
R2	0.0030	18.60	0.0010	56.50	0.0020	-37.90
2Q(1)	0.0020	243.90	0.0020	171.00	0.0000	72.90
P(1)	0.0290	193.50	0.0360	199.20	-.0070	-5.70
2SM(2	******	******	0.0000	0.00	******	*******
M(3)	******	******	0.0050	94.10	******	*******
L(2)	0.0230	324.30	0.0370	43.90	-.0140	-79.60
2MK(3	******	******	0.0040	110.50	******	*******
K(2)	0.0950	20.40	0.0330	54.50	0.0620	-34.10
M(8)	0.0050	339.10	0.0000	0.00	0.0050	-20.90
MS(4)	******	******	0.0050	128.10	******	*******

GAIN (-): 1.38
PHASE (HR): -1.30
EST. RMS (M): 0.59

Table 3.5. RTOFS vs. NOS Harmonic Analysis Results at Charleston, SC for January 2006

	RTOFS		NOS ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	1.1250	295.20	0.7830	10.40	0.3420	-75.20
S(2)	0.5000	334.50	0.1190	36.10	0.3810	-61.60
N(2)	0.1870	284.80	0.1720	354.90	0.0150	-70.10
K(1)	0.0800	186.30	0.1050	199.70	-.0250	-13.40
M(4)	0.0250	316.90	0.0330	209.60	-.0080	107.30
O(1)	0.0740	204.00	0.0790	203.40	-.0050	0.60
M(6)	0.0080	233.70	0.0060	135.30	0.0020	98.40
MK(3)	******	******	0.0080	4.40	******	*******
S(4)	0.0010	73.90	0.0000	0.00	0.0010	73.90
MN(4)	******	******	0.0140	201.40	******	*******
NU(2)	0.0360	286.20	0.0350	351.40	0.0010	-65.20
S(6)	0.0010	354.50	0.0000	0.00	0.0010	-5.50
MU(2)	******	******	0.0250	40.00	******	*******
2N(2)	0.0250	274.40	0.0220	343.30	0.0030	-68.90
OO(1)	0.0030	168.60	0.0050	217.30	-.0020	-48.70
LAMBD	0.0080	313.40	0.0130	356.10	-.0050	-42.70
S1	******	******	0.0180	173.90	******	*******
M(1)	0.0050	195.20	0.0050	243.30	0.0000	-48.10
J(1)	0.0060	177.50	0.0050	213.50	0.0010	-36.00
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	211.60	0.0040	198.00	-.0010	13.60
Q(1)	0.0140	212.80	0.0170	198.90	-.0030	13.90
T2	0.0290	332.90	0.0150	19.90	0.0140	-47.00
R2	0.0040	336.00	0.0050	263.80	-.0010	72.20
2Q(1)	0.0020	221.60	0.0020	207.10	0.0000	14.50
P(1)	0.0260	187.60	0.0360	198.30	-.0100	-10.70
2SM(2	******	******	0.0000	0.00	******	*******
M(3)	******	******	0.0170	114.80	******	*******
L(2)	0.0270	284.80	0.0340	5.00	-.0070	-80.20
2MK(3	******	******	0.0050	30.60	******	*******
K(2)	0.1360	337.60	0.0300	37.10	0.1060	-59.50
M(8)	0.0010	333.70	0.0000	0.00	0.0010	-26.30
MS(4)	******	******	0.0100	237.70	******	*******

GAIN (-): 1.53
PHASE (HR): -2.04
EST. RMS (M): 0.92

Table 3.6. RTOFS vs. NOS Harmonic Analysis Results at Mayport, FL for January 2006

	RTOFS		NOS ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	1.4490	328.30	0.6760	25.30	0.7730	-57.00
S(2)	0.6350	13.20	0.1050	48.30	0.5300	-35.10
N(2)	0.2360	317.30	0.1570	7.30	0.0790	-50.00
K(1)	0.0900	202.90	0.0840	202.50	0.0060	0.40
M(4)	0.0140	54.20	0.0330	159.40	-.0190	-105.20
O(1)	0.0780	213.50	0.0580	210.90	0.0200	2.60
M(6)	0.0090	204.50	0.0090	196.00	0.0000	8.50
MK(3)	******	******	0.0080	20.40	******	*******
S(4)	0.0060	198.50	0.0050	290.70	0.0010	-92.20
MN(4)	******	******	0.0130	156.00	******	*******
NU(2)	0.0460	318.80	0.0320	2.70	0.0140	-43.90
S(6)	0.0010	283.70	0.0000	0.00	0.0010	-76.30
MU(2)	******	******	0.0120	31.20	******	*******
2N(2)	0.0310	306.30	0.0190	354.60	0.0120	-48.30
OO(1)	0.0030	192.40	0.0040	212.60	-.0010	-20.20
LAMBD	0.0100	349.10	0.0090	47.80	0.0010	-58.70
S1	******	******	0.0110	158.30	******	*******
M(1)	0.0060	208.20	0.0030	221.20	0.0030	-13.00
J(1)	0.0060	197.70	0.0050	210.20	0.0010	-12.50
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	218.00	0.0020	214.50	0.0010	3.50
Q(1)	0.0150	218.70	0.0110	209.50	0.0040	9.20
T2	0.0370	11.40	0.0100	22.10	0.0270	-10.70
R2	0.0050	15.00	0.0050	291.80	0.0000	83.20
2Q(1)	0.0020	223.90	0.0020	219.20	0.0000	4.70
P(1)	0.0300	203.70	0.0290	202.20	0.0010	1.50
2SM(2	******	******	0.0030	60.10	******	*******
M(3)	******	******	0.0060	186.40	******	*******
L(2)	0.0340	317.30	0.0410	31.40	-.0070	-74.10
2MK(3	******	******	0.0080	44.00	******	*******
K(2)	0.1730	16.80	0.0280	48.20	0.1450	-31.40
M(8)	0.0060	338.00	0.0030	4.20	0.0030	-26.20
MS(4)	******	******	0.0130	175.80	******	*******

GAIN (-): 2.20
PHASE (HR): -1.52
EST. RMS (M): 0.96

Table 3.7. RTOFS vs. NOS Harmonic Analysis Results at St Petersburg, FL for January 2006

	RTOFS		NOS ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.8740	179.90	0.1750	197.00	0.6990	-17.10
S(2)	0.2320	217.10	0.0570	211.70	0.1750	5.40
N(2)	0.1450	161.40	0.0300	191.30	0.1150	-29.90
K(1)	0.1530	24.40	0.1670	49.90	-.0140	-25.50
M(4)	0.0130	332.90	0.0030	230.80	0.0100	102.10
O(1)	0.1450	19.50	0.1550	37.70	-.0100	-18.20
M(6)	0.0050	233.10	0.0000	0.00	0.0050	-126.90
MK(3)	******	******	0.0040	129.00	******	*******
S(4)	0.0010	245.60	0.0000	0.00	0.0010	-114.40
MN(4)	******	******	0.0000	0.00	******	*******
NU(2)	0.0280	163.90	0.0090	198.70	0.0190	-34.80
S(6)	0.0000	174.00	0.0000	0.00	0.0000	174.00
MU(2)	******	******	0.0090	20.70	******	*******
2N(2)	0.0190	142.90	0.0040	193.50	0.0150	-50.60
OO(1)	0.0060	29.30	0.0060	62.00	0.0000	-32.70
LAMBD	0.0060	197.10	0.0040	226.20	0.0020	-29.10
S1	******	******	0.0170	138.50	******	*******
M(1)	0.0100	22.00	0.0050	79.30	0.0050	-57.30
J(1)	0.0110	26.90	0.0080	91.10	0.0030	-64.20
MM	******	******	0.0000	0.00	******	*******
SSA	******	******	0.0330	41.00	******	*******
SA	******	******	0.0920	150.80	******	*******
MSF	******	******	0.0000	0.00	******	*******
MF	******	******	0.0000	0.00	******	*******
RHO(1	0.0050	17.40	0.0050	4.20	0.0000	13.20
Q(1)	0.0280	17.10	0.0290	26.20	-.0010	-9.10
T2	0.0140	215.60	0.0040	187.10	0.0100	28.50
R2	0.0020	218.60	0.0000	212.40	0.0020	6.20
2Q(1)	0.0040	14.60	0.0050	9.50	-.0010	5.10
P(1)	0.0510	24.00	0.0490	57.60	0.0020	-33.60
2SM(2	******	******	0.0000	0.00	******	*******
M(3)	******	******	0.0000	0.00	******	*******
L(2)	0.0210	161.40	0.0110	219.80	0.0100	-58.40
2MK(3	******	******	0.0000	0.00	******	*******
K(2)	0.0630	220.10	0.0250	215.00	0.0380	5.10
M(8)	0.0020	113.60	0.0000	0.00	0.0020	113.60
MS(4)	******	******	0.0000	0.00	******	*******

GAIN (-): 2.43
PHASE (HR): -1.10
EST. RMS (M): 0.53

Table 3.8. RTOFS vs. NOS Harmonic Analysis Results at Panama City, FL for January 2006

	RTOFS		NOS ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.0970	72.00	0.0340	91.10	0.0630	-19.10
S(2)	0.0370	105.40	0.0200	94.50	0.0170	10.90
N(2)	0.0170	58.80	0.0070	102.00	0.0100	-43.20
K(1)	0.1260	13.30	0.1450	17.00	-.0190	-3.70
M(4)	0.0070	299.40	0.0110	315.10	-.0040	-15.70
O(1)	0.1160	12.20	0.1410	8.50	-.0250	3.70
M(6)	0.0110	338.50	0.0030	77.00	0.0080	-98.50
MK(3)	******	******	0.0000	0.00	******	*******
S(4)	0.0020	225.40	0.0030	77.50	-.0010	147.90
MN(4)	******	******	0.0050	281.20	******	*******
NU(2)	0.0030	60.60	0.0010	100.50	0.0020	-39.90
S(6)	0.0010	309.70	0.0000	0.00	0.0010	-50.30
MU(2)	******	******	0.0000	0.00	******	*******
2N(2)	0.0020	45.70	0.0010	113.00	0.0010	-67.30
OO(1)	0.0050	14.50	0.0040	24.60	0.0010	-10.10
LAMBD	0.0010	87.50	0.0000	0.00	0.0010	87.50
S1	******	******	0.0050	46.30	******	*******
M(1)	0.0080	12.80	0.0060	62.90	0.0020	-50.10
J(1)	0.0090	13.90	0.0080	20.30	0.0010	-6.40
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	0.0040	11.70	0.0050	353.40	-.0010	18.30
Q(1)	0.0220	11.60	0.0310	353.80	-.0090	17.80
T2	0.0020	104.00	0.0010	94.30	0.0010	9.70
R2	0.0000	106.70	0.0000	0.00	0.0000	106.70
2Q(1)	0.0030	11.10	0.0040	327.40	-.0010	43.70
P(1)	0.0420	13.20	0.0490	17.60	-.0070	-4.40
2SM(2	******	******	0.0000	0.00	******	*******
M(3)	******	******	0.0000	0.00	******	*******
L(2)	0.0020	58.80	0.0010	80.00	0.0010	-21.20
2MK(3	******	******	0.0000	0.00	******	*******
K(2)	0.0100	108.10	0.0050	75.10	0.0050	33.00
M(8)	0.0000	71.70	0.0000	0.00	0.0000	71.70
MS(4)	******	******	0.0050	325.50	******	*******

GAIN (-): 1.09
PHASE (HR): 0.00
EST. RMS (M): 0.06

Table 3.9. RTOFS vs. NOS Harmonic Analysis Results at Sabine Pass, TX for January 2006

