HMTAP Task Order 18

Mississippi Coastal Analysis Project

Tide Simulation Report (Task 4)

September 25, 2007

FEMA

U.S. Department of Homeland Security
500 C Street, SW
Washington, DC 20472

This document was prepared by

URS Group, Inc.

200 Orchard Ridge Drive, Suite 101
Gaithersburg, MD 20878

HSFEHQ-06-D-0162
Task Order 18

15707018.04070

TABLE OF CONTENTS

Section 1 Introduction 1-1

Section 2 ADCIRC Grid and Bathymetric/Topographic Data 2-1

Section 3 ADCIRC Model Input Parameters 3-1

Section 4 NOAA Data 4-1

Section 5 Discussion of Model Results Versus NOAA Data 5-1

Section 6 Conclusions 6-1

Tables

Table 3.1. Parameter name, description, and value for the ADCIRC fort.15 file used for all model runs. 3-3

Table 4.1. Station identification information for NOAA stations with at least some recorded water level time series data between June 1, 2005, and August 31, 2005. 4-2

Table 4.2. List of stations and length of record with NOAA harmonic constituent data available. 4-3

Table 5.1. Station information and harmonic constituent data from NOAA and the ADCIRC model output. 5-12

TABLE OF CONTENTS

Figures

Figure 2.1. The final node and element configuration for the URS grid. 2-2
Figure 4.1. Water surface elevation station locations in (a) Alabama and Mississippi, and (b) Louisiana, with station numbers corresponding to those in Table 4.2 and Figures 5.2 – 5.11. 4-4
Figure 4.2. Harmonic Constituent station locations in (a) Florida, (b) Alabama and Mississippi, (c) Louisiana, and (d) Texas, with station numbers corresponding to those in Table 4.3 and Table 5.1. 4-5
Figure 5.1. ADCIRC model results versus NOAA-predicted water level surface height at the Dauphin Island, AL, station. 5-2
Figure 5.2. ADCIRC model results versus NOAA-predicted water level surface height at the Pascagoula Point, MS, station. 5-3
Figure 5.3. ADCIRC model results versus NOAA-predicted water level surface height at the Horn Island, MS, station. 5-4
Figure 5.4. ADCIRC model results versus NOAA-predicted water level surface height at the Ocean Springs, MS, station. 5-5
Figure 5.5. ADCIRC model results versus NOAA-predicted water level surface height at the Biloxi, MS, station. 5-6
Figure 5.6. ADCIRC model results versus NOAA-predicted water level surface height at the Bay Waveland Yacht Club, MS, station. 5-7
Figure 5.7. ADCIRC model results versus NOAA-predicted water level surface height at the Waveland, MS, station. 5-8
Figure 5.8. ADCIRC model results versus NOAA-predicted water level surface height at the Pilots Station SW Pass, LA, station. 5-9
Figure 5.9. ADCIRC model results versus NOAA-predicted water level surface height at the Grand Isle, LA, station. 5-10
Figure 5.10. RMS Error of the daily high-water and low-water points of the water level time series for the 9 stations shown in Figures 5.1 through 5.9. 5-11
Figure 5.11. Average phase shift at the daily high-water and low-water points of the water level time series for the 9 stations shown in Figures 5.1 through 5.9. 5-11
Figure 5.12. RMS Error for the amplitude of the K_1 and M_2 constituents, by State. The Error in Alabama is not an RMS error, but the difference (in centimeters) between the model results and the NOAA data at the one station in that State. 5-19
Figure 5.13. RMS Error for the phase of the K_1 and M_2 constituents, by State. The Error in Alabama is not an RMS error, but the difference (in centimeters) between the model results and the NOAA data at the one station in that State. 5-20

URS Group, Inc. (URS) has an Indefinite Delivery/Indefinite Quantity (IDIQ) contract with the Federal Emergency Management Agency (FEMA) to support the Hazard Mitigation Technical Assistance Program (HMTAP). Task Order 18 under that contract is to provide coastal storm surge modeling and floodplain mapping along the Gulf Coasts of Hancock, Harrison, and Jackson counties in Mississippi; this report documents the tidal simulations conducted as part of the surge modeling analysis. The purpose of tide simulations is to demonstrate model skill in representing the hydrodynamic ocean and bay circulation patterns and tidal exchange due to normal astronomical cycles. Simulated tides were compared to measured tides at tide gage stations across the region. The simulated water surface elevation time series were compared to measured tides over a 30-day period. Tidal constituents derived from 90-day simulations were also compared to published tidal constituents for each tide gage station.

The model used for the coastal analysis of Mississippi is the two-dimensional version of the Advanced Circulation model (ADCIRC), developed by Drs. Rick Luettich and Joannes Westerink. This finite element model solves the shallow water equations for water surface elevation and depth integrated velocity at every node in the triangulated grids that are used with ADCIRC. A detailed description of the governing equations, numerical solution methods, and the theory is available in the online model documentation: "Formulation and Numerical Implementation of the 2D/3D ADCIRC Finite Element Model" available on the Internet at: http://adcirc.org/adcirc_theory_2004_12_08.pdf. For this project, version 46.52.03 was used.

The primary purpose of the ADCIRC model grid and input files for Task Order 18 is the simulation of coastal surges due to hurricane forcing, and therefore much of the model grid and input files containing model parameters and wind and wave forcing have been developed for this purpose. Details of the grid generation and input file preparation in support of the surge modeling are contained in separate reports on Grid Generation and Surge Modeling Validation. The simulation of tides involves only the offshore regions of the model grid and does not require wind or wave forcing files. The documentation in this tide simulation report provides a brief summary of the grid generation and input files, but only for the parameters directly affecting the tide simulation.

The triangulated grid used with the ADCIRC model allows for a flexible design that can closely mimic complex shorelines. Also, it is easy to have a large range of element sizes, allowing high resolution in areas of hydrologic importance, and coarse resolution in other areas where the tides and waves are more stable (such as the deep ocean waters). Developing these grids can be a long, labor-intensive process; to save some time, this project began with a base grid developed by Dr. Joannes Westerink at the University of Notre Dame (called the *TF01_v6* grid). This grid had a high level of resolution in southeast Louisiana and extended from the Gulf of Mexico out to the 60 degree W longitude line in the Western North Atlantic Ocean. Previous storm surge studies have demonstrated the usefulness of having a large domain grid allowing for simplified boundary conditions in the deep ocean waters. A large grid also provides more accurate tracking of the storms into the Gulf of Mexico and onto the shore by capturing the full storm response through its development.

URS extended this base grid to include the hydrologic and topographic features in the three coastal counties in Mississippi—Hancock, Harrison, and Jackson counties. The shoreline, which defined the change between water and land elements, was based on the National Oceanic and Atmospheric Administration's (NOAA's) Vector Shoreline. After the Mississippi area was added, additional changes were made to this portion of the grid by Dr. Westerink and his group at the University of Notre Dame to increase the grid stability. (The grids used in ADCIRC are sensitive to the element configuration and the elevation changes from node to node.) All of these developments are examined in detail in the Grid Development Report.

The initial *TF01_v6* grid incorporated bathymetric data in the offshore regions from the ETOPO5 and Digital Nautical Charts (DNC) databases, as well as many National Ocean Service (NOS) sounding databases in the nearshore region. In the expanded Mississippi grid, the topography of the land (which does not play a role in tide-only model simulations) came from recent LIDAR data sources. The bathymetric data in the nearshore Mississippi area came from the Northern Gulf Littoral Initiative (NGLI), the Naval Oceanographic Office (NAVO) multibeam and singlebeam bathymetry, NOAA bathymetric surveys, and NOAA navigational charts. In the rivers, the data was extracted from Flood Insurance Studies. More detailed information on these data sources can be found in the Geospatial Data Report, and details on the incorporation of these data sources into the model grid are described in the Grid Development Report.

The final grid is shown in Figure 2.1. This grid contains 900,450 nodes and 1,766,128 elements. The element sizes (measured from node-to-node) range in size from about 60 meters in Mississippi to 2 kilometers in the deep ocean. Approximately 40 percent of these nodes are in Mississippi, Mississippi Sound, and over the Mississippi barrier islands.

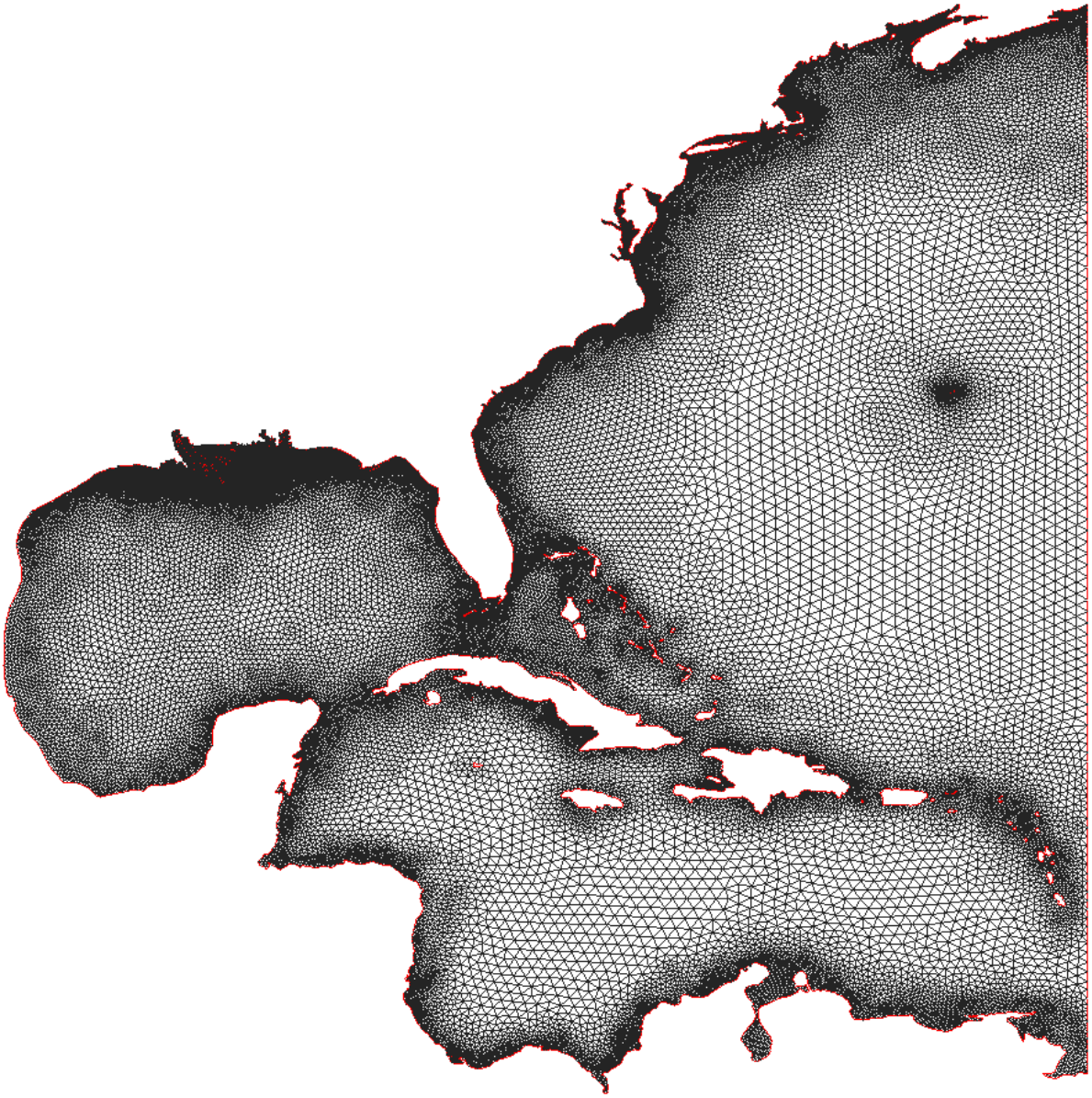


Figure 2.1. The final node and element configuration for the URS grid.

The ADCIRC model requires two parameter input files: fort.15 and fort.13. In the fort.13 file, spatially varying parameters are specified. For all the model simulations, including both the tide and the storm surge simulations, the identical fort.13 file was used. This file contained information for six parameters: primitive weighting in the continuity equation, Manning's N at the sea floor, surface submergence state, surface canopy coefficient, and surface directional effective roughness length. The values for each of these parameters were set by Ayres Associates, and the rationale and methodology for their parameter selection is described in detail in the Parameterization Report and summarized in the Grid Development Report. Of the six spatially varying parameters, only the primitive weighting in the continuity equation (T_0) and Manning's N applied in the offshore grid elements affected the tide simulations.

The T_0 parameter controls the dispersion properties of the formulation of the shallow water equations that is used in the ADCIRC model. As water depth decreases, a higher T_0 is required to maintain model stability. It is also important to apply larger T_0 values in high-flow regions such as rivers and inlets. For this project, T_0 was set to T_0 = 0.005 in waters deeper than 30 feet outside of Southern Louisiana and Mississippi; T_0 = 0.002 in waters shallower than 30 feet, but still outside Southern Louisiana and Mississippi; and T_0 = 0.03 in waters shallower than 30 feet or in rivers and inlets in Southern Louisiana and Mississippi. In addition, T_0 was increased in the project area, based on the total water column height and local currents, automatically by the ADCIRC code to increase stability during the hurricane simulations.

