NOAA Technical Memorandum NOS CS 15

VDATUM FOR CHESAPEAKE BAY, DELAWARE BAY, AND ADJACENT COASTAL WATER AREAS: TIDAL DATUMS AND SEA SURFACE TOPOGRAPHY

Silver Spring, Maryland
November 2008

noaa National Oceanic and Atmospheric Administration

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

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

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

An application of the vertical datum transformation software tool, VDatum, is developed for Chesapeake Bay, Delaware Bay, and adjacent coastal waters. Conversions between various tidal datums fields and mean sea level as well as between mean sea level and North American Vertical Datum of 1988 (NAVD 88) were developed for this VDatum application and are presented here.

The tidal datums fields were derived from hydrodynamic simulations using the two-dimensional, barotropic hydrodynamic model, ADCIRC. A triangular finite-element grid consisting of 318,860 nodes and 558,718 cells was created. The model was forced with nine tidal constituents (M_2, S_2, N_2, K_2, K_1, P_1, O_1, Q_1, and M_4) for a 60 day simulation. Water level harmonic analysis was conducted for 37 tidal constituents. Time series over the entire Nation Tidal Datum Epoch (1983-2001) were reconstructed from the harmonic constants. Various tidal datum fields, including mean lower low water (MLLW), mean low water (MLW), mean high water (MHW), and mean higher high water (MHHW), were derived from these reconstructed time series. Model results were validated by comparing with observations from 298 water level stations maintained by the NOAA's Center for Operational Oceanographic Products and Services (CO-OPS). Discrepancies between model results and datums derived from observations were attributed to model errors and interpolated over the whole model domain using the tidal constituent and residual interpolation (TCARI) software to obtain a domain wide error field for each of the tidal datums. The error fields were applied to the direct model results to achieve error-corrected tidal datums on the unstructured grid. Finally, tidal datum fields were interpolated onto a regular VDatum marine grid.

The Topography of Sea Surface (TSS), defined as the elevation of NAVD 88 relative to mean sea level (MSL), was developed based on data from the National Tidal Datum Epoch (1983-2001). The NAVD88-to-MSL values were derived either by fitting tidal model results to tidal benchmarks leveled in NAVD 88 or by calculating orthometric-to-tidal datum relationships at NOAA tidal gauges. Results from both methodologies were combined to create the final TSS grids by spatial interpolation.

Key Words: tides, tidal datums, Chesapeake Bay, Delaware Bay, ADCIRC, mean sea level, bathymetry, coastline, spatial interpolation, marine grid, North American Vertical Datum of 1998

1. INTRODUCTION

NOAA's National Ocean Service (NOS) is developing a software tool called VDatum to transform elevation data among approximately 30 vertical datums (Milbert, 2002; Parker, 2003; Myers et al., 2005; Spargo, et al., 2006). Once VDatum has been established for a region, data can be incorporated into integrated bathymetric-topographic digital elevation models for use in coastal GIS applications (Parker et al., 2003). VDatum allows bathymetric and topographic data referenced to different vertical datums to be integrated through its inherent orthometric, ellipsoidal, and tidal relationships.

To be applicable over coastal waters, VDatum requires spatially-varying fields of the tidal datums and the Topography of Sea Surface (TSS). The former concerns tidally-influenced datums such as MHHW, MHW, MLW, MLLW, MTL, and DTL as well as MSL. The TSS field refers to the elevation of the North American Vertical Datum of 1988 (NAVD88) relative to MSL.

The VDatum tool software is currently available for Tampa Bay (Hess, 2001), New York Bight (Hess, 2001), Delaware Bay (Hess et al., 2003), central California (Myers and Hess, 2006), central/northern North Carolina (Hess et al., 2005), Lake Calcasieu and Charles River (Spargo and Woolard, 2005), Port Fourchon, Puget Sound (Hess and Gill, 2003; Hess and White, 2004), and the Strait of Juan de Fuca (Spargo et al., 2006). These VDatum regions cover about 18% of the coastal regions of the contiguous United States, and it is anticipated that full national coverage can be attained within a five year period.

As a continuing effort in support of VDatum development, this report describes the development of VDatum for an area encompassing Chesapeake Bay (CB), Delaware Bay (DB), and adjacent coastal waters. Figure 1 displays a map of the area. In the figure, the black lines represent MHW coastline and the green line denotes the 25-nm offshore limit. Water areas between the coastline and the 25-nm limit represent the VDatum domain for tidal datum and TSS development.

Creation of VDatum begins with tidal simulations using an unstructured two-dimensional hydrodynamic model. Harmonic constants for 37 tidal constituents were analyzed from a 40-day water level time series at each node in the model grid. After obtaining tidal harmonic constants, water level time series over the full National Tidal Datum Epoch (1983-2001) were complied from the harmonic constants and used to compute tidal datums. The tidal datums are verified through comparisons with observational data, and error corrections were made. Regularly structured VDatum marine grids were then created and populated with corrected tidal datums. Finally, for the same marine grids, the topography of the sea surface was derived by fitting tidal model results to tidal benchmarks leveled in NAVD 88 and calculating orthometric-to-tidal datum relationships at NOAA tidal gauges.

This technical report is organized as follows: after an introduction in Section 1, Section 2 discusses input data needed for driving the hydrodynamic model run and verifying its results, which include the digital coastline, bathymetry, and observational tidal datum data. Section 3 details tidal datum simulation procedures, including an introduction of the tidal hydrodynamic model, its setup, result validation, and error corrections. Section 4 discusses creation of the structured VDatum marine grid required for the VDatum software tool and its population with error-corrected model datums. In Section 5, creation of TSS for the area is described. Finally, a summary is given in Section 6.

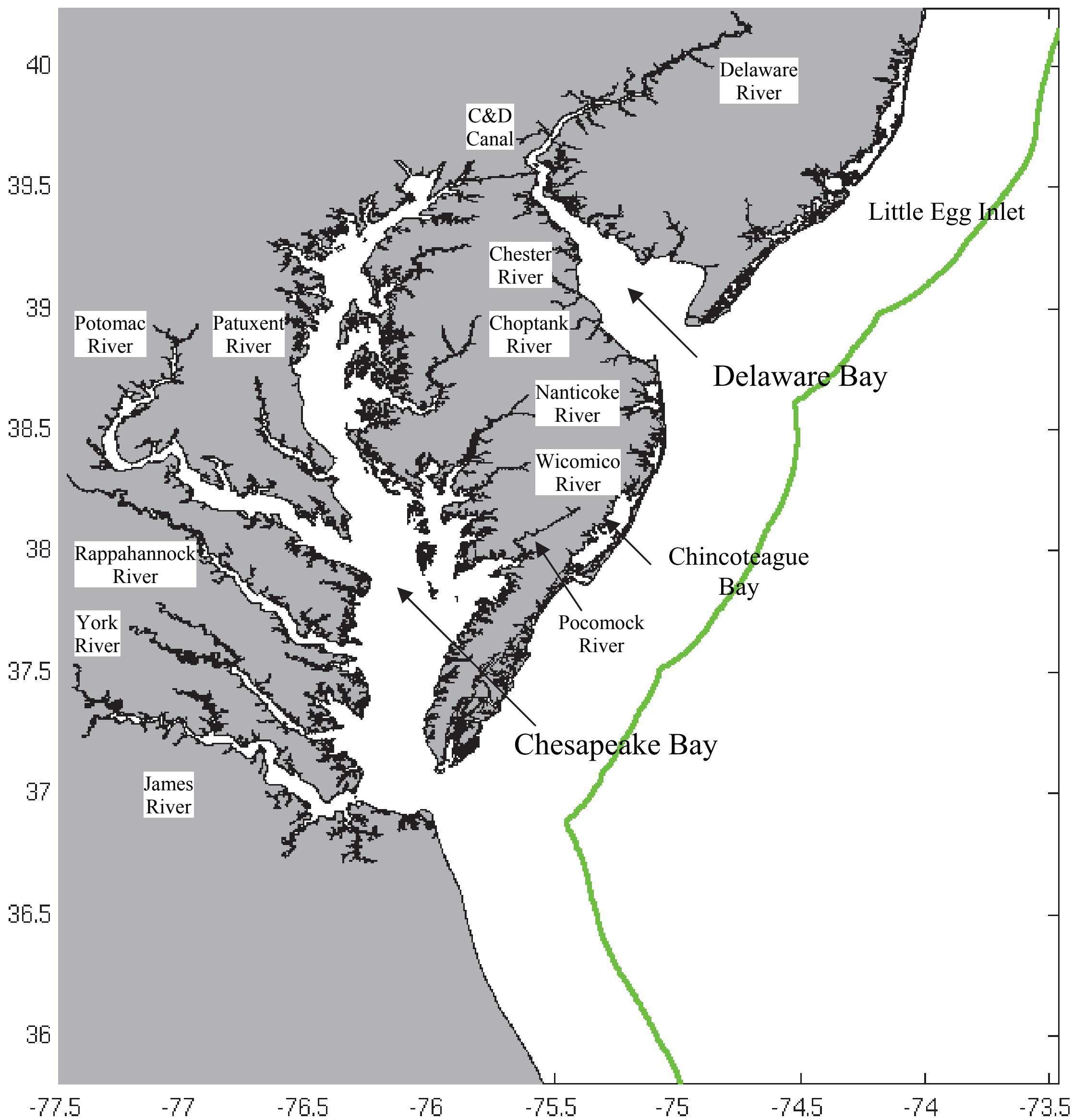


Figure 1. Map of the Chesapeake Bay, Delaware Bay, and adjacent coastal water areas. Black lines illustrate the MHW coastline. Green line marks locations at a distance of 25-nautical miles offshore.

