

# SMAST Technical Report 09-0207

## Project: Transient Tidal Eddies **Model Configuration and Sensitivity**

Gustavo Mastrococco Marques & Wendell S. Brown

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## Abstract

This report presents a bottom friction sensitivity study for the fine-element coastal ocean circulation model (QUODDY) in the context of the Transient Tidal Eddy Project. A detailed description of the model's configuration is also presented. Three different model's simulations, with varying bottom friction values, are analyzed based on tidal analyzes for the most important tidal constituents in the region (M2, S2, N2, K1, O1). In terms of the whole model domain, the results suggest that the semi-diurnal constituents are sensible to bottom friction values while the diurnal constituents are less sensible to this parameter. In general simulation 08 (where  $C_d=0.005$ ) produced the most reliable tidal sea level with respect to the entire model's domain.

## 1 Introduction

In this report tidal elevation analysis in terms of ( $M_2$ ,  $S_2$ ,  $N_2$ ,  $K_1$  and  $O_1$ ) for three different model's simulations, with different bottom friction values, are presented. A description of the procedures done to implement the new boundary conditions (elevation and velocity) on the GHSD mesh (Figure 1) is also presented. It is important to mention that we have modified the old model configuration that was used by Fan et al. (2001) and Brown and Yu (2006) and was originally developed by Holboke (1998). The former application involved wind forcing and baroclinic variability and thus employed a radiating boundary condition. Since our purpose is barotropic modeling forced by the five most important tidal constituents for the Gulf of Maine, the radiational boundary condition is not necessary.

The goal of this report is to define QUODDY4 bottom friction value that will lead to the best simulation of the observed Gulf of Maine tidal sea level variability. The report consists of 1) a short description of the numerical model QUODDY4; 2) the boundary conditions that were implemented; 3) a sensitivity study of different bottom drag values.

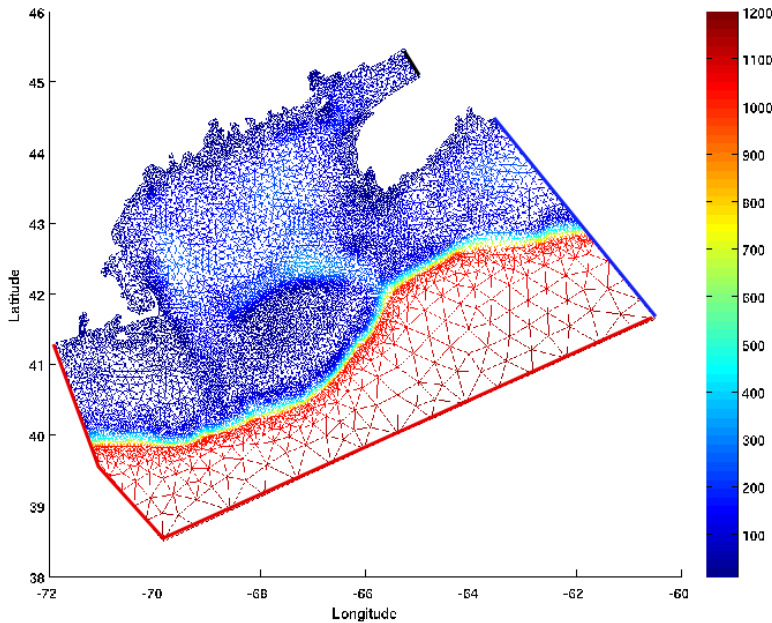


Figure 1: The Holboke (1998) GHSD mesh for the QUODDY model domain, with the open ocean boundaries - (a) deep ocean, (b) western cross-shelf, (c) Halifax cross-shelf, and (d) Bay of Fundy - highlighted by the thick red, blue and black lines respectively. The water depths (in meters) are color-coded according to the scale on the right.

## 2 Numerical Model

### 2.1 Model Description

The finite element numerical circulation model, called QUODDY used here was developed at Dartmouth College's Thayer School of Engineering (Lynch et al. 1996). QUODDY is a three-dimension, non-linear, prognostic, f-plane, finite-element coastal ocean circulation model. This model uses the Mellor-Yamada level 2.5 turbulent closure model (MY25) in the vertical with a linearized partial-slip condition enforced at the bottom. The horizontal viscosity can be either uniform or velocity and mesh-size dependent. A complete description of this model can be found in Lynch et al. (1996). The QUODDY model domain used is defined by the the Holboke (1998) GHSD mesh (Figure 1). The resolution of this mesh varies from about 10 km in the gulf to about 5 km near the coastlines with even finer resolution in the regions of steep bathymetric slopes like the north flank Georges

Bank. A 10 meters minimum depth was adopted for the coastal boundary elements.

## 2.2 Model Operation

The barotropic QUODDY model simulations were initialized with zero velocity and elevation fields for this application, which employed a constant homogeneous water density. The calculations were performed in the GHSD mesh (Figure 1) and a detailed specification of the boundary conditions is presented in the following section. Each prescribed ( $M_2$ ,  $S_2$ ,  $N_2$ ,  $K_1$  and  $O_1$ ) tidal sea level forcing was linearly increased (i.e. ramped-up) to full forcing during the first six  $M_2$  tidal cycles. The initial “rest-state” was applied so that the model nonlinearities and advection could dynamically adjust to the initial fields (Holboke 1998). Holboke (1998) has shown that QUODDY reaches dynamical equilibrium after six tidal cycles. After ramp-up, the model was run with a 21.83203125 second (= the 12.42-hour  $M_2$  tidal period/2048) time-step between 27 June to 8 August 1999. There were used 21 sigma layers in the vertical. In this application, the Mellor-Yamada level 2.5 turbulent closure model (MY25) was used in the vertical, while a velocity-dependent method was used to calculate horizontal viscosity. The bottom flow  $V_b$  was subject to quadratic bottom boundary stress, according to  $C_d|V_b^2$ , where the time/space constant bottom drag coefficient  $C_d$  varied for each experiment as described in the following section.

## 2.3 Boundary Conditions

It is important to mention that the old model configuration that was being used at the OCEANOL laboratory, which was originally developed by Holboke (1998), has been modified. First, the depth values of two nodes located in the Bay of Fundy have been modified from 12.94 to 21.31 (node 878) and 12.83 to 21.31 (node 8787). This was done because the 5-constituents 30 days simulations were ending after 25 days of simulation due to negative depth at those nodes. Second, in the model former configuration there was a Radiation Boundary Condition (RBC) which is necessary when using baroclinic mode or

wind forcing. For example, if tides were known for a specific region then it is possible to externally force with tides and allow for internally generated waves (i.e. from wind) to move out through the boundary without sacrificing the tidal boundary forcing. However, this method requires a user-specified external component of the solution which includes the tidal and residual components (Holboke 1998). Since our purpose, at this level, is to force the model using just the five most important tidal constituents (M2, S2, k1, N2 and O1) the radiation boundary condition was removed in order to simplify the operations. The last modification that was done in the code is with regarding to the normal transport used as boundary conditions. Normal flow conditions are utilized for boundaries that cut across some type of embayment (i.e. black line on Figure 1). In the way the model was previously configured, the user provided the normal transport (mean normal velocity times depth) for a specific tidal constituent directly as a boundary condition. This transport could be calculated as following: a) obtain velocity components (amplitudes and phases for u and v) from FUNDY6 calculations (see FUNDY6 description below); b) use these velocities and the model's grid information to calculate the respective normal velocity and phase at each node (note this is similar to use a curvilinear system where s is the streamwise depth-averaged flow direction and n is the direction perpendicular to the flow, where  $v_n$  is zero by definition) and c) multiply the normal velocity by depth to obtain normal transport. These normal flow boundary values were then imposed on the velocity solution at those nodes. The code was then modified so the user just provides the depth-averaged velocities (item a described above) and the respective normal transport is then calculated inside the code. This results in an easier and faster boundary conditions implementation.

### **2.3.1 Tidal Elevations**

The predicted semidiurnal (M2, N2 and S2) and diurnal (K1 and O1) tidal elevations were used to force QUODDY at the deep ocean and western cross-shelf sections (red line; Figure 1). These forcing tidal elevations were calculated using the EastCoast 2001

tidal constituent database by Mukai et al. (2002), which is based on the ADvanced CIRCulation (ADCIRC) finite element hydrodynamic numerical model simulations. The EastCoast 2001 grid resolution varies from 1 to 4 km along the land boundaries to a maximum of 25 Km in the deep ocean. For this ADCIRC application the computed harmonics constants compare to within 6 to 13 percent to measured amplitude data; to within 7 to 13 degree to measured phase data on a globally averaged basis (Mukai et al. 2002). The EastCoast 2001 tidal database comes with a FORTRAN code that extract the tidal information for the set of user-specified coordinates.

### 2.3.2 Normal Transports

The predicted  $M_2$ ,  $M_4$ ,  $M_6$ ,  $N_2$ ,  $S_2$ ,  $K_1$  and  $O_1$  depth-averaged velocities were calculated for the GHSD mesh using a 3-D linear, finite element diagnostic (Lynch et al. (1996), referred to as FUNDY6). The FUNDY6 calculations were performed in the GHSD mesh (Figure 1). Solutions are obtained in the frequency domain with the limit of zero frequency representing the steady state. FUNDY6 was forced with tidal elevations from the EastCoast 2001 tidal database along the entire boundary (lines black, blue and red on Figure 1). Individual FUNDY6 simulations were conducted for each of the seven tidal constituents listed above and the depth-averaged velocities (amplitudes and phases for u and v) at the Bay of Fundy section (black line; Figure 1) were then extracted. These velocities were converted to normal transport inside QUODDY's code as previously explained.

## 2.4 Experiments conducted

There were conducted a total set of 10 different experiment located at:

( /gmarques/Tidal\_eddies\_project/Model\_simulations/QUODDY4)

(Note: each simulation had a specific purpose which can be found in the respective README files located at each simulation's directory). The simulations presented here

Table 1: Description of the numerical simulations that were conducted in order to examine the model’s sensitivity regarding bottom drag coefficient ( $C_d$ ).

Simulation #	$C_d$
08	0.005
09	0.0025
10	0.03

aimed to provide a sensitivity study regarding bottom drag coefficient. Table (1) summarizes these experiments. The bottom drag coefficient was variable; (0.005; simulation 08), (0.0025; simulation 09) and (0.03; simulation 10). These values were chosen based on the previous work conducted by Fan et al. (2001). Although these authors have found that a variety of realistic Cd values did not improve model results significantly, their simulations were forced only with M2 while the present study uses seven tidal constituents, as mentioned before..

### 3 Results

The sea level results of the simulations were compared at 49 model’s nodes to the corresponding Moody et al. (1984) results based on observations (Figure 2) (Tables 3 to 17 See Appendix A). Table (2) presents a comparison between the experiments where averages and standard deviations for the amplitude percentage error and phase, based on the 49 nodes nodes, are presented.

There are some valuable conclusions that we can extract from this table: 1) the diurnal constituents (K1 and O1) are not very sensitive to changes in bottom friction as the three simulations have similar values in terms of sea level amplitude and phase (see last two lines on Table 2); 2) simulation 08 ( $C_d=0.005$ ) is far the one that best represents M2 (both amplitude and phase) and S2 (phase); 3) simulation 09 is the one that best represents N2 (both amplitude and phase) and S2 (amplitude). However, in general, simulation 08

produced the most reliable tidal sea level.