For the Manning's N values, the coefficients were spatially assigned to each model node using the United States Geological Survey's (USGS') "GAP" and National Land Cover Data (NLCD) land type definitions. The input data sets and the algorithm used to translate this data onto the ADCIRC grid is described in detail in the Parameterization Report and summarized in the Grid Development Report.

The fort.15 file used for the tide simulations was the same as the fort.15 file used for the storm surge validation runs (except that the storm surge runs included wind and radiation stress forcings and were timed for tidal contributions from different periods of time). Table 3.1 lists the parameter name, description, and value used for all of the tidal simulation runs. (The parameter descriptions are from the ADCIRC manual, available at the Web site: http://adcirc.org/ documentv46/ fort_15.html.) The justification for the choice of the parameter values is listed in the final column of the table. The standard recommended values are those listed in the online ADCIRC user's manual.

At the open boundary grid nodes in the deep Atlantic Ocean, the model is forced with seven major harmonic constituents (K_1, O_1, Q_1, M_2, S_2, N_2, and K_2) extracted from the EastCoast2001 tidal database (available from the ADCIRC Web site at: http://www.unc.edu/ims/ccats/ tides/tides.htm). The ADCIRC model uses these constituents to create a water surface elevation at each of the nodes, which is then propagated into the model domain. Because of the large domain, these same constituents are used to model the tidal potential. For both the open boundary and tidal potential calculations, a nodal factor and equilibrium argument are provided for each constituent, which ties the model run to a specific period in time. For the tide simulation, these factors were chosen for the starting date of May 1, 2005. The node factors and equilibrium arguments were calculated using a program based on NOAA's publication "Manual of Harmonic Analysis and Prediction of Tides" from 1958. There is a 15-day ramp period at the beginning of the run to avoid "shocking" the system with sudden forcing at the boundary. There

is an additional boundary at the upstream end of the Mississippi River. This boundary is forced with periodic normal flow at each node on the boundary. This type of boundary also allows flow to exit the domain and not reflect back down the Mississippi River. This data is given 2 days to ramp up to the full forcing to allow the Mississippi River flow to stabilize.

Table 3.1. Parameter name, description, and value for the ADCIRC fort.15 file used for all model runs.

PARAMETER NAME	PARAMETER DESCRIPTION	PARAMETER VALUE	PARAMETER JUSTIFICATION
ICS	Parameter controlling whether the model is run in (1) spherical or (2) Cartesian coordinates.	2	Standard recommended value.
NOLIBF	Parameter controlling the type of bottom stress parameterization: (0) linear, (1) quadratic, or (2) hybrid nonlinear.	1	Quadratic parameterization is required for the use of the "mannings_n_at_sea_floor" parameter in the fort.13 file.
NOLIFA	Parameter controlling the finite amplitude terms: (0) finite amplitude terms are not included, (1) finite amplitude terms are included but wetting and drying of elements is disabled, or (2) finite amplitude terms are included and wetting and drying of elements is enabled.	2	Standard recommended value.
NOLICA	Parameter controlling the advective terms (with the exception of the time derivative portion that occurs in the Generalized Wave Continuity Equation (GWCE) form of the continuity equation): (0) advective terms are not included, or (1) advective terms are included.	0	The advective terms were not included to provide additional model stability.
NOLICAT	Parameter controlling the time derivative portion of the advective terms that occurs in the GWCE form of the continuity equation: (0) time derivative portion of the advective terms that occur in the GWCE continuity equation are not included, or (1) time derivative portion of the advective terms that occur in the GWCE continuity equation are included.	0	The advective terms were not included to provide additional model stability.
NWP	Number of nodal attributes used in the run (described in the fort.13 input file). These attributes are: (1) *primitive weighting in continuity equation*, (2) *Manning's n at sea floor*, (3) *surface submergence state*, (4) *surface canopy coefficient*, (5) *surface directional effective roughness length*, and (6) *sea surface height above geoid*.	6	The 6 parameters in the fort.13 file are described in the separate Parameterization Report (submitted separately).
NCOR	Parameter controlling whether the Coriolis parameter: (0) read in a spatially constant Coriolis parameter, or (1) compute a spatially variable Coriolis parameter.	1	Standard recommended value.
DT	Time step (in seconds).	1.0	The timestep is Courant Number limited and based on the smallest element size in the model grid.

Table 3.1. Continued.

PARAMETER NAME	PARAMETER DESCRIPTION	PARAMETER VALUE	PARAMETER JUSTIFICATION
DRAMP, DRampExtFlux, FluxSettlingTime	Ramp function applied to ADCIRC forcings (in decimal days), ramp function for nonzero external flux boundary conditions (in decimal days), and the time for the river flux boundary condition and river bottom friction to equilibrate (in decimal days).	15.0, 2.0, 2.0	The DRAMP parameter matches that used for previous tide studies with ADCIRC. The other two parameters were provided by Dr. Westerink (UND) based on studies with a similar grid containing the MS River boundary.
A00, B00, C00	Time weighting factors at time levels k+1, k, and k-1 in the GWCE.	0.35, 0.30, 0.35	Standard recommended value.
H0, NODEDRYMIN, NODEWETMIN, VELMIN	(for NOLIFA=2): Nominal water depth for a node to be considered dry (in meters), minimum number of time steps after a node dries that it must remain dry before it can wet again, minimum number of time steps after a node wets that it must remain wet before it can dry again, and minimum velocity for wetting (in meters per second).	0.10, 0.0, 0.0, 0.10	Standard recommended value.
SLAMO, SFEAO	Longitude and latitude on which the Carte Parallelo-grammatique Projection (CPP) coordinate projection is centered.	265.5, 29.0	This is the approximate center of the model grid.
CF, HBREAK, FTHETA, FGAMMA	(for NOLIFA=2): Minimum friction coefficient in the hybrid bottom friction relationship, break depth (in meters), parameter that determines how rapidly the hybrid bottom friction relationship approaches its deep water and shallow water limits, and parameter that determines how the friction factor increases as the water depth decreases.	0.003, 2.0, 10.0, 1.33	Standard recommended value.
ESLM	Spatially constant horizontal eddy viscosity for the momentum equations.	50.0	This value of horizontal eddy viscosity matches that used in previous tide studies with ADCIRC.
ANGIN	Minimum angle for tangential flow.	110	Standard recommended value.
ITITER, ISLDIA, CONVCR, ITMAX	Parameters that provide information about the solver that will be used for the GWCE: ITITER = 1 – Jacobi preconditioned conjugate gradient (JCG) solver (from ITPACKV 2D), ISLDIA = 0 = fatal error messages only from ITPACKV 2D, CONVCR = absolute convergence criteria, ITMAX = maximum number of iterations each time step.	1, 0, 1.0E-7, 25	Standard recommended value.

The tide gage data used for the comparison with the tide simulations were obtained from the NOAA's Center for Operational Oceanographic Products and Services' (CO-OPS) Web site: www.tidesandcurrents.noaa.gov. The data consisted of the water surface elevation time series and the harmonic constituents.

Available stations were reviewed for their location relative to the Mississippi coast and their period of record. Eleven stations in the vicinity of the Mississippi coast with concurrent records were found and are summarized in Table 4.1. The summary includes the station ID, station name, location, and the corresponding location in the ADCIRC grid. The location of the NOAA station would sometime fall just onshore in the ADCIRC grid, due to grid resolution or uncertainty in the coordinate transformations. Therefore, the station location was shifted slightly in the ADCIRC grid so that it would lie in an offshore grid element. The Lower Bryant Landing station in Alabama (#8737373) and the Port Fourchon station in Louisiana (#8762075) are located in channels that are not represented in the ADCIRC model grid. Since these locations are beyond the Mississippi border, there is a coarser grid structure in these areas that does not capture the small-scale channel features. Therefore, these stations were not used for the model versus NOAA data comparisons. The location of the remaining nine stations is shown in Figure 4.1.

The water surface elevation levels recorded at the NOAA gages include not only the tides, but also meteorological forcing and other factors not represented in the tides-only run of the ADCIRC model. For the water surface elevation plots, the NOAA-predicted tidal levels were used. NOAA develops these predictions by using their standard techniques to remove the meteorological effects from the data and reduce the signal to include only the tidal influences.

For the model comparison, it was important to compare the results to relatively recent datasets which have the advantage of being available for download online as well as being representative of current bathymetric conditions. During the Katrina hurricane in August 2005, several tide gages were destroyed, so the time period immediately before then provided the greatest amount of data. URS chose the month closest to that storm with the most gages available (i.e., June 2005, since in July 2005, Pascagoula was taken offline.)

The second method of model validation was to compare the simulated harmonic constituents (amplitude and phase) for the seven major constituents (K_1, O_1, Q_1, M_2, S_2, N_2, and K_2) to those computed by NOAA. Thirty-four stations with constituent data were found along the Gulf Coast of Florida, Alabama, Mississippi, Louisiana, and Texas. These stations are listed in Table 4.2 with the station location, the corresponding location in the model grid, and the installation dates. The installation dates were reviewed to assure that the gage was in operation long enough to establish the harmonic constituents. All of the selected stations have more than 30 days of recordings, which is enough time to establishing the major tidal constituents with NOAA's analysis. The station locations are shown in Figure 4.2.

Table 4.1. Station identification information for NOAA stations with at least some recorded water level time series data between June 1, 2005, and August 31, 2005.

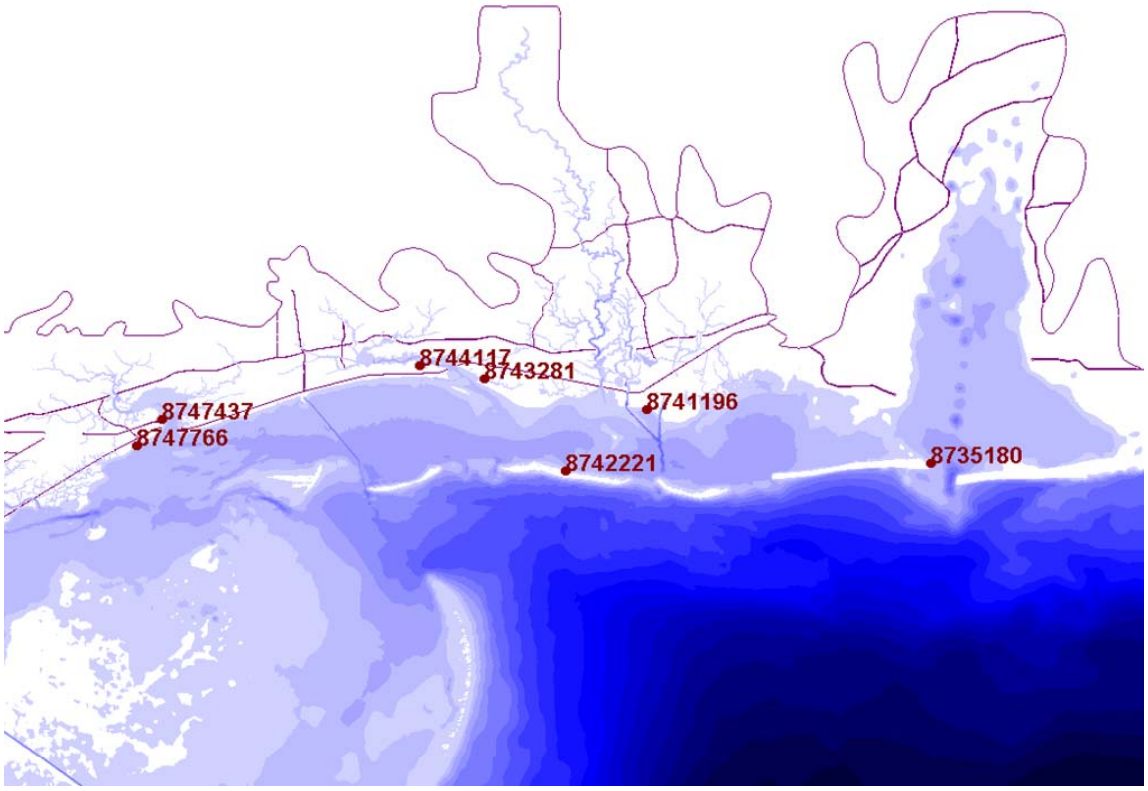
Station Number	Station Name	NOAA Lon	NOAA Lat	Model Lon	Model Lat	Record Length
8735180	Dauphin Island, AL	-88.075000	30.250000	-88.0689493	30.2526077	06/01/1996 – present
8737373	Lower Bryant Landing, AL*	-87.873333	30.978333	N/A	N/A	06/24/2004 – present
8741196	Pascagoula Point, MS	-88.533333	30.340000	-88.5333333	30.3400000	10/20/2004 – 07/03/2005
8742221	Horn Island, MS	-88.666667	30.238333	-88.6663519	30.2405000	01/04/2005 – 08/29/2005
8743281	Ocean Springs, MS	-88.798333	30.391667	-88.7983333	30.3913000	04/29/2005 – 08/29/2005
8744117	Biloxi, MS	-88.903333	30.411667	-88.9032357	30.4125100	07/09/2005 – 08/29/2005
8747437	Bay Waveland Yacht Club, MS	-89.325000	30.325000	-89.3250000	30.3250000	01/14/1997 – present
8747766	Waveland, MS	-89.366667	30.281667	-89.3666667	30.2816667	11/12/1996 – 08/29/2005
8760922	Pilots Station East, LA	-89.406667	28.931667	-89.4066667	28.9316667	04/18/2004 – present
8761724	Grand Isle, LA	-89.956667	29.263333	-89.9509200	29.2669017	01/01/1996 – present
8762075	Port Fourchon, LA*	-90.200000	29.115000	N/A	N/A	07/21/2003 – present

*These gages are not represented in the grid, and will not be included in analysis.