2. COASTLINE, BATHYMETRIC, AND WATER LEVEL DATA

Knowledge of the spatial distribution of tidal datums is necessary for developing VDatum applications (Milbert and Hess, 2001). NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) computes tidal datums using water level time histories available from their National Water Level Observation Network (NWLON) and other historical stations. To compute the spatially-varying fields of tidal datums between these stations, tidal models can be used to simulate water level time histories from which modeled tidal datums may be computed. Hydrodynamic models are capable of resolving the spatial variability of tidal datum fields with flexible resolutions (Myers, 2001; Spargo and Woolard, 2005).

To setup the tide simulations, coastline data are required for delineating land-water boundaries. In addition, bathymetric data are needed to provide the model grid bathymetry. Tidal datums computed by CO-OPS from observations are also required to verify the model results and provide corrections in producing final tidal datum fields.

2.1. Digital Coastline

The MHW shoreline is used to delineate the land-water boundary in VDatum applications (Parker, 2002). It is also used as a boundary in the construction of grids for tidal modeling and for interpolating the computed tidal datums onto the structured marine grid used by the VDatum software. The shoreline data used for the Chesapeake and Delaware (C&D) Bays were primarily based on the digital Extracted Vector Shoreline (EVS) datasets from NOAA's Office of Coast Survey (OCS). However, when compared with MHW shorelines on raster nautical charts (RNCs), the EVS data shows errors in certain nearshore marshland areas. These errors were manually corrected to agree with the RNCs using the Surface Water Modeling System (SMS) software. In SMS, the two shorelines were visually contrasted. Figure 1 shows the final corrected MHW shoreline for the C&D Bays project.

2.2. Bathymetric Data

Bathymetric data used in this study were from two sources: NOS soundings and the NOAA Electronic Navigational Charts (ENCs) bathymetry. The former were from the NOS/OCS hydrographic database maintained at the National Geophysical Data Center (NGDC) and the latter were extracted from NOAA ENCs. The NOS sounding data include surveys conducted between approximately 1930 and 2000. The datums were referenced to either MLW or MLLW, depending on the years of data collections. Figure 2 shows the survey years and locations. Figure 3 displays the spatial distribution of the ENC data points. It was known that the ENC data were referenced to both MLW and MLLW. However, available documents do not ensure any feasible way to distinguish the two for individual data points. Therefore, the whole ENC data set was treated as being solely referenced to MLLW. The horizontal and vertical accuracy standards for NOAA surveys are listed in Table A.1 of Appendix A.

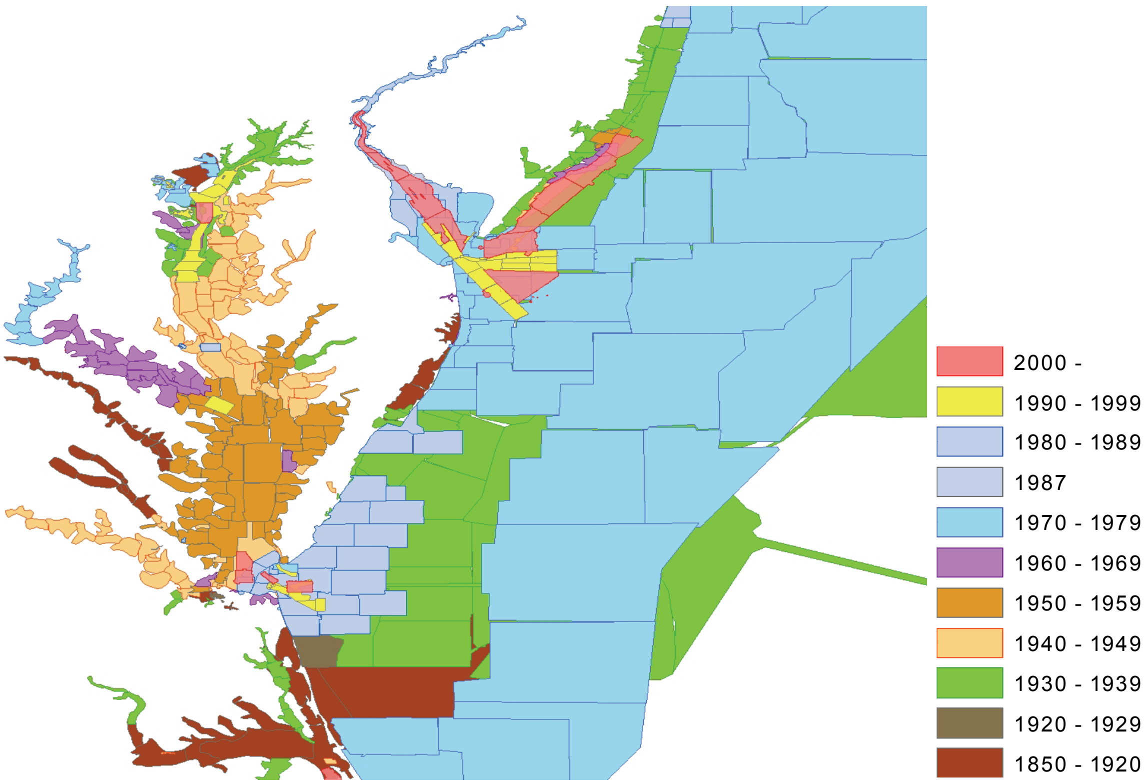


Figure 2. Dates and locations of NOS sounding surveys.

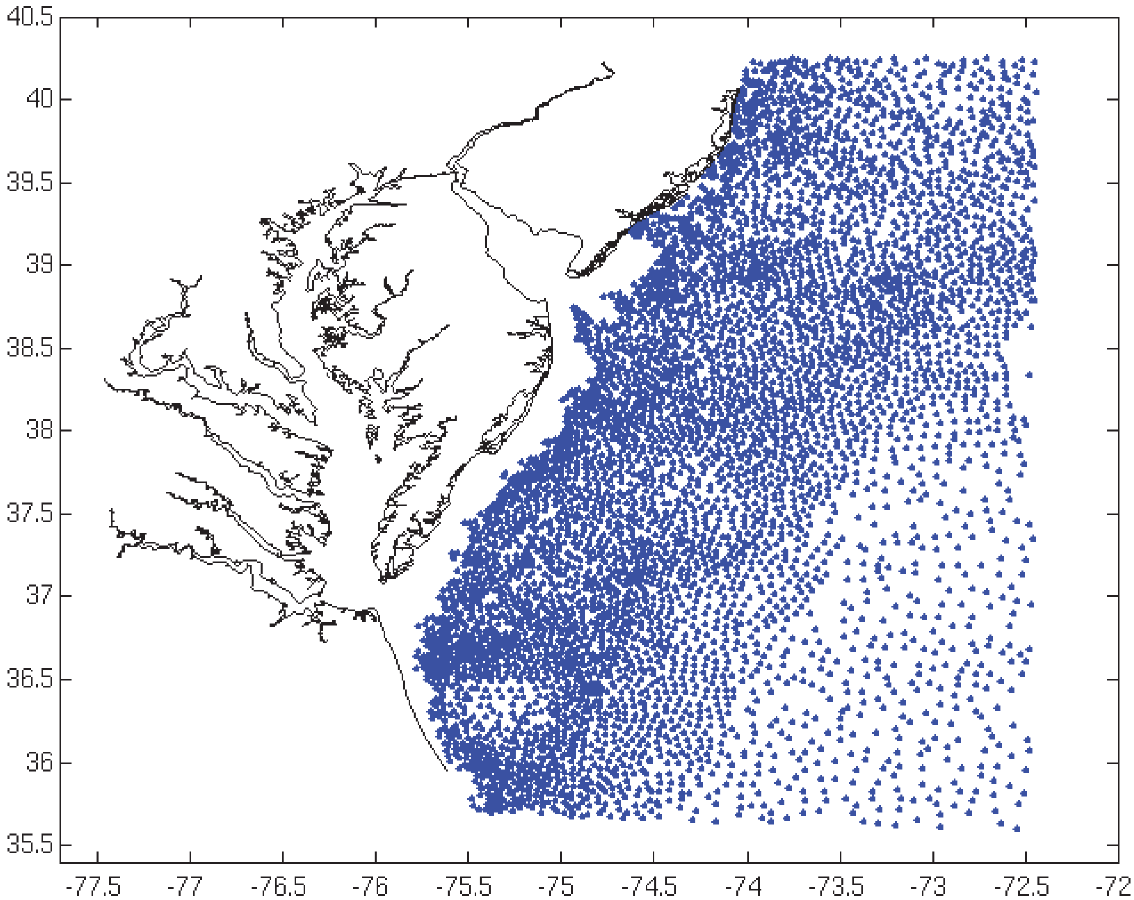


Figure 3. Spatial distribution of the ENC bathymetric data.

The NOS soundings possess a higher spatial distribution density than the ENC data. In some areas, the two are both available. However, neither of them provides complete coverage for the whole study area. Hence, they were blended for a better regional coverage. It is noted that even the merged data set left certain nearshore areas uncovered. NOAA nautical chart bathymetry was then manually digitized to compensate for the missing coverage. Since both the ENC and manually digitized bathymetry data were derived from nautical chart data, they were merged to form one data set and hereafter referred to as the ENC bathymetry without differentiation.