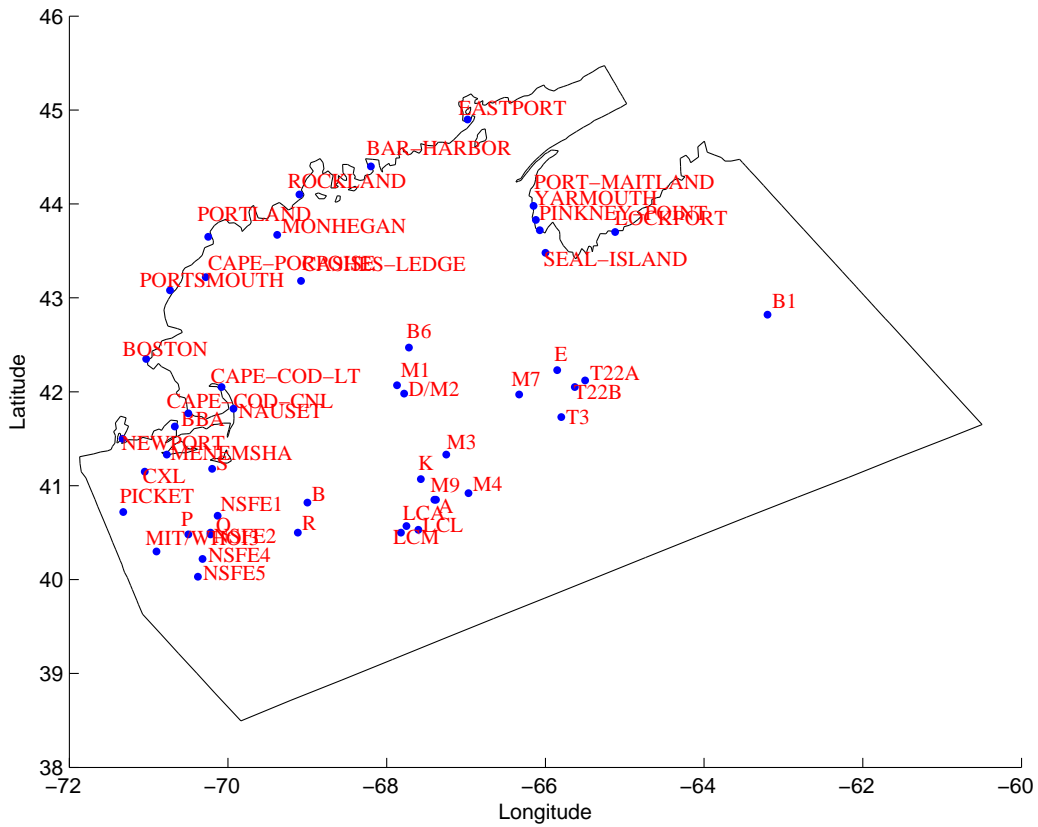


Figure 2: Location map for tidal sea level pressure observation sites (Moody et al., 1984) used for the model-observation comparison studies.

Table 2: Comparison between the three simulations based on averages and standard deviations for the amplitude % error and phase

	Simulation 08 Cd=0.005				Simulation 09 Cd=0.0025				Simulation 10 Cd=0.03			
	Amp. % Error		Phase		Amp. % Error		Phase		Amp. % Error		Phase	
	Ave.	Std.	Ave.	Std.	Ave.	Std.	Ave.	Std.	Ave.	Std.	Ave.	Std.
M2	7.7	8.6	3.5	3.8	17.1	12	7.3	4	23.7	23.4	7.5	6.1
N2	13.6	8.5	12.3	6.0	9.8	6.8	11	5.5	35.7	41.9	13.9	9.8
S2	18.1	7.9	15.1	9.7	21.8	9.9	13.3	9.4	18.6	11.3	18.7	12.6
K1	28.0	18.6	11.2	8.2	27.5	18.6	11.4	8.5	28.1	18.6	10.3	7.3
O1	10.8	9.4	8.9	9.3	11.4	10.2	9.4	10.5	10.7	8.0	7.8	7.7

## References

- Brown, W. and Z. Yu (2006). Codar measurement and model simulation of transient tidal eddies in the western gulf of maine. Technical Report 06-0503, SMAST, <http://www.smast.umassd.edu/OCEANOL/reports.php>.
- Fan, Y., W. S. Brown, and C. Naime (2001). Simulations of the gulf of maine storm response subject to surface wave-induced effects on bottom friction. Technical Report 01-03-22, Ocean Process Analysis Laboratory, Institute for the Study of Earth Oceans and Space/Department of Earth Sciences, University of New Hampshire, <http://www.smast.umassd.edu/OCEANOL/reports.php>.
- Holboke, M. (1998). *Variability of the Maine coastal current under Spring Conditions*. Ph. D. thesis, Thayer School of Engineering-Dartmouth College.
- Lynch, D., J. Ip, C. Naimie, and F. Werner (1996). Comprehensive coastal circulation model with application to the gulf of maine. *Cont. Shelf Res.* 16, 875–906.
- Lynch, D., F. Werner, D. Greenberg, and J. Loder (1996). Diagnostic model for baroclinic, wind-driven and tidal circulation in shallow seas. *Cont. Shelf Res.* 12, 37–64.

Moody, J. A., B. Butman, R. Beardsley, W. Boicourt, W. Brown, P. Daifuku, J. Irish, D. Mayer, H. Mofjeld, B. Petrie, S. Ramp, P. Smith, and W. Wright (1984). Atlas of tidal elevation and current observations on the northeast american continental shelf and slope. Technical Report 1611, U.S. Department of the Interior.

Mukai, A., R. Westerink, J. Luettich, and D. Mark (2002). Eastcoast 2001, a tidal constituent database for western north atlantic, gulf of mexico, and caribbean sea. Technical report, Coastal and Hydraulics Laboratory, US Army Corps of Engineers., <http://www.unc.edu/ims/ccats/tides/tides.htm>.

## 4 Appendix A

Table 3: Comparison of observed, model (simulation 08), and model-observed M2 tidal harmonic sea level amplitudes and phases in Greenwich epoch ( $^{\circ}$ ) for the observed stations in Figure 2.

Station	Comparison						
	Observed		Model		Model-Obs		Error
	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	% Amp
B1	0.4820	351.00	0.4908	350.78	0.0088	-0.2225	1.79
LOCKPORT	0.6980	359.00	0.7870	358.01	0.0890	-0.9861	11.31
T22A	0.4580	4.00	0.4754	12.39	0.0174	8.3906	3.66
T22B	0.4420	9.00	0.4576	14.83	0.0156	5.8333	3.41
T3	0.3910	2.00	0.4075	9.37	0.0165	7.3709	4.05
E	0.4520	24.00	0.5002	30.30	0.0482	6.2962	9.64
M1	0.7820	92.00	0.8097	92.50	0.0277	0.5040	3.42
D/M2	0.7650	93.00	0.7707	93.07	0.0057	0.0651	0.74
M7	0.4100	38.00	0.4277	41.39	0.0177	3.3864	4.14
M4	0.3890	1.00	0.3830	2.72	-0.0060	1.7218	1.57
M3	0.3960	22.00	0.3581	28.96	-0.0379	6.9554	10.58
M9	0.3890	6.00	0.3862	8.52	-0.0028	2.5215	0.73
A	0.3890	5.00	0.3854	6.36	-0.0036	1.3648	0.93
K	0.3990	18.00	0.3929	22.95	-0.0061	4.9481	1.55
LCL	0.3940	354.00	0.3879	358.21	-0.0061	4.2089	1.57
LCA	0.3920	358.00	0.3851	1.67	-0.0069	3.6716	1.79
LCM	0.3940	356.00	0.3846	359.31	-0.0094	3.3111	2.44
B	0.2590	47.00	0.2345	51.01	-0.0245	4.0102	10.45
R	0.3140	3.00	0.2937	6.33	-0.0203	3.3302	6.91
S	0.3230	1.00	0.2146	3.90	-0.1084	2.9009	50.51
NSFE1	0.3870	356.00	0.3339	355.01	-0.0531	-0.9853	15.90
Q	0.3870	353.00	0.3609	351.66	-0.0261	-1.3436	7.23
NSFE2	0.4040	354.00	0.3609	351.66	-0.0431	-2.3436	11.94
NSFE4	0.4200	353.00	0.3830	349.64	-0.0370	-3.3588	9.66
NSFE5	0.4190	351.00	0.3924	348.96	-0.0266	-2.0366	6.78
P	0.4160	352.00	0.3792	350.32	-0.0368	-1.6801	9.70
BBA	0.5380	8.00	0.4020	354.56	-0.1360	-13.4414	33.83
MENEMSHA	0.4510	5.00	0.3695	347.13	-0.0815	-17.8701	22.06
MIT/WHOI3	0.4220	347.00	0.4005	348.85	-0.0215	1.8486	5.37
CXL	0.4440	1.00	0.3982	351.52	-0.0458	-9.4840	11.50
PICKET	0.4400	349.00	0.4090	350.22	-0.0310	1.2209	7.58
NEWPORT	0.5130	1.00	0.4647	353.95	-0.0483	-7.0489	10.39
B6	0.8800	87.00	0.8989	85.71	0.0189	-1.2922	2.10
CASHES_LEDGE	1.2000	98.00	1.2645	97.20	0.0645	-0.7954	5.10
MONHEGAN	1.3030	99.00	1.3864	98.17	0.0834	-0.8292	6.02
CAPE_PORPOISE	1.2720	103.00	1.3514	102.77	0.0794	-0.2270	5.88
SEAL_ISLAND	1.2040	52.00	1.3614	49.24	0.1574	-2.7611	11.56
PINKNEY_POINT	1.5540	59.00	1.6119	55.46	0.0579	-3.5428	3.59
YARMOUTH	1.6320	63.00	1.7600	62.26	0.1280	-0.7417	7.27
PORT_MAITLAND	1.8510	66.00	1.9747	67.87	0.1237	1.8714	6.26
EASTPORT	2.6130	99.00	2.7334	98.32	0.1204	-0.6830	4.40
BAR_HARBOR	1.5490	93.00	1.6569	92.53	0.1079	-0.4653	6.51
ROCKLAND	1.5000	98.00	1.5640	97.56	0.0640	-0.4420	4.09
PORTLAND	1.3300	103.00	1.4205	101.95	0.0905	-1.0519	6.37
PORTSMOUTH	1.3030	107.00	1.3595	104.29	0.0565	-2.7069	4.16
BOSTON	1.3450	111.00	1.3910	108.03	0.0460	-2.9674	3.31
CAPE_COD_CNL	1.2440	109.00	1.4378	111.77	0.1938	2.7651	13.48
CAPE_COD_LT	1.1600	113.00	1.1833	112.82	0.0233	-0.1835	1.97
NAUSET	1.0320	102.00	1.0580	116.46	0.0260	14.4579	2.46
Average					0.0512	3.5193	7.7073
STD					0.0453	3.8167	8.5872

Table 4: Comparison of observed, model (simulation 08), and model-observed N2 tidal harmonic sea level amplitudes and phases in Greenwich epoch ( $^{\circ}$ ) for the observed stations in Figure 2.