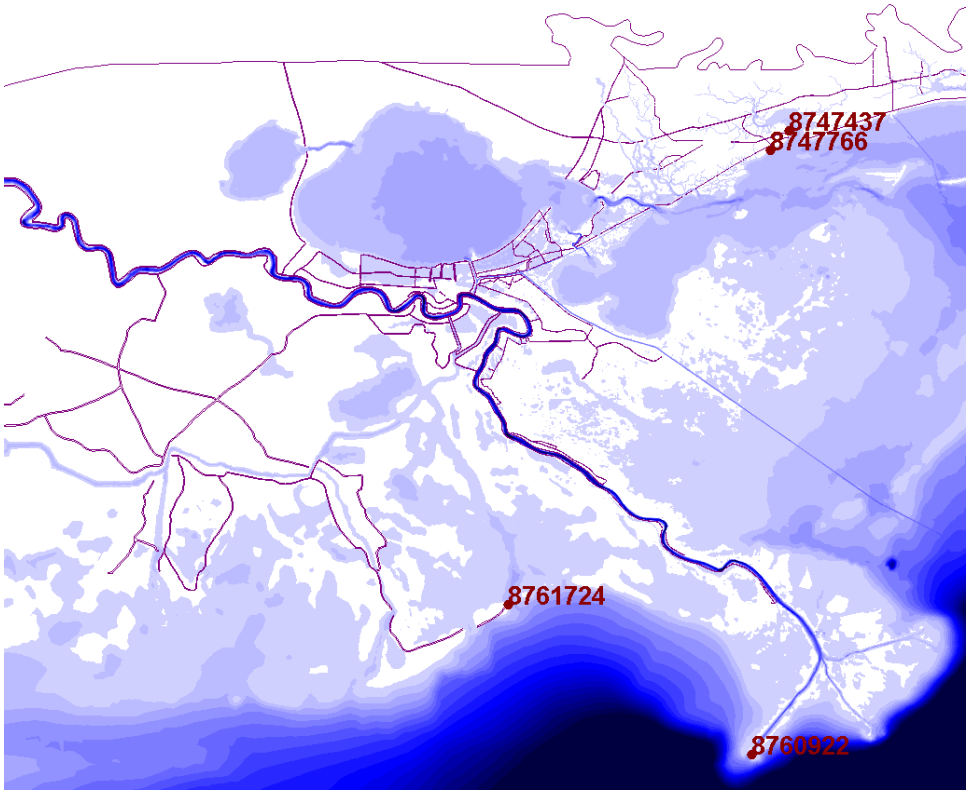
Table 4.2. List of stations and length of record with NOAA harmonic constituent data available.

Station ID	Station Name	NOAA Longitude	NOAA Latitude	Station Longitude	Station Latitude	Installation Date	Removal Date
8723962	Key Colony Beach, FL	-80.0166667	24.718333	-81.008205	24.717205	06/16/1976	12/31/1996
8724580	Key West, FL	-81.808333	24.553333	-81.810743	24.546611	01/18/1913	-
8725110	Naples, FL	-81.806667	26.130000	-81.808321	26.122808	03/04/1965	-
8726724	Clearwater Beach, FL	-82.831667	27.978333	-82.831660	27.978330	04/19/1973	-
8727520	Cedar Key, FL	-83.031667	29.135000	-83.031660	29.135000	03/12/1914	12/31/1996
8728130	St. Mark's Lighthouse, FL	-84.178333	30.078333	-84.182124	30.073209	01/01/1970	04/21/1977
8728360	Turkey Point, FL	-84.511667	29.915000	-84.511268	29.912336	05/01/1973	01/01/1977
8729678	Navarre Beach, FL	-86.865000	30.376667	-86.865000	30.376660	01/18/1978	11/11/1989
8735180	Dauphin Island, AL	-88.07500	30.250000	-88.0689493	30.2526077	03/30/1966	-
8741196	Pascagoula Point, MS	-88.533333	30.340000	-88.5333333	30.3400000	03/24/1980	08/11/2005
8741533	Pascagoula NOAA Lab, MS	-88.566667	30.358333	-88.565962	30.358440	09/09/2005	-
8742221	Horn Island, MS	-88.666667	30.238333	-88.6663519	30.2405000	04/16/1980	08/29/2005
8743281	Ocean Springs, MS*	-88.798333	30.391667	-88.7983333	30.3913000	04/29/2005	08/29/2005
8744117	Biloxi, MS	-88.903333	30.411667	-88.9032357	30.4125100	06/25/2004	08/29/2005
8745557	Gulfport Harbor, MS	-89.081667	30.360000	-89.081667	30.360000	07/31/1979	-
8747437	Bay Waveland Yacht Club, MS	-89.325000	30.325000	-89.3250000	30.3250000	05/31/1978	-
8747766	Waveland, MS	-89.366667	30.281667	-89.3666667	30.2816667	10/28/1996	08/29/2005
8760551	South Pass, LA	-89.140000	28.990000	-89.140000	28.990000	11/08/1977	08/26/2000
8760922	Pilots Station SW Pass, LA	-89.406667	28.931667	-89.4066667	28.9316667	03/15/2004	-
8760943	SW Pass, LA	-89.418333	28.925000	-89.418333	28.925000	05/27/1996	03/08/2004
8761720	Grand Isle, LA	-89.968333	29.255000	-89.983918	29.251330	08/02/1947	05/14/1980
8761724	Grand Isle East Point, LA	-89.956667	29.263333	-89.9509200	29.2669017	11/09/1979	-
8761927	New Canal Station, LA	-90.113333	30.026667	-90.113205	30.028850	11/21/1982	-
8762075	Port Fourchon, LA	-90.200000	29.115000	-90.2067000	29.1322200	06/19/2003	-
8762372	East Bank, LA	-90.368333	30.050000	-90.3656239	30.0669008	11/30/1982	-
8762482	West Bank, LA	-90.418333	29.776667	-90.418333	29.776667	05/02/2003	-
8764025	Stouts Pass at Six Mile Lake, LA*	-91.230000	29.743333	-91.230000	29.743333	02/09/2006	-
8764044	Tesoro Marine Terminal, LA	-91.236667	29.666667	-91.2366667	29.6666667	07/24/2003	-
8764227	Amerada Pass, LA	-91.338333	29.448333	-91.327551	29.437913	11/01/2005	-
8764311	Eugene Island, LA	-91.385000	29.371667	-91.385000	29.371667	04/01/1934	08/16/2005
8768094	Calcasieu Pass, LA	-93.343333	29.765000	-93.3372400	29.7543900	02/21/1933	-
8771510	Galveston Pleasure Pier, TX	-94.788333	29.285000	-94.788300	29.285000	01/01/1957	-
8775870	Corpus Christi, TX	-97.216667	27.580000	-97.216700	27.580000	05/09/1983	-
8779770	Port Isabel Laguna Madre, TX	-97.215000	26.060000	-97.158182	26.057023	03/31/1944	-

*Stations with less than 1 year of recorded data.



(a)



(b)

Figure 4.1. Water surface elevation station locations in (a) Alabama and Mississippi, and (b) Louisiana, with station numbers corresponding to those in Table 4.2 and Figures 5.2 – 5.11.

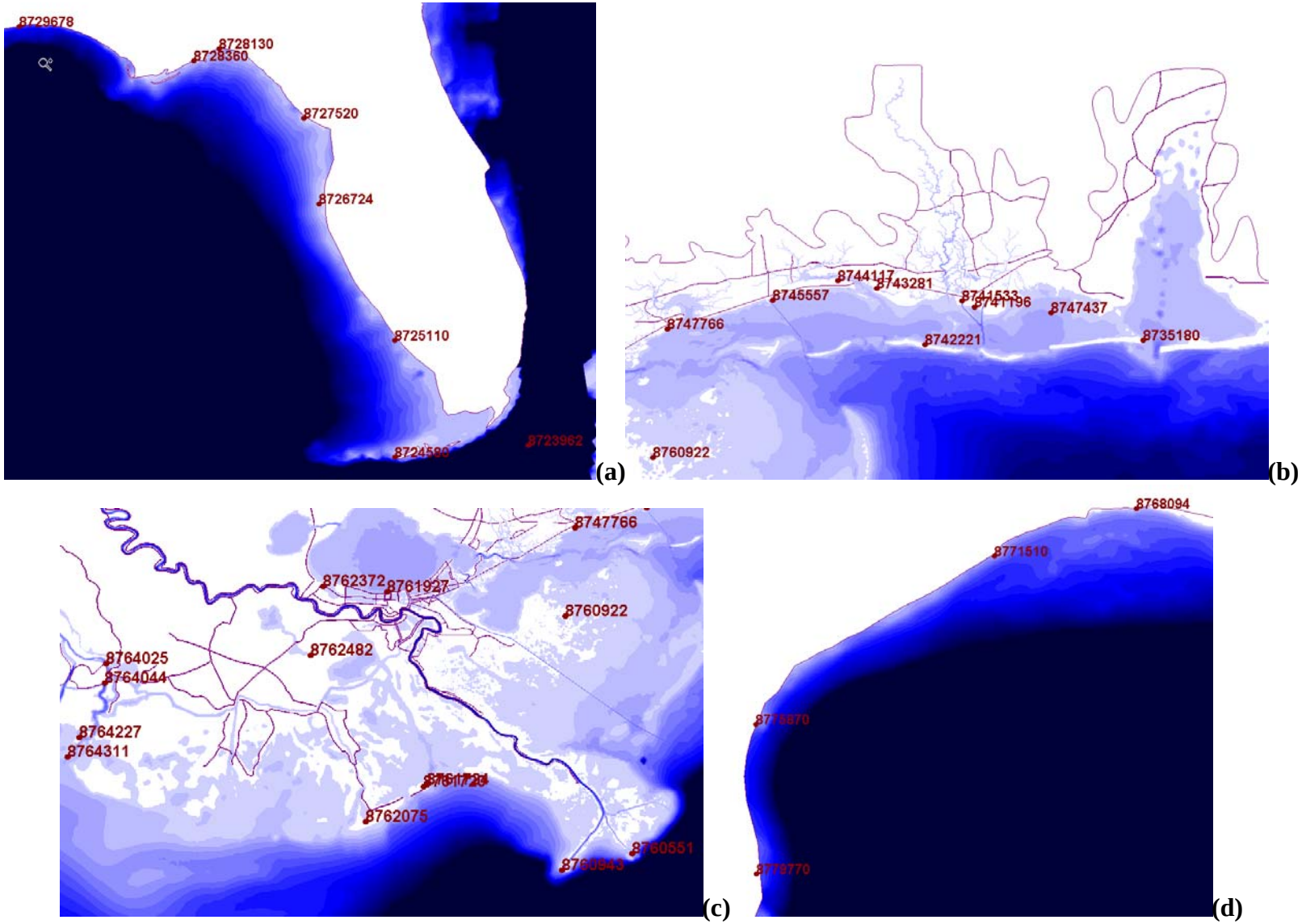


Figure 4.2. Harmonic Constituent station locations in (a) Florida, (b) Alabama and Mississippi, (c) Louisiana, and (d) Texas, with station numbers corresponding to those in Table 4.3 and Table 5.1.

The ADCIRC tide simulation consisted of a 123-day simulation from May 1, 2005, through the end of August 2005. The first 31 days (the month of May) was a “spin-up” period in which uncertainties in the model initial conditions for the simulation were allowed to dissipate. The subsequent 30-day period (the month of June) was used for the time series comparisons, and the 90-day period from June 1 through the end of August was used to calculate the harmonic constituents. (Although 30 days of data is sufficient to determine the amplitude and phase of most of the major harmonic constituents, another 60 days of data allows for accurate determination of additional minor constituents.)

The time series plots are shown in Figures 5.1 through 5.9. The daily highs and lows were tabulated at each station and then used to compute a root mean square (RMS) error. Figure 5.10 represents this data. This calculation of the RMS error assumes that the peaks and troughs of the time series occur at the same time; a calculation of the absolute value of the average phase difference of the daily high- and low-water times at each station is shown in Figure 5.11.

A comparison of the tide gage and simulated tidal constituents are summarized in Table 5.1. The RMS error for the major diurnal constituent (K1) and the major semi-diurnal constituent (M2) was determined separately for Mississippi, Louisiana, Texas, Alabama, and Florida. The RMS error for the amplitude and phase of these two constituents is shown in Figures 5.12 and 5.13. (Since there is only one station in Alabama, instead of the RMS error, the absolute difference between the model results and the tide gage data is shown.) The lowest RMS errors are in Mississippi (not counting AL, where there was only one station) which demonstrates the closest match with the data in the area of interest.