2.3. Tidal Datum Data

Tidal datums derived from observations at CO-OPS water level stations were used to verify and correct model results. Many stations are located within either embayments or near obstructions not represented in the present model grid (Section 3.2). Observations at these stations were deemed to be unsuitable for validating model results and discarded. The observational data correspond to either the present tidal epoch (1983-2001) or the older one (1960-1979), with some historical observations that were lacking epoch information. It is noted that at some stations, datums are available for both the present epoch and previous ones. In this case, only those with the most recent epoch are used. This resulted in 298 stations finally used for model validations. Tables C.1 and C.2 in Appendix C list the station and tidal datum information.

3. TIDAL DATUM SIMULATION

3.1. Hydrodynamic Model

The ADvanced CIRCulation (ADCIRC) model (Westerink et al., 1993) was employed to simulate water level time histories and derive spatially-varying fields of the tidal constituents. The ADCIRC model is an unstructured hydrodynamic circulation model. It simulates tides by solving the shallow water equations and has been proved to be valid for modeling tides in various oceanic environments from open oceans to coastal and estuarine waters (Luettich et al., 1999; Mukai et al., 2002; Myers et al., 2005). The ADCIRC model provides a variety of options for users to specify various parameters relevant to tidal dynamics and execution modes. For instance, simulations can be performed in either 2- or 3-dimensonal modes, serial or parallel execution dependent on machine infrastructures, linear or quadratic bottom friction formulations with constant or variable friction coefficients, etc. More details on the model setup including the grid generation, bathymetry specification, and parameter selections are addressed in following sections.

3.2. Model Grid

The model domain encompasses Delaware Bay, Chesapeake Bay and adjacent coastal waters. Embayments along the New Jersey (NJ), Delaware (DE), Maryland (MD), and Virginia (VA) coasts (Figure 4) are also included in the model domain. The model grid was set up to extend from the coastline to an area slightly beyond the continental shelf break. A high-resolution, unstructured grid with 318,860 nodes and 558,718 triangular elements was created to represent this domain. The nodal spacing in the grid ranges from around 13 m to 19 km. In general, finer grid spacing is used in nearshore areas compared to those in deep waters, so as to accurately resolve fine coastline features and reflect bathymetric variability. Figures 5(a) and (b) show close-up views of the grid at Chesapeake Bay and Delaware Bay, respectively. The grid resolves various rivers and small tributaries, as well as embayments and inlets along the NJ, DE, MD, and VA coasts.

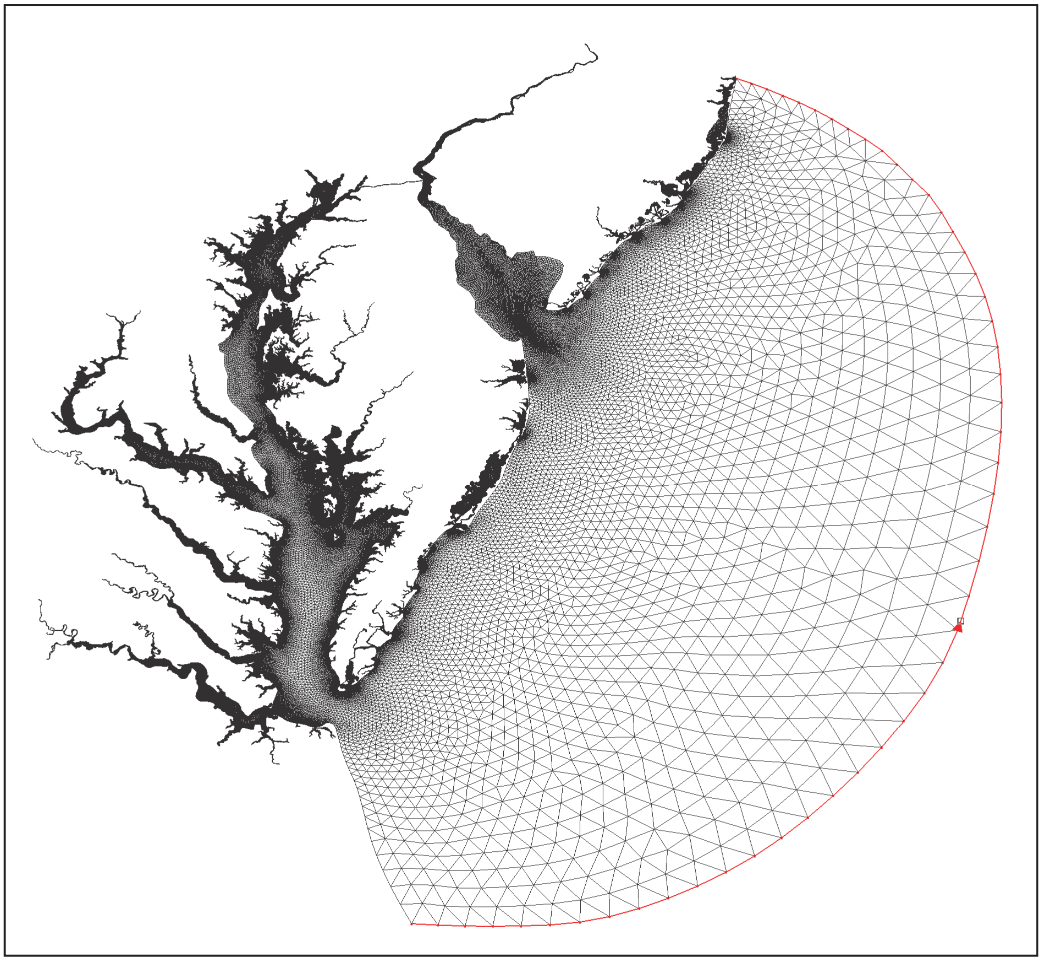


Figure 4. Finite element grid for the entire model domain. Red line denotes the model open ocean boundary.

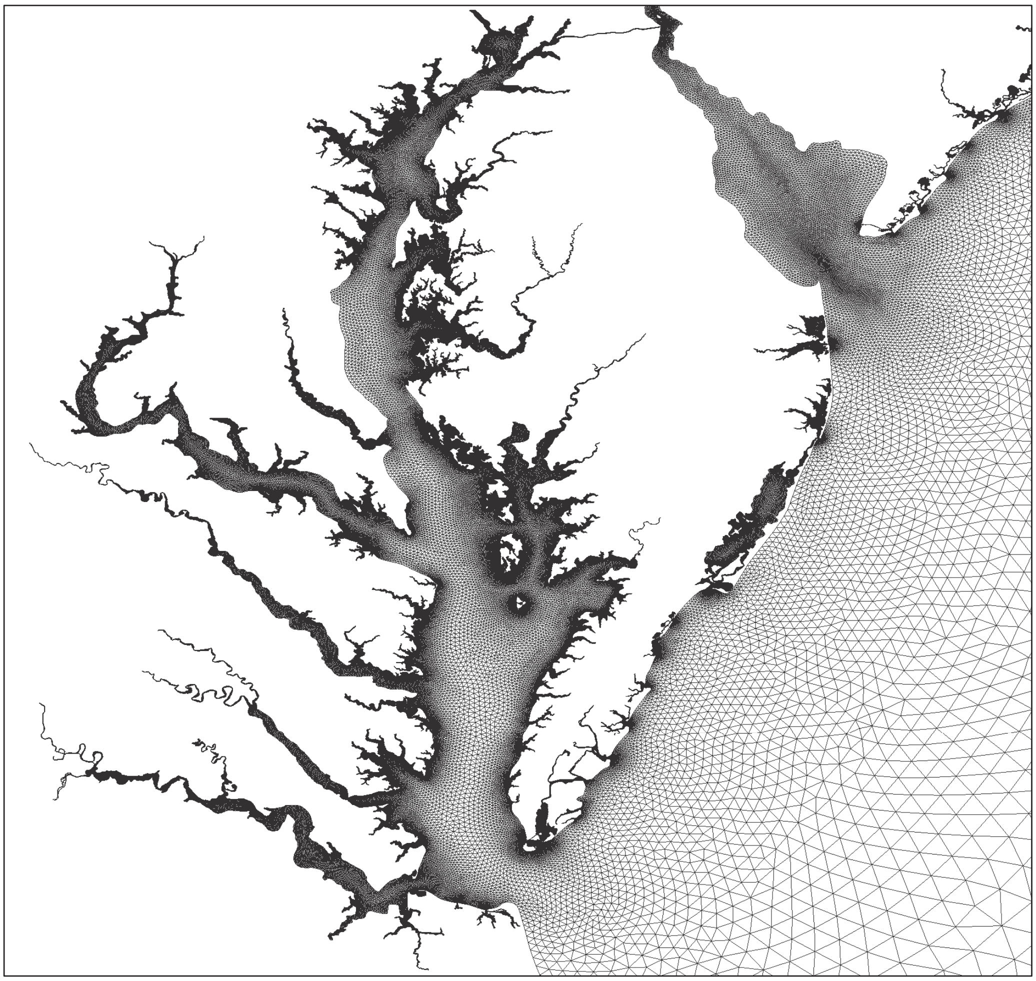


Figure 5. Close-up view of the hydrodynamic model grid, (a) Chesapeake Bay as well as embayments along the DE, MD, and VA coasts and (b) Delaware Bay as well as embayments along NJ coast.