Station	Comparison						
	Observed		Model		Model-Obs		Error
	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	% Amp
B1	0.1190	329.00	0.1269	339.81	0.0079	10.8055	6.23
LOCKPORT	0.1710	337.00	0.1883	346.03	0.0173	9.0320	9.19
T22A	0.1070	343.00	0.1243	357.95	0.0173	14.9468	13.92
T22B	0.1040	346.00	0.1206	359.75	0.0166	13.7475	13.76
T3	0.1030	341.00	0.1105	355.36	0.0075	14.3614	6.79
E	0.1100	360.00	0.1274	12.23	0.0174	12.2255	13.66
M1	0.1800	63.00	0.1456	75.23	-0.0344	12.2260	23.63
D/M2	0.1860	64.00	0.1390	75.69	-0.0470	11.6875	33.81
M7	0.0970	12.00	0.1097	19.59	0.0127	7.5905	11.58
M4	0.1010	349.00	0.1068	350.30	0.0058	1.3019	5.43
M3	0.1000	354.00	0.1001	7.86	0.0001	13.8560	0.10
M9	0.1070	346.00	0.1087	354.35	0.0017	8.3484	1.56
A	0.0960	344.00	0.1084	352.96	0.0124	8.9596	11.44
K	0.0990	354.00	0.1102	4.29	0.0112	10.2910	10.16
LCL	0.0910	330.00	0.1076	347.58	0.0166	17.5812	15.43
LCA	0.0980	338.00	0.1079	350.04	0.0099	12.0432	9.18
LCM	0.0950	334.00	0.1073	348.51	0.0123	14.5123	11.46
B	0.0750	20.00	0.0729	21.35	-0.0021	1.3540	2.88
R	0.0790	344.00	0.0907	353.88	0.0117	9.8761	12.90
S	0.0910	339.00	0.0836	354.58	-0.0074	15.5824	8.85
NSFE1	0.0940	340.00	0.1041	346.82	0.0101	6.8187	9.70
Q	0.0930	337.00	0.1063	344.43	0.0133	7.4271	12.51
NSFE2	0.0960	338.00	0.1063	344.43	0.0103	6.4271	9.69
NSFE4	0.0970	336.00	0.1078	342.72	0.0108	6.7229	10.02
NSFE5	0.1030	335.00	0.1082	342.10	0.0052	7.0986	4.81
P	0.1030	337.00	0.1089	343.63	0.0059	6.6271	5.42
BBA	0.1380	351.00	0.1276	351.88	-0.0104	0.8766	8.15
MENEMSHA	0.1190	356.00	0.1141	344.60	-0.0049	-11.3952	4.29
MIT/WHOI3	0.1050	327.00	0.1112	342.67	0.0062	15.6662	5.58
CXL	0.1030	334.00	0.1178	347.58	0.0148	13.5776	12.56
PICKET	0.1200	317.00	0.1153	345.47	-0.0047	28.4668	4.08
NEWPORT	0.1240	345.00	0.1347	351.90	0.0107	6.8977	7.94
B6	0.2160	57.00	0.1625	69.28	-0.0535	12.2843	32.92
CASHES_LEDGE	0.2820	66.00	0.2190	81.73	-0.0630	15.7328	28.77
MONHEGAN	0.3030	67.00	0.2378	83.03	-0.0652	16.0347	27.42
CAPE_PORPOISE	0.2920	71.00	0.2308	86.87	-0.0612	15.8681	26.52
SEAL_ISLAND	0.2530	24.00	0.2997	34.17	0.0467	10.1713	15.58
PINKNEY_POINT	0.2990	49.00	0.3468	41.10	0.0478	-7.8995	13.78
YARMOUTH	0.3490	33.00	0.3770	47.99	0.0280	14.9874	7.43
PORT_MAITLAND	0.3870	47.00	0.4205	54.12	0.0335	7.1201	7.97
EASTPORT	0.5430	68.00	0.4830	92.81	-0.0600	24.8131	12.42
BAR_HARBOR	0.3560	60.00	0.2845	80.76	-0.0715	20.7629	25.13
ROCKLAND	0.3300	65.00	0.2665	83.76	-0.0635	18.7570	23.83
PORTLAND	0.2960	73.00	0.2421	86.39	-0.0539	13.3932	22.26
PORTSMOUTH	0.2780	76.00	0.2316	88.21	-0.0464	12.2112	20.03
BOSTON	0.3010	82.00	0.2360	91.64	-0.0650	9.6357	27.54
CAPE_COD_CNL	0.2890	74.00	0.2438	95.27	-0.0452	21.2687	18.54
CAPE_COD_LT	N/A	N/A	-	-	-	-	-
NAUSET	0.2220	70.00	0.1790	98.78	-0.0430	28.7782	24.02
Average					0.0255	12.2510	13.5598
STD					0.0221	6.0358	8.5303

Table 5: Comparison of observed, model (simulation 08), and model-observed S2 tidal harmonic sea level amplitudes and phases in Greenwich epoch ( $^{\circ}$ ) for the observed stations in Figure 2.

Station	Comparison						
	Observed		Model		Model-Obs		Error
	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	% Amp
B1	0.1030	22.00	0.1437	10.14	0.0407	-11.8598	28.32
LOCKPORT	0.1370	29.00	0.2035	20.04	0.0665	-8.9561	32.68
T22A	0.0940	28.00	0.1310	25.24	0.0370	-2.7569	28.24
T22B	0.0890	31.00	0.1267	26.56	0.0377	-4.4371	29.76
T3	0.0820	28.00	0.1180	21.84	0.0360	-6.1594	30.51
E	0.0880	47.00	0.1284	38.75	0.0404	-8.2479	31.46
M1	0.1220	121.00	0.1480	99.86	0.0260	-21.1432	17.57
D/M2	0.1900	162.00	0.1410	99.94	-0.0490	62.1	34.75
M7	0.0860	59.00	0.1089	44.49	0.0229	-14.5103	21.03
M4	0.0840	26.00	0.1099	15.93	0.0259	-10.0660	23.57
M3	0.0980	15.00	0.0999	33.07	0.0019	18.0742	1.90
M9	0.0790	32.00	0.1090	19.35	0.0300	-12.6515	27.52
A	0.0870	27.00	0.1088	17.75	0.0218	-9.2539	20.04
K	0.0860	38.00	0.1073	29.20	0.0213	-8.7997	19.85
LCL	0.0950	19.00	0.1088	11.77	0.0138	-7.2326	12.68
LCA	0.0880	21.00	0.1080	14.00	0.0200	-7.0030	18.52
LCM	0.0920	21.00	0.1077	12.24	0.0157	-8.7594	14.58
B	0.0500	59.00	0.0649	40.40	0.0149	-18.5970	22.96
R	0.0760	21.00	0.0878	14.30	0.0118	-6.6986	13.44
S	0.0780	21.00	0.0808	8.92	0.0028	-12.0845	3.47
NSFE1	0.0890	18.00	0.1012	4.32	0.0122	-13.6767	12.06
Q	0.0870	18.00	0.1042	2.82	0.0172	-15.1806	16.51
NSFE2	0.0870	17.00	0.1042	2.82	0.0172	-14.1806	16.51
NSFE4	0.0920	18.00	0.1058	1.98	0.0138	-16.0247	13.04
NSFE5	0.0910	17.00	0.1063	1.82	0.0153	-15.1814	14.39
P	0.0950	15.00	0.1072	1.93	0.0122	-13.0670	11.38
BBA	0.1160	32.00	0.1295	6.82	0.0135	-25.1837	10.42
MENEMSHA	0.1000	24.00	0.1143	359.82	0.0143	-24.1830	12.51
MIT/WHOI3	0.1010	13.00	0.1103	0.85	0.0093	-12.1488	8.43
CXL	0.0990	0.00	0.1191	2.99	0.0201	2.9930	16.88
PICKET	0.0950	0.00	0.1176	1.56	0.0226	1.5589	19.22
NEWPORT	0.1190	23.00	0.1380	6.95	0.0190	-16.0491	13.77
B6	0.1290	119.00	0.1668	94.76	0.0378	-24.2415	22.66
CASHES_LEDGE	0.1950	126.00	0.2223	108.31	0.0273	-17.6875	12.28
MONHEGAN	0.2110	128.00	0.2405	109.51	0.0295	-18.4912	12.27
CAPE_PORPOISE	0.2030	134.00	0.2349	113.10	0.0319	-20.8976	13.58
SEAL_ISLAND	0.2100	86.00	0.2773	68.21	0.0673	-17.7867	24.27
PINKNEY_POINT	0.2350	92.00	0.3161	76.47	0.0811	-15.5330	25.66
YARMOUTH	0.2690	97.00	0.3376	84.14	0.0686	-12.8636	20.32
PORT_MAITLAND	0.2970	101.00	0.3713	91.41	0.0743	-9.5946	20.01
EASTPORT	0.4350	137.00	0.4548	130.72	0.0198	-6.2751	4.35
BAR_HARBOR	0.2530	127.00	0.2771	109.66	0.0241	-17.3428	8.70
ROCKLAND	0.1950	133.00	0.2673	110.88	0.0723	-22.1242	27.05
PORTLAND	0.2170	138.00	0.2464	112.70	0.0294	-25.2953	11.93
PORTSMOUTH	0.2030	143.00	0.2362	114.40	0.0332	-28.5984	14.06
BOSTON	0.2190	146.00	0.2422	117.93	0.0232	-28.0700	9.58
CAPE_COD_CNL	0.1990	144.00	0.2510	121.89	0.0520	-22.1141	20.72
CAPE_COD_LT	N/A	N/A	-	-	-	-	-
NAUSET	0.1440	133.00	0.1797	124.83	0.0357	-8.1732	19.87
Average					0.0298	15.0814	18.0267
STD					0.0194	9.7349	7.8578

Table 6: Comparison of observed, model (simulation 08), and model-observed K1 tidal harmonic sea level amplitudes and phases in Greenwich epoch ( $^{\circ}$ ) for the observed stations in Figure 2.