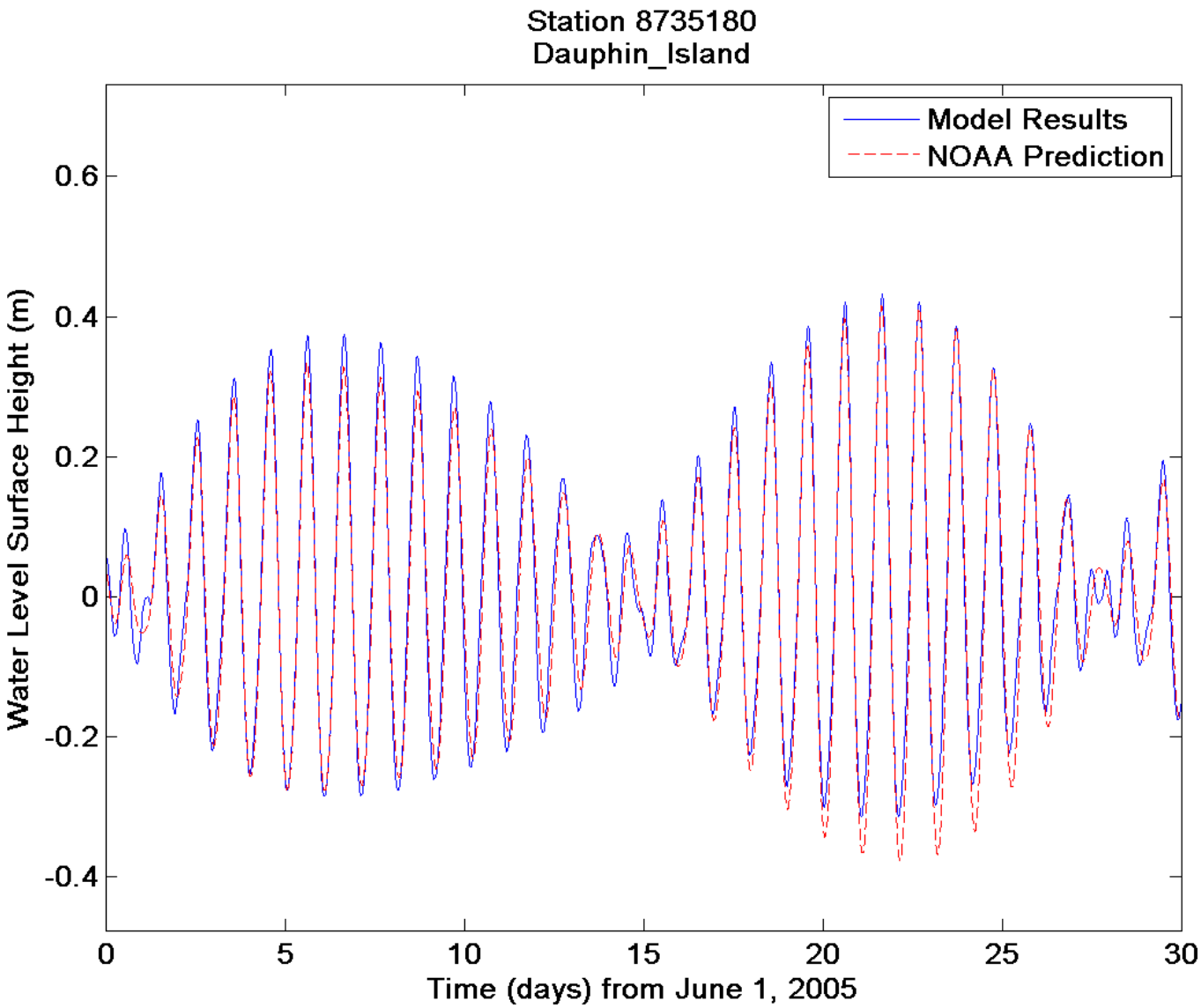


Figure 5.1. ADCIRC model results versus NOAA-predicted water level surface height at the Dauphin Island, AL, station.

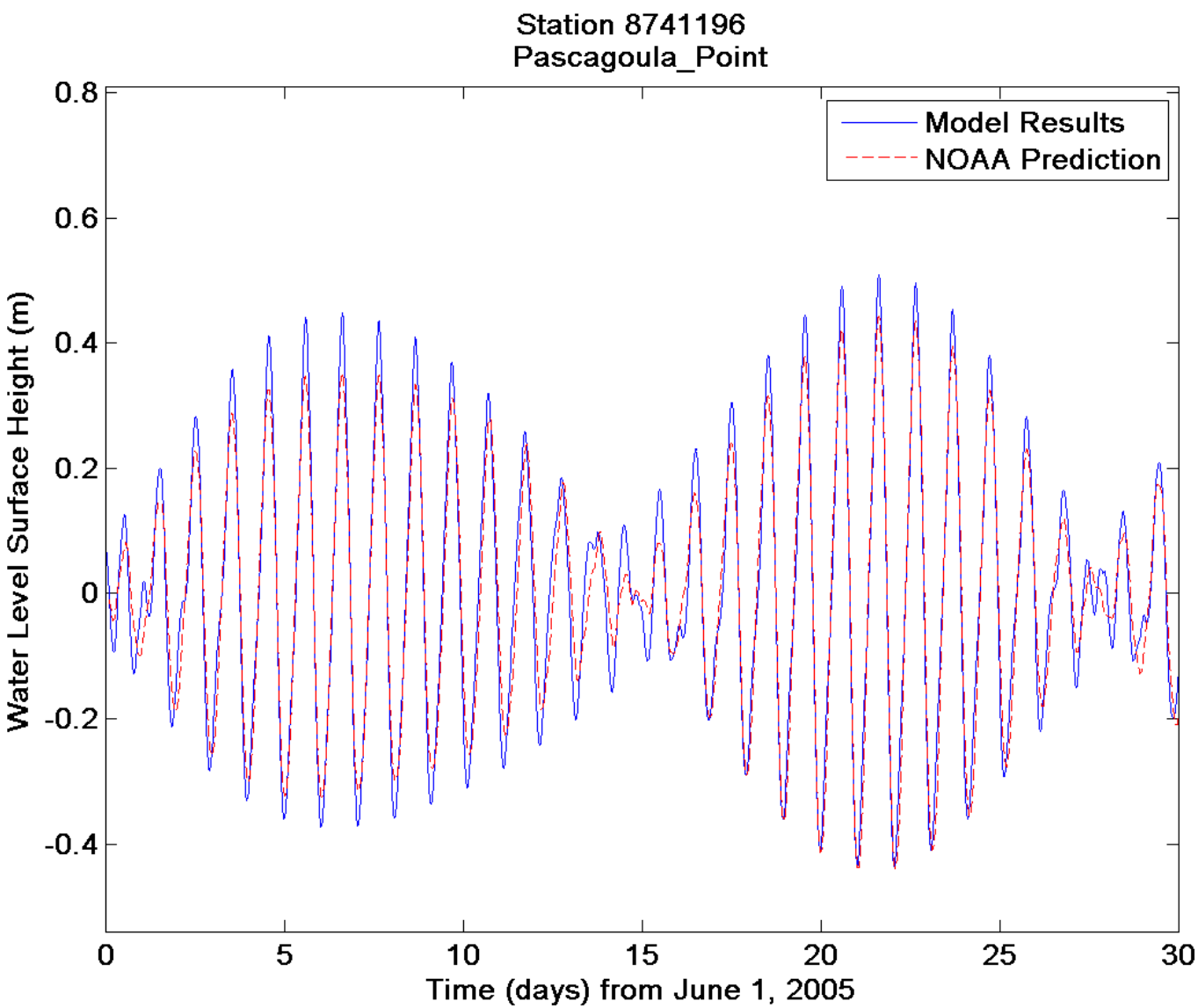


Figure 5.2. ADCIRC model results versus NOAA-predicted water level surface height at the Pascagoula Point, MS, station.

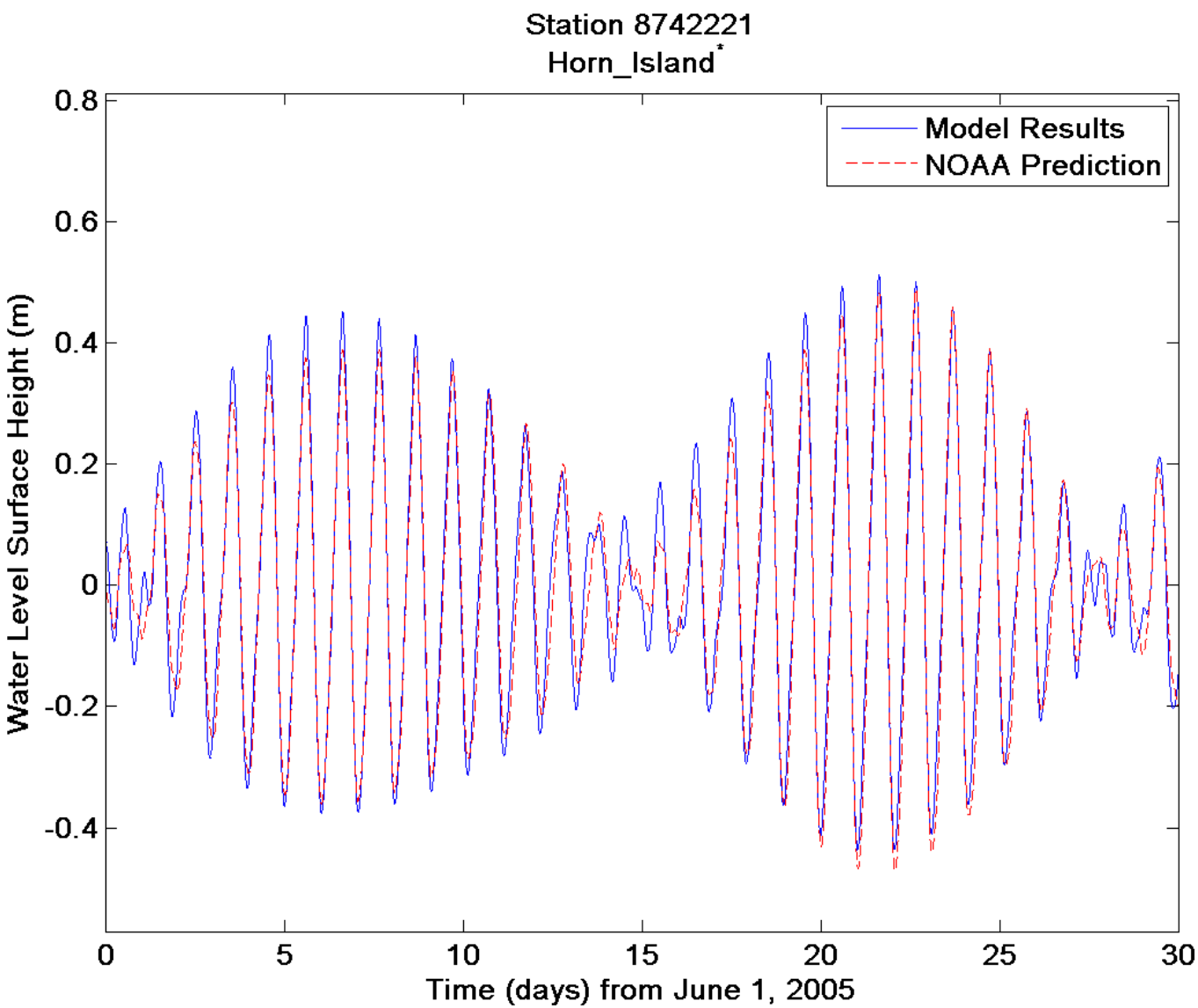


Figure 5.3. ADCIRC model results versus NOAA-predicted water level surface height at the Horn Island, MS, station.