(b)

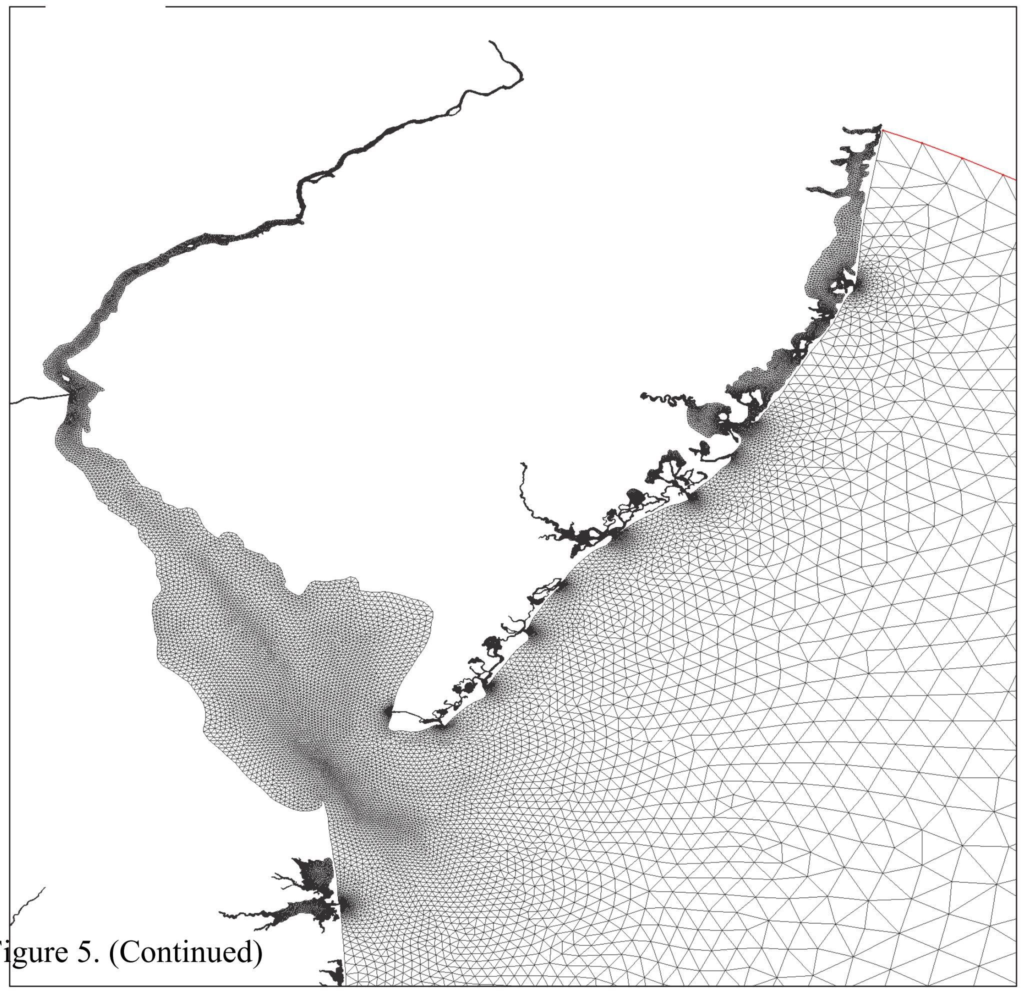


Figure 5. (Continued)

3.3. Bathymetry on Model Grid

The bathymetry datasets described in Section 2.2 were used to specify the model grid bathymetry. Note that NOS soundings and ENC data were of different spatial resolution and coverage. As for the soundings alone, bathymetry may be referenced to either MLW or MLLW. Hence, they were categorized into two groups and applied to the grid separately. In short, the bathymetry data were classified into three groups: (1) MLLW NOS soundings (2) MLW NOS soundings, and (3) MLLW ENC data. The three groups were interpolated onto the model grid separately, resulting in three meshes respectively corresponding to the three bathymetric datasets.

The algorithm used for interpolating bathymetry onto the three meshes was the same. Bathymetry at each model node represents an average of data points within the node's surrounding elements. Since element size changes throughout the model domain, the searching range for bathymetric data points vary from node to node. As the element size is smaller in coastal waters, bathymetry for nodes near the coastline were from more locally distributed data points compared to those in deep waters.

As none of the three data sets provided complete coverage of the model domain, each of the three meshes left numerous unpopulated nodes. Hence, the three meshes were combined to obtain a more complete coverage. At nodes where bathymetric data were available in more than one mesh, an arithmetic average was taken; otherwise, the value from the solely available mesh was taken. After merging the three meshes, there still remained some nodes without valid bathymetry. These nodes were populated by averaging bathymetry from adjacent nodes.

It is worthwhile to note that the bathymetry of the three meshes had two different reference datums: MLW and MLLW. Setup of the tidal model requires the grid bathymetry to be referenced to the model zero (MZ) reference. It is therefore necessary to adjust the reference datum from MLLW/MLW to MZ prior to any data blending. However, the *(MZ – MLLW/MLW)* values are unknown prior to the model runs. The adjustment was accomplished by iteratively updating the $\Delta_{MLLW} = (MZ\text{-}MLLW)$ and $\Delta_{MLW} = (MZ\text{-}MLW)$ fields based on model results from a series of simulations: initial constant values of $\Delta_{MLLW} = 0.5\ m$ and $\Delta_{MLW} = 0.4\ m$ were assumed for the whole grid. Following each model run, new sets of tidal datum fields were derived and were used to update the Δ_{MLLW} and Δ_{MLW} fields. Multiple runs were conducted until invariant Δ_{MLLW} and Δ_{MLW} values were achieved. In the present study, five iterations were made to meet a convergence criteria of both $|\Delta_{MLLW}|$ and $|\Delta_{MLW}|$ less than 10^{-3} m. Figure 4 shows the bathymetry used in the final model run.

Figure 6(a) and (b) show bathymetry used in conducting the final model run. Considering the wide range of bathymetry distribution, each figure displays a portion of its total dynamic range for clarity of display, with figure 6(a) for [0, 100] m and figure 6(b) for [100, 3000] m.

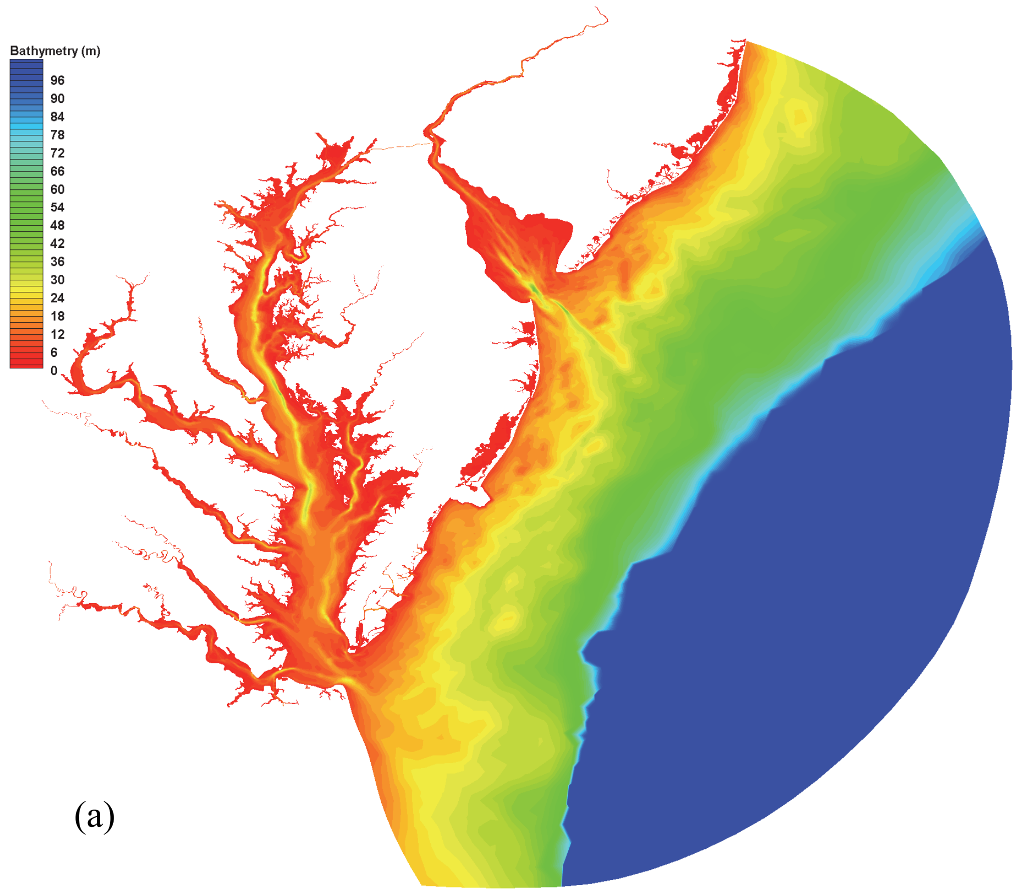


Figure 6. Model grid bathymetry relative to MSL, (a) bathymetries between [0, 100] m; those beyond 100 m are shown in the same scale as the 100-m bathymetry; (b) bathymetries between [100, 3000] m; those less than 100 m are shown in the same scale as the 100-m bathymetry. The colorbar is labelled in meters.