	RTOFS		NOS ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.6710	248.30	0.1230	275.50	0.5480	-27.20
S(2)	0.2310	315.30	0.0390	271.50	0.1920	43.80
N(2)	0.1320	227.50	0.0330	254.40	0.0990	-26.90
K(1)	0.1700	35.90	0.1320	40.70	0.0380	-4.80
M(4)	0.0100	316.70	0.0050	318.90	0.0050	-2.20
O(1)	0.1480	27.40	0.1230	34.60	0.0250	-7.20
M(6)	0.0120	103.70	0.0000	0.00	0.0120	103.70
MK(3)	******	******	0.0070	141.20	******	*******
S(4)	0.0030	108.20	0.0000	0.00	0.0030	108.20
MN(4)	******	******	0.0000	0.00	******	*******
NU(2)	0.0260	230.30	0.0070	269.50	0.0190	-39.20
S(6)	0.0000	304.40	0.0000	0.00	0.0000	-55.60
MU(2)	******	******	0.0050	210.30	******	*******
2N(2)	0.0180	206.80	0.0050	220.40	0.0130	-13.60
OO(1)	0.0060	44.40	0.0060	61.40	0.0000	-17.00
LAMBD	0.0050	279.40	0.0010	273.60	0.0040	5.80
S1	******	******	0.0120	306.30	******	*******
M(1)	0.0100	31.60	0.0060	36.90	0.0040	-5.30
J(1)	0.0120	40.10	0.0070	47.10	0.0050	-7.00
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	0.0060	23.70	0.0060	23.80	0.0000	-0.10
Q(1)	0.0290	23.10	0.0260	21.80	0.0030	1.30
T2	0.0140	312.70	0.0020	271.70	0.0120	41.00
R2	0.0020	318.00	0.0000	271.30	0.0020	46.70
2Q(1)	0.0040	18.90	0.0030	28.50	0.0010	-9.60
P(1)	0.0560	35.30	0.0400	33.10	0.0160	2.20
2SM(2	******	******	0.0000	0.00	******	*******
M(3)	******	******	0.0000	0.00	******	*******
L(2)	0.0190	227.50	0.0040	5.10	0.0150	-137.60
2MK(3	******	******	0.0060	132.80	******	*******
K(2)	0.0630	320.80	0.0080	338.50	0.0550	-17.70
M(8)	0.0000	288.90	0.0000	0.00	0.0000	-71.10
MS(4)	******	******	0.0000	0.00	******	*******

GAIN (-): 2.83
PHASE (HR): -0.41
EST. RMS (M): 0.43

Table 3.10. RTOFS vs. NOS Harmonic Analysis Results at Galveston, TX for January 2006

	RTOFS		NOS ACCEPTED VALUES		DIFFERENCE	
	AMPL(m)	KPRIME	AMPL(m)	KPRIME	AMPL(m)	KPRIME
M(2)	0.5310	276.70	0.1390	276.10	0.3920	0.60
S(2)	0.1670	346.20	0.0340	267.90	0.1330	78.30
N(2)	0.1010	252.90	0.0360	254.60	0.0650	-1.70
K(1)	0.1600	41.10	0.1710	28.00	-.0110	13.10
M(4)	0.0010	263.30	0.0060	203.30	-.0050	60.00
O(1)	0.1470	32.20	0.1610	20.30	-.0140	11.90
M(6)	0.0050	29.50	0.0000	0.00	0.0050	29.50
MK(3)	******	******	0.0000	0.00	******	*******
S(4)	0.0000	358.70	0.0000	0.00	0.0000	-1.30
MN(4)	******	******	0.0000	0.00	******	*******
NU(2)	0.0200	256.10	0.0080	270.90	0.0120	-14.80
S(6)	0.0000	158.00	0.0000	0.00	0.0000	158.00
MU(2)	******	******	0.0050	197.10	******	*******
2N(2)	0.0130	229.10	0.0060	228.80	0.0070	0.30
OO(1)	0.0060	49.90	0.0060	46.20	0.0000	3.70
LAMBD	0.0040	309.00	0.0010	272.20	0.0030	36.80
S1	******	******	0.0140	327.00	******	*******
M(1)	0.0100	36.60	0.0080	24.20	0.0020	12.40
J(1)	0.0120	45.50	0.0100	34.50	0.0020	11.00
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	0.0060	28.40	0.0070	4.00	-.0010	24.40
Q(1)	0.0290	27.80	0.0360	7.00	-.0070	20.80
T2	0.0100	343.50	0.0020	268.10	0.0080	75.40
R2	0.0010	349.00	0.0000	267.50	0.0010	81.50
2Q(1)	0.0040	23.40	0.0040	349.50	0.0000	33.90
P(1)	0.0530	40.40	0.0510	24.30	0.0020	16.10
2SM(2	******	******	0.0000	0.00	******	*******
M(3)	******	******	0.0000	0.00	******	*******
L(2)	0.0140	252.90	0.0040	352.10	0.0100	-99.20
2MK(3	******	******	0.0000	0.00	******	*******
K(2)	0.0450	351.90	0.0060	275.60	0.0390	76.30
M(8)	0.0010	347.50	0.0000	0.00	0.0010	-12.50
MS(4)	******	******	0.0040	224.70	******	*******

GAIN (-): 1.92
PHASE (HR): 0.77
EST. RMS (M): 0.31

Table 3.11. RTOFS vs. NOS Harmonic Constituent Weighted Gain and Phase Results For January-April 2006.

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

Station	Gain (-)				Phase Difference (Hrs)			
	Jan	Feb	Mar	Apr	Jan	Feb	Mar	Apr
Eastport	1.09	0.99	1.02	1.08	-1.10	-1.02	-0.89	-0.85
Portland	1.16	1.07	1.08	1.13	-0.97	-0.92	-0.78	-0.76
Boston	1.14	1.05	1.07	1.11	-0.92	-0.88	-0.73	-0.67
Woods Hole	1.16	1.13	1.12	1.16	-1.86	-1.73	-2.13	-2.25
Sandy Hook	1.38	1.27	1.30	1.36	-2.09	-1.92	-1.88	-2.00
Atlantic City	1.30	1.20	1.22	1.27	-1.39	-1.29	-1.14	-1.32
Cape May	1.38	1.27	1.26	1.32	-1.30	-1.26	-1.09	-1.29
Lewes	1.32	1.22	1.21	1.26	-1.33	-1.30	-1.15	-1.36
Duck	0.31	0.29	0.29	0.31	3.03	3.33	2.82	3.00
Wilmington	1.36	1.27	1.27	1.32	-3.81	-3.70	-3.69	-3.80
Springmaid	1.53	1.41	1.43	1.47	-1.48	-1.35	-1.38	-1.43
Charleston	1.53	1.41	1.42	1.48	-2.04	-1.94	-1.90	-1.98
Fort Pulaski	1.75	1.61	1.61	1.69	-1.86	-1.86	-1.69	-1.87
Fernadina	1.90	1.73	1.74	1.82	-1.85	-1.75	-1.65	-1.77
Mayport	2.20	2.00	2.02	2.11	-1.52	-1.42	-1.30	-1.45
Naples	2.06	1.95	1.96	2.01	-1.03	-1.06	-1.03	-0.94
St Petersburg	2.43	2.28	2.30		-1.10	-1.13	-1.06	
Clearwater	1.63	1.53	1.57	1.59	1.01	1.05	1.15	1.09
Apalachicola	1.32	1.28	1.31	1.33	-0.55	-0.33	-0.43	-0.47
Panama City	1.09	1.05	1.08	1.10	0.00	0.24	0.10	0.05
Pensacola	1.10	1.10	1.10	1.13	-2.04	-1.94	-2.20	-2.11
Sabine Pass	2.83	2.60	2.55	2.64	-0.41	-0.69	-0.50	-0.50
Pleasure Pier	1.92	1.76	1.71	1.78	0.77	0.51	0.67	0.56
Freeport	1.27	1.19	1.15	1.21	0.56	0.41	0.47	0.27

Table 3.12. RTOFS vs. NOS Harmonic Constituent Estimated RMS Error for January-April 2006.

Station	Estimated RMS Error (m)			
	Jan	Feb	Mar	Apr
Eastport	1.43	1.39	1.36	1.29
Portland	0.76	0.74	0.73	0.69
Boston	0.77	0.75	0.74	0.69
Woods Hole	0.37	0.35	0.37	0.37
Sandy Hook	0.31	0.68	0.69	0.68
Atlantic City	0.49	0.47	0.48	0.48
Cape May	0.59	0.57	0.57	0.57
Lewes	0.51	0.50	0.50	0.50
Duck	0.47	0.47	0.47	0.47
Wilmington	0.99	0.97	0.98	0.97
Springmaid	0.73	0.71	0.71	0.70
Charleston	0.92	0.89	0.89	0.88
Fort Pulaski	1.25	1.20	1.20	1.19
Fernadina	1.16	1.11	1.11	1.10
Mayport	0.96	0.91	0.91	0.91
Naples	0.57	0.55	0.54	0.53
St Petersburg	0.39	0.51	0.51	
Clearwater	0.53	0.39	0.39	0.39
Apalachicola	0.16	0.15	0.16	0.16
Panama City	0.06	0.06	0.05	0.05
Pensacola	0.12	0.11	0.12	0.12
Sabine Pass	0.43	0.43	0.44	0.44
Pleasure Pier	0.31	0.30	0.31	0.31
Freeport	0.10	0.10	0.10	0.10

4. RTOFS VS. ETSS: WATER LEVEL ANALYSIS RESULTS

To assess the RTOFS water level forecasts and to compare them with the ETSS water level forecasts, several different cases were considered as given in Table 2.1 and evaluated for each of the months January-April 2006. Since RTOFS produces total water level forecasts and ETSS produces only nontidal water level forecasts, direct comparisons in general cannot be made. Only if the tidal error in the RTOFS water level forecast approaches zero, would the error in the total water level forecast represent the nontidal error allowing for a direct comparison. As we have seen in Chapter 3, significant tidal errors are present in RTOFS.

Initially, we present results for January 2006 as shown in Table 4.1. We first considered Case 1 for the ETSS nontidal water level forecast evaluation and Case 2 for the RTOFS total water level forecast evaluation. One notes the significantly larger errors in Case 2 compared to Case1 confirming the significant tidal errors in RTOFS found in Chapter 3. In Case 3, the RTOFS nowcast results were concatenated and then hours 6-36 of each forecast horizon were compared versus NOS total water level observations. Note NOS water level observations were with respect to MLLW, while RTOFS nowcast results were with respect to hydrodynamic model datum, which represents a near geopotential surface, not necessarily equal to mean sea level. In retrospect, a modified Case 3 in which both series were demeaned would have allowed a more realistic comparison, since a large portion of the noted errors may be due to the difference in datums. In Cases 4 and 5 RTOFS total water level nowcasts and forecasts were directly compared to NOS observations over hours 6-36 of each forecast horizon. While no correction to the difference in datums was made in each case, the results for nowcast and forecast are nearly identical, indicating that nowcast and forecast results over the first 36 hours are very similar. In Case 6, we attempted to determine the RTOFS nontidal forecast water level by working with the concatenated nowcasts. We first 30hr low pass filtered both the RTOFS nowcast data and the NOS water level observations. Next for each daily 6-36 hour forecast horizon, an offset was applied based on the difference between the low pass filtered RTOFS nowcast value and the NOS low pass filtered observation at hour 6. The application of this offset effectively removes the difference in datums. One notes now that the RTOFS nontidal nowcast results in Case 6 are now comparable to Case 1 or perhaps are nearer to NOS low pass filtered observations at most stations with the exception of Duck and Wilmington, NC near Gulf Stream separation. In Case 7, we detided the RTOFS total water level forecasts, by subtracting the tidal signal reconstructed from the RTOFS derived harmonic constituents for January 2006. The detided water levels for each daily 6-36 hour forecast horizon were adjusted using the same procedure for Case 6 and then compared with the NOS low pass observations. One notes in general, that the results for Case 7 are degraded with respect to Case 6 indicating that with the removal of only 24 harmonic constituents, some tidal energy remains at frequencies removed by the 30 hr low pass filter.