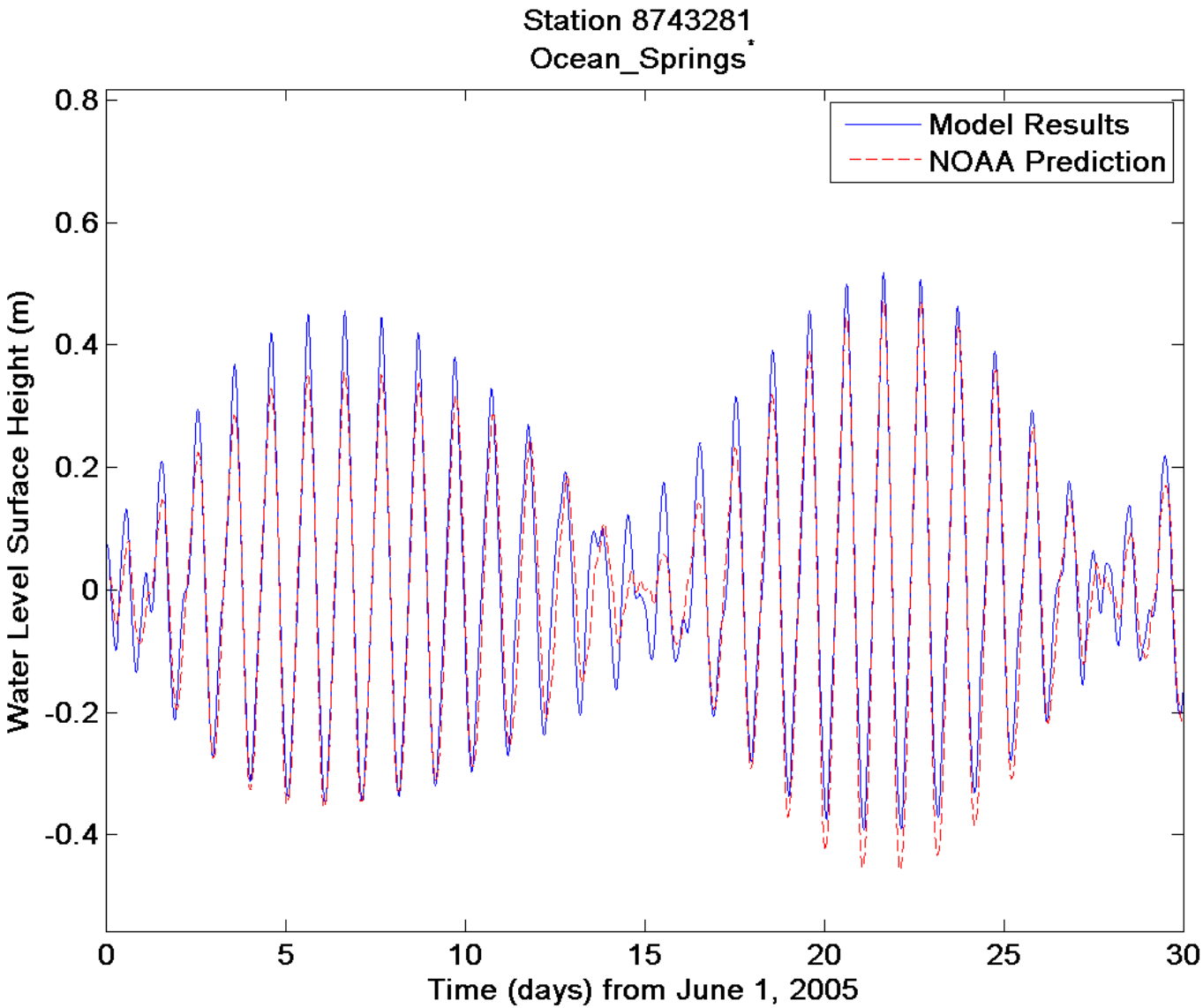


Figure 5.4. ADCIRC model results versus NOAA-predicted water level surface height at the Ocean Springs, MS, station.

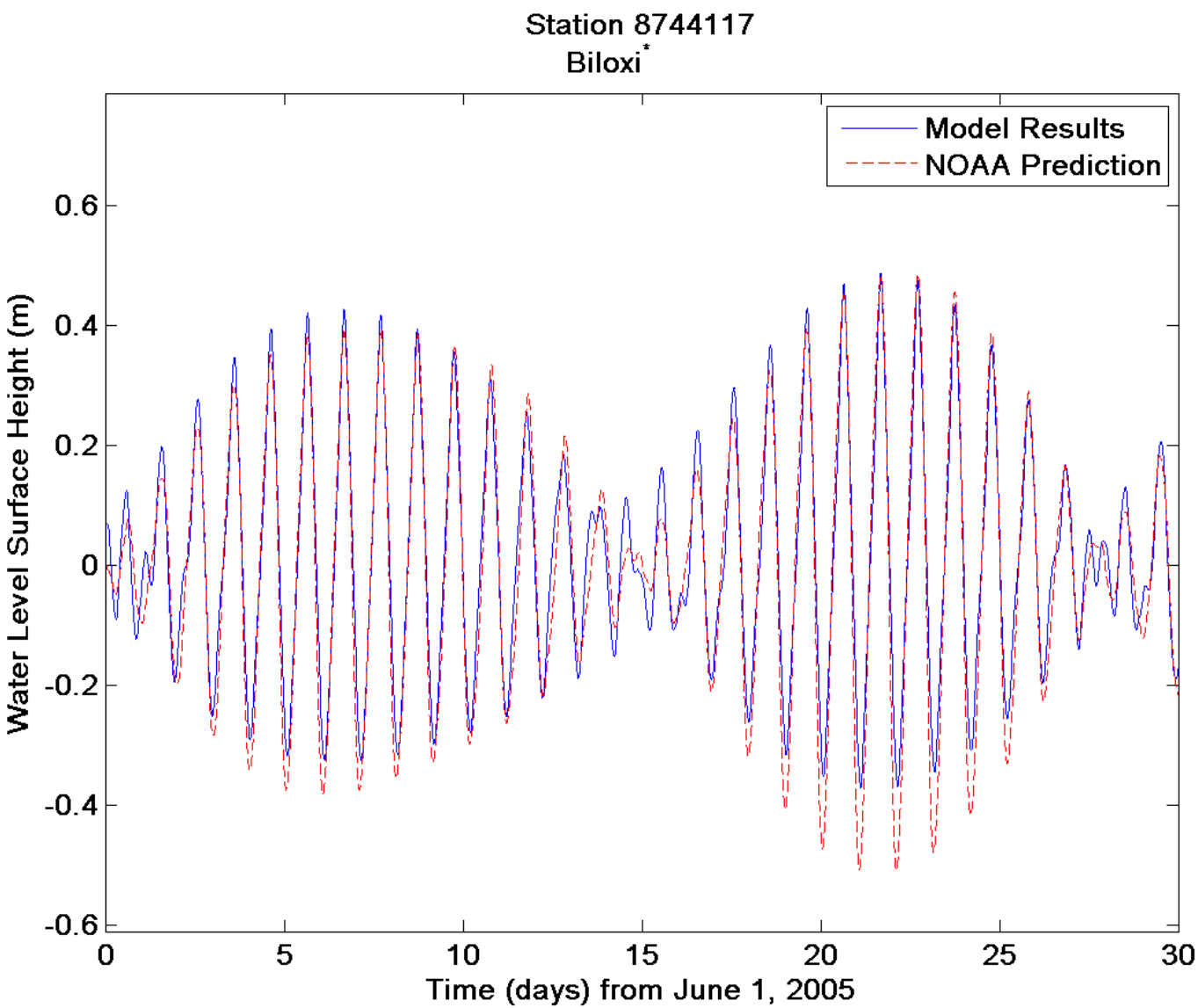


Figure 5.5. ADCIRC model results versus NOAA-predicted water level surface height at the Biloxi, MS, station.

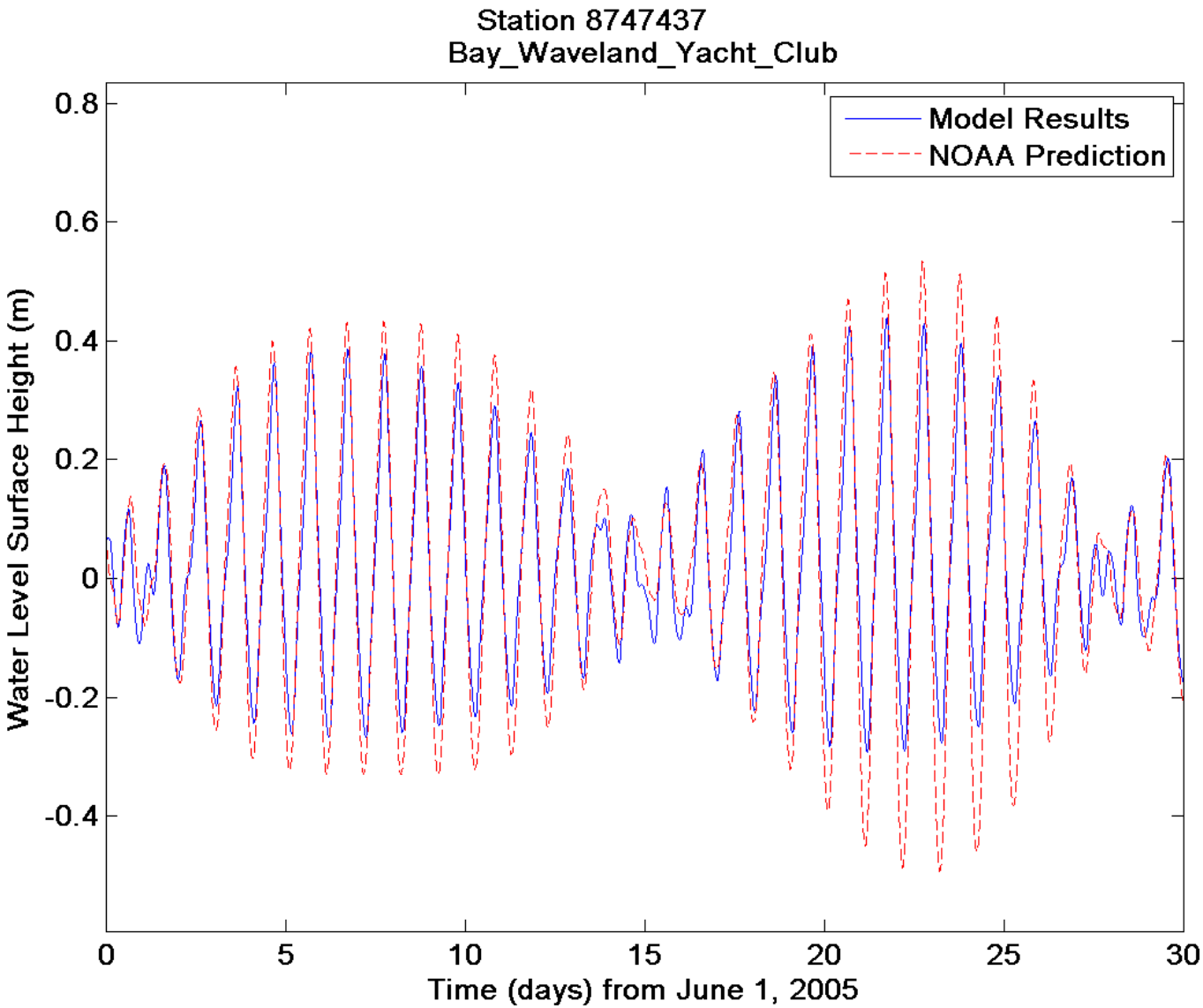


Figure 5.6. ADCIRC model results versus NOAA-predicted water level surface height at the Bay Waveland Yacht Club, MS, station.

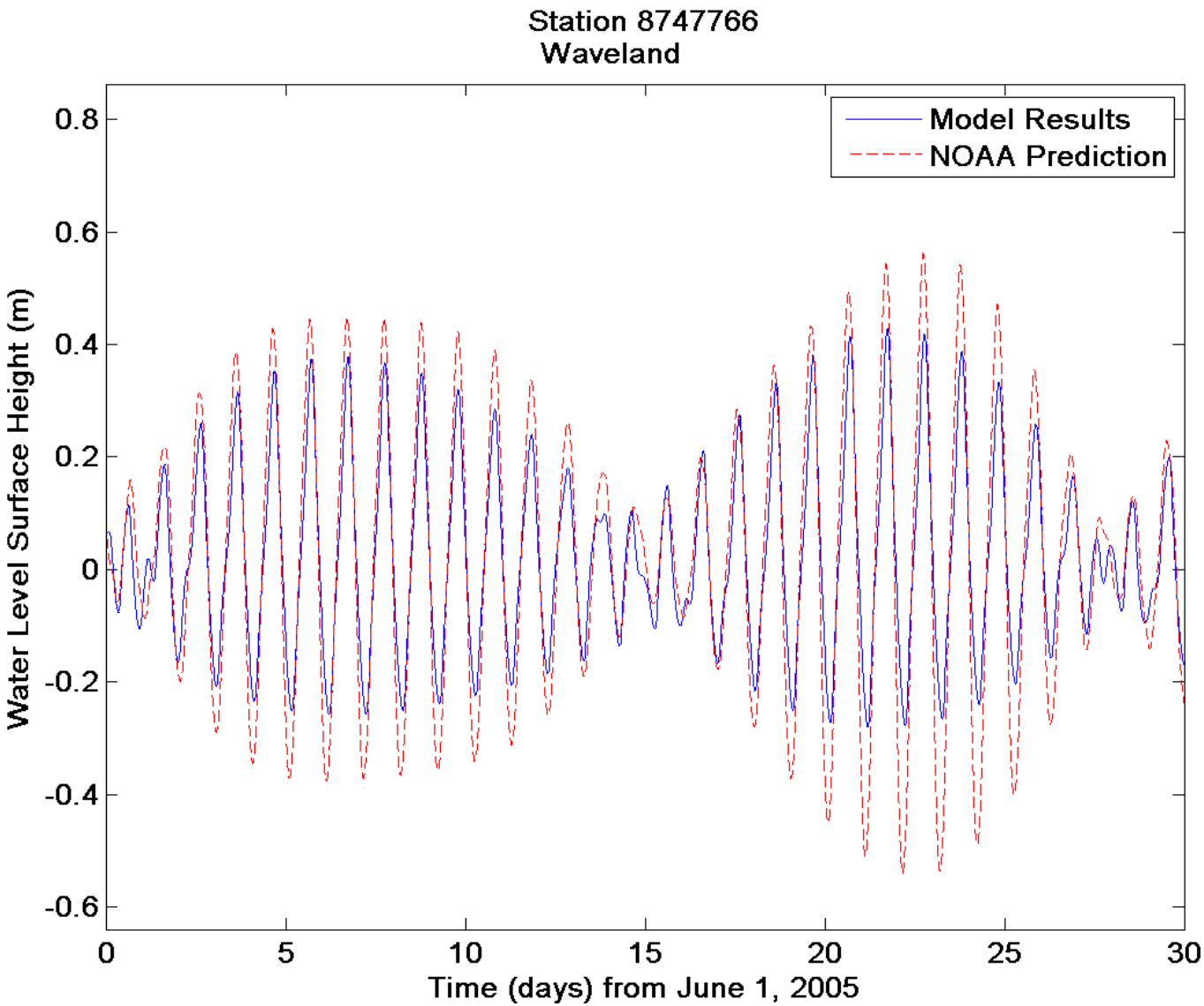


Figure 5.7. ADCIRC model results versus NOAA-predicted water level surface height at the Waveland, MS, station.