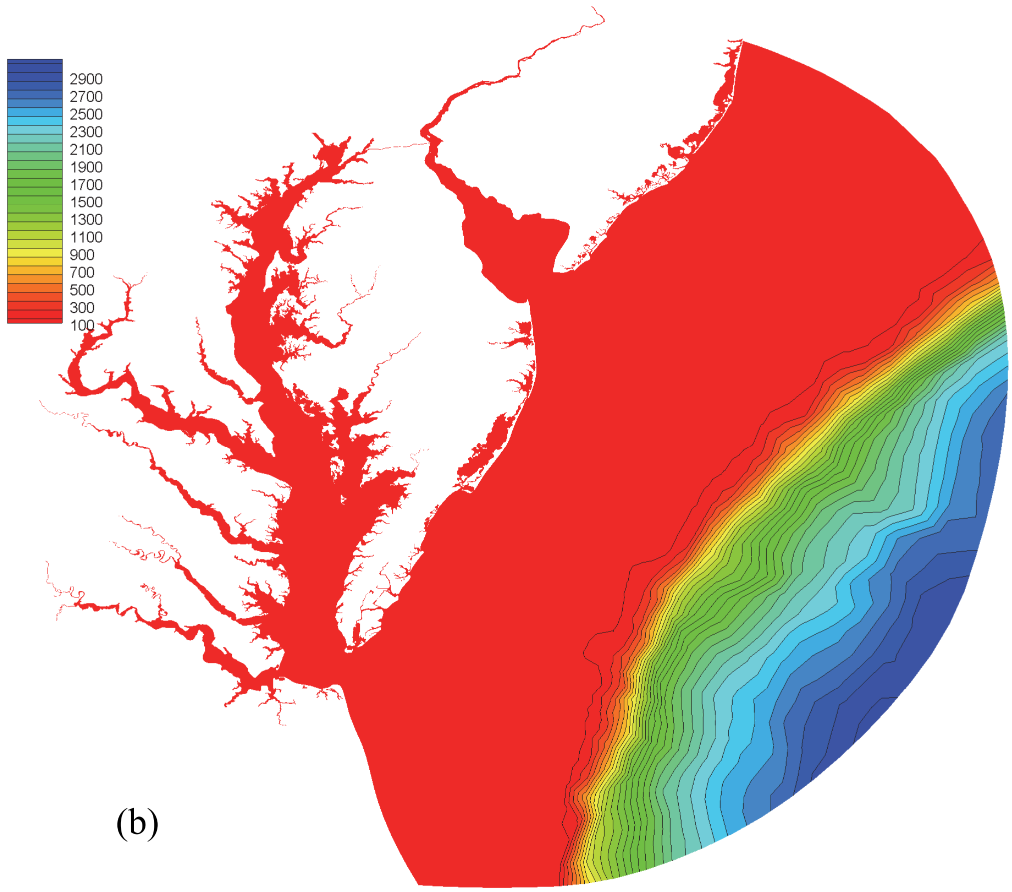


Figure 6. (Continued)

3.4. Model Parameters Setup

In the present study, model parameters in ADCIRC were set up to solve the shallow water equations in two-dimensional depth-integrated (2DDI) mode with finite amplitude and convection terms. Lateral viscosity was set as a constant, 5.0 m s^{-2}, throughout the model domain. A quadratic friction scheme with spatially-varying coefficients (C_f) was specified to calculate bottom friction. Multiple runs were conducted to test various C_f values in an attempt to minimize model-data discrepancies in the tidal datums. Figure 7 shows the calibrated C_f values used for the final tidal simulations.

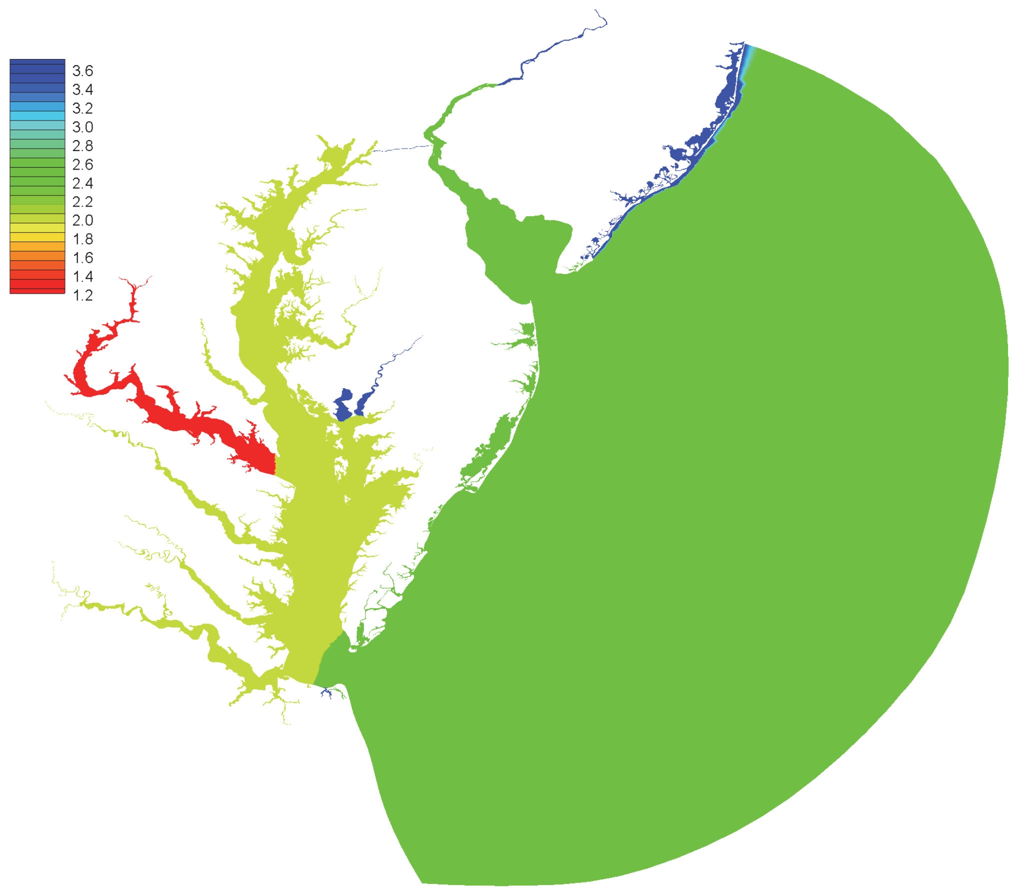


Figure 7. Spatially variable bottom friction coefficients used for the model simulations.

The nine most significant astronomical tidal constituents (M_2, S_2, N_2, K_2, K_1, P_1, O_1, Q_1, and M_4) in the area were input as tidal forcings along the model's open boundary. Corresponding harmonic constants were interpolated based on a tidal database derived from the Western North Atlantic Ocean tidal model (WNATM) (Myers, unpublished manuscript). A time step equal to 2.0 seconds was used to ensure computational stability. The simulation was integrated over 60 days. First, the model was ramped up for 10 days with a hyperbolic tangent function. Simulations continued for another 10 days to allow the tidal fields to reach an equilibrium state. Afterwards, 30-minute interval water level time series were recorded for 40 days to facilitate harmonic analysis of 37 tidal constituents (see Appendix B for a list of the names and speeds of the 37 constituents).

The parallel version of the ADCIRC model was adopted and the model run was conducted on 128-processors on the JET computing system at NOAA's Earth System Research Laboratory. It took approximately fifteen hours to complete the 60-day simulation.

3.5. Tidal Datum Computation and Results

Model derived harmonic constants were used to reconstruct longer water level time series from which tidal datums could be computed. For each model grid node, water level time series were reconstructed at six-minute intervals for the whole 1983-2001 national tidal datum epoch using the following relation:

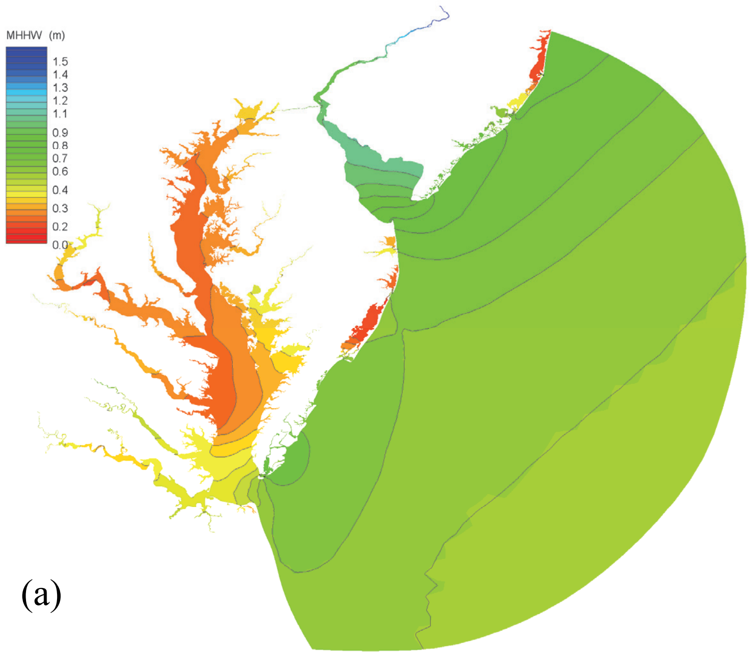
$$\varsigma(t) = \sum_{i=1}^{37} f_i A_i \cos(\sigma_i t + [V_o + u]_i - \kappa_i),$$

where ζ represent the instantaneous water level relative to MSL, t is the time, i denotes one of the 37 constituents, f_i is the nodal factor, A_i is the constituent amplitude, σ_i is the constituent speed, $[V_o+u]_i$ represents the equilibrium argument at time zero, and κ_i is the Greenwich epoch. In the computations, f_i and $[V_o+u]_i$ were updated every six minutes.