Station	Comparison						
	Observed		Model		Model-Obs		Error
	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	% Amp
B1	0.0690	173.00	0.0586	147.62	-0.0104	-25.3786	17.75
LOCKPORT	0.1280	147.00	0.1102	165.92	-0.0178	18.9178	16.15
T22A	0.0710	167.00	0.0844	165.22	0.0134	-1.7753	15.88
T22B	0.0730	169.00	0.0824	166.73	0.0094	-2.2747	11.41
T3	0.0710	170.00	0.0778	168.17	0.0068	-1.8254	8.74
E	0.0840	172.00	0.0808	169.00	-0.0032	-3.0020	3.96
M1	0.1120	199.00	0.0732	184.89	-0.0388	-14.1051	53.01
D/M2	0.1070	197.00	0.0724	184.61	-0.0346	-12.3858	47.79
M7	0.0760	182.00	0.0718	170.50	-0.0042	-11.5000	5.85
M4	0.0750	168.00	0.0626	173.43	-0.0124	5.4305	19.81
M3	0.0660	178.00	0.0622	177.30	-0.0038	-0.6991	6.11
M9	0.0720	170.00	0.0592	172.59	-0.0128	2.5939	21.62
A	0.0760	173.00	0.0587	171.03	-0.0173	-1.9717	29.47
K	0.0740	176.00	0.0585	175.97	-0.0155	-0.0306	26.50
LCL	0.0800	171.00	0.0603	165.40	-0.0197	-5.6018	32.67
LCA	0.0780	169.00	0.0593	165.80	-0.0187	-3.2007	31.53
LCM	0.0800	172.00	0.0608	164.53	-0.0192	-7.4700	31.58
B	0.0730	196.00	0.0497	180.02	-0.0233	-15.9827	46.88
R	0.0730	178.00	0.0545	163.33	-0.0185	-14.6695	33.94
S	0.0610	177.00	0.0457	156.67	-0.0153	-20.3273	33.48
NSFE1	0.0650	173.00	0.0604	148.53	-0.0046	-24.4658	7.62
Q	0.0730	173.00	0.0692	154.18	-0.0038	-18.8188	5.49
NSFE2	0.0730	173.00	0.0692	154.18	-0.0038	-18.8188	5.49
NSFE4	0.0810	177.00	0.0767	159.55	-0.0043	-17.4530	5.61
NSFE5	0.0860	175.00	0.0797	162.27	-0.0063	-12.7274	7.90
P	0.0830	177.00	0.0744	158.40	-0.0086	-18.6024	11.56
BBA	0.0660	168.00	0.0676	145.79	0.0016	-22.2096	2.37
MENEMSHA	0.0540	176.00	0.0607	141.30	0.0067	-34.7049	11.04
MIT/WHOI3	0.0830	173.00	0.0774	165.03	-0.0056	-7.9711	7.24
CXL	0.0650	178.00	0.0706	151.64	0.0056	-26.3569	7.93
PICKET	0.0790	167.00	0.0733	162.90	-0.0057	-4.0982	7.78
NEWPORT	0.0620	168.00	0.0756	145.31	0.0136	-22.6879	17.99
B6	0.1080	196.00	0.0774	182.45	-0.0306	-13.5472	39.53
CASHES_LEDGE	0.1250	198.00	0.0860	188.04	-0.0390	-9.9639	45.35
MONHEGAN	0.1360	198.00	0.0903	188.30	-0.0457	-9.7019	50.61
CAPE_PORPOISE	0.1290	204.00	0.0891	190.87	-0.0399	-13.1330	44.78
SEAL_ISLAND	0.1370	179.00	0.0979	177.12	-0.0391	-1.8778	39.94
PINKNEY_POINT	0.1220	184.00	0.1006	179.39	-0.0214	-4.6096	21.27
YARMOUTH	0.1350	182.00	0.1014	181.01	-0.0336	-0.9922	33.14
PORT_MAITLAND	0.1510	183.00	0.1034	183.01	-0.0476	0.0089	46.03
EASTPORT	0.1470	196.00	0.1000	188.57	-0.0470	-7.4277	47.00
BAR_HARBOR	0.1400	196.00	0.0941	184.60	-0.0459	-11.4035	48.78
ROCKLAND	0.1520	201.00	0.0938	187.61	-0.0582	-13.3869	62.05
PORTLAND	0.1390	202.00	0.0911	190.42	-0.0479	-11.5812	52.58
PORTSMOUTH	0.1410	204.00	0.0894	191.67	-0.0516	-12.3287	57.72
BOSTON	0.1400	207.00	0.0895	193.71	-0.0505	-13.2907	56.42
CAPE_COD_CNL	0.1310	206.00	0.0898	195.53	-0.0412	-10.4663	45.88
CAPE_COD_LT	N/A	N/A	-	-	-	-	-
NAUSET	0.1310	201.00	0.0827	196.48	-0.0483	-4.5168	58.40
Average					0.0224	11.1728	27.9506
STD					0.0172	8.2210	18.6418

Table 7: Comparison of observed, model (simulation 08), and model-observed O1 tidal harmonic sea level amplitudes and phases in Greenwich epoch ( $^{\circ}$ ) for the observed stations in Figure 2.

Station	Comparison						
	Observed		Model		Model-Obs		Error
	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	% Amp
B1	0.0570	170.00	0.0419	200.04	-0.0151	30.0400	36.04
LOCKPORT	0.0760	116.00	0.1147	125.50	0.0387	9.4999	33.74
T22A	0.0550	179.00	0.0626	141.64	0.0076	-37.3572	12.14
T22B	0.0540	179.00	0.0637	145.15	0.0097	-33.8519	15.23
T3	0.0580	179.00	0.0648	149.51	0.0068	-29.4946	10.49
E	0.0660	178.00	0.0650	149.09	-0.0010	-28.9086	1.54
M1	0.0850	185.00	0.0922	188.33	0.0072	3.3282	7.81
D/M2	0.0880	186.00	0.0920	189.12	0.0040	3.1242	4.35
M7	0.0650	178.00	0.0575	158.48	-0.0075	-19.5194	13.04
M4	0.0580	185.00	0.0786	163.99	0.0206	-21.0109	26.21
M3	0.0660	179.00	0.0652	165.95	-0.0008	-13.0535	1.23
M9	0.0560	188.00	0.0804	167.46	0.0244	-20.5425	30.35
A	0.0610	179.00	0.0815	169.45	0.0205	-9.5527	25.15
K	0.0620	180.00	0.0780	166.38	0.0160	-13.6193	20.51
LCL	0.0610	180.00	0.0804	175.68	0.0194	-4.3237	24.13
LCA	0.0630	178.00	0.0817	175.36	0.0187	-2.6355	22.89
LCM	0.0620	180.00	0.0802	176.80	0.0182	-3.1990	22.69
B	0.0750	192.00	0.0837	186.73	0.0087	-5.2717	10.39
R	0.0630	185.00	0.0801	186.21	0.0171	1.2093	21.35
S	0.0580	197.00	0.0679	199.95	0.0099	2.9505	14.58
NSFE1	0.0560	190.00	0.0632	196.03	0.0072	6.0341	11.39
Q	0.0590	186.00	0.0602	191.76	0.0012	5.7571	1.99
NSFE2	0.0590	188.00	0.0602	191.76	0.0012	3.7571	1.99
NSFE4	0.0650	185.00	0.0577	185.45	-0.0073	0.4481	12.65
NSFE5	0.0650	183.00	0.0578	180.77	-0.0072	-2.2291	12.46
P	0.0590	185.00	0.0586	185.58	-0.0004	0.5787	0.68
BBA	0.0490	204.00	0.0556	205.26	0.0066	1.2568	11.87
MENEMSHA	0.0600	195.00	0.0559	204.77	-0.0041	9.7684	7.33
MIT/WHOI3	0.0680	178.00	0.0659	178.11	-0.0021	0.1105	3.19
CXL	0.0510	183.00	0.0538	195.58	0.0028	12.5778	5.20
PICKET	0.0530	182.00	0.0596	184.27	0.0066	2.2694	11.07
NEWPORT	0.0490	199.00	0.0493	204.11	0.0003	5.1100	0.61
B6	0.0920	181.00	0.0910	183.03	-0.0010	2.0268	1.10
CASHES_LEDGE	0.1010	186.00	0.1050	184.47	0.0040	-1.5340	3.81
MONHEGAN	0.1030	181.00	0.1097	184.20	0.0067	3.2011	6.11
CAPE_PORPOISE	0.1060	185.00	0.1097	186.85	0.0037	1.8497	3.37
SEAL_ISLAND	0.1040	163.00	0.1083	155.22	0.0043	-7.7815	3.97
PINKNEY_POINT	0.1040	169.00	0.1119	157.10	0.0079	-11.9018	7.06
YARMOUTH	0.1010	164.00	0.1136	159.13	0.0126	-4.8692	11.09
PORT_MAITLAND	0.1100	167.00	0.1179	160.86	0.0079	-6.1414	6.70
EASTPORT	0.1140	177.00	0.1396	181.62	0.0256	4.6209	18.34
BAR_HARBOR	0.1100	174.00	0.1143	180.00	0.0043	6.0048	3.76
ROCKLAND	0.1180	170.00	0.1137	183.21	-0.0043	13.2134	3.78
PORTLAND	0.1110	183.00	0.1117	186.19	0.0007	3.1905	0.63
PORTSMOUTH	0.1120	185.00	0.1105	187.61	-0.0015	2.6087	1.36
BOSTON	0.1110	189.00	0.1117	189.48	0.0007	0.4776	0.63
CAPE_COD_CNL	0.1080	187.00	0.1133	191.18	0.0053	4.1782	4.68
CAPE_COD_LT	N/A	N/A	-	-	-	-	-
NAUSET	0.1150	182.00	0.1048	192.94	-0.0102	10.9366	9.73
Average					0.0087	8.8943	10.8419
STD					0.0081	9.5367	9.4385

Table 8: Comparison of observed, model (simulation 09), and model-observed M2 tidal harmonic sea level amplitudes and phases in Greenwich epoch ( $^{\circ}$ ) for the observed stations in Figure 2.

Station	Comparison						
	Observed		Model		Model-Obs		Error
	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	% Amp
B1	0.4820	351.00	0.4992	350.49	0.0172	-0.5106	3.45
LOCKPORT	0.6980	359.00	0.8379	355.21	0.1399	-3.7907	16.70
T22A	0.4580	4.00	0.5122	13.90	0.0542	9.9026	10.58
T22B	0.4420	9.00	0.4964	16.91	0.0544	7.9082	10.96
T3	0.3910	2.00	0.4288	12.37	0.0378	10.3731	8.82
E	0.4520	24.00	0.5761	31.86	0.1241	7.8609	21.54
M1	0.7820	92.00	1.0220	85.58	0.2400	-6.4244	23.48
D/M2	0.7650	93.00	0.9772	86.04	0.2122	-6.9614	21.72
M7	0.4100	38.00	0.5171	44.34	0.1071	6.3364	20.71
M4	0.3890	1.00	0.3892	5.47	0.0002	4.4650	0.05
M3	0.3960	22.00	0.4114	35.62	0.0154	13.6168	3.74
M9	0.3890	6.00	0.4000	12.11	0.0110	6.1107	2.75
A	0.3890	5.00	0.3960	9.53	0.0070	4.5310	1.77
K	0.3990	18.00	0.4313	27.92	0.0323	9.9237	7.49
LCL	0.3940	354.00	0.3910	359.56	-0.0030	5.5551	0.77
LCA	0.3920	358.00	0.3910	3.71	-0.0010	5.7056	0.26
LCM	0.3940	356.00	0.3888	0.87	-0.0052	4.8736	1.34
B	0.2590	47.00	0.3126	59.18	0.0536	12.1814	17.15
R	0.3140	3.00	0.2994	13.24	-0.0146	10.2357	4.88
S	0.3230	1.00	0.1955	19.07	-0.1275	18.0692	65.22
NSFE1	0.3870	356.00	0.3165	359.68	-0.0705	3.6835	22.27
Q	0.3870	353.00	0.3483	353.95	-0.0387	0.9453	11.11
NSFE2	0.4040	354.00	0.3483	353.95	-0.0557	-0.0547	15.99
NSFE4	0.4200	353.00	0.3769	350.44	-0.0431	-2.5600	11.44
NSFE5	0.4190	351.00	0.3894	349.22	-0.0296	-1.7751	7.60
P	0.4160	352.00	0.3695	351.56	-0.0465	-0.4384	12.58
BBA	0.5380	8.00	0.3653	356.04	-0.1727	-11.9579	47.28
MENEMSHA	0.4510	5.00	0.3387	347.67	-0.1123	-17.3274	33.16
MIT/WHOI3	0.4220	347.00	0.3964	349.09	-0.0256	2.0850	6.46
CXL	0.4440	1.00	0.3789	351.81	-0.0651	-9.1862	17.18
PICKET	0.4400	349.00	0.4038	350.31	-0.0362	1.3141	8.96
NEWPORT	0.5130	1.00	0.4442	352.45	-0.0688	-8.5514	15.49
B6	0.8800	87.00	1.1236	79.40	0.2436	-7.5979	21.68
CASHES_LEDGE	1.2000	98.00	1.5623	89.65	0.3623	-8.3518	23.19
MONHEGAN	1.3030	99.00	1.7099	90.40	0.4069	-8.5992	23.80
CAPE_PORPOISE	1.2720	103.00	1.6731	94.98	0.4011	-8.0189	23.97
SEAL_ISLAND	1.2040	52.00	1.6073	43.72	0.4033	-8.2838	25.09
PINKNEY_POINT	1.5540	59.00	1.9205	48.99	0.3665	-10.0075	19.08
YARMOUTH	1.6320	63.00	2.0906	55.56	0.4586	-7.4378	21.94
PORT_MAITLAND	1.8510	66.00	2.3396	60.66	0.4886	-5.3372	20.88
EASTPORT	2.6130	99.00	3.1583	88.69	0.5453	-10.3129	17.27
BAR_HARBOR	1.5490	93.00	2.0039	84.25	0.4549	-8.7493	22.70
ROCKLAND	1.5000	98.00	1.9168	89.47	0.4168	-8.5344	21.74
PORTLAND	1.3300	103.00	1.7560	94.11	0.4260	-8.8941	24.26
PORTSMOUTH	1.3030	107.00	1.6841	96.47	0.3811	-10.5290	22.63
BOSTON	1.3450	111.00	1.7255	100.12	0.3805	-10.8803	22.05
CAPE_COD_CNL	1.2440	109.00	1.7845	103.75	0.5405	-5.2527	30.29
CAPE_COD_LT	1.1600	113.00	1.4708	104.93	0.3108	-8.0720	21.13
NAUSET	1.0320	102.00	1.3175	108.51	0.2855	6.5136	21.67
Average					0.1815	7.2773	17.0667
STD					0.1776	3.9707	11.9716

Table 9: Comparison of observed, model (simulation 09), and model-observed N2 tidal harmonic sea level amplitudes and phases in Greenwich epoch ( $^{\circ}$ ) for the observed stations in Figure 2.