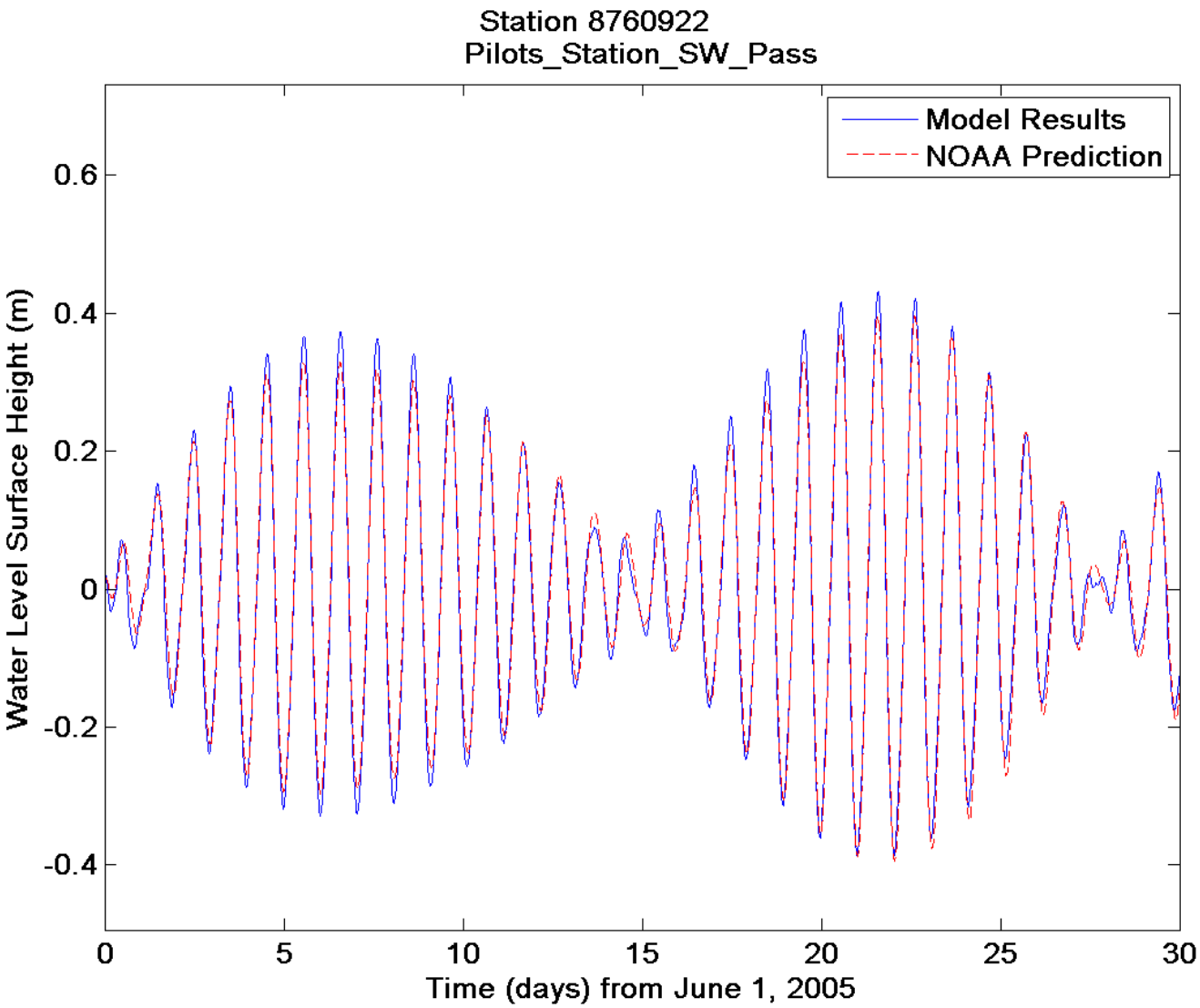


Figure 5.8. ADCIRC model results versus NOAA-predicted water level surface height at the Pilots Station SW Pass, LA, station.

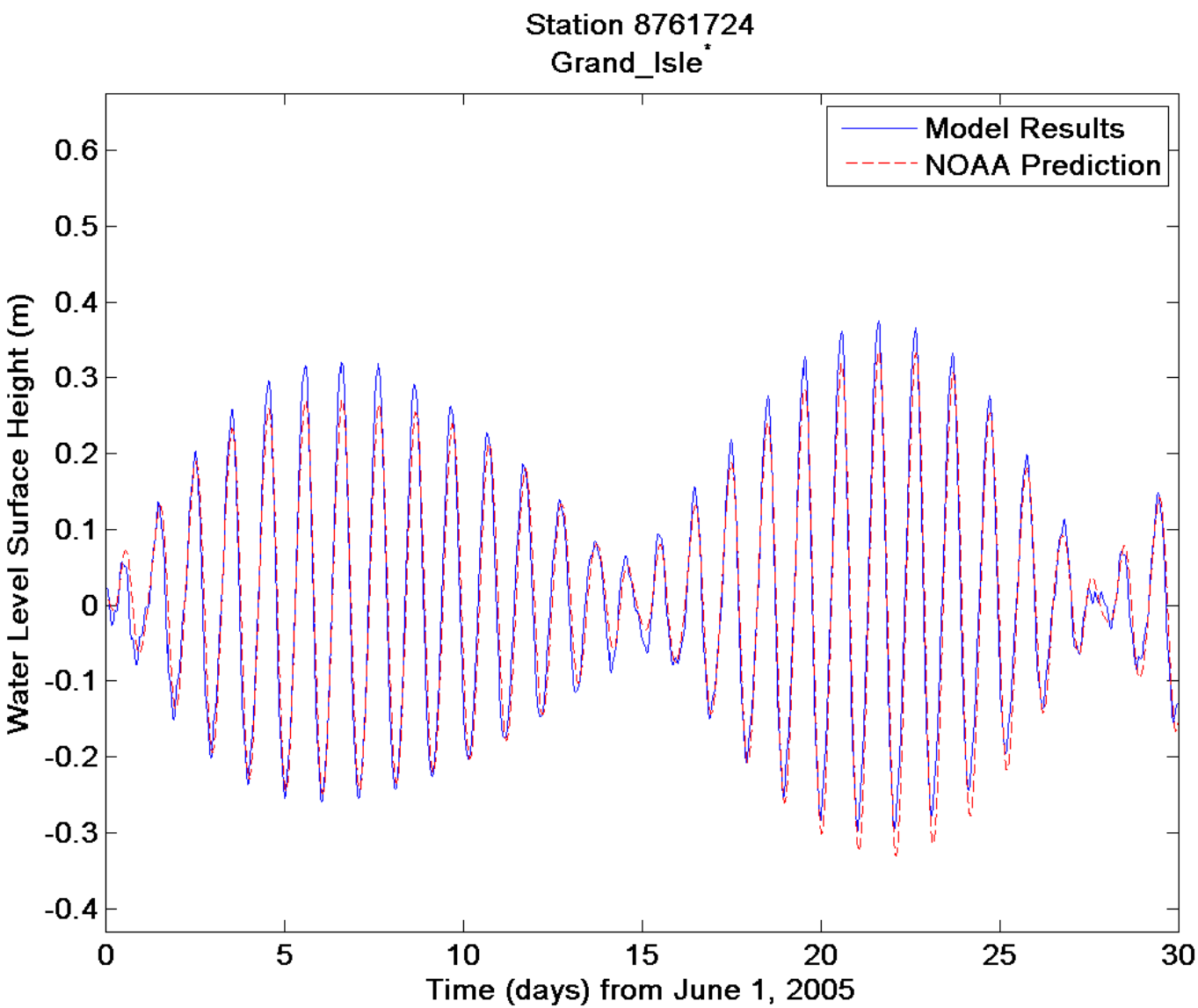


Figure 5.9. ADCIRC model results versus NOAA-predicted water level surface height at the Grand Isle, LA, station.

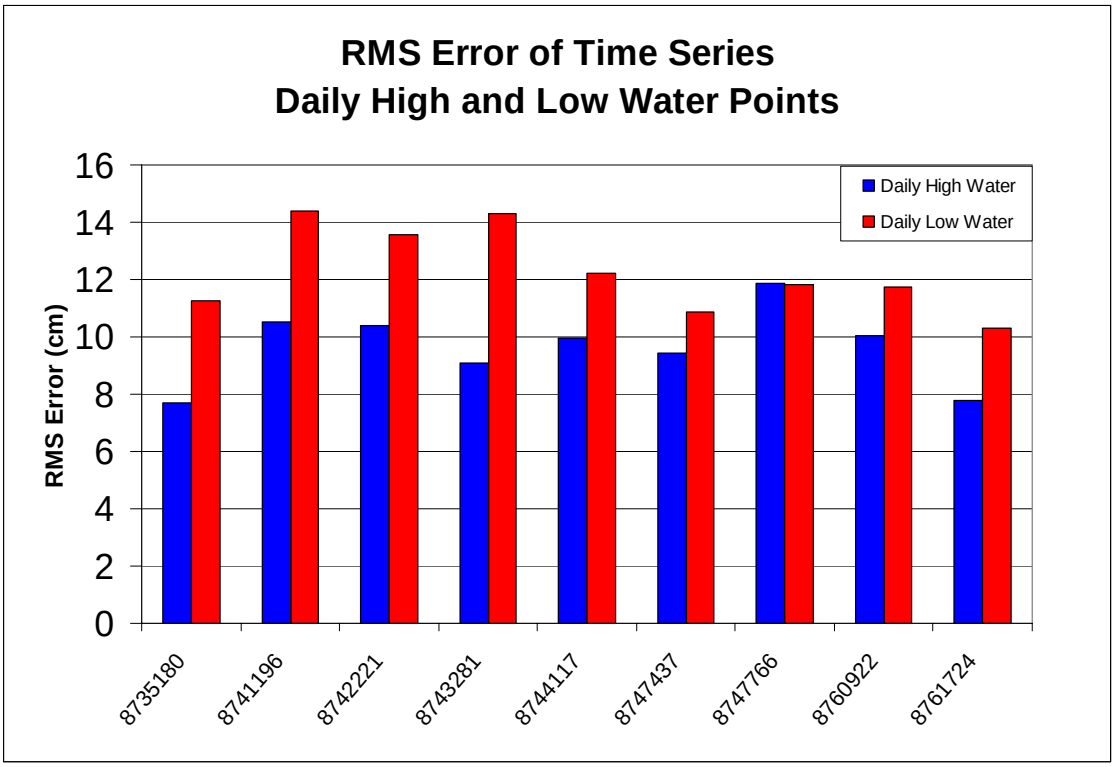


Figure 5.10. RMS Error of the daily high-water and low-water points of the water level time series for the 9 stations shown in Figures 5.1 through 5.9.

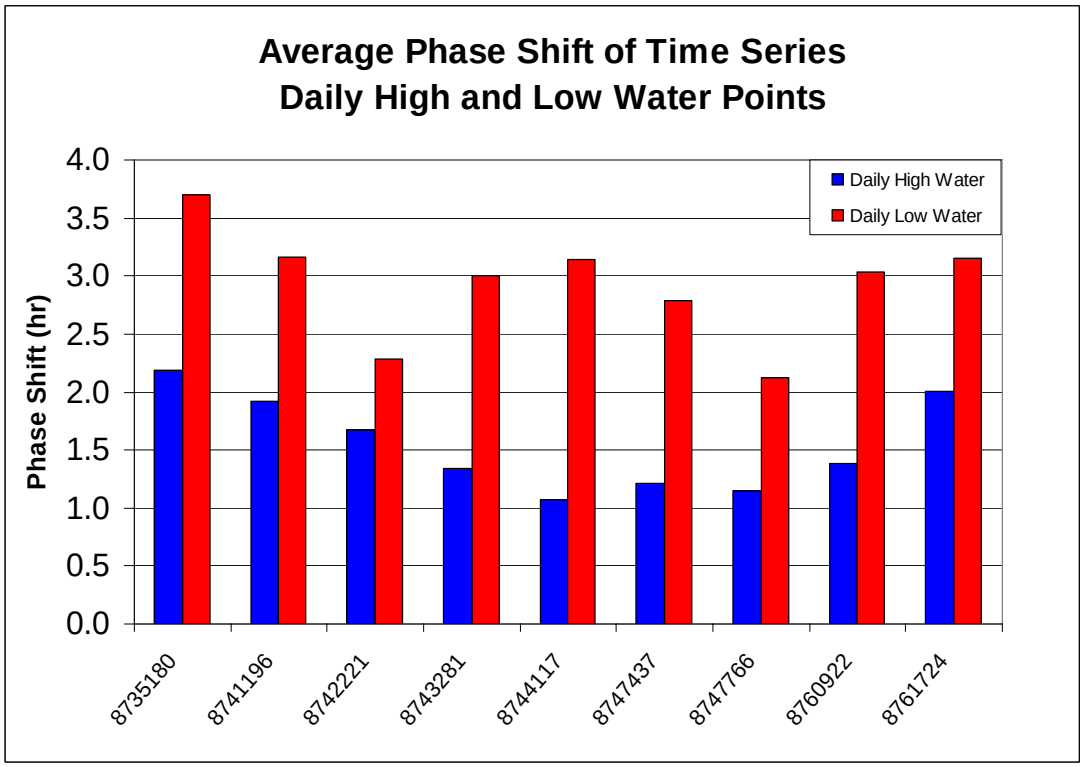


Figure 5.11. Average phase shift at the daily high-water and low-water points of the water level time series for the 9 stations shown in Figures 5.1 through 5.9.