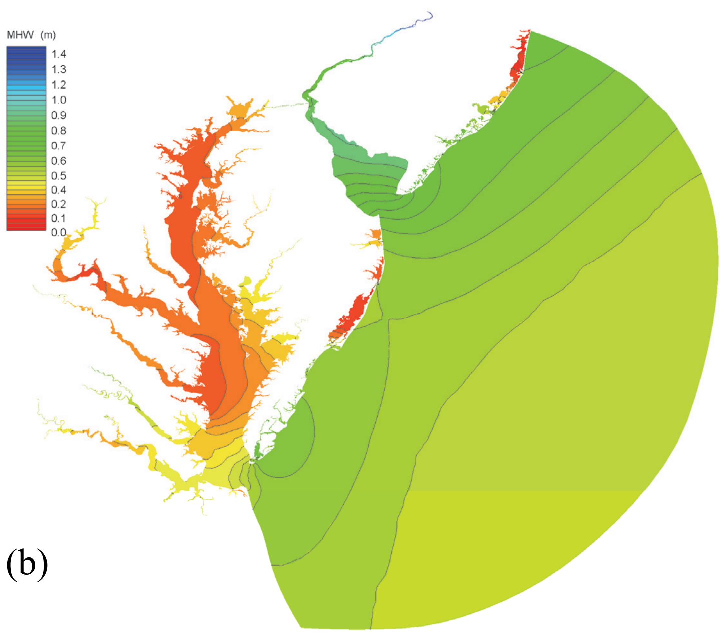
The 19-year long time series were analyzed to derive tidal datum fields for MSL, MHHW, MHW, MLW, and MLLW. The latter four were then adjusted to be referenced to the MSL field. It is noted that since the reconstructed time series cover a complete 19-year epoch, the derived MSL field actually resulted as a constant zero.

Note that the MTL is defined as the algebraic average of MHW and MLW, and DTL is the algebraic average of MHHW and MLLW. The two fields were not computed until error-corrected MHHW, MHW, MLW, and MLLW fields were obtained (Section 4.2).

Figures 8(a-d) display the model derived tidal datum fields for MHHW, MHW, MLW, and MLLW, respectively. The four fields exhibit a similar spatial pattern. Magnitudes of the tidal datums are amplified as the tides approach the shoreline; they start from about 0.5 m along the shelf break and reach up to about 0.8 m near the entrances to either Delaware Bay or Chesapeake Bay. In Delaware Bay, tides are enhanced further toward the upper reaches of Delaware River. MHHW reaches a maximum of approximately 1.6 m and the magnitudes of the other three datums end up with an absolute maximum of around 1.4 m. In contrast to the tidal amplification in Delaware Bay, tides in Chesapeake Bay are damped as they propagate northward toward the upper Bay. The tidal datum magnitudes dropped from around 0.6 m at the Bay entrance to about 0.4 m near the upper Bay.

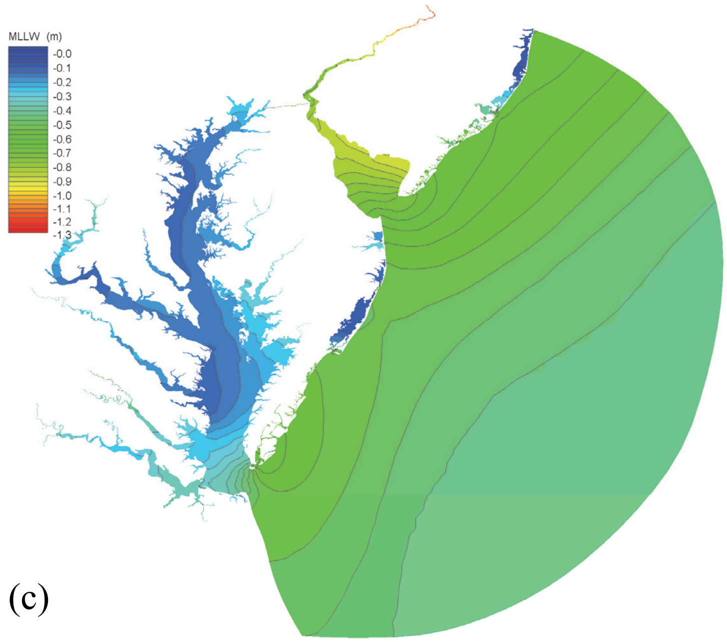


(a)

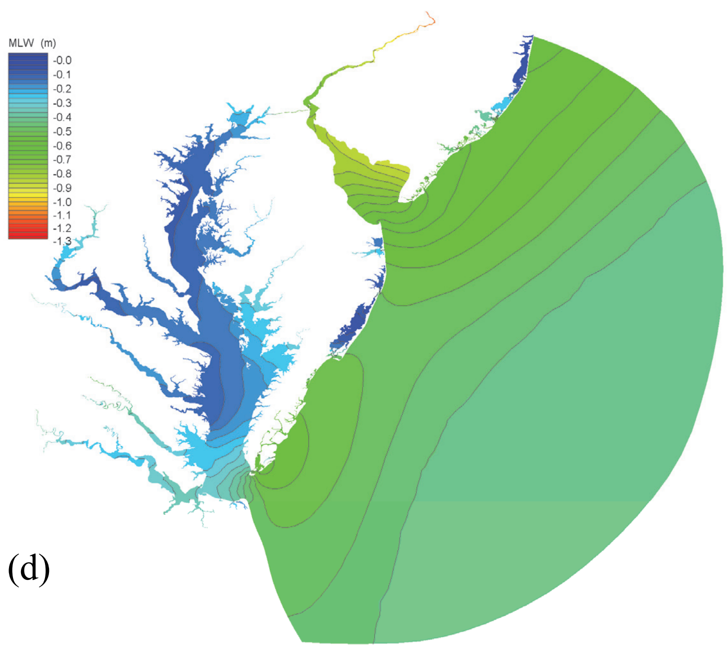


(b)

Figure 8. Model derived tidal datum fields, (a) MHHW, b) MHW, (c) MLW, and (d) MLLW. Units are meters.



(c)



(d)

Figure 8. (Continued)

3.6. Verifications and Error Corrections

3.6.1. Comparisons with Observations

To verify the model results, simulated tidal datums were compared with those from 298 CO-OPS tidal gauge observations (Appendix C). Figures 9(a-d) display model-data comparisons for MHHW, MHW, MLW, and MLLW, respectively. In general, there is good model-data agreement. Over the 298 stations, magnitudes of the model-data differences are averaged to be 4.1 cm, 3.2 cm, 2.9 cm, and 5.2 cm for MHHW, MHW, MLW, and MLLW, respectively. The model-data correlation coefficients demonstrate a constant 0.99 for all four tidal datums.

For each individual station, averaged magnitudes (|Avg|) of model-data differences over the four datums were examined. Figures 10(a) and 10(b) illustrate |Avg|'s scaled in color-coded symbols. Figure 10(a) shows those in Chesapeake Bay and adjacent coastal waters and Figure 10(b) displays those in Delaware Bay as well as adjacent embayments and coastal waters. The largest discrepancy occurs at six stations in the upper reaches of Delaware River. Errors increase in magnitude from south to north here, with corresponding |Avg|'s equal to 11.5 cm, 13.8 cm, 14.3 cm, 14.7 cm, 16.96 cm, and 17.3 cm. These errors appear to be associated with the stronger river influences upstream. The Delaware River discharges demonstrate strong seasonal variability in both volume and water temperature. These influences in turn introduce significant seasonal and semiannual constituents into the total tidal spectrum. Tidal datums could therefore be modulated enormously. Note that in the present tidal simulations, the long term seasonal/semi-annual constituents are not included in the tidal boundary forcings. The apparent model-data discrepancy is therefore attributed to the river discharge effects. This reflects the limitation of the present tidal simulation.