Station	Comparison						
	Observed		Model		Model-Obs		Error
	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	% Amp
B1	0.1190	329.00	0.1282	339.50	0.0092	10.4998	7.18
LOCKPORT	0.1710	337.00	0.1959	343.61	0.0249	6.6065	12.71
T22A	0.1070	343.00	0.1310	358.82	0.0240	15.8215	18.32
T22B	0.1040	346.00	0.1276	1.03	0.0236	15.0347	18.50
T3	0.1030	341.00	0.1145	357.25	0.0115	16.2497	10.04
E	0.1100	360.00	0.1411	13.47	0.0311	13.4675	22.04
M1	0.1800	63.00	0.1795	69.52	-0.0005	6.5183	0.28
D/M2	0.1860	64.00	0.1721	69.91	-0.0139	5.9094	8.08
M7	0.0970	12.00	0.1256	22.40	0.0286	10.4042	22.77
M4	0.1010	349.00	0.1081	351.91	0.0071	2.9062	6.57
M3	0.1000	354.00	0.1089	12.50	0.0089	18.4962	8.17
M9	0.1070	346.00	0.1113	356.43	0.0043	10.4259	3.86
A	0.0960	344.00	0.1105	354.78	0.0145	10.7780	13.12
K	0.0990	354.00	0.1168	7.41	0.0178	13.4100	15.24
LCL	0.0910	330.00	0.1083	348.32	0.0173	18.3220	15.97
LCA	0.0980	338.00	0.1092	351.17	0.0112	13.1670	10.26
LCM	0.0950	334.00	0.1083	349.36	0.0133	15.3647	12.28
B	0.0750	20.00	0.0856	28.27	0.0106	8.2693	12.38
R	0.0790	344.00	0.0924	357.66	0.0134	13.6613	14.50
S	0.0910	339.00	0.0822	0.48	-0.0088	21.4796	10.71
NSFE1	0.0940	340.00	0.1020	349.38	0.0080	9.3824	7.84
Q	0.0930	337.00	0.1047	345.88	0.0117	8.8776	11.17
NSFE2	0.0960	338.00	0.1047	345.88	0.0087	7.8776	8.31
NSFE4	0.0970	336.00	0.1069	343.30	0.0099	7.3030	9.26
NSFE5	0.1030	335.00	0.1078	342.32	0.0048	7.3170	4.45
P	0.1030	337.00	0.1076	344.49	0.0046	7.4941	4.28
BBA	0.1380	351.00	0.1232	352.83	-0.0148	1.8258	12.01
MENEMSHA	0.1190	356.00	0.1097	345.28	-0.0093	-10.7218	8.48
MIT/WHOI3	0.1050	327.00	0.1106	342.88	0.0056	15.8828	5.06
CXL	0.1030	334.00	0.1150	347.95	0.0120	13.9526	10.43
PICKET	0.1200	317.00	0.1146	345.59	-0.0054	28.5946	4.71
NEWPORT	0.1240	345.00	0.1316	350.99	0.0076	5.9925	5.78
B6	0.2160	57.00	0.1981	64.05	-0.0179	7.0480	9.04
CASHES_LEDGE	0.2820	66.00	0.2657	75.03	-0.0163	9.0295	6.13
MONHEGAN	0.3030	67.00	0.2883	76.05	-0.0147	9.0546	5.10
CAPE_PORPOISE	0.2920	71.00	0.2812	79.95	-0.0108	8.9468	3.84
SEAL_ISLAND	0.2530	24.00	0.3431	29.26	0.0901	5.2636	26.26
PINKNEY_POINT	0.2990	49.00	0.4011	35.13	0.1021	-13.8691	25.45
YARMOUTH	0.3490	33.00	0.4349	41.81	0.0859	8.8092	19.75
PORT_MAITLAND	0.3870	47.00	0.4845	47.31	0.0975	0.3055	20.12
EASTPORT	0.5430	68.00	0.5424	82.88	-0.0006	14.8814	0.11
BAR_HARBOR	0.3560	60.00	0.3375	72.82	-0.0185	12.8205	5.48
ROCKLAND	0.3300	65.00	0.3210	76.23	-0.0090	11.2288	2.80
PORTLAND	0.2960	73.00	0.2946	79.39	-0.0014	6.3852	0.48
PORTSMOUTH	0.2780	76.00	0.2826	81.27	0.0046	5.2704	1.63
BOSTON	0.3010	82.00	0.2889	84.60	-0.0121	2.5975	4.19
CAPE_COD_CNL	0.2890	74.00	0.2984	88.21	0.0094	14.2114	3.15
CAPE_COD_LT	N/A	N/A	-	-	-	-	-
NAUSET	0.2220	70.00	0.2202	91.82	-0.0018	21.8196	0.82
Average					0.0185	10.9074	9.7731
STD					0.0240	5.5245	6.7504

Table 10: Comparison of observed, model (simulation 09), and model-observed S2 tidal harmonic sea level amplitudes and phases in Greenwich epoch ( $^{\circ}$ ) for the observed stations in Figure 2.

Station	Comparison						
	Observed		Model		Model-Obs		Error
	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	% Amp
B1	0.1030	22.00	0.1447	10.41	0.0417	-11.5877	28.82
LOCKPORT	0.1370	29.00	0.2128	20.38	0.0758	-8.6225	35.62
T22A	0.0940	28.00	0.1327	27.50	0.0387	-0.5047	29.16
T22B	0.0890	31.00	0.1280	29.14	0.0390	-1.8555	30.47
T3	0.0820	28.00	0.1175	23.93	0.0355	-4.0740	30.21
E	0.0880	47.00	0.1328	43.09	0.0448	-3.9084	33.73
M1	0.1220	121.00	0.1742	104.84	0.0522	-16.1611	29.97
D/M2	0.1900	162.00	0.1660	105.00	-0.0240	57.01	14.46
M7	0.0860	59.00	0.1126	50.75	0.0266	-8.2534	23.62
M4	0.0840	26.00	0.1084	17.38	0.0244	-8.6169	22.51
M3	0.0980	15.00	0.0985	38.69	0.0005	23.6910	0.51
M9	0.0790	32.00	0.1071	21.63	0.0281	-10.3682	26.24
A	0.0870	27.00	0.1069	19.68	0.0199	-7.3151	18.62
K	0.0860	38.00	0.1055	33.59	0.0195	-4.4073	18.48
LCL	0.0950	19.00	0.1079	12.52	0.0129	-6.4813	11.96
LCA	0.0880	21.00	0.1065	15.19	0.0185	-5.8120	17.37
LCM	0.0920	21.00	0.1066	13.11	0.0146	-7.8895	13.70
B	0.0500	59.00	0.0615	49.59	0.0115	-9.4051	18.70
R	0.0760	21.00	0.0836	16.16	0.0076	-4.8396	9.09
S	0.0780	21.00	0.0713	8.48	-0.0067	-12.5219	9.40
NSFE1	0.0890	18.00	0.0960	4.69	0.0070	-13.3144	7.29
Q	0.0870	18.00	0.1010	2.87	0.0140	-15.1331	13.86
NSFE2	0.0870	17.00	0.1010	2.87	0.0140	-14.1331	13.86
NSFE4	0.0920	18.00	0.1045	1.94	0.0125	-16.0633	11.96
NSFE5	0.0910	17.00	0.1057	1.75	0.0147	-15.2524	13.91
P	0.0950	15.00	0.1049	1.85	0.0099	-13.1542	9.44
BBA	0.1160	32.00	0.1232	4.76	0.0072	-27.2411	5.84
MENEMSHA	0.1000	24.00	0.1096	357.72	0.0096	-26.2789	8.76
MIT/WHOI3	0.1010	13.00	0.1096	0.72	0.0086	-12.2825	7.85
CXL	0.0990	0.00	0.1161	1.80	0.0171	1.8040	14.73
PICKET	0.0950	0.00	0.1168	1.27	0.0218	1.2679	18.66
NEWPORT	0.1190	23.00	0.1359	4.51	0.0169	-18.4896	12.44
B6	0.1290	119.00	0.1959	99.40	0.0669	-19.5964	34.15
CASHES_LEDGE	0.1950	126.00	0.2671	112.35	0.0721	-13.6452	26.99
MONHEGAN	0.2110	128.00	0.2906	113.45	0.0796	-14.5539	27.39
CAPE_PORPOISE	0.2030	134.00	0.2838	117.46	0.0808	-16.5413	28.47
SEAL_ISLAND	0.2100	86.00	0.3158	69.99	0.1058	-16.0113	33.50
PINKNEY_POINT	0.2350	92.00	0.3668	77.42	0.1318	-14.5819	35.93
YARMOUTH	0.2690	97.00	0.3935	84.95	0.1245	-12.0483	31.64
PORT_MAITLAND	0.2970	101.00	0.4364	91.47	0.1394	-9.5291	31.94
EASTPORT	0.4350	137.00	0.5472	126.84	0.1122	-10.1620	20.50
BAR_HARBOR	0.2530	127.00	0.3385	111.36	0.0855	-15.6380	25.26
ROCKLAND	0.1950	133.00	0.3253	113.97	0.1303	-19.0289	40.06
PORTLAND	0.2170	138.00	0.2981	116.89	0.0811	-21.1085	27.21
PORTSMOUTH	0.2030	143.00	0.2853	118.84	0.0823	-24.1575	28.85
BOSTON	0.2190	146.00	0.2929	122.51	0.0739	-23.4923	25.23
CAPE_COD_CNL	0.1990	144.00	0.3036	126.48	0.1046	-17.5225	34.45
CAPE_COD_LT	N/A	N/A	-	-	-	-	-
NAUSET	0.1440	133.00	0.2174	130.15	0.0734	-2.8510	33.76
Average					0.0467	13.2960	21.8035
STD					0.0404	9.3710	9.9528

Table 11: Comparison of observed, model (simulation 09), and model-observed K1 tidal harmonic sea level amplitudes and phases in Greenwich epoch ( $^{\circ}$ ) for the observed stations in Figure 2.