Table 5.1. Station information and harmonic constituent data from NOAA and the ADCIRC model output.

Station ID	Station Name	Station Longitude (deg)	Station Latitude (deg)	Model Amp (m)	Model Phase (deg)	NOAA Amp (m)	NOAA Phase (deg)	Constituent Name
8723962	Key Colony Beach, FL	-80.016667	24.718333	0.0624	339.54	0.0650	337.60	K1
				0.0711	349.07	0.0720	338.80	O1
				0.2211	35.64	0.2430	41.00	M2
				0.0613	59.79	0.0590	66.30	S2
				0.0459	18.36	0.0520	22.90	N2
				0.0150	60.32	0.0160	64.70	K2
				0.0158	337.01	0.0180	326.40	Q1
8724580	Key West, FL	-81.808333	24.553333	0.0846	352.78	0.0900	356.10	K1
				0.0907	359.96	0.0940	352.20	O1
				0.1832	51.00	0.1860	66.90	M2
				0.0623	72.08	0.0520	88.20	S2
				0.0343	35.46	0.0370	48.30	N2
				0.0150	69.85	0.0150	92.40	K2
				0.0200	347.13	0.0230	342.10	Q1
8725110	Naples, FL	-81.80667	26.130000	0.1477	7.01	0.1580	9.90	K1
				0.1431	11.73	0.1430	2.80	O1
				0.2929	123.63	0.2860	144.20	M2
				0.1164	134.45	0.0960	156.10	S2
				0.0498	112.77	0.0570	130.60	N2
				0.0272	130.96	0.0270	149.40	K2
				0.0295	359.24	0.0300	349.40	Q1
8726724	Clearwater Beach, FL	-82.831667	27.978333	0.1605	8.91	0.1580	12.40	K1
				0.1515	13.42	0.1510	3.60	O1
				0.2542	128.97	0.2460	123.10	M2
				0.1127	138.50	0.0960	141.00	S2
				0.0433	119.65	0.0460	120.30	N2
				0.0270	129.90	0.0270	134.60	K2
				0.0312	359.95	0.0320	348.00	Q1
8727520	Cedar Key, FL	-83.031667	29.130000	0.1860	27.52	0.1770	34.60	K1
				0.1726	30.01	0.1630	27.60	O1
				0.4053	185.69	0.3860	189.50	M2
				0.1733	203.84	0.1350	218.10	S2
				0.0619	177.10	0.0620	185.30	N2
				0.0365	194.57	0.0420	211.40	K2
				0.0343	20.20	0.0330	12.10	Q1

Table 5.1. Continued

Station ID	Station Name	Station Longitude (deg)	Station Latitude (deg)	Model Amp (m)	Model Phase (deg)	NOAA Amp (m)	NOAA Phase (deg)	Constituent Name
8728130	St. Mark's Lighthouse, FL	-84.178333	30.073333	0.1896	34.90	0.1730	30.80	K1
				0.1762	36.02	0.1530	27.60	O1
				0.3739	213.51	0.3560	197.90	M2
				0.1597	232.84	0.1480	224.80	S2
				0.0583	202.65	0.0660	193.50	N2
				0.0334	227.54	0.0380	212.30	K2
				0.0354	25.14	0.0420	11.80	Q1
8728360	Turkey Point, FL	-84.511267	29.915000	0.1732	30.60	0.1720	29.80	K1
				0.1613	32.08	0.1570	24.00	O1
				0.2614	210.38	0.2560	200.30	M2
				0.1090	227.50	0.0960	221.80	S2
				0.0422	195.73	0.0480	190.10	N2
				0.0241	217.69	0.0320	232.80	K2
				0.0324	18.42	0.0380	1.90	Q1
8729678	Navarre Beach, FL	-86.865000	30.376667	0.1514	17.50	0.1420	19.10	K1
				0.1485	20.08	0.1370	10.70	O1
				0.0271	86.53	0.0320	90.30	M2
				0.0159	81.14	0.0160	97.30	S2
				0.0058	96.08	0.0060	105.60	N2
				0.0049	80.47	0.0040	97.20	K2
				0.0305	4.27	0.0300	357.80	Q1
8735180	Dauphin Island, AL	-88.075000	30.250000	0.1511	37.62	0.1410	50.60	K1
				0.1463	38.98	0.1380	41.90	O1
				0.0209	133.03	0.0150	132.50	M2
				0.0116	138.46	0.0070	117.30	S2
				0.0040	152.92	0.0000	0.00	N2
				0.0038	80.36	0.0050	222.80	K2
				0.0302	23.62	0.0300	26.60	Q1
8741196	Pascagoula Point, MS	-88.533333	30.340000	0.1668	28.32	0.1440	33.80	K1
				0.1593	30.11	0.1550	28.30	O1
				0.0283	124.06	0.0290	142.00	M2
				0.0189	121.49	0.0150	163.50	S2
				0.0061	140.71	0.0090	202.80	N2
				0.0038	120.09	0.0040	165.30	K2
				0.0326	14.27	0.0300	25.60	Q1

Table 5.1. Continued

Station ID	Station Name	Station Longitude (deg)	Station Latitude (deg)	Model Amp (m)	Model Phase (deg)	NOAA Amp (m)	NOAA Phase (deg)	Constituent Name
8741533	Pascagoula NOAA Lab, MS	-88.566667	30.358333	0.1644	30.55	0.1940	40.80	K1
				0.1570	32.24	0.1490	31.80	O1
				0.0276	129.16	0.0280	147.30	M2
				0.0188	125.39	0.0140	151.60	S2
				0.0062	146.63	0.0060	175.00	N2
				0.0036	129.80	0.0080	146.90	K2
				0.0321	16.33	0.0400	7.90	Q1
8742221	Horn Island, MS	-88.666667	30.238333	0.1698	31.40	0.1590	38.30	K1
				0.1619	32.79	0.1620	26.80	O1
				0.0280	131.70	0.0330	135.50	M2
				0.0192	129.56	0.0200	185.50	S2
				0.0061	148.97	0.0010	246.40	N2
				0.0035	125.73	0.0050	189.60	K2
				0.0330	16.83	0.0310	21.10	Q1
8743281	Ocean Springs, MS	-88.798333	30.391667	0.1599	45.92	0.1480	49.10	K1
				0.1519	46.92	0.1670	38.00	O1
				0.0206	136.61	0.0310	181.90	M2
				0.0179	156.69	0.0150	185.20	S2
				0.0038	171.08	0.0090	160.40	N2
				0.0041	48.64	0.0040	185.50	K2
				0.0309	31.01	0.0320	32.40	Q1
8744117	Biloxi, MS	-88.903333	30.411667	0.1580	50.41	0.1620	51.50	K1
				0.1500	51.14	0.1690	39.80	O1
				0.0200	160.44	0.0390	175.70	M2
				0.0178	165.74	0.0330	216.00	S2
				0.0047	193.31	0.0110	237.10	N2
				0.0014	29.09	0.0090	219.30	K2
				0.0308	35.39	0.0330	33.90	Q1
8745557	Gulfport Harbor, MS	-89.081667	30.360000	0.1711	41.44	0.1340	40.90	K1
				0.1618	42.05	0.1610	31.20	O1
				0.0260	154.02	0.0380	163.40	M2
				0.0195	153.57	0.0170	161.40	S2
				0.0057	175.21	0.0120	212.00	N2
				0.0022	132.02	0.0050	161.20	K2
				0.0330	26.04	0.0310	26.40	Q1

Table 5.1. Continued

Station ID	Station Name	Station Longitude (deg)	Station Latitude (deg)	Model Amp (m)	Model Phase (deg)	NOAA Amp (m)	NOAA Phase (deg)	Constituent Name
8747437	Bay Waveland Yacht Club, MS	-89.325000	30.325000	0.1430	66.65	0.1740	63.70	K1
				0.1348	66.22	0.1670	49.60	O1
				0.0181	185.50	0.0310	213.20	M2
				0.0149	195.68	0.0260	225.00	S2
				0.0040	217.96	0.0070	240.10	N2
				0.0024	90.50	0.0130	210.50	K2
				0.0279	50.21	0.0370	35.20	Q1
8747766	Waveland, MS	-89.366667	30.281667	0.1392	66.10	0.1900	59.50	K1
				0.1315	65.67	0.1760	48.30	O1
				0.0171	184.16	0.0340	210.70	M2
				0.0139	193.85	0.0280	222.10	S2
				0.0037	215.81	0.0090	228.00	N2
				0.0025	95.99	0.0140	196.10	K2
				0.0272	49.70	0.0420	30.40	Q1
8760551	South Pass, LA	-89.140000	28.990000	0.1453	17.36	0.1390	18.00	K1
				0.1441	20.10	0.1350	10.90	O1
				0.0144	100.31	0.0180	116.30	M2
				0.0087	94.91	0.0110	108.30	S2
				0.0032	109.85	0.0050	137.60	N2
				0.0034	78.41	0.0030	107.60	K2
				0.0296	4.11	0.0300	358.60	Q1
8760922	Pilots Station SW Pass, LA	-89.406667	28.931667	0.1433	17.20	0.1330	20.60	K1
				0.1419	20.08	0.1320	12.00	O1
				0.0114	105.56	0.0170	123.00	M2
				0.0078	101.25	0.0130	105.60	S2
				0.0028	124.06	0.0050	141.80	N2
				0.0029	75.38	0.0030	90.60	K2
				0.0293	4.08	0.0330	357.60	Q1
8760943	SW Pass, LA	-89.418333	28.925000	0.1462	16.51	0.1330	20.60	K1
				0.1447	19.42	0.1320	12.00	O1
				0.0118	111.28	0.0170	123.00	M2
				0.0079	99.82	0.0130	105.50	S2
				0.0031	125.92	0.0050	141.80	N2
				0.0028	85.83	0.0030	90.60	K2
				0.0299	3.37	0.0330	357.60	Q1

Table 5.1. Continued

Station ID	Station Name	Station Longitude (deg)	Station Latitude (deg)	Model Amp (m)	Model Phase (deg)	NOAA Amp (m)	NOAA Phase (deg)	Constituent Name
8761720	Grand Isle, LA	-89.968333	29.255000	0.0983	43.96	0.1160	47.00	K1
				0.0991	46.11	0.1140	40.30	O1
				0.0063	147.11	0.0130	169.40	M2
				0.0036	131.49	0.0000	0.00	S2
				0.0016	158.76	0.0000	0.00	N2
				0.0019	105.52	0.0000	0.00	K2
				0.0207	31.04	0.0240	29.70	Q1
8761724	Grand Isle East Point, LA	-89.956667	29.263333	0.0983	43.96	0.1140	37.40	K1
				0.0991	46.11	0.1140	30.80	O1
				0.0063	147.11	0.0130	163.00	M2
				0.0036	131.49	0.0070	154.60	S2
				0.0016	158.76	0.0050	176.10	N2
				0.0019	105.52	0.0020	153.80	K2
				0.0207	31.04	0.0250	19.20	Q1
8761927	New Canal Station, LA	-90.113333	30.026667	0.0264	206.05	0.0340	181.50	K1
				0.0260	199.45	0.0370	177.50	O1
				0.0018	34.50	0.0010	288.80	M2
				0.0012	57.60	0.0040	16.40	S2
				0.0004	69.21	0.0010	58.20	N2
				0.0006	293.32	0.0010	23.50	K2
				0.0059	182.46	0.0070	175.50	Q1
8762075	Port Fourchon, LA	-90.200000	29.115000	0.1496	18.69	0.1320	30.30	K1
				0.1475	21.59	0.1290	22.70	O1
				0.0139	147.51	0.0180	174.60	M2
				0.0074	119.98	0.0080	170.50	S2
				0.0042	148.10	0.0060	178.30	N2
				0.0035	115.80	0.0010	122.80	K2
				0.0303	5.45	0.0270	1.60	Q1
8762372	East Bank, LA	-90.368333	30.050000	0.0212	227.53	0.0330	195.50	K1
				0.0215	221.63	0.0310	181.20	O1
				0.0032	358.09	0.0010	21.70	M2
				0.0007	88.07	0.0020	51.20	S2
				0.0001	314.46	0.0010	337.20	N2
				0.0014	357.95	0.0020	69.30	K2
				0.0053	205.41	0.0060	165.10	Q1