The January 2006 results for ETSS in Case 1 and RTOFS in Case 6 are further compared in Figures 4.1-4.6 at Sandy Hook, NJ, Cape May, NJ, Charleston, SC, Mayport, FL, St. Petersburg, FL, and Galveston Pleasure Pier, respectively. For each daily forecast horizon hour 6-36, four points are plotted using the plus, triangle, square, and asterisk symbols for the start time, the end time, and the maximum and minimum water level times, respectively. In general both predicted nontidal water levels are in good agreement with the observed 30hr low pass filtered NOS observations.

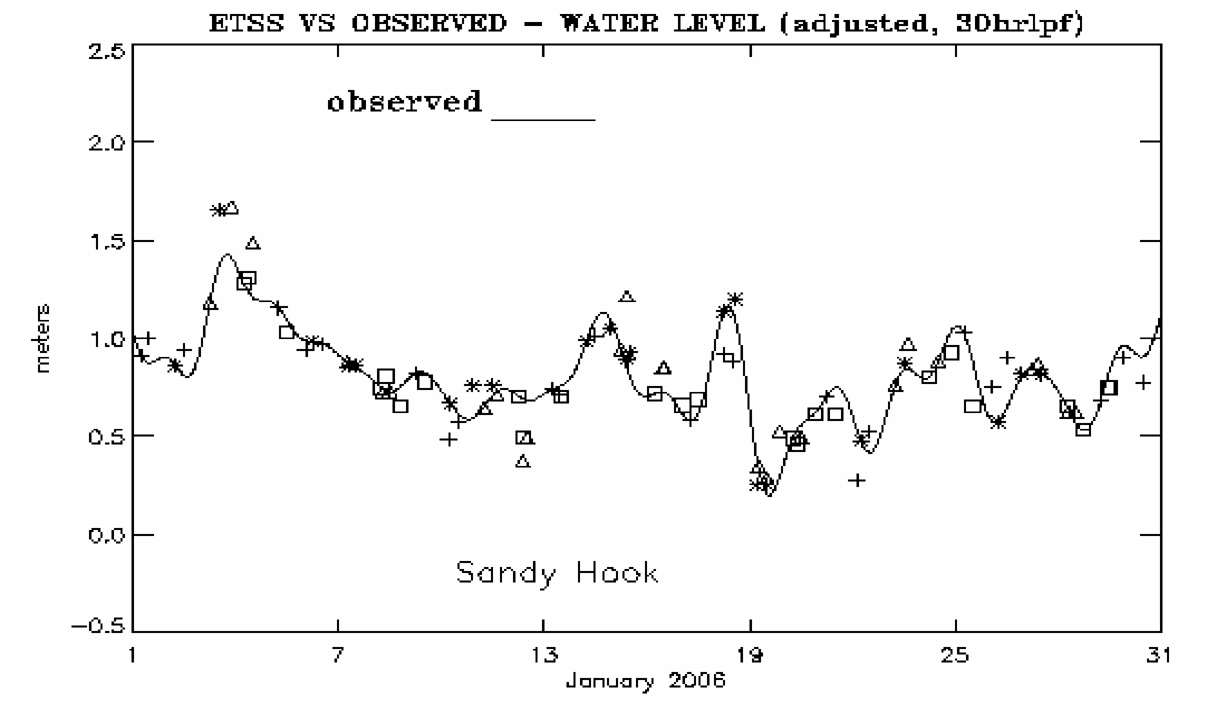
We also examined the spatial variation of RMS error for the months of January through April, 2006. Figure 4.7 (a) shows RMS error, by station, for both ETSS and RTOFS for the month of January 2006 for all east coast stations. The ETSS and RTOFS RMS errors are pretty close, except for the mid Atlantic bight region, where RTOFS has much more difficulty. Specifically, at the stations of Duck and Wilmington, the RTOFS RMS errors are about 0.2m and 0.15m, respectively. This spike in RMS error for RTOFS is very consistent through all four months, as Figures 4.7 through 4.10 indicate.

Figure 4.7 (b) depicts rms error for January 2006, by station, for both forecasts for all Gulf of Mexico stations. In terms of RMS error, the performance of the two systems is similar, except at Apalachicola and St Petersburg, where the ETSS RMS error spikes. This behavior is consistent for the months of January through March 2006, as Figures 4.7 through 4.9 indicate. This behavior diminishes by April 2006, as Figure 4.10 indicates.

Table 4.1 Case 1-7 RMS Errors for RTOFS and ETSS Water Level Comparisons, January 2006

Case 1=ETSS Nontidal Comparison: Adjusted Forecast vs. Filtered Observations
Case 2=RTOFS Total Water Level Comparison: Adjusted Forecast vs. Observations
Case 3=RTOFS Nontidal Comparison: Filtered Nowcast vs. Filtered Observations
Case 4=RTOFS Total Water Level Comparison: Nowcast vs. Observations
Case 5=RTOFS Total Water Level Comparison: Forecast vs. Observations
Case 6=RTOFS Nontidal Comparison: Nowcast vs. Filtered Observations
Case 7=RTOFS Nontidal Comparison: Detided and Adjusted Forecast vs. Filtered Observations

Stations	Case 1	Case2	Case 3	Case 4	Case 5	Case 6	Case 7
Eastport	0.137	1.840	3.544	3.857	3.863	0.116	0.218
Portland	0.109	1.013	2.050	2.216	2.224	0.102	0.160
Boston	0.109	1.007	2.115	2.275	2.290	0.107	0.162
Woods Hole	0.114	0.470	0.845	0.899	0.904	0.098	0.136
Sandy Hook	0.112	0.989	1.353	1.494	1.507	0.096	0.135
Atlantic City	0.107	0.673	1.228	1.305	1.314	0.098	0.125
Cape May	0.107	0.805	1.429	1.544	1.551	0.102	0.150
Lewes	0.110	0.704	1.277	1.372	1.381	0.104	0.135
Duck	0.059	0.687	1.104	1.211	1.211	0.212	0.220
Wilmington	0.069	1.382	1.293	1.601	1.618	0.144	0.177
Springmaid	0.078	0.997	1.303	1.464	1.478	0.096	0.155
Charleston	0.069	1.200	1.395	1.616	1.629	0.087	0.147
Fort Pulaski	0.084	1.656	1.645	2.008	2.016	0.088	0.181
Fernadina	0.071	1.512	1.472	1.834	1.843	0.079	0.163
Mayport	0.056	1.251	1.225	1.530	1.541	0.075	0.145
Naples	0.063	0.769	0.724	0.919	0.929	0.067	0.108
St Petersburg	0.131	0.727	0.601	0.800	0.806	0.069	0.287
Clearwater	0.077	0.537	0.669	0.752	0.753	0.066	0.268
Apalachicola	0.127	0.237	0.497	0.540	0.550	0.078	0.093
Panama City	0.067	0.146	0.383	0.410	0.418	0.058	0.074
Pensacola	0.073	0.192	0.357	0.405	0.414	0.069	0.078
Sabine Pass	0.094	0.609	0.322	0.538	0.551	0.090	0.142
Pleasure Pier	0.076	0.444	0.385	0.487	0.499	0.068	0.103
Freeport	0.064	0.186	0.343	0.359	0.367	0.061	0.088



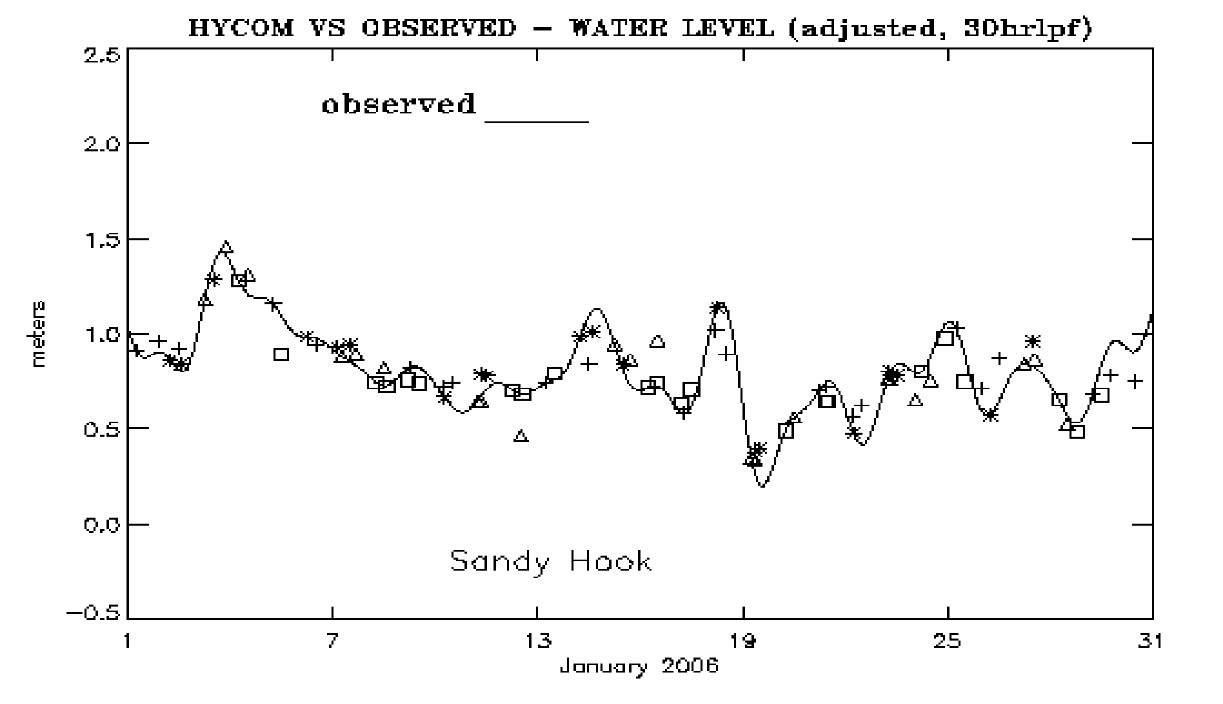
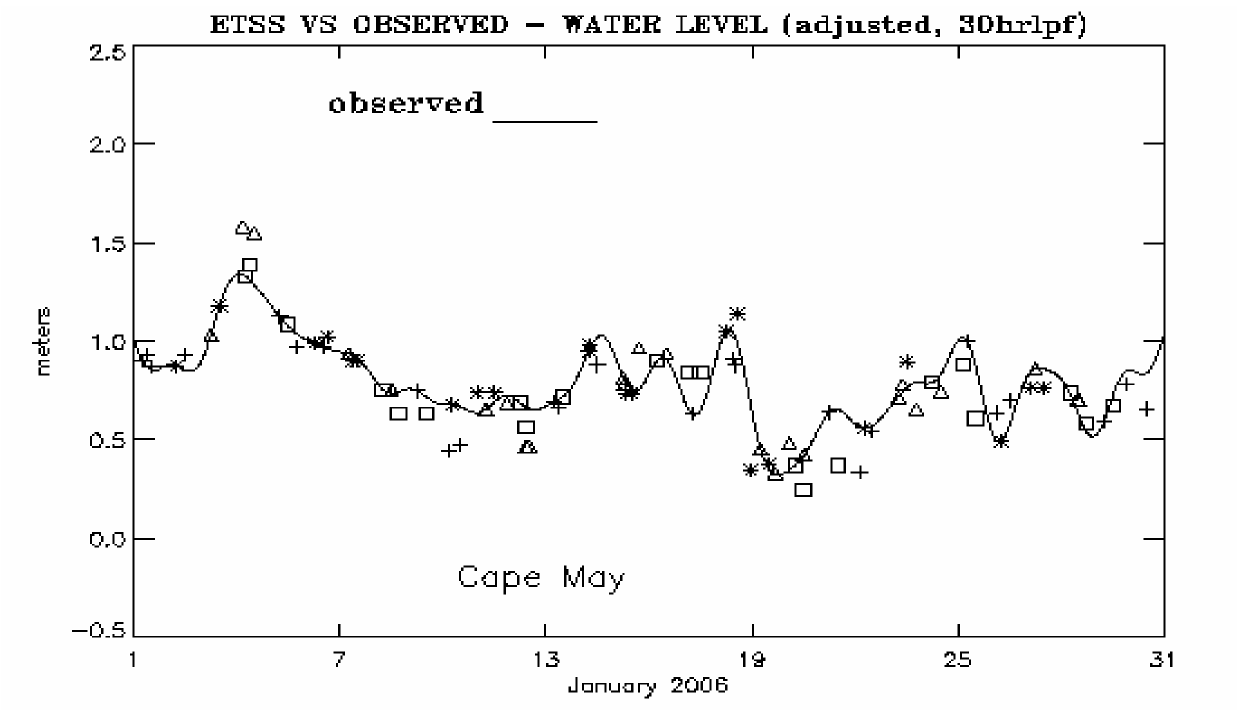