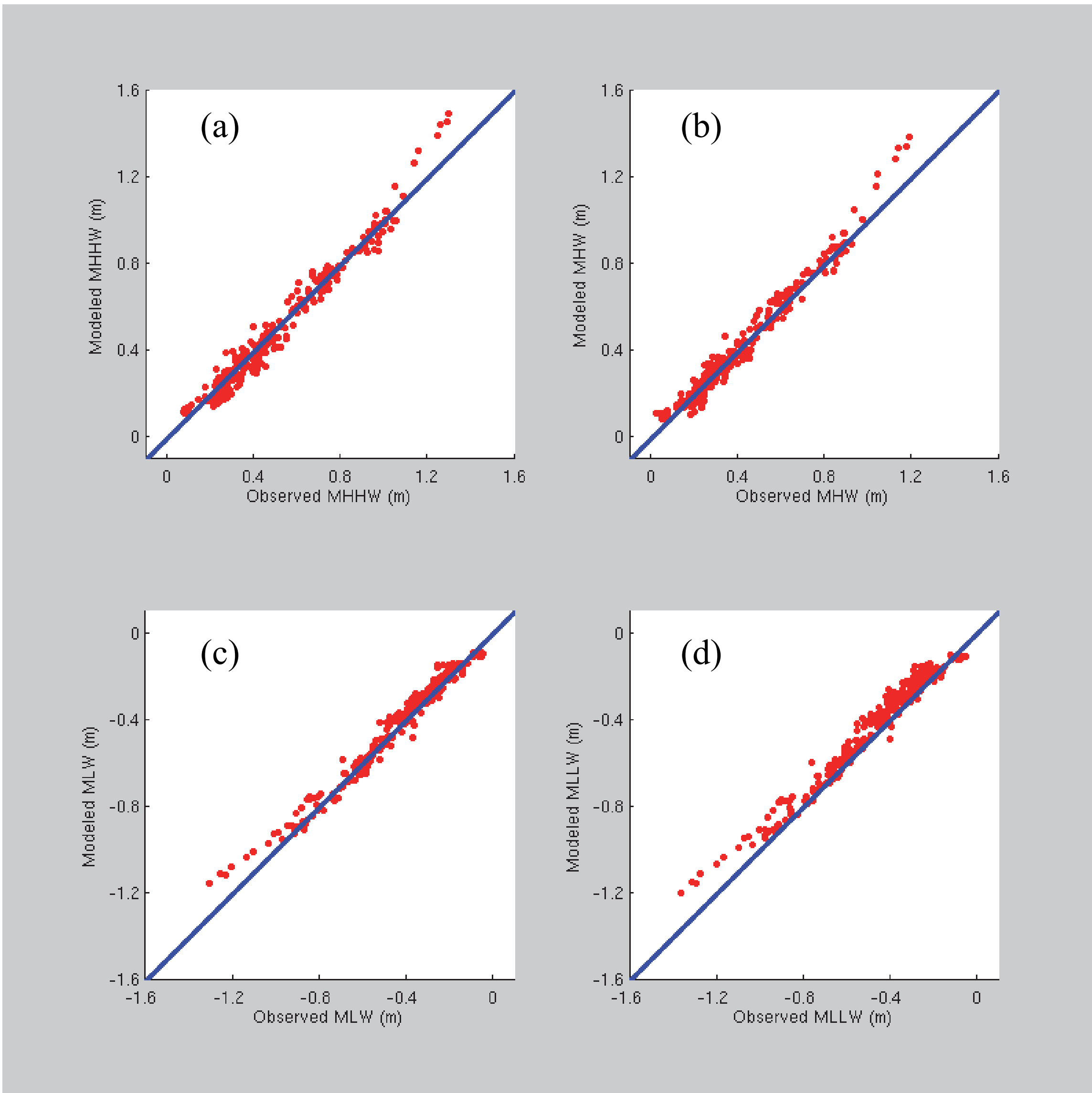


Figure 9. Comparisons of the modeled (a) MHHW, (b) MHW, (c) MLW, and (d) MLLW datums against observations.

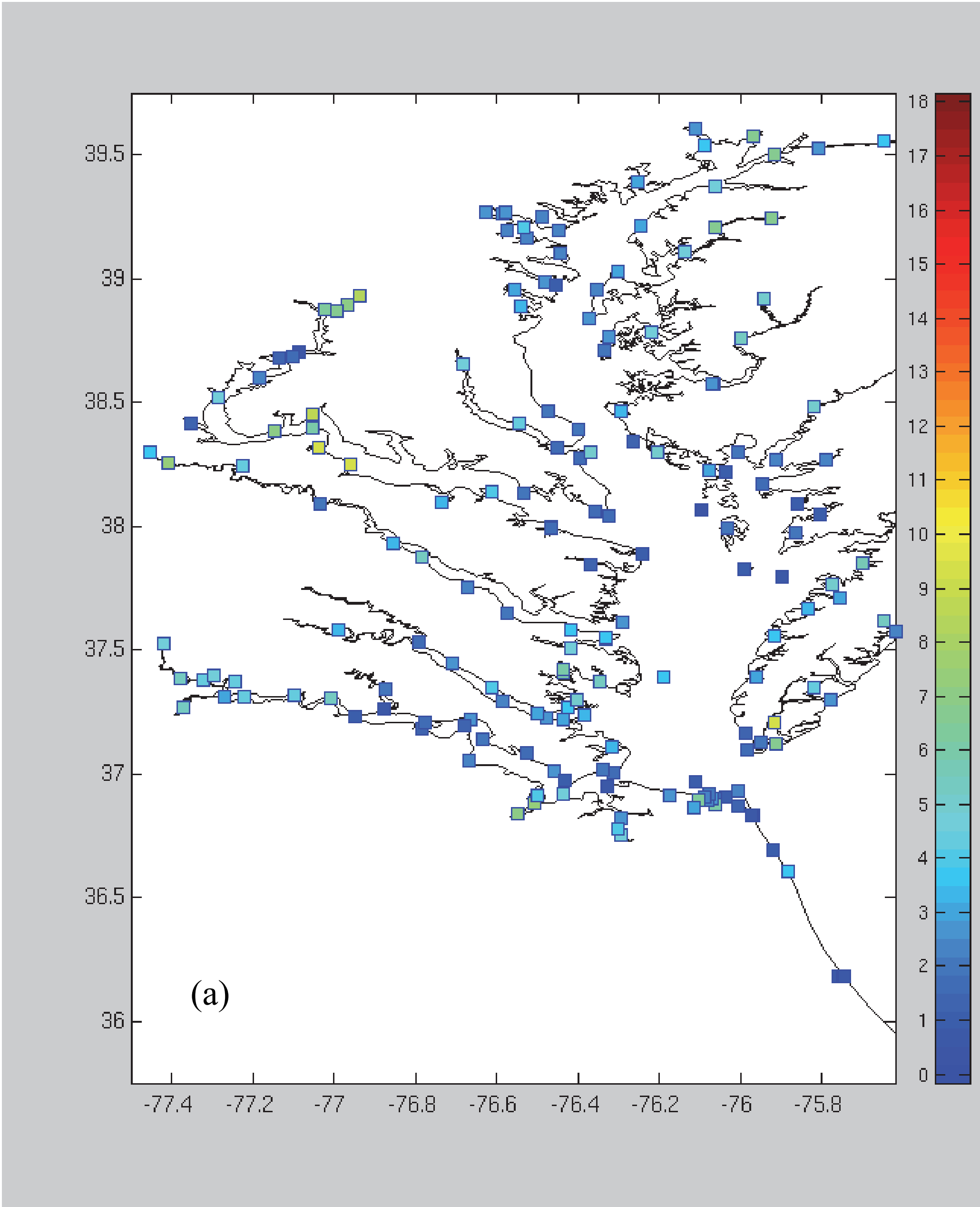


Figure 10. Color-coded model-data differences at each observational station, (a) Chesapeake Bay and (b) Delaware Bay. Units are meters.