Station	Comparison						
	Observed		Model		Model-Obs		Error
	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	% Amp
B1	0.0690	173.00	0.0587	146.40	-0.0103	-26.6013	17.55
LOCKPORT	0.1280	147.00	0.1101	166.35	-0.0179	19.3533	16.26
T22A	0.0710	167.00	0.0858	165.27	0.0148	-1.7281	17.25
T22B	0.0730	169.00	0.0837	166.70	0.0107	-2.2980	12.78
T3	0.0710	170.00	0.0792	168.31	0.0082	-1.6913	10.35
E	0.0840	172.00	0.0823	168.89	-0.0017	-3.1096	2.07
M1	0.1120	199.00	0.0724	184.48	-0.0396	-14.5237	54.70
D/M2	0.1070	197.00	0.0715	184.13	-0.0355	-12.8690	49.65
M7	0.0760	182.00	0.0737	169.70	-0.0023	-12.2984	3.12
M4	0.0750	168.00	0.0629	174.15	-0.0121	6.1475	19.24
M3	0.0660	178.00	0.0629	176.57	-0.0031	-1.4341	4.93
M9	0.0720	170.00	0.0593	172.97	-0.0127	2.9669	21.42
A	0.0760	173.00	0.0586	171.37	-0.0174	-1.6350	29.69
K	0.0740	176.00	0.0589	175.98	-0.0151	-0.0246	25.64
LCL	0.0800	171.00	0.0600	165.52	-0.0200	-5.4800	33.33
LCA	0.0780	169.00	0.0592	165.94	-0.0188	-3.0627	31.76
LCM	0.0800	172.00	0.0607	164.62	-0.0193	-7.3778	31.80
B	0.0730	196.00	0.0489	179.24	-0.0241	-16.7574	49.28
R	0.0730	178.00	0.0544	163.07	-0.0186	-14.9327	34.19
S	0.0610	177.00	0.0416	157.42	-0.0194	-19.5778	46.63
NSFE1	0.0650	173.00	0.0596	149.87	-0.0054	-23.1310	9.06
Q	0.0730	173.00	0.0688	155.38	-0.0042	-17.6243	6.10
NSFE2	0.0730	173.00	0.0688	155.38	-0.0042	-17.6243	6.10
NSFE4	0.0810	177.00	0.0766	160.36	-0.0044	-16.6446	5.74
NSFE5	0.0860	175.00	0.0795	162.82	-0.0065	-12.1831	8.18
P	0.0830	177.00	0.0738	159.29	-0.0092	-17.7108	12.47
BBA	0.0660	168.00	0.0631	143.10	-0.0029	-24.8988	4.60
MENEMSHA	0.0540	176.00	0.0561	138.69	0.0021	-37.3104	3.74
MIT/WHOI3	0.0830	173.00	0.0768	165.28	-0.0062	-7.7223	8.07
CXL	0.0650	178.00	0.0673	150.71	0.0023	-27.2920	3.42
PICKET	0.0790	167.00	0.0723	162.87	-0.0067	-4.1298	9.27
NEWPORT	0.0620	168.00	0.0721	141.96	0.0101	-26.0439	14.01
B6	0.1080	196.00	0.0772	181.77	-0.0308	-14.2268	39.90
CASHES_LEDGE	0.1250	198.00	0.0868	187.88	-0.0382	-10.1202	44.01
MONHEGAN	0.1360	198.00	0.0913	188.20	-0.0447	-9.8039	48.96
CAPE_PORPOISE	0.1290	204.00	0.0900	190.81	-0.0390	-13.1891	43.33
SEAL_ISLAND	0.1370	179.00	0.0986	177.11	-0.0384	-1.8859	38.95
PINKNEY_POINT	0.1220	184.00	0.1023	179.13	-0.0197	-4.8678	19.26
YARMOUTH	0.1350	182.00	0.1034	180.74	-0.0316	-1.2553	30.56
PORT_MAITLAND	0.1510	183.00	0.1060	182.67	-0.0450	-0.3271	42.45
EASTPORT	0.1470	196.00	0.1040	188.04	-0.0430	-7.9645	41.35
BAR_HARBOR	0.1400	196.00	0.0959	184.38	-0.0441	-11.6154	45.99
ROCKLAND	0.1520	201.00	0.0954	187.39	-0.0566	-13.6097	59.33
PORTLAND	0.1390	202.00	0.0921	190.34	-0.0469	-11.6641	50.92
PORTSMOUTH	0.1410	204.00	0.0903	191.64	-0.0507	-12.3620	56.15
BOSTON	0.1400	207.00	0.0901	193.67	-0.0499	-13.3283	55.38
CAPE_COD_CNL	0.1310	206.00	0.0903	195.49	-0.0407	-10.5143	45.07
CAPE_COD_LT	N/A	N/A	-	-	-	-	-
NAUSET	0.1310	201.00	0.0827	196.48	-0.0483	-4.5239	58.40
Average					0.0219	11.4051	27.5502
STD					0.0168	8.5198	18.6266

Table 12: Comparison of observed, model (simulation 09), and model-observed O1 tidal harmonic sea level amplitudes and phases in Greenwich epoch ( $^{\circ}$ ) for the observed stations in Figure 2.

Station	Comparison						
	Observed		Model		Model-Obs		Error
	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	% Amp
B1	0.0570	170.00	0.0411	202.96	-0.0159	32.9605	38.69
LOCKPORT	0.0760	116.00	0.1161	126.22	0.0401	10.2204	34.54
T22A	0.0550	179.00	0.0624	138.65	0.0074	40.3500	11.86
T22B	0.0540	179.00	0.0636	142.23	0.0096	-36.7692	15.09
T3	0.0580	179.00	0.0652	146.84	0.0072	-32.1641	11.04
E	0.0660	178.00	0.0651	146.14	-0.0009	-31.8630	1.38
M1	0.0850	185.00	0.0904	187.72	0.0054	2.7181	5.97
D/M2	0.0880	186.00	0.0904	188.52	0.0024	2.5239	2.65
M7	0.0650	178.00	0.0573	154.45	-0.0077	-23.5458	13.44
M4	0.0580	185.00	0.0806	163.20	0.0226	-21.8046	28.04
M3	0.0660	179.00	0.0657	164.21	-0.0003	-14.7851	0.46
M9	0.0560	188.00	0.0825	167.22	0.0265	-20.7770	32.12
A	0.0610	179.00	0.0837	169.40	0.0227	-9.5963	27.12
K	0.0620	180.00	0.0797	165.91	0.0177	-14.0865	22.21
LCL	0.0610	180.00	0.0827	175.98	0.0217	-4.0185	26.24
LCA	0.0630	178.00	0.0840	175.78	0.0210	-2.2170	25.00
LCM	0.0620	180.00	0.0823	177.37	0.0203	-2.6340	24.67
B	0.0750	192.00	0.0835	186.49	0.0085	-5.5123	10.18
R	0.0630	185.00	0.0810	186.99	0.0180	1.9853	22.22
S	0.0580	197.00	0.0642	201.11	0.0062	4.1144	9.66
NSFE1	0.0560	190.00	0.0607	197.22	0.0047	7.2161	7.74
Q	0.0590	186.00	0.0576	192.49	-0.0014	6.4906	2.43
NSFE2	0.0590	188.00	0.0576	192.49	-0.0014	4.4906	2.43
NSFE4	0.0650	185.00	0.0547	185.16	-0.0103	0.1623	18.83
NSFE5	0.0650	183.00	0.0551	179.72	-0.0099	-3.2752	17.97
P	0.0590	185.00	0.0562	185.07	-0.0028	0.0715	4.98
BBA	0.0490	204.00	0.0514	207.06	0.0024	3.0591	4.67
MENEMSHA	0.0600	195.00	0.0518	207.25	-0.0082	12.2520	15.83
MIT/WHOI3	0.0680	178.00	0.0655	177.17	-0.0025	-0.8270	3.82
CXL	0.0510	183.00	0.0513	195.97	0.0003	12.9670	0.58
PICKET	0.0530	182.00	0.0590	184.11	0.0060	2.1068	10.17
NEWPORT	0.0490	199.00	0.0446	204.42	-0.0044	5.4228	9.87
B6	0.0920	181.00	0.0888	181.91	-0.0032	0.9097	3.60
CASHES_LEDGE	0.1010	186.00	0.1034	183.37	0.0024	-2.6296	2.32
MONHEGAN	0.1030	181.00	0.1082	183.15	0.0052	2.1499	4.81
CAPE_PORPOISE	0.1060	185.00	0.1082	185.92	0.0022	0.9188	2.03
SEAL_ISLAND	0.1040	163.00	0.1076	154.73	0.0036	-8.2671	3.35
PINKNEY_POINT	0.1040	169.00	0.1116	155.88	0.0076	-13.1185	6.81
YARMOUTH	0.1010	164.00	0.1128	157.59	0.0118	-6.4063	10.46
PORT_MAITLAND	0.1100	167.00	0.1171	158.90	0.0071	-8.0986	6.06
EASTPORT	0.1140	177.00	0.1387	178.81	0.0247	1.8102	17.81
BAR_HARBOR	0.1100	174.00	0.1132	178.49	0.0032	4.4919	2.83
ROCKLAND	0.1180	170.00	0.1125	181.88	-0.0055	11.8819	4.89
PORTLAND	0.1110	183.00	0.1102	185.18	-0.0008	2.1804	0.73
PORTSMOUTH	0.1120	185.00	0.1090	186.72	-0.0030	1.7244	2.75
BOSTON	0.1110	189.00	0.1102	188.56	-0.0008	-0.4360	0.73
CAPE_COD_CNL	0.1080	187.00	0.1119	190.32	0.0039	3.3176	3.49
CAPE_COD_LT	N/A	N/A	-	-	-	-	-
NAUSET	0.1150	182.00	0.1029	192.64	-0.0121	10.6363	11.76
Average					0.0090	9.41597	11.3819
STD					0.0087	10.4911	10.1757

Table 13: Comparison of observed, model (simulation 10), and model-observed M2 tidal harmonic sea level amplitudes and phases in Greenwich epoch ( $^{\circ}$ ) for the observed stations in Figure 2.