Figure 4.1. ETSS Case 1 vs. RTOFS Case 6 Nontidal Water Level vs. NOS Nontidal Observations at Sandy Hook, NJ for January 2006



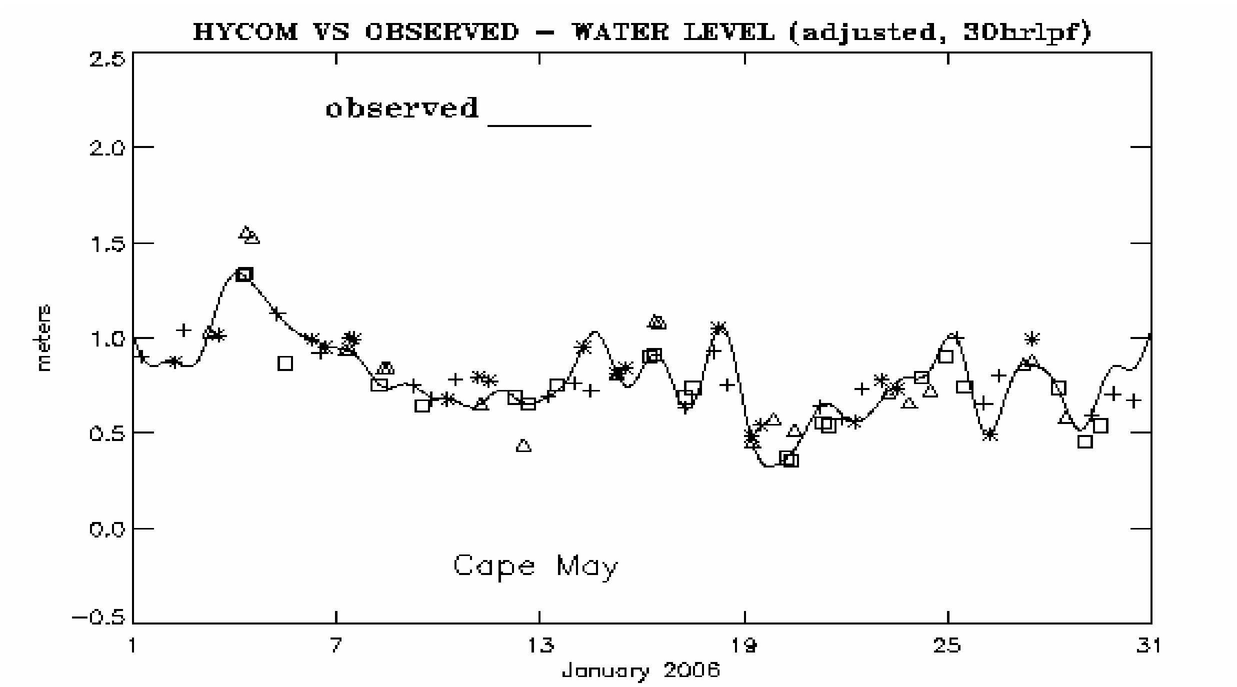
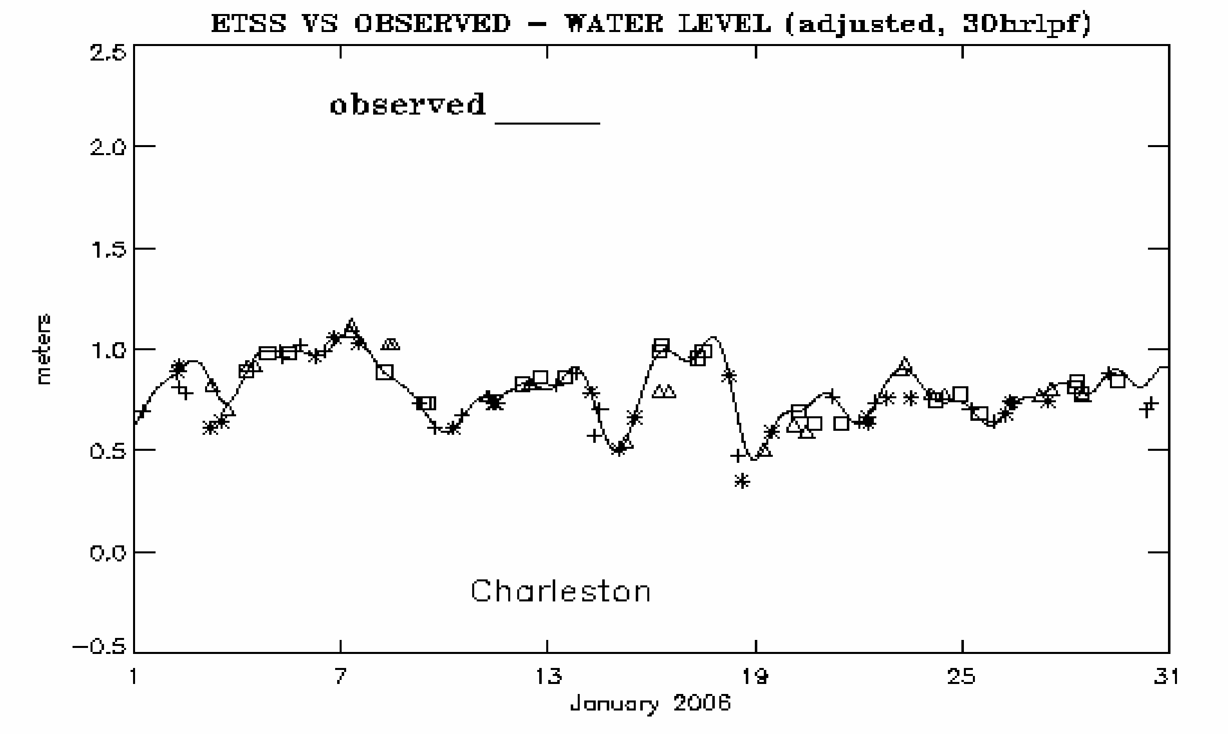


Figure 4.2. ETSS Case 1 vs. RTOFS Case 6 Nontidal Water Level vs. NOS Nontidal Observations at Cape May, NJ for January 2006



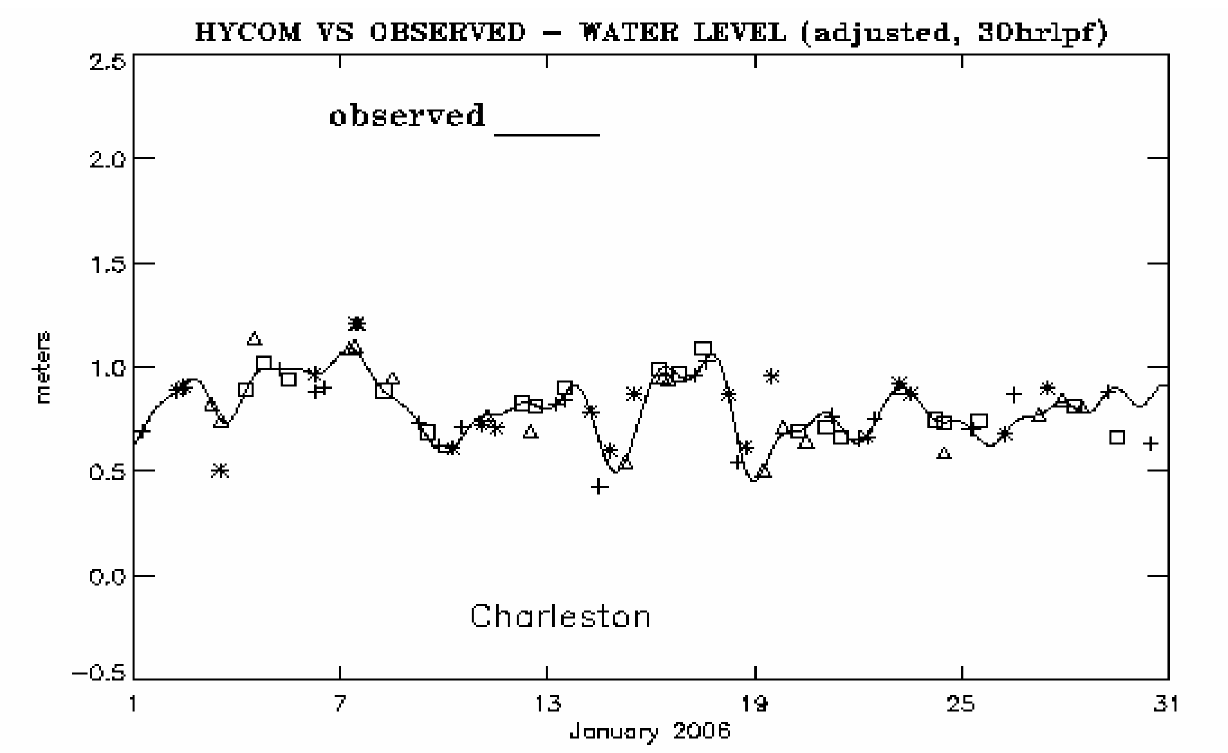


Figure 4.3. ETSS Case 1 vs. RTOFS Case 6 Nontidal Water Level vs. NOS Nontidal Observations at Charleston, SC for January 2006