Table 5.1. Continued

Station ID	Station Name	Station Longitude (deg)	Station Latitude (deg)	Model Amp (m)	Model Phase (deg)	NOAA Amp (m)	NOAA Phase (deg)	Constituent Name
8762482	West Bank, LA	-90.418333	29.776667	0.0125	219.60	0.0070	232.40	K1
				0.0132	213.93	0.0080	211.00	O1
				0.0008	352.10	0.0010	330.70	M2
				0.0002	37.46	0.0020	295.60	S2
				0.0001	335.44	0.0000	0.00	N2
				0.0002	350.74	0.0000	0.00	K2
				0.0030	196.38	0.0020	197.20	Q1
8764025	Stouts Pass at Six Mile Lake, LA	-91.230000	29.743333	0.1358	63.21	0.0790	77.30	K1
				0.1252	63.59	0.0760	75.90	O1
				0.0656	340.01	0.0490	18.00	M2
				0.0254	325.73	0.0230	16.90	S2
				0.0140	322.73	0.0160	352.50	N2
				0.0082	86.28	0.0060	16.80	K2
				0.0261	50.65	0.0150	75.20	Q1
8764044	Tesoro Marine Terminal, LA	-91.236667	29.666667	0.1578	54.59	0.0370	78.90	K1
				0.1456	55.58	0.0370	67.20	O1
				0.0785	323.92	0.0240	358.10	M2
				0.0306	311.84	0.0090	333.30	S2
				0.0166	307.37	0.0060	343.70	N2
				0.0088	76.21	0.0040	332.20	K2
				0.0302	42.87	0.0070	50.20	Q1
8764227	Amerada Pass, LA	-91.338333	29.448333	0.1635	42.61	0.1300	44.10	K1
				0.1534	44.81	0.1230	32.90	O1
				0.0705	295.20	0.0920	284.80	M2
				0.0289	284.02	0.0360	295.90	S2
				0.0152	280.13	0.0270	269.90	N2
				0.0059	56.95	0.0040	299.70	K2
				0.0317	31.79	0.0290	17.80	Q1
8764311	Eugene Island, LA	-91.385000	29.371667	0.1676	33.78	0.1570	28.50	K1
				0.1583	36.49	0.1480	20.30	O1
				0.0681	274.40	0.1020	256.80	M2
				0.0284	266.26	0.0360	254.20	S2
				0.0145	258.58	0.0360	209.20	N2
				0.0027	67.54	0.0100	254.00	K2
				0.0326	22.79	0.0290	16.20	Q1

Table 5.1. Continued

Station ID	Station Name	Station Longitude (deg)	Station Latitude (deg)	Model Amp (m)	Model Phase (deg)	NOAA Amp (m)	NOAA Phase (deg)	Constituent Name
8768094	Calcasieu Pass, LA	-93.343333	29.765000	0.1801	25.01	0.1400	29.60	K1
				0.1688	27.37	0.1270	22.40	O1
				0.1340	270.24	0.1430	253.40	M2
				0.0560	269.45	0.0440	236.00	S2
				0.0261	250.68	0.0380	237.10	N2
				0.0106	258.12	0.0110	289.00	K2
				0.0338	11.66	0.0280	11.80	Q1
8771510	Galveston Pleasure Pier, TX	-94.788300	29.285000	0.1764	27.29	0.1710	28.00	K1
				0.1679	28.90	0.1610	20.30	O1
				0.1106	285.66	0.1390	276.10	M2
				0.0458	286.20	0.0340	267.90	S2
				0.0216	267.08	0.0360	254.60	N2
				0.0086	276.72	0.0060	275.60	K2
				0.0338	12.22	0.0360	7.00	Q1
8775870	Corpus Christi, TX	-97.216667	27.580000	0.1670	23.01	0.1600	24.50	K1
				0.1645	25.48	0.1620	16.80	O1
				0.0691	270.30	0.0830	260.10	M2
				0.0273	269.17	0.0220	269.30	S2
				0.0137	255.61	0.0200	240.70	N2
				0.0059	256.47	0.0060	266.90	K2
				0.0337	8.26	0.0370	0.70	Q1
8779770	Port Isabel Laguna Madre, TX	-97.215000	26.060000	0.1625	22.56	0.1370	39.50	K1
				0.1606	25.38	0.1370	31.80	O1
				0.0643	267.54	0.0620	277.40	M2
				0.0253	265.68	0.0190	289.50	S2
				0.0130	253.41	0.0140	260.80	N2
				0.0056	252.74	0.0050	289.40	K2
				0.0330	8.17	0.0300	24.10	Q1

Figure 5.12. RMS Error for the amplitude of the K_1 and M_2 constituents, by State. The Error in Alabama is not an RMS error, but the difference (in centimeters) between the model results and the NOAA data at the one station in that State.

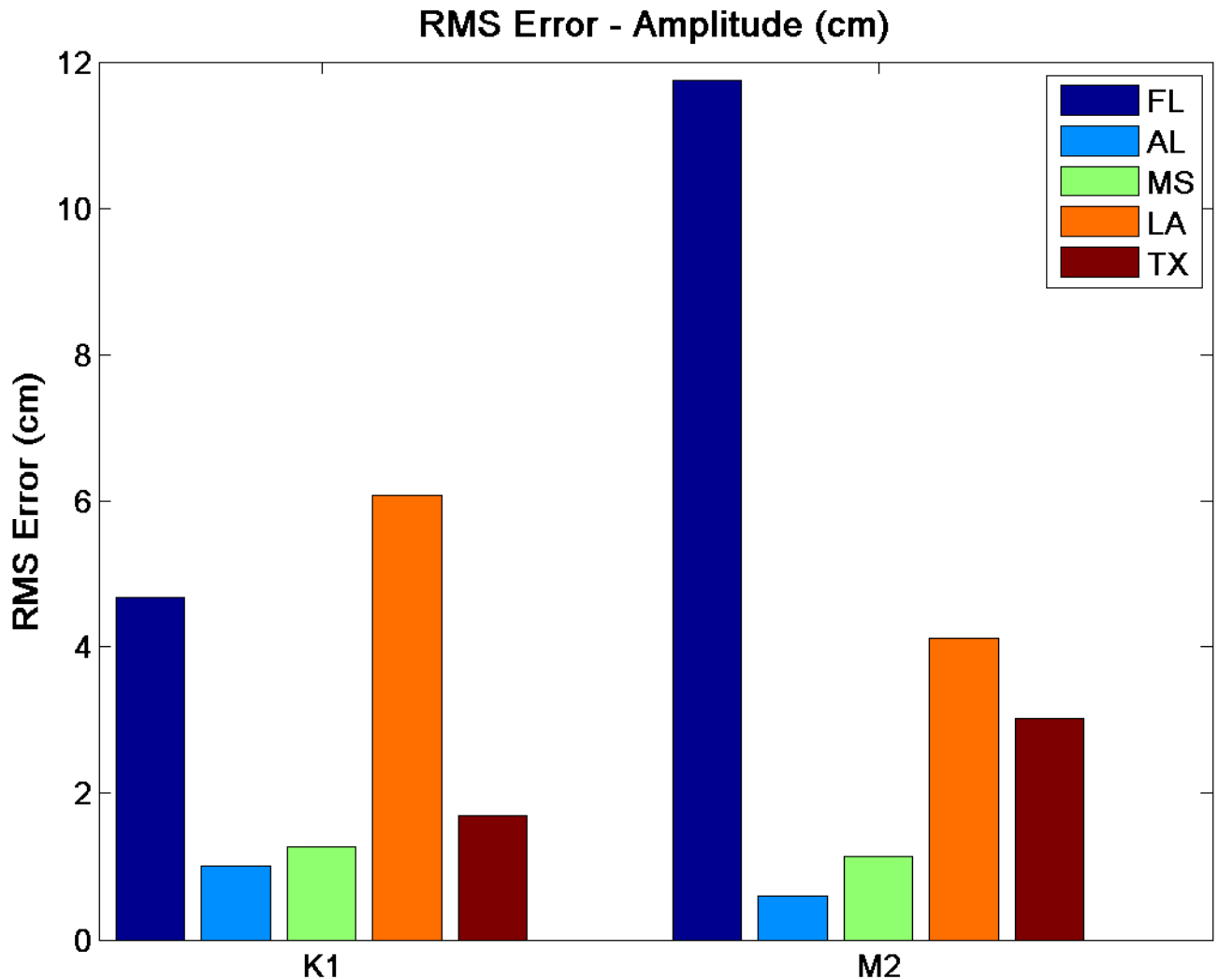
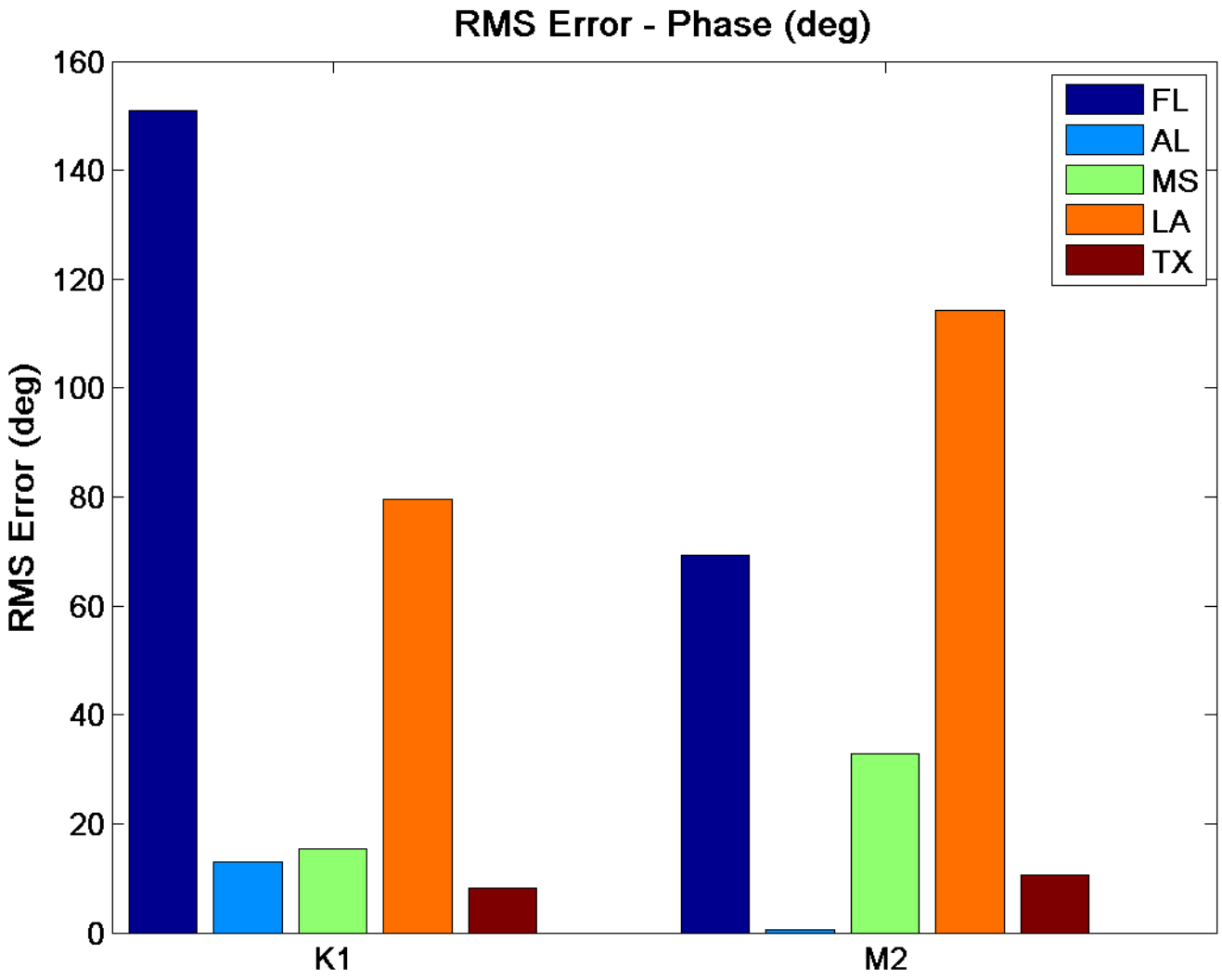


Figure 5.13. RMS Error for the phase of the K_1 and M_2 constituents, by State. The Error in Alabama is not an RMS error, but the difference (in centimeters) between the model results and the NOAA data at the one station in that State.



While the Guidelines and Specifications for Flood Hazard Mapping Partners Appendix D does not provide any specific parameters for determining the quality of a tide simulation, we believe that the above comparisons to recorded data demonstrate a good fit between the ADCIRC tide model of coastal Mississippi and the data. A visual inspection of the nine time series figures (5.1 through 5.9) shows a close match between the model and recorded data in AL, MS, and LA. The RMS error in Mississippi between the high and low water points and the measured data high and low water marks is less than 16 cm (Figure 5.10). The RMS error for the phase shift at these peaks and troughs between the model results and the measured data is less than 4 degrees (Figure 5.11). Low RMS errors in MS (compared to higher errors in FL and LA) demonstrate a high level of accuracy in the study area (Figures 5.12 and 5.13). In conclusion, the ADCIRC model and grid effectively represent the hydraulic character of the study area and can be used to predict hydraulic flow and water surface elevations under low flow conditions.