Station	Comparison						
	Observed		Model		Model-Obs		Error
	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	% Amp
B1	0.4820	351.00	0.4782	350.72	-0.0038	-0.2808	0.79
LOCKPORT	0.6980	359.00	0.7010	0.88	0.0030	1.8806	0.43
T22A	0.4580	4.00	0.4324	7.72	-0.0256	3.7211	5.92
T22B	0.4420	9.00	0.4148	8.99	-0.0272	-0.0123	6.56
T3	0.3910	2.00	0.3912	3.48	0.0002	1.4843	0.05
E	0.4520	24.00	0.4066	22.46	-0.0454	-1.5417	11.17
M1	0.7820	92.00	0.4774	100.67	-0.3046	8.6744	63.80
D/M2	0.7650	93.00	0.4504	101.36	-0.3146	8.3550	69.85
M7	0.4100	38.00	0.3266	27.89	-0.0834	-10.1061	25.54
M4	0.3890	1.00	0.3831	358.46	-0.0059	-2.5380	1.54
M3	0.3960	22.00	0.3201	13.47	-0.0759	-8.5320	23.71
M9	0.3890	6.00	0.3796	2.23	-0.0094	-3.7686	2.48
A	0.3890	5.00	0.3811	0.93	-0.0079	-4.0745	2.07
K	0.3990	18.00	0.3625	11.81	-0.0365	-6.1929	10.07
LCL	0.3940	354.00	0.3875	355.96	-0.0065	1.9581	1.68
LCA	0.3920	358.00	0.3834	358.16	-0.0086	0.1564	2.24
LCM	0.3940	356.00	0.3839	356.64	-0.0101	0.6361	2.63
B	0.2590	47.00	0.1835	19.01	-0.0755	-27.9896	41.14
R	0.3140	3.00	0.3105	356.85	-0.0035	-6.1540	1.13
S	0.3230	1.00	0.2901	351.96	-0.0329	-9.0358	11.34
NSFE1	0.3870	356.00	0.3725	350.27	-0.0145	-5.7261	3.89
Q	0.3870	353.00	0.3856	349.35	-0.0014	-3.6507	0.36
NSFE2	0.4040	354.00	0.3856	349.35	-0.0184	-4.6507	4.77
NSFE4	0.4200	353.00	0.3940	348.87	-0.0260	-4.1272	6.60
NSFE5	0.4190	351.00	0.3973	348.77	-0.0217	-2.2343	5.46
P	0.4160	352.00	0.3969	349.13	-0.0191	-2.8660	4.81
BBA	0.5380	8.00	0.4626	356.39	-0.0754	-11.6052	16.30
MENEMSHA	0.4510	5.00	0.4184	348.64	-0.0326	-16.3580	7.79
MIT/WHOI3	0.4220	347.00	0.4073	348.72	-0.0147	1.7191	3.61
CXL	0.4440	1.00	0.4286	352.13	-0.0154	-8.8709	3.59
PICKET	0.4400	349.00	0.4173	350.34	-0.0227	1.3398	5.44
NEWPORT	0.5130	1.00	0.4899	358.68	-0.0231	-2.3177	4.72
B6	0.8800	87.00	0.5452	92.79	-0.3348	5.7940	61.41
CASHES_LEDGE	1.2000	98.00	0.7817	108.11	-0.4183	10.1094	53.51
MONHEGAN	1.3030	99.00	0.8596	109.77	-0.4434	10.7658	51.58
CAPE_PORPOISE	1.2720	103.00	0.8279	114.27	-0.4441	11.2697	53.64
SEAL_ISLAND	1.2040	52.00	0.9639	55.84	-0.2401	3.8400	24.91
PINKNEY_POINT	1.5540	59.00	1.1157	64.78	-0.4383	5.7841	39.28
YARMOUTH	1.6320	63.00	1.2212	72.18	-0.4108	9.1817	33.64
PORT_MAITLAND	1.8510	66.00	1.3736	79.08	-0.4774	13.0832	34.76
EASTPORT	2.6130	99.00	2.0358	116.62	-0.5772	17.6208	28.35
BAR_HARBOR	1.5490	93.00	1.0870	106.32	-0.4620	13.3241	42.50
ROCKLAND	1.5000	98.00	0.9879	110.48	-0.5121	12.4836	51.84
PORTLAND	1.3300	103.00	0.8743	113.68	-0.4557	10.6844	52.12
PORTSMOUTH	1.3030	107.00	0.8308	115.84	-0.4722	8.8362	56.84
BOSTON	1.3450	111.00	0.8462	119.81	-0.4988	8.8119	58.95
CAPE_COD_CNL	1.2440	109.00	0.8743	123.94	-0.3697	14.9394	42.29
CAPE_COD_LT	1.1600	113.00	0.7144	124.36	-0.4456	11.3569	62.37
NAUSET	1.0320	102.00	0.6325	128.08	-0.3995	26.0754	63.16
Average					0.1789	7.4800	23.7271
STD					0.2025	6.1246	23.4231

Table 14: Comparison of observed, model (simulation 10), and model-observed N2 tidal harmonic sea level amplitudes and phases in Greenwich epoch ( $^{\circ}$ ) for the observed stations in Figure 2.

Station	Comparison						
	Observed		Model		Model-Obs		Error
	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	% Amp
B1	0.1190	329.00	0.1246	339.87	0.0056	10.8737	4.49
LOCKPORT	0.1710	337.00	0.1734	348.59	0.0024	11.5869	1.38
T22A	0.1070	343.00	0.1163	354.74	0.0093	11.7354	8.00
T22B	0.1040	346.00	0.1126	355.72	0.0086	9.7171	7.64
T3	0.1030	341.00	0.1074	351.43	0.0044	10.4264	4.10
E	0.1100	360.00	0.1104	6.16	0.0004	6.1596	0.36
M1	0.1800	63.00	0.0908	77.75	-0.0892	14.7451	98.24
D/M2	0.1860	64.00	0.0862	78.07	-0.0998	14.0730	115.78
M7	0.0970	12.00	0.0925	9.08	-0.0045	-2.9207	4.86
M4	0.1010	349.00	0.1064	347.64	0.0054	-1.3602	5.08
M3	0.1000	354.00	0.0939	358.18	-0.0061	4.1781	6.50
M9	0.1070	346.00	0.1070	350.43	0.0000	4.4349	0.00
A	0.0960	344.00	0.1071	349.56	0.0111	5.5580	10.36
K	0.0990	354.00	0.1047	357.26	0.0057	3.2579	5.44
LCL	0.0910	330.00	0.1072	346.15	0.0162	16.1457	15.11
LCA	0.0980	338.00	0.1072	347.81	0.0092	9.8104	8.58
LCM	0.0950	334.00	0.1068	346.80	0.0118	12.8017	11.05
B	0.0750	20.00	0.0664	3.06	-0.0086	-16.9383	12.95
R	0.0790	344.00	0.0929	348.22	0.0139	4.2223	14.96
S	0.0910	339.00	0.0950	348.31	0.0040	9.3125	4.21
NSFE1	0.0940	340.00	0.1099	343.66	0.0159	3.6570	14.47
Q	0.0930	337.00	0.1102	342.70	0.0172	5.7010	15.61
NSFE2	0.0960	338.00	0.1102	342.70	0.0142	4.7010	12.89
NSFE4	0.0970	336.00	0.1096	342.07	0.0126	6.0657	11.50
NSFE5	0.1030	335.00	0.1091	341.88	0.0061	6.8815	5.59
P	0.1030	337.00	0.1117	342.65	0.0087	5.6474	7.79
BBA	0.1380	351.00	0.1368	353.68	-0.0012	2.6844	0.88
MENEMSHA	0.1190	356.00	0.1223	345.02	0.0033	-10.9761	2.70
MIT/WHOI3	0.1050	327.00	0.1124	342.48	0.0074	15.4819	6.58
CXL	0.1030	334.00	0.1229	347.63	0.0199	13.6333	16.19
PICKET	0.1200	317.00	0.1167	345.43	-0.0033	28.4321	2.83
NEWPORT	0.1240	345.00	0.1384	356.18	0.0144	11.1773	10.40
B6	0.2160	57.00	0.1041	71.89	-0.1119	14.8854	107.49
CASHES_LEDGE	0.2820	66.00	0.1377	88.46	-0.1443	22.4552	104.79
MONHEGAN	0.3030	67.00	0.1488	90.63	-0.1542	23.6252	103.63
CAPE_PORPOISE	0.2920	71.00	0.1425	93.87	-0.1495	22.8700	104.91
SEAL_ISLAND	0.2530	24.00	0.2231	39.09	-0.0299	15.0856	13.40
PINKNEY_POINT	0.2990	49.00	0.2514	48.87	-0.0476	-0.1316	18.93
YARMOUTH	0.3490	33.00	0.2725	56.39	-0.0765	23.3912	28.07
PORT_MAITLAND	0.3870	47.00	0.2596	68.12	-0.1274	21.1232	49.08
EASTPORT	0.5430	68.00	0.3705	112.68	-0.1725	44.68	46.56
BAR_HARBOR	0.3560	60.00	0.1876	92.87	-0.1684	32.8687	89.77
ROCKLAND	0.3300	65.00	0.1690	93.62	-0.1610	28.6238	95.27
PORTLAND	0.2960	73.00	0.1500	93.82	-0.1460	20.8232	97.33
PORTSMOUTH	0.2780	76.00	0.1424	95.16	-0.1356	19.1553	95.22
BOSTON	0.3010	82.00	0.1442	98.75	-0.1568	16.7461	108.74
CAPE_COD_CNL	0.2890	74.00	0.1489	102.52	-0.1401	28.5195	94.09
CAPE_COD_LT	N/A	N/A	-	-	-	-	-
NAUSET	0.2220	70.00	0.1068	104.76	-0.1152	34.7610	107.87
Average					0.0516	13.8550	35.6598
STD					0.0617	9.8185	41.9436

Table 15: Comparison of observed, model (simulation 10), and model-observed S2 tidal harmonic sea level amplitudes and phases in Greenwich epoch ( $^{\circ}$ ) for the observed stations in Figure 2.

Station	Comparison						
	Observed		Model		Model-Obs		Error
	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	% Amp
B1	0.1030	22.00	0.1425	9.74	0.0395	-12.2632	27.72
LOCKPORT	0.1370	29.00	0.1910	19.60	0.0540	-9.4013	28.27
T22A	0.0940	28.00	0.1294	22.13	0.0354	-5.8653	27.36
T22B	0.0890	31.00	0.1255	23.04	0.0365	-7.9563	29.08
T3	0.0820	28.00	0.1191	19.12	0.0371	-8.8827	31.15
E	0.0880	47.00	0.1240	32.67	0.0360	-14.3333	29.03
M1	0.1220	121.00	0.1191	89.18	-0.0029	-31.8247	2.43
D/M2	0.1900	162.00	0.1141	89.20	-0.0759	72.8	66.52
M7	0.0860	59.00	0.1065	35.99	0.0205	-23.0127	19.25
M4	0.0840	26.00	0.1120	14.04	0.0280	-11.9649	25.00
M3	0.0980	15.00	0.1031	26.51	0.0051	11.5056	4.95
M9	0.0790	32.00	0.1117	16.29	0.0327	-15.7063	29.27
A	0.0870	27.00	0.1114	15.10	0.0244	-11.8983	21.90
K	0.0860	38.00	0.1107	23.48	0.0247	-14.5235	22.31
LCL	0.0950	19.00	0.1102	10.65	0.0152	-8.3473	13.79
LCA	0.0880	21.00	0.1101	12.26	0.0221	-8.7354	20.07
LCM	0.0920	21.00	0.1094	10.96	0.0174	-10.0399	15.90
B	0.0500	59.00	0.0734	31.74	0.0234	-27.2571	31.88
R	0.0760	21.00	0.0938	12.53	0.0178	-8.4734	18.98
S	0.0780	21.00	0.0949	10.62	0.0169	-10.3839	17.81
NSFE1	0.0890	18.00	0.1081	3.78	0.0191	-14.2155	17.67
Q	0.0870	18.00	0.1084	2.66	0.0214	-15.3440	19.74
NSFE2	0.0870	17.00	0.1084	2.66	0.0214	-14.3440	19.74
NSFE4	0.0920	18.00	0.1076	1.99	0.0156	-16.0055	14.50
NSFE5	0.0910	17.00	0.1070	1.88	0.0160	-15.1189	14.95
P	0.0950	15.00	0.1101	1.99	0.0151	-13.0126	13.71
BBA	0.1160	32.00	0.1373	11.59	0.0213	-20.4096	15.51
MENEMSHA	0.1000	24.00	0.1207	3.01	0.0207	-20.9927	17.15
MIT/WHOI3	0.1010	13.00	0.1113	1.01	0.0103	-11.9906	9.25
CXL	0.0990	0.00	0.1230	4.54	0.0240	4.5444	19.51
PICKET	0.0950	0.00	0.1186	1.90	0.0236	1.8992	19.90
NEWPORT	0.1190	23.00	0.1384	12.85	0.0194	-10.1538	14.02
B6	0.1290	119.00	0.1325	85.01	0.0035	-33.9869	2.64
CASHES_LEDGE	0.1950	126.00	0.1666	98.24	-0.0284	-27.7572	17.05
MONHEGAN	0.2110	128.00	0.1773	99.27	-0.0337	-28.7266	19.01
CAPE_PORPOISE	0.2030	134.00	0.1750	101.92	-0.0280	-32.0812	16.00
SEAL_ISLAND	0.2100	86.00	0.2249	65.06	0.0149	-20.9392	6.63
PINKNEY_POINT	0.2350	92.00	0.2461	75.13	0.0111	-16.8722	4.51
YARMOUTH	0.2690	97.00	0.2585	82.93	-0.0105	-14.0680	4.06
PORT_MAITLAND	0.2970	101.00	0.2774	91.55	-0.0196	-9.4500	7.07
EASTPORT	0.4350	137.00	0.3175	142.68	-0.1175	5.6802	37.01
BAR_HARBOR	0.2530	127.00	0.1912	104.72	-0.0618	-22.2829	32.32
ROCKLAND	0.1950	133.00	0.1916	102.65	-0.0034	-30.3456	1.77
PORTLAND	0.2170	138.00	0.1824	101.87	-0.0346	-36.1264	18.97
PORTSMOUTH	0.2030	143.00	0.1761	102.96	-0.0269	40.04	15.28
BOSTON	0.2190	146.00	0.1813	106.32	-0.0377	-39.6820	20.79
CAPE_COD_CNL	0.1990	144.00	0.1876	110.24	-0.0114	-33.7569	6.08
CAPE_COD_LT	N/A	N/A	-	-	-	-	-
NAUSET	0.1440	133.00	0.1358	111.01	-0.0082	-21.9947	6.04
Average					0.0259	18.6874	18.6156
STD					0.0197	12.6462	11.3310

Table 16: Comparison of observed, model (simulation 10), and model-observed K1 tidal harmonic sea level amplitudes and phases in Greenwich epoch ( $^{\circ}$ ) for the observed stations in Figure 2.