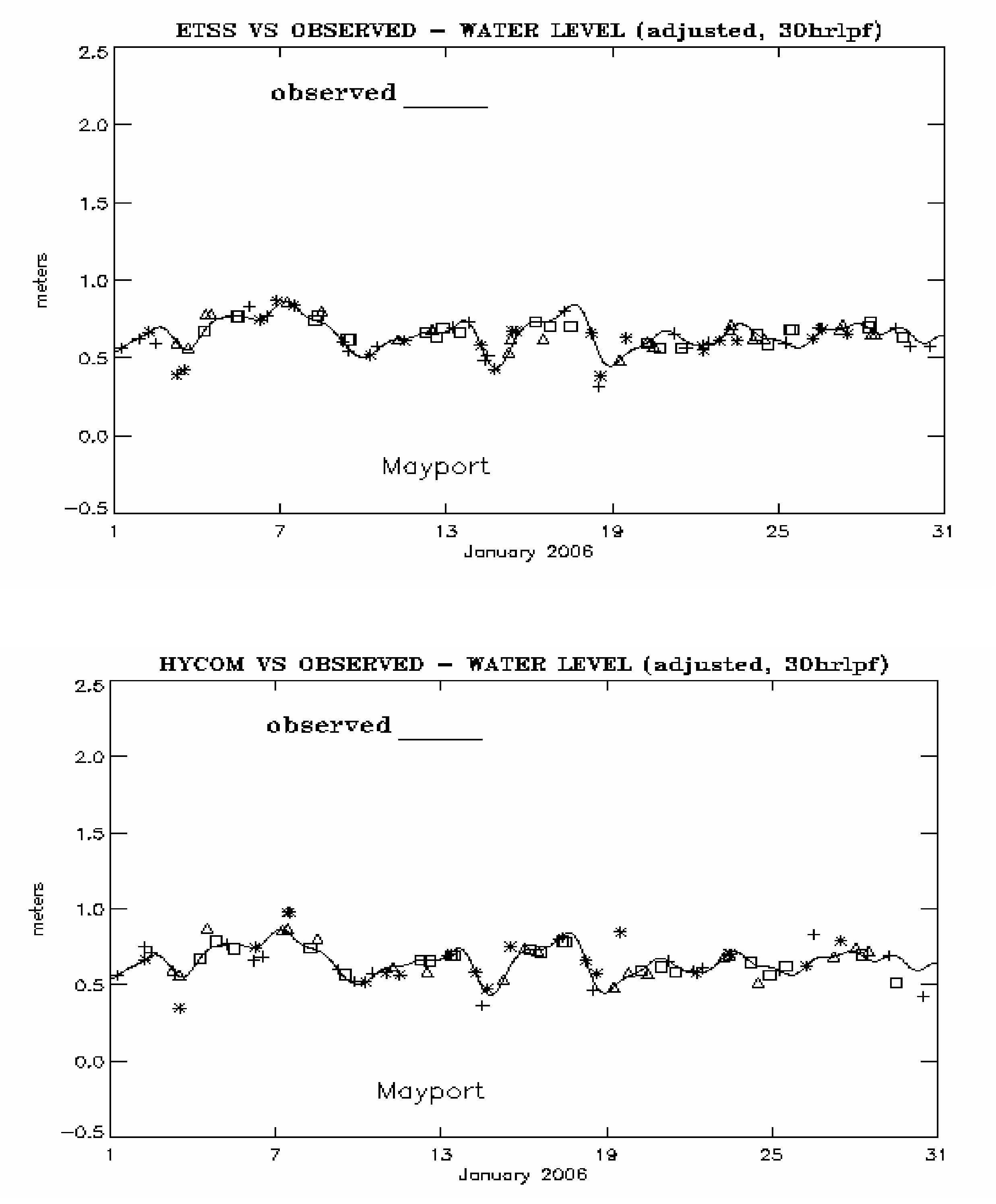
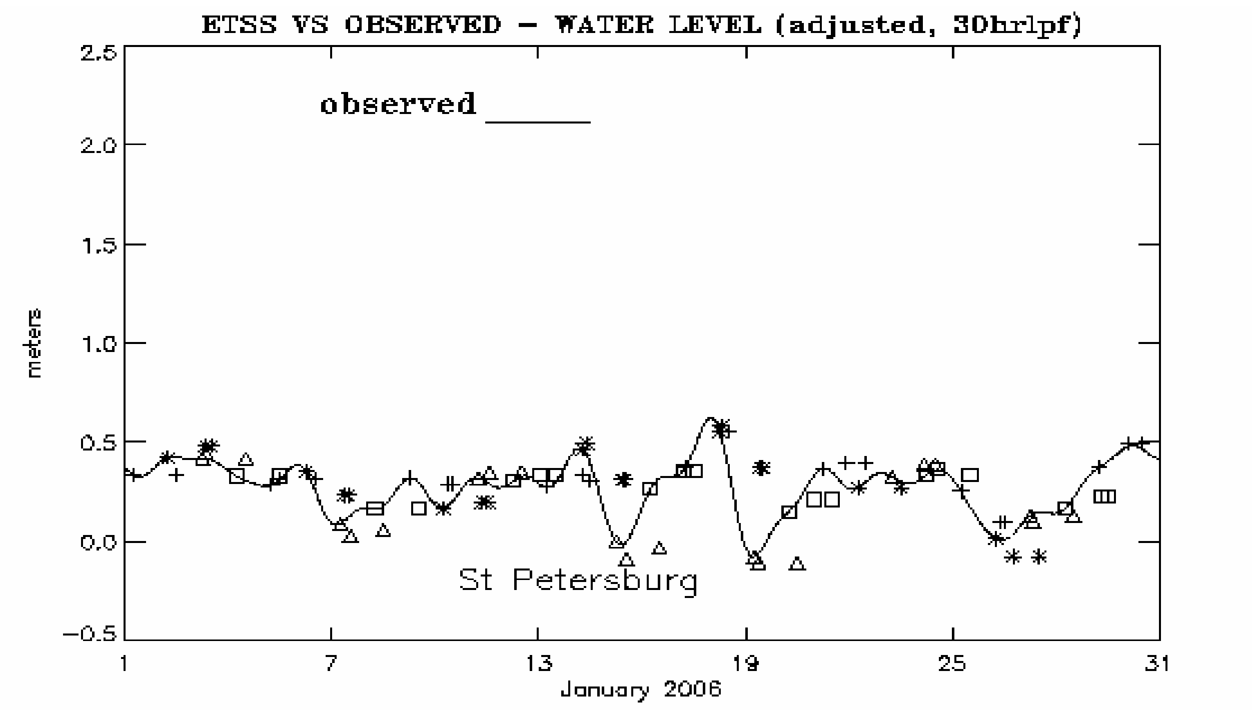


Figure 4.4. ETSS Case 1 vs. RTOFS Case 6 Nontidal Water Level vs. NOS Nontidal Observations at Mayport, FL for January 2006



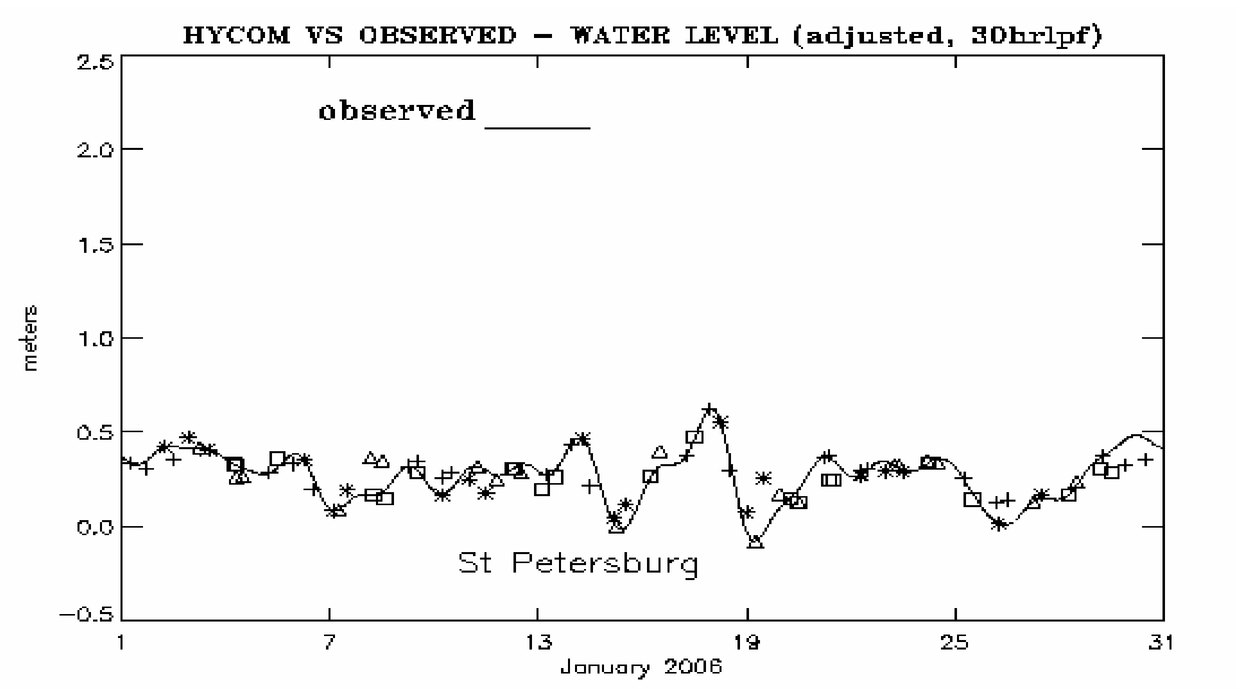
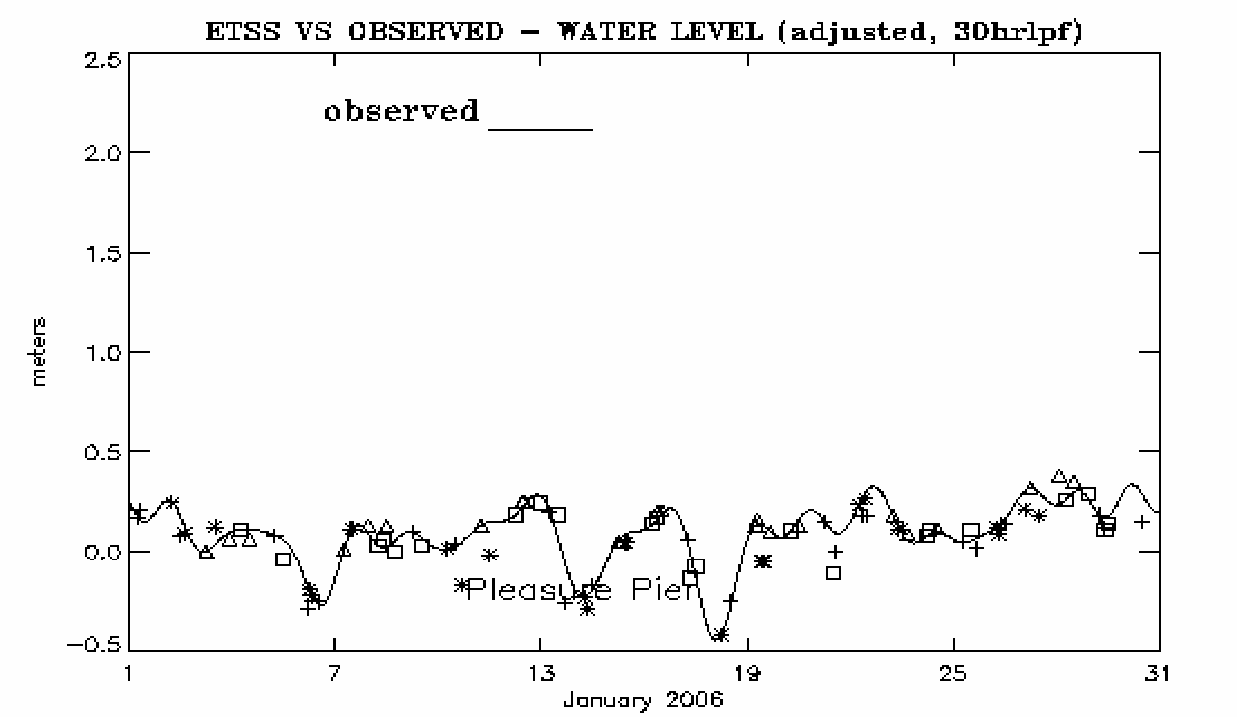


Figure 4.5. ETSS Case 1 vs. RTOFS Case 6 Nontidal Water Level vs. NOS Nontidal Observations at St. Petersburg, FL for January 2006



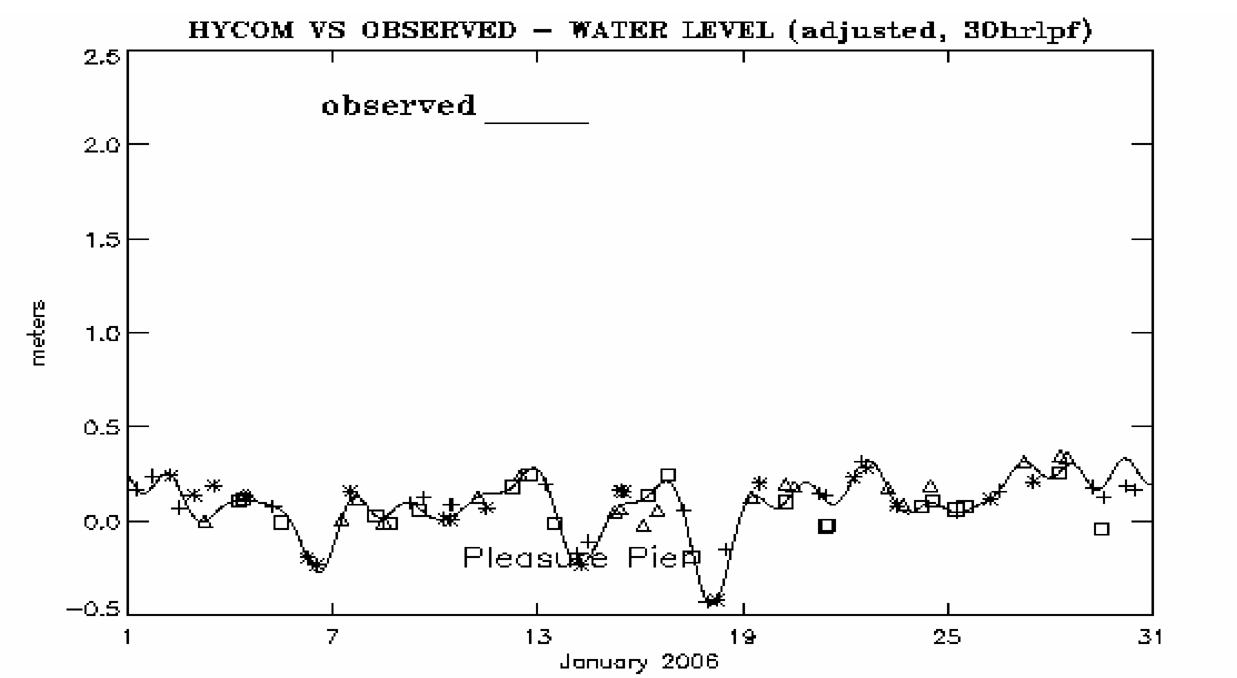
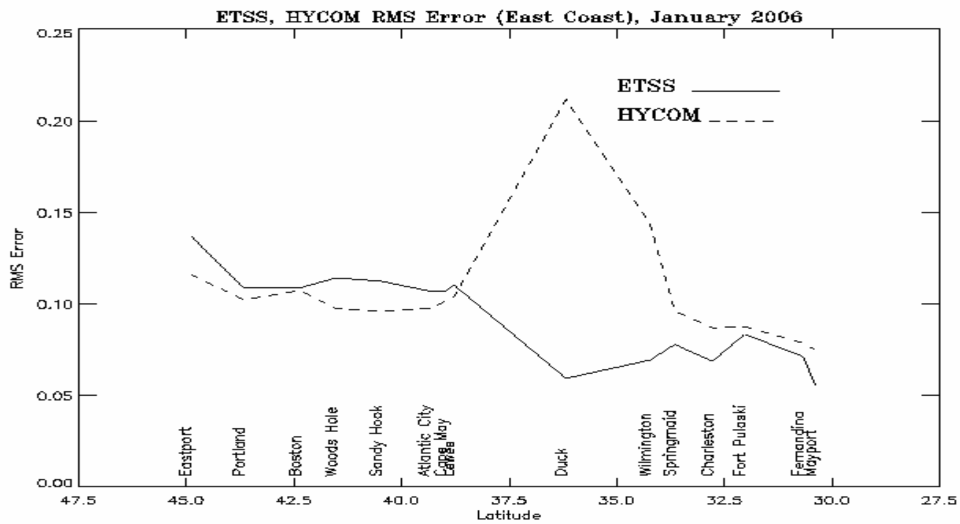
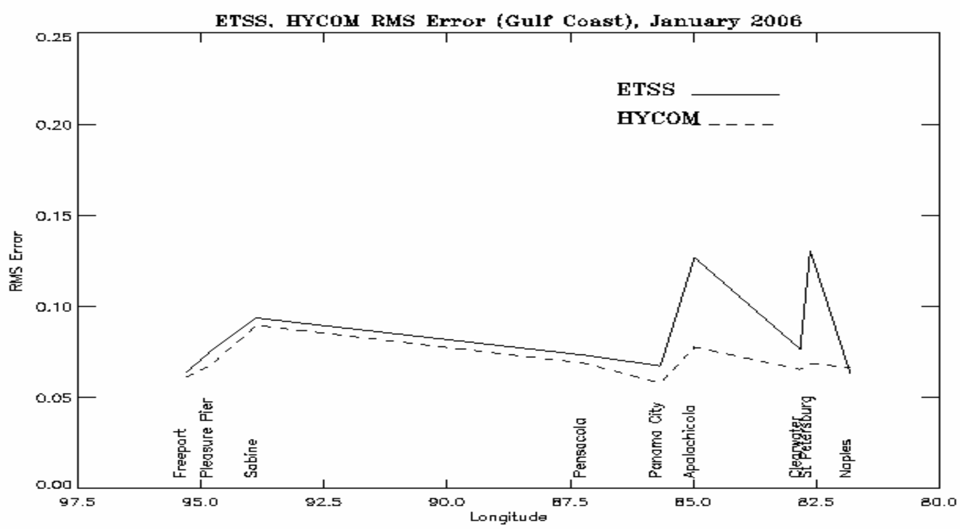


Figure 4.6. ETSS Case 1 vs. RTOFS Case 6 Nontidal Water Level vs. NOS Nontidal Observations at Galveston Pleasure Pier, TX for January 2006

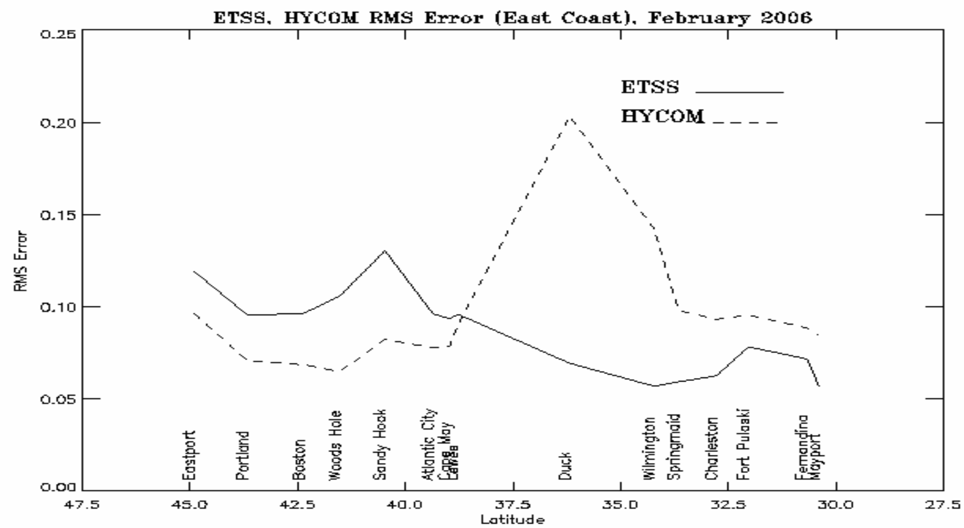


(a)

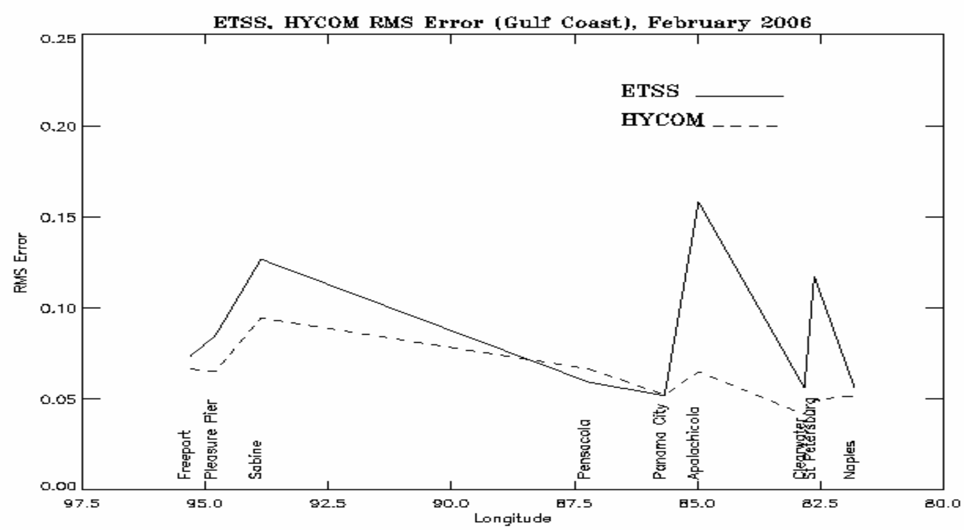


(b)

Figure 4.7. ETSS Case 1 and RTOFS Case 6 RMS Errors for East Coast Stations (Part a) and Gulf Coast Stations (Part b) for January 2006

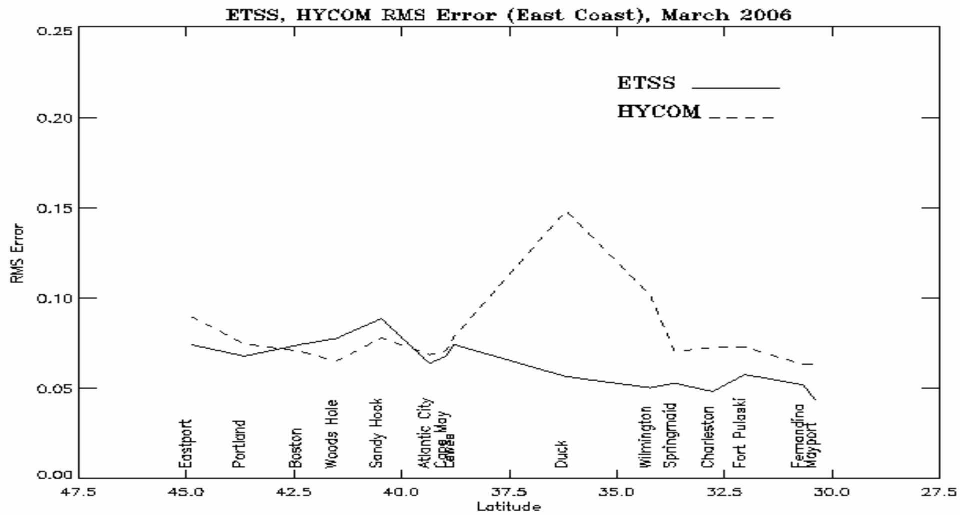


(a)

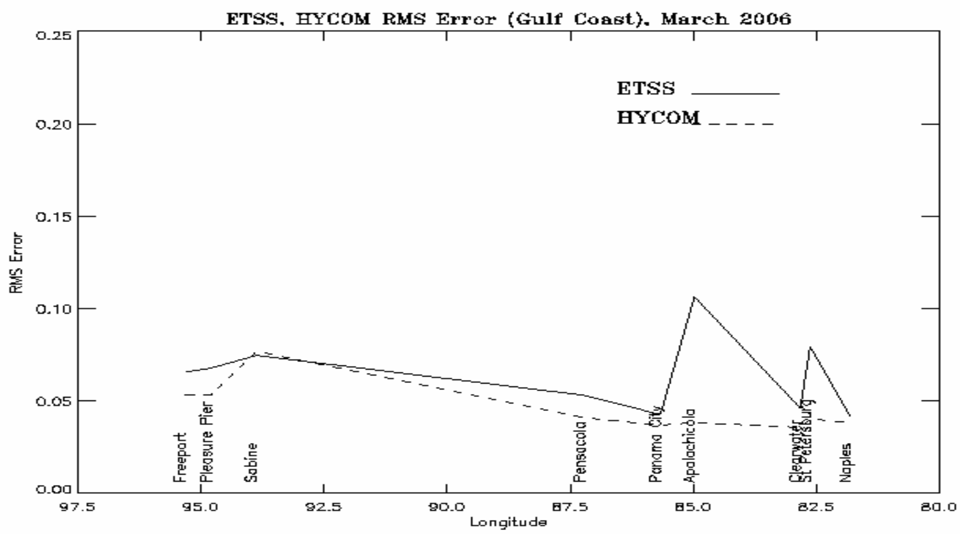


(b)

Figure 4.8. ETSS Case 1 and RTOFS Case 6 RMS Errors for East Coast Stations (Part a) and Gulf Coast Stations (Part b) for February 2006