Station	Comparison						
	Observed		Model		Model-Obs		Error
	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	% Amp
B1	0.0690	173.00	0.0584	150.78	-0.0106	-22.2250	18.15
LOCKPORT	0.1280	147.00	0.1099	164.87	-0.0181	17.8724	16.47
T22A	0.0710	167.00	0.0815	165.18	0.0105	-1.8156	12.88
T22B	0.0730	169.00	0.0795	166.89	0.0065	-2.1134	8.18
T3	0.0710	170.00	0.0747	167.98	0.0037	-2.0159	4.95
E	0.0840	172.00	0.0780	169.56	-0.0060	-2.4423	7.69
M1	0.1120	199.00	0.0751	186.39	-0.0369	-12.6140	49.13
D/M2	0.1070	197.00	0.0745	186.22	-0.0325	-10.7824	43.62
M7	0.0760	182.00	0.0683	172.81	-0.0077	-9.1932	11.27
M4	0.0750	168.00	0.0615	171.77	-0.0135	3.7663	21.95
M3	0.0660	178.00	0.0607	178.68	-0.0053	0.6793	8.73
M9	0.0720	170.00	0.0584	171.25	-0.0136	1.2477	23.29
A	0.0760	173.00	0.0582	169.68	-0.0178	-3.3235	30.58
K	0.0740	176.00	0.0573	175.27	-0.0167	-0.7252	29.14
LCL	0.0800	171.00	0.0607	164.50	-0.0193	-6.4952	31.80
LCA	0.0780	169.00	0.0595	164.73	-0.0185	-4.2703	31.09
LCM	0.0800	172.00	0.0611	163.71	-0.0189	-8.2895	30.93
B	0.0730	196.00	0.0515	180.71	-0.0215	-15.2927	41.75
R	0.0730	178.00	0.0555	162.76	-0.0175	-15.2415	31.53
S	0.0610	177.00	0.0544	157.49	-0.0066	-19.5095	12.13
NSFE1	0.0650	173.00	0.0632	148.04	-0.0018	-24.9613	2.85
Q	0.0730	173.00	0.0710	153.10	-0.0020	-19.8970	2.82
NSFE2	0.0730	173.00	0.0710	153.10	-0.0020	-19.8970	2.82
NSFE4	0.0810	177.00	0.0775	158.78	-0.0035	-18.2188	4.52
NSFE5	0.0860	175.00	0.0802	161.82	-0.0058	-13.1774	7.23
P	0.0830	177.00	0.0761	157.60	-0.0069	-19.3982	9.07
BBA	0.0660	168.00	0.0753	152.77	0.0093	-15.2310	12.35
MENEMSHA	0.0540	176.00	0.0692	147.70	0.0152	-28.2965	21.97
MIT/WHOI3	0.0830	173.00	0.0785	164.89	-0.0045	-8.1124	5.73
CXL	0.0650	178.00	0.0761	154.77	0.0111	-23.2274	14.59
PICKET	0.0790	167.00	0.0750	163.44	-0.0040	-3.5627	5.33
NEWPORT	0.0620	168.00	0.0808	153.67	0.0188	-14.3340	23.27
B6	0.1080	196.00	0.0785	184.21	-0.0295	-11.7936	37.58
CASHES_LEDGE	0.1250	198.00	0.0861	189.01	-0.0389	-8.9935	45.18
MONHEGAN	0.1360	198.00	0.0899	189.17	-0.0461	-8.8264	51.28
CAPE_PORPOISE	0.1290	204.00	0.0892	191.64	-0.0398	-12.3615	44.62
SEAL_ISLAND	0.1370	179.00	0.0969	177.95	-0.0401	-1.0492	41.38
PINKNEY_POINT	0.1220	184.00	0.0985	180.75	-0.0235	-3.2549	23.86
YARMOUTH	0.1350	182.00	0.0988	182.28	-0.0362	0.2830	36.64
PORT_MAITLAND	0.1510	183.00	0.1014	178.41	-0.0496	-4.5895	48.92
EASTPORT	0.1470	196.00	0.0942	190.67	-0.0528	-5.3268	56.05
BAR_HARBOR	0.1400	196.00	0.0924	185.73	-0.0476	-10.2721	51.52
ROCKLAND	0.1520	201.00	0.0927	188.85	-0.0593	-12.1506	63.97
PORTLAND	0.1390	202.00	0.0908	191.26	-0.0482	-10.7397	53.08
PORTSMOUTH	0.1410	204.00	0.0896	192.42	-0.0514	-11.5831	57.37
BOSTON	0.1400	207.00	0.0899	194.48	-0.0501	-12.5210	55.73
CAPE_COD_CNL	0.1310	206.00	0.0906	196.37	-0.0404	-9.6287	44.59
CAPE_COD_LT	N/A	N/A	-	-	-	-	-
NAUSET	0.1310	201.00	0.0838	197.12	-0.0472	-3.8751	56.32
Average					0.0227	10.3224	28.0396
STD					0.0174	7.3109	18.6284

Table 17: Comparison of observed, model (simulation 10), and model-observed O1 tidal harmonic sea level amplitudes and phases in Greenwich epoch ( $^{\circ}$ ) for the observed stations in Figure 2.

Station	Comparison						
	Observed		Model		Model-Obs		Error
	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	Amp(m)	G( $^{\circ}$ )	% Amp
B1	0.0570	170.00	0.0444	193.00	-0.0126	23.0001	28.38
LOCKPORT	0.0760	116.00	0.1107	123.87	0.0347	7.8671	31.35
T22A	0.0550	179.00	0.0627	147.93	0.0077	-31.0707	12.28
T22B	0.0540	179.00	0.0637	151.14	0.0097	-27.8605	15.23
T3	0.0580	179.00	0.0638	154.97	0.0058	-24.0347	9.09
E	0.0660	178.00	0.0650	154.85	-0.0010	-23.1520	1.54
M1	0.0850	185.00	0.0937	189.70	0.0087	4.6958	9.28
D/M2	0.0880	186.00	0.0932	190.47	0.0052	4.4713	5.58
M7	0.0650	178.00	0.0589	165.70	-0.0061	-12.3037	10.36
M4	0.0580	185.00	0.0749	165.94	0.0169	-19.0648	22.56
M3	0.0660	179.00	0.0653	169.77	-0.0007	-9.2314	1.07
M9	0.0560	188.00	0.0765	168.62	0.0205	-19.3824	26.80
A	0.0610	179.00	0.0774	170.16	0.0164	-8.8357	21.19
K	0.0620	180.00	0.0750	168.46	0.0130	-11.5375	17.33
LCL	0.0610	180.00	0.0766	175.27	0.0156	-4.7256	20.37
LCA	0.0630	178.00	0.0778	174.98	0.0148	-3.0173	19.02
LCM	0.0620	180.00	0.0766	176.14	0.0146	-3.8556	19.06
B	0.0750	192.00	0.0832	187.56	0.0082	-4.4439	9.86
R	0.0630	185.00	0.0779	185.13	0.0149	0.1260	19.13
S	0.0580	197.00	0.0714	198.10	0.0134	1.1020	18.77
NSFE1	0.0560	190.00	0.0659	193.78	0.0099	3.7798	15.02
Q	0.0590	186.00	0.0636	189.90	0.0046	3.8955	7.23
NSFE2	0.0590	188.00	0.0636	189.90	0.0046	1.8955	7.23
NSFE4	0.0650	185.00	0.0621	184.97	-0.0029	-0.0325	4.67
NSFE5	0.0650	183.00	0.0622	181.54	-0.0028	-1.4646	4.50
P	0.0590	185.00	0.0620	185.48	0.0030	0.4834	4.84
BBA	0.0490	204.00	0.0612	201.92	0.0122	-2.0811	19.93
MENEMSHA	0.0600	195.00	0.0610	200.09	0.0010	5.0874	1.64
MIT/WHOI3	0.0680	178.00	0.0667	179.23	-0.0013	1.2331	1.95
CXL	0.0510	183.00	0.0575	194.18	0.0065	11.1837	11.30
PICKET	0.0530	182.00	0.0604	184.41	0.0074	2.4130	12.25
NEWPORT	0.0490	199.00	0.0562	202.52	0.0072	3.5201	12.81
B6	0.0920	181.00	0.0936	184.89	0.0016	3.8927	1.71
CASHES_LEDGE	0.1010	186.00	0.1065	186.35	0.0055	0.3532	5.16
MONHEGAN	0.1030	181.00	0.1111	186.03	0.0081	5.0338	7.29
CAPE_PORPOISE	0.1060	185.00	0.1112	188.45	0.0052	3.4535	4.68
SEAL_ISLAND	0.1040	163.00	0.1084	156.48	0.0044	-6.5239	4.06
PINKNEY_POINT	0.1040	169.00	0.1116	159.87	0.0076	-9.1279	6.81
YARMOUTH	0.1010	164.00	0.1139	162.20	0.0129	-1.7972	11.33
PORT_MAITLAND	0.1100	167.00	0.1210	167.37	0.0110	0.3697	9.09
EASTPORT	0.1140	177.00	0.1399	187.21	0.0259	10.2147	18.51
BAR_HARBOR	0.1100	174.00	0.1149	182.65	0.0049	8.6506	4.26
ROCKLAND	0.1180	170.00	0.1145	185.61	-0.0035	15.6128	3.06
PORTLAND	0.1110	183.00	0.1129	187.96	0.0019	4.9635	1.68
PORTSMOUTH	0.1120	185.00	0.1120	189.17	0.0000	4.1704	0.00
BOSTON	0.1110	189.00	0.1131	191.02	0.0021	2.0166	1.86
CAPE_COD_CNL	0.1080	187.00	0.1144	192.75	0.0064	5.7451	5.59
CAPE_COD_LT	N/A	N/A	-	-	-	-	-
NAUSET	0.1150	182.00	0.1069	193.74	-0.0081	11.7419	7.58
Average					0.0086	7.8024	10.7144
STD					0.0068	7.7904	7.9736