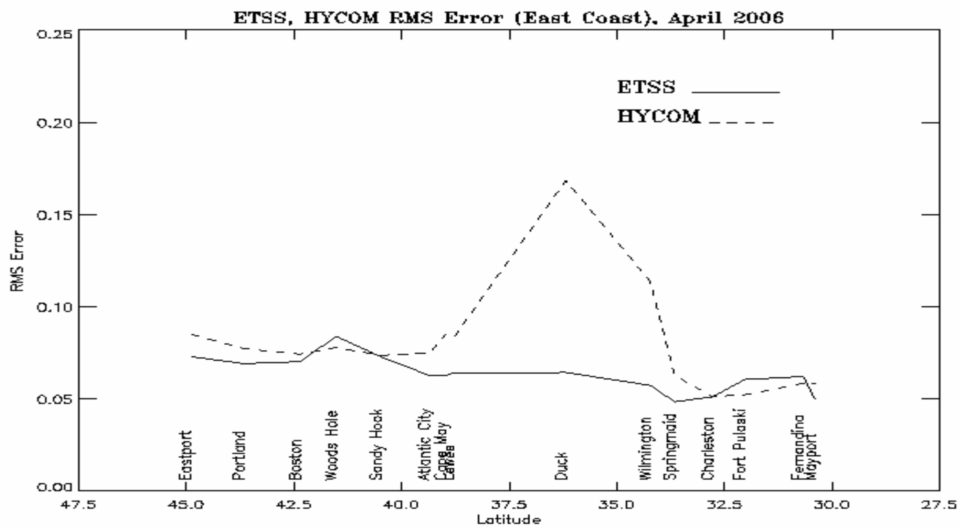


(a)

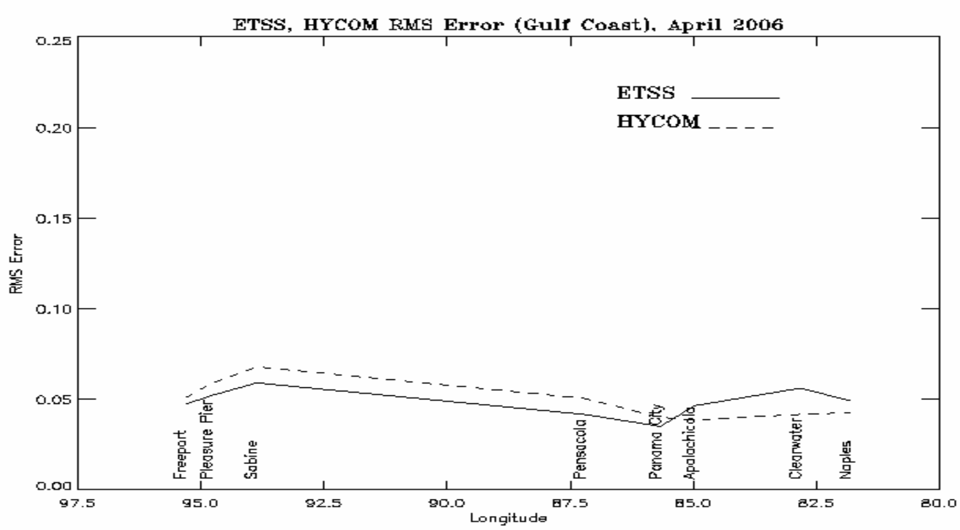


(b)

Figure 4.9. ETSS Case 1 and RTOFS Case 6 RMS Errors for East Coast Stations (Part a) and Gulf Coast Stations (Part b) for March 2006



(a)



(b)

Figure 4.10. ETSS Case 1 and RTOFS Case 6 RMS Errors for East Coast Stations (Part a) and Gulf Coast Stations (Part b) for April 2006

5. NGOM vs. ETSS NONTIDAL WATER LEVEL RESULTS, JANUARY 2006

It should be noted that NGOM was formerly know as DGOM the Dynalysis Gulf of Mexico forecast system, which was transferred to NOS in 2005. Richardson and Schmalz (2004) compared ETSS and DGOM on a monthly basis for November 2002, January 2003, May 2003, and July 2003 to represent the four seasons. Here we repeated these analysis procedures to consider the performance of the NGOM vs ETSS for January 2006 with the results shown in Table 5.1. These results for January 2006 are comparable to the January 2003 results in terms of quality of performance. However during January 2003, the RMS errors were substantially larger than during January 2006. In Table 5.1, the forecast with the lowest RMS error is the preferred forecast for that day. Note that only 15 NGOM forecasts were available for comparison due to computer system problems at CSDL. The forecast comparisons were made for the hours 6-36 of the daily12z forecasts. The RMS errors given in Table 5.1 are plotted in Figure 5.1 and indicate a large error in the ETSS forecast at Appalachicola Bay not seen in the NGOM forecast.

Table 5.1. ETSS vs. NGOM NontidalWater Level RMS Errors for January 2006

NOS Station	State	ETSS RMSE(m)	npf (-)	NGOM RMSE(m)	npf(-)
Naples	FL	0.0589	12	0.0985	3
Clearwater	FL	0.0566	13	0.0897	2
Apalachicola	FL	0.1454	4	0.0673	11
Panama City	FL	0.0603	4	0.0465	11
Pensacola	FL	0.0531	9	0.0568	6
Sabine	TX	0.0738	11	0.0969	4
Pleasure Pier	TX	0.0644	12	0.0786	3
Freeport	TX	0.0575	9	0.0682	6

Note : rmse is root mean square error and npf is defined to be the number of preferred forecasts.

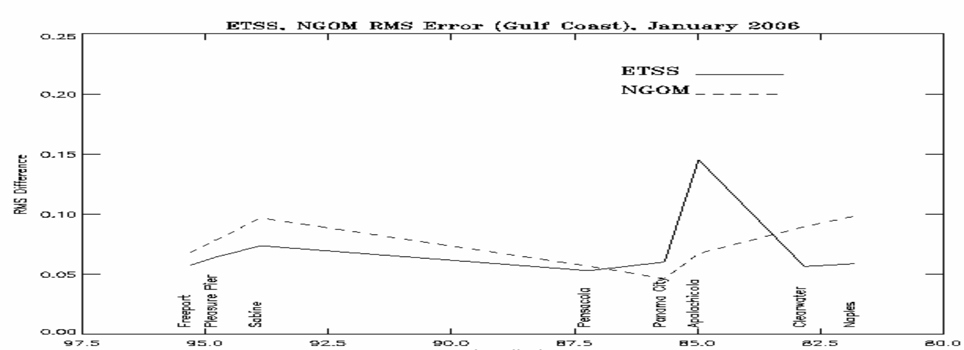


Figure 5.1. ETSS Case 1 and NGOM Case 1 RMS Errors Gulf Coast for January 2006

6. CONCLUSIONS

Nontidal and total water level comparisons with observations for ETSS (Case 1) and RTOFS (Case 2) forecasts were performed for the months of January through April 2006. Case 2 RTOFS total water level RMS errors were much larger than the Case 1 ETSS nontidal water level RMS errors, indicating a large tidal error in the RTOFS water levels. 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.

In addition, five additional evaluations, Cases 3 through 7, were performed for RTOFS with the results compared on a monthly basis. These evaluations served as a consistency check. It is recommended that Case 3 be modified to include demeaning of both signals to remove the effect of datum differences. Case 4 and 5 comparisons demonstrated that RTOFS nowcast and forecast water levels were nearly the same. Case 6 RTOFS nontidal water levels were of equal if not slightly higher quality than those of the Case 1 ETSS nontidal water levels except at Duck, NC and Wilmington, NC in the vicinity of Gulf Stream separation. Note Case 7 was only performed for January 2006. For Case 7 water levels reconstructed from RTOFS tidal constituents were subtracted from the RTOFS total water level signals to obtain the nontidal signal. Case 7 results were degraded with respect to Case 6 indicating that based on the 29 day 24 constituent analysis, some tidal energy could not be removed. A secondary objective in performing Case 7 was to enable the use of a RTOFS nontidal forecast water level and density predictions to provide the offshore boundary conditions for three-dimensional baroclinic NOS nowcast/forecast systems. It is recommended that to further this objective that a Case 8 be performed in which the preceeding 30 day nowcasts and the latest forecast are concatenated and then 30 hr low pass filtered to obtain the nontidal signal. The forecast would then be adjusted over the 6-36 hour forecast horizon and used as the nontidal forecast.

Fifteen NGOM nontidal water level forecasts were directly compared with the corresponding fifteen ETSS forecasts using Case 1 procedures and were similar to results obtained by Richardson and Schmalz (2004). The cause of the differences in forecast nontidal water levels is in part due to the use of different wind and sea level atmospheric forcings. NGOM uses the U.S. Navy COAMPS, while RTOFS and ETSS use the NWS GFS forcings. Since only NGOM is run at CSDL, it would be useful to run the NGOM system with COAMPS and GFS forcings for a common time period and use the analysis procedures developed here to compare the water level responses. Note prior to the water level comparisons, surface wind forecasts can be compared using the methods in Richardson and Schmalz (2005).

The analysis procedures developed here are sufficiently general to evaluate both nontidal water level and total water level forecasts. Total water level evaluation for the January through April 2006 period of the Advanced Circulation Model (ADCIRC) East Coast Nowcast/Forecast System is presently under consideration.

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APPENDIX A : PROGRAM DESCRIPTIONS

A.1. Program Read_tdlblk.f

Program read_tdlblk.f first reads *nstn_r*, the number of stations to read. There are forecast data for 61 stations in an east coast MDL (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 data 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 TDL forecast 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 output filename.

Read_tdlblk.f is a very straight forward program. The MDL forecast data file (00z or 12z) is opened, and the output files are opened for stations 1 through *nstn_wr*. Read_tdlblk 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 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 file (either 00z or 12z) and uses the next 30 hours. This condition simulates the use of the forecast within a nowcast/forecast system mode; e.g., there is a 6 hour meteorological forecast processing time. The output is written in the format 8f7.4.

A.2. 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 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 is read. The program skips over 24 hours of nowcast data, then skips over the first five hours of forecast data. Starting with hour six, the next 31 values are stored in array *wl_hyc*(). The forecast water level values are then written to output in standard “block” format (8f7.4).

A.3. Program Readhyc_nowc.f

Readhyc_nowc.f is very similar to the previously described Readhycom.f. Readhyc_nowc.f reads from the same RTOFS nowcast/forecast files as Readhycom.f. The program reads the 24 nowcast values beginning at hour -23, and ending at hour 0.

A.4. Program Adjust_blk.f

The purpose for Adjust_blk.f is to adjust each data point of the daily forecast 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 files are used for all analysis work. Adjust_blk.f reads the forecast or nowcast data in "block" format, and writes the output in the same "block" format.

A.5. Program Hycom_nowcha.f

Hycom_nowcha.f was created to perform two steps necessary to run harm29, the harmonic analysis program. The nowcast data is read from the daily nowcast files created from Readhyc_nowc.f. Hycom_nowcha.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 is 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 is read in the station loop (150). For each station, the water level values are read from block format (8f7.4) for hours 1 through 24. The concatenated nowcast vlues, by station, are written to output in the 200 loop.

A.6. 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 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 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 values are 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 "block" format for hours 6 through 36 of each forecast cycle.

A.7. Program Hyc_reform.f

Hyc_reform was created to read nowcast water level data, either filtered or non-filtered, from the concatonated, station data files. From this, the program will create the daily nowcast water level data file in block format (8f7.4) for hours 6 through 36.

The nowcast data is 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 block format (8f7.4) for *idat* = 1 through 31. *Idat* = 1 through 31 corresponds to hours 6 through 36 of that day's nowcast.

A.8. 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.

A.9. Program Wl_sa.phblk.f

Following the parameter and dimension statements, and after the character variables are declared, wl_sa.phblk.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 model file, from either ETSS or RTOFS, is opened, along with the observed data file. Wl_sa.phblk.f calculates the variance and mean for the forecast system water level values, and for the observed data. Subroutine compare is called to calculate the rms difference between the forecast system values and the observations.

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.10. 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 forecasts. From each daily forecast, four points are plotted : the start, the end, the max, and the min. The symbols used to represent forecast 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 points. The plots are annotated with a title, station name, and a legend.

APPENDIX B. SCRIPT AND CONTROL FILES

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

~/3mod_com/observed/reform_coops.f
~/3mod_com/dynal/NGOM/read_dyn.f
~/3mod_com/hyc/nowcast/readhyc_nowc.f
~/3mod_com/hyc/nc_ha/hycom_nowcha.f
~/3mod_com/hyc/nc_ha/h29/nc/hyc_reform.f
~/3mod_com/comp/wl_sa.phblk.f
~/3mod_com/etss/read_tdlblk.f
~/3mod_com/hyc/readhycom.f
~/3mod_com/comp/adjust/block/adjust_blk.f
~/3mod_com/astro/readpred.f
~/3mod_com/hyc/nc_ha/const_ha/const2.f
~3mod_com/plot/plot_wlanblk.pro

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

Script	**Source File**	**Example Control File**
read_tdl.sh	read_tdlblk.f	read_jan06.n
readdyn.sh	read_dyn.f	readdyn.n
readhy.jcl	readhycom.f	readhy.jan06.n
readhy.jcl	readhyc_nowc.f	readhy_jan06.n
adjust.jcl	adjust_blk.f	adj_etss.jan06.n
hycomha.jcl	hycom_nowcha.f	hycomha_jan06.n
read_pred.jcl	readpred.f	read.n
hycref.jcl	hyc_reform.f	hycref.jan06.n
const.jcl	const2.f	constt.jan06.n
wl_sa.jcl	wl_sa.phblk.f	wl_tdl.jan06.n
	plot_wlanblk.pro	cnt.tdl_adj.jan06.n

Listings for script and control files are provided in turn below. The IDL plot program does not have a script file. To run the IDL program, type idl <return>, then type .r plot_wlanblk.pro <return>.

read_tdl.sh

```
# lf95 read_tdl.f calcjd.f -o readtdl
# lf95 read_tdlstn.f calcjd.f -o readtdl

# rm *.o


# ./readtdl < read_jan06.n > out
  ./readtdl < rstn_jan06.n > out
# ./readtdl < read_feb06.n > out
# ./readtdl < read_mar06.n > out
# ./readtdl < read_apr06.n > out
```

read_jan06.n

```
 0     idebug
61     number of stations to read
15     number of station to write output
/disks/NASUSER/philr/3model_comp/etss/200601/ec/2006010112.ec
 1     station number
 3     station number
 5
 9
23
24
25
28
46
51
54
56
59
60
61
 22    number of stations to read
 9     number of station output files
/disks/NASUSER/philr/3model_comp/etss/200601/gm/2006010112.gm
 1     station number
 4     station number
 5
 8
 9
10
18
19
20
 1  2006     month, year
 9     lunout
etss.01012006
```

readdyn.sh

```
# lf95 read_dyn.f -o read_dyn


  read_dyn < readdyn.n > out

  rm out
```

readdyn.n

```
 1     idebug
metr   unit designation
/disks/NASUSER/philr/3mod_com/dynal/NGOM/2D/jan06/GOM_2D.2006.030.1300.NOS
 8      number of Dynalysis stations to read
  1NAPLES
 dyn.01naple.030
 10CLWATR
 dyn.10clear.030
 22APALAC
 dyn.22apala.030
 25PANAMA
 dyn.25panam.030
 27PENSAC
 dyn.27pensa.030
 20SABINE
 dyn.20sabin.030
 36GALVEP
 dyn.36pleas.030
 50FREEPT
 dyn.50freep.030
```

readhy.jcl

```
# lf95 readhycom.f -o readhyc

# ./readhyc < readhy.feb06.n > out
# ./readhyc < readhy.mar06.n > out
  ./readhyc < readhy.apr06.n > out
```

readhy.jan06.n

```
 0   idebug
/disks/NASUSER/philr/3model_comp/hycom/2006/200601/20060130.hyc.00z
24   nsta
Eastport
Portland
Boston
Woods Hole
Sandy Hook
Atlantic City
Cape May
Lewes
Duck
Wilmington
Springmaid
Charleston
Fort Pulaski
Fernandina
Mayport
Naples
St Petersburg
Clearwater
Apalachicola
Panama City
Pensacola
Sabine Pass
Pleasure Pier
Freeport
 1    4     nst1, nstend1
 5    9     nst2, nstend2
hycom.01302006
```

readhyn.jcl

```
# lf95 readhyc_nowc.f -o readhynow

  ./readhynow < readhy_jan06.n > out
# ./readhynow < readhy_feb06.n > out
# ./readhynow < readhy_mar06.n > out
# ./readhynow < readhy_apr06.n > out
```

readhy_jan06.n

```
 0   idebug
/disks/NASUSER/philr/3mod_com/hyc/2006/nowcforc/feb06/hyc_nowc.02012006
24   nsta
Eastport
Portland
Boston
Woods Hole
Sandy Hook
Atlantic City
Cape May
Lewes
Duck
Wilmington
Springmaid
Charleston
Fort Pulaski
Fernandina
Mayport
Naples
St Petersburg
Clearwater
Apalachicola
Panama City
Pensacola
Sabine Pass
Pleasure Pier
Freeport
 1    4     nst1, nstend1
 5    9     nst2, nstend2
hycom.01312006
```

adjust.jcl

```
  f77 adjust_blk.f -o adjust


# ./adjust < adj_etss.jan06.n > out
# ./adjust < adj_etss.feb06.n > out
# ls -ll *.tdl.*

# ./adjust < adj_hyc.n30.jan06.n
  ./adjust < adj_hyc.fdet.jan06.n
# ./adjust < adj_hyc.n30.feb06.n
# ./adjust < adj_hyc.jan06.n
# ./adjust < adj_hyc.feb06.n

# ./adjust < adj_hyc.n30.mar06.n
# ./adjust < adj_hyc.mar06.n
# ./adjust < adj_etss.mar06.n

# ./adjust < adj_etss.apr06.n
# ./adjust < adj_hyc.apr06.n
# ./adjust < adj_hyc.n30.apr06.n
```

adj_etss.jan06.n

```
 0          idebug
24          number of stations
 31.249     start time (daily)
 9          logical unit number
/disks/NASUSER/philr/3model_comp/etss/00z/jan06/etss.01312006
20
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/east.jan06.wl.30
Eastport
36
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/port.jan06.wl.30
Portland
40
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/bost.jan06.wl.30
Boston
43
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/wood.jan06.wl.30
Woods Hole
46
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/sand.jan06.wl.30
Sandy Hook
49
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/atlc.jan06.wl.30
Atlantic City
52
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/capm.jan06.wl.30
Cape May
55
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/lews.jan06.wl.30
```

```
Lewes
58
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/duck.jan06.wl.30
Duck
61
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/wilm.jan06.wl.30
Wilmington
64
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/sprn.jan06.wl.30
Springmaid
67
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/char.jan06.wl.30
Charleston
70
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/ftpl.jan06.wl.30
Fort Pulaski
73
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/fern.jan06.wl.30
Fernadina
76
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/mayp.jan06.wl.30
Mayport
26
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/napl.jan06.wl.30
Naples
27
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/stpt.jan06.wl.30
St Petersburg
28
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/clea.jan06.wl.30
Clearwater
29
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/apal.jan06.wl.30
Apalachicola
31
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/panm.jan06.wl.30
Panama City
32
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/pens.jan06.wl.30
Pensacola
33
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/sabn.jan06.wl.30
Sabine Pass
34
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/galv.jan06.wl.30
Pleasure Pier
35
/disks/NASUSER/philr/3model_comp/obs/2006/jan06/filter/free.jan06.wl.30
Freeport
25
etss.01312006_adj
```

hycomha.jcl

```
  f77 hycom29.f calcjd.f -o hycha

# ./hycha < hycomha_jan06.n > out
# ./hycha < hycomha_feb06.n > out
# ./hycha < hycomha.feb06r.n > out
# ./hycha < hycomha_mar06.n > out

  ./hycha < hycomha_apr06.n > out
```

hycomha_jan06.n

```
0       idebug
24      nsta
31      ndays
7       lun
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01012006
32
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01022006
33
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01032006
34
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01042006
35
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01052006
36
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01062006
37
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01072006
38
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01082006
39
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01092006
40
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01102006
41
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01112006
42
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01122006
43
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01132006
44
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01142006
45
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01152006
46
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01162006
47
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01172006
48
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01182006
49
```

```
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01192006
50
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01202006
51
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01212006
52
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01222006
53
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01232006
54
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01242006
55
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01252006
56
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01262006
57
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01272006
58
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01282006
59
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01292006
60
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01302006
61
/disks/NASUSER/philr/3mod_com/hyc/nowcast/jan06/hycom.01312006
8
east_nowc.jan06
9
port_nowc.jan06
10
bost_nowc.jan06
11
wood_nowc.jan06
12
sand_nowc.jan06
13
atlc_nowc.jan06
14
capm_nowc.jan06
15
lews_nowc.jan06
16
duck_nowc.jan06
17
wilm_nowc.jan06
18
spri_nowc.jan06
19
char_nowc.jan06
20
ftpl_nowc.jan06
21
fern_nowc.jan06
22
mayp_nowc.jan06
23
napl_nowc.jan06
24
```

```
stpt_nowc.jan06
25
clea_nowc.jan06
26
apal_nowc.jan06
27
panm_nowc.jan06
28
pens_nowc.jan06
29
sabn_nowc.jan06
30
plea_nowc.jan06
31
free_nowc.jan06
/disks/NASUSER/philr/3mod_com/hyc/nowc_ha/h29/
```

read_pred.jcl

```
lf95 readpred.f predsub.f compin.f conctj.f conjtc.f -o readpred

rm *.o


readpred < read.n > out
```

read.n

```
 0       idebug
 24      nsta
 1.0     conversion factor
 0.0     time shift in hours
harm29.jan06
 9.0     xmaxd
 2006    iyear
east.jan06.pred
port.jan06.pred
bost.jan06.pred
wood.jan06.pred
sand.jan06.pred
atlc.jan06.pred
cape.jan06.pred
lews.jan06.pred
duck.jan06.pred
wilm.jan06.pred
spri.jan06.pred
char.jan06.pred
ftpl.jan06.pred
fern.jan06.pred
mayp.jan06.pred
napl.jan06.pred
stpt.jan06.pred
clea.jan06.pred
apal.jan06.pred
panm.jan06.pred
pens.jan06.pred
sabn.jan06.pred
plea.jan06.pred
free.jan06.pred
 1       beginning month
 1       start day
 1.0     start hour
 1       end month
 31      end day
 24.0    end time
 1       number of data pts per hour
30       nday
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01012006
19
jan06.detide1
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01022006
```

```
20
jan06.detide2
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01032006
21
jan06.detide3
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01042006
22
jan06.detide4
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01052006
23
jan06.detide5
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01062006
24
jan06.detide6
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01072006
25
jan06.detide7
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01082006
26
jan06.detide8
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01092006
27
jan06.detide9
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01102006
28
jan06.detide10
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01112006
29
jan06.detide11
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01122006
30
jan06.detide12
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01132006
31
jan06.detide13
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01142006
32
jan06.detide14
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01152006
33
jan06.detide15
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01162006
34
jan06.detide16
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01172006
35
jan06.detide17
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01182006
36
jan06.detide18
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01192006
37
jan06.detide19
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01202006
38
jan06.detide20
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01212006
39
```

```
jan06.detide21
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01222006
40
jan06.detide22
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01232006
41
jan06.detide23
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01242006
42
jan06.detide24
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01252006
43
jan06.detide25
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01262006
44
jan06.detide26
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01272006
45
jan06.detide27
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01282006
46
jan06.detide28
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01292006
47
jan06.detide29
/disks/NASUSER/philr/3mod_com/hyc/00z/jan06/hycom.01302006
48
jan06.detide30
```