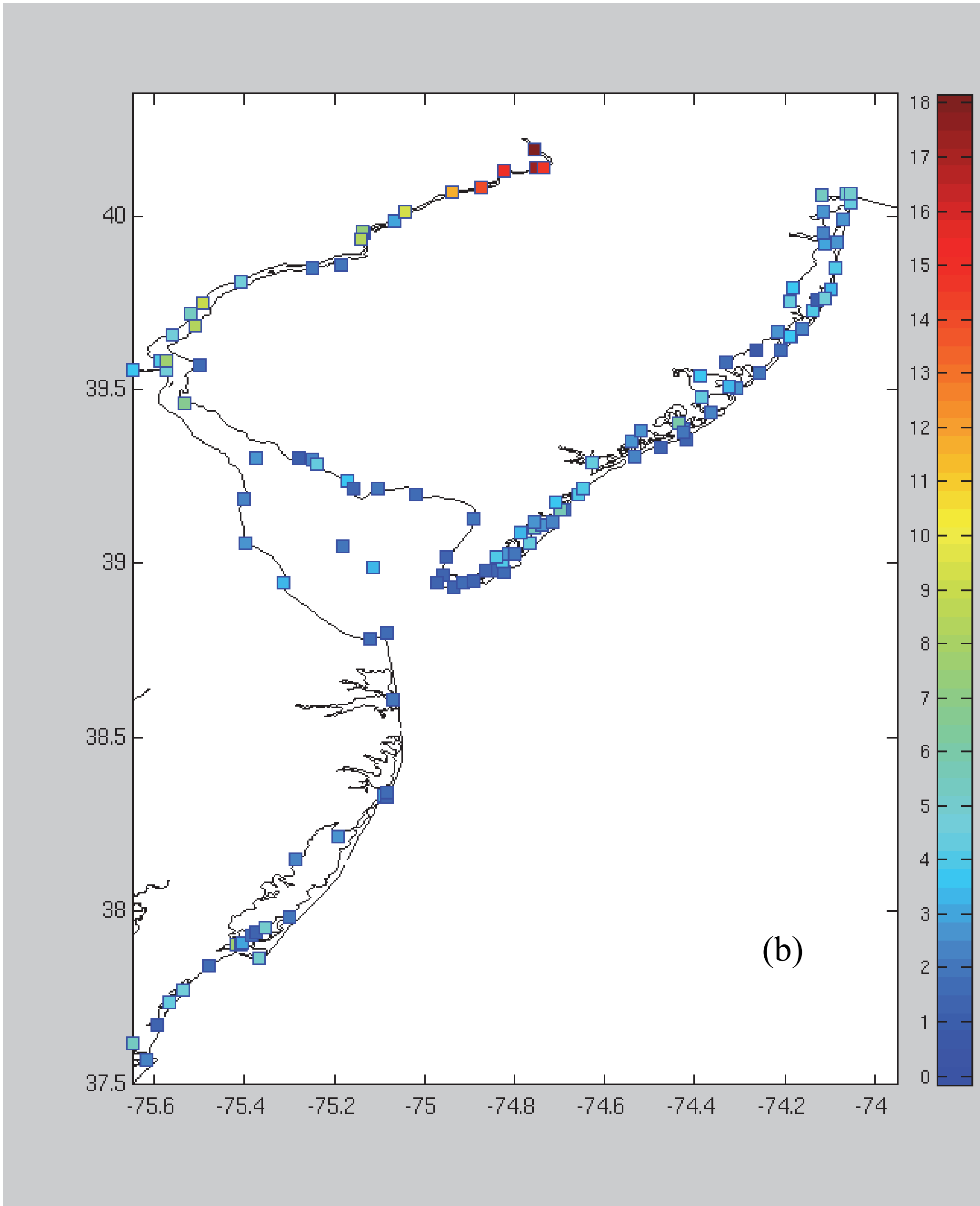


Figure 10. (Continued)

3.6.2. Match with Tidal Datums in Adjacent Areas

Prior to the present VDatum project for the Chesapeake and Delaware (C&D) Bays area, tidal datums were previously developed for two adjacent areas: the Long Island Sound and New York Bight (LIS-NYB) to the north (Yang et. al, 2006) and the central/northern North Carolina (NC) region to the south (Hess et. al, 2005).

Figure 11 illustrates the coverage of these three VDatum domains, including the CB-DB study area. In the figure, the black line delineates the CB-DB domain, while blue and red lines delineate the NC and LIS-NYB domains, respectively. They intersect at two boundaries along transects AA' and BB', respectively. The green line denotes 25-nm offshore locations.

In an effort to develop a national VDatum utility, tidal datum fields should be matched seamlessly across the boundaries of regional applications. However, this is not necessarily achieved since the three tidal datum fields were developed separately. Therefore, it is worthwhile to examine discrepancies and explore ways to reach seamless matches if needed.

In Figure 11, black circles and red triangles correspond to the CB-DB model grid nodes located near the model domain boundaries of the LIS-NYB (transect AA') model domain and NC (transect BB') VDatum domains, respectively. Four datums (MHHW, MHW, MLW, and MLLW) from the LIS_NYB model and NC VDatum applications were separately interpolated onto these comparison locations. Figures 12 and 13 show the comparisons along transects AA' and BB', respectively. Table 1 tabulated root mean squares (rms) of the differences. In general, the MHHW and MLW differences at boundary BB' are greater than at AA'; and vice versa for MHW and MLW.

Table 1. The root mean square differences of MHHW, MHW, MLW, and MLLW across boundaries of different VDatum regimes.

Boundaries	MHHW (cm)	MHW (cm)	MLW (cm)	MLLW (cm)
AA'	1.1	2.5	1.9	1.4
BB'	3.1	2.1	0.6	3.1

In general, the rms differences are greater than 1 cm, which suggest the necessity of adjustments to reach seamless matches between the present results and those developed previously. Procedures for the adjustment are described in the next section.

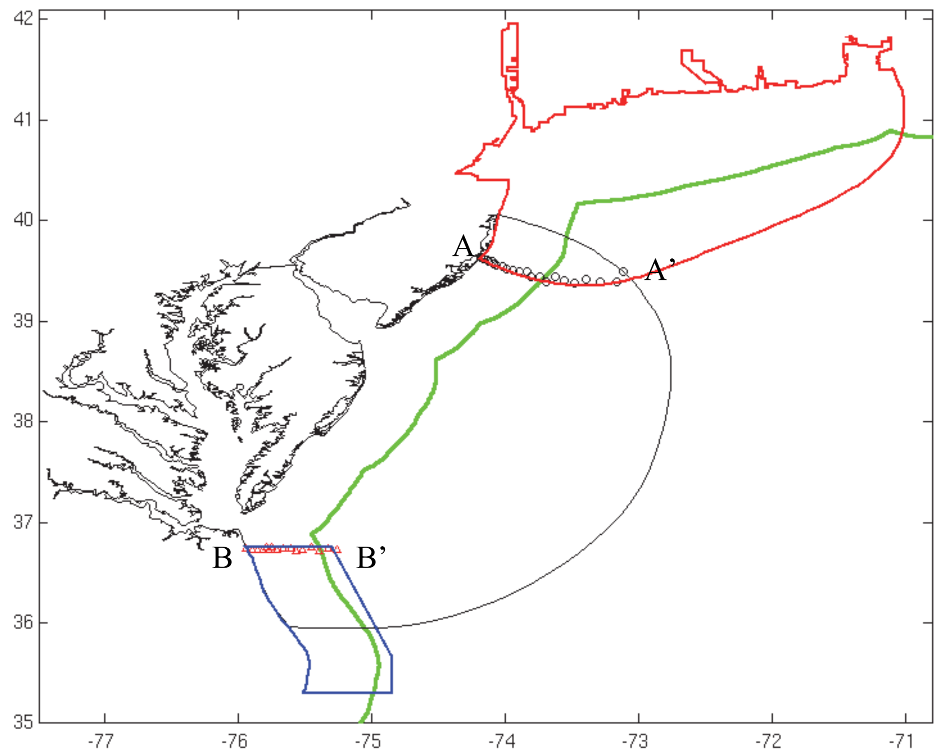


Figure 11. Map of the CB-DB model domain (black line) and the outlines of the bounding polygons of the NC (blue line) and LIS-NYB (red line) VDatum areas. Black circles (transect AA’) and red triangles (Transect BB’) represent CB-DB model grid nodes close to the LIS-NY and NC VDatum domains, respectively. Green line delineates the 25-nm offshore limit.

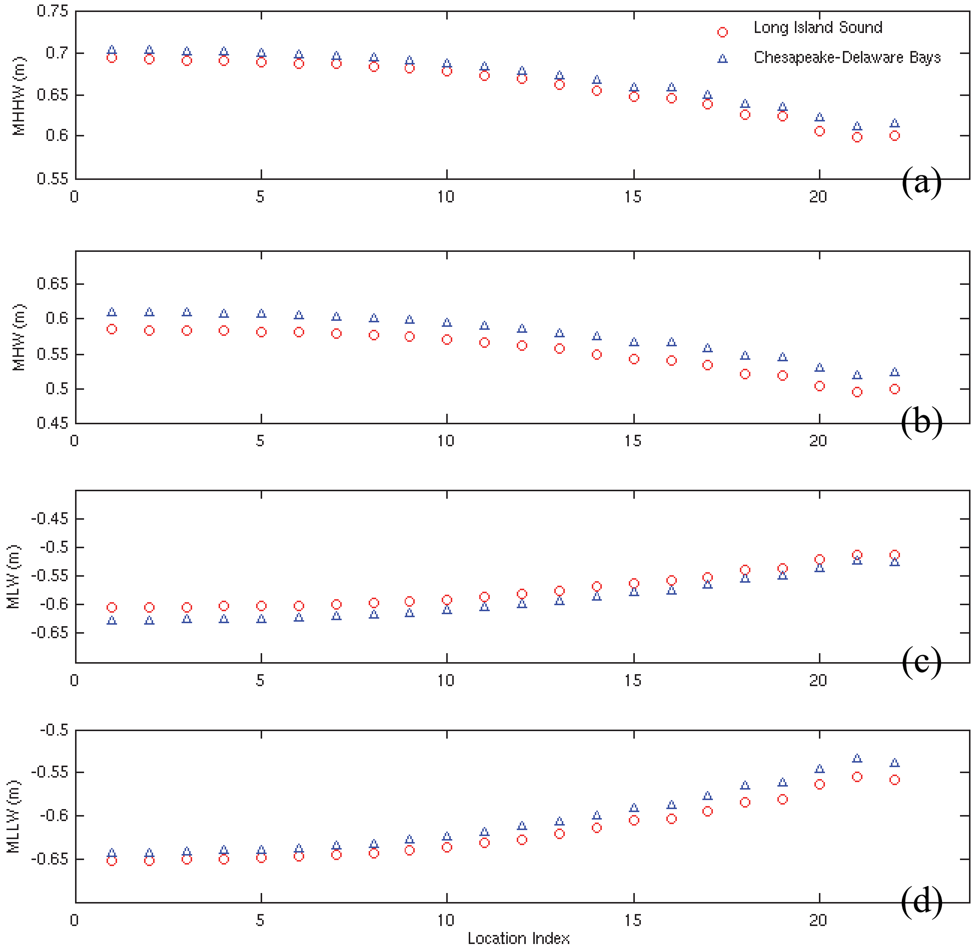


Figure 12. Comparisons of tidal datums along the CB-DB and LIS-NYB boundary, (a) MHHW, (b) MHW, (c) MLW, and (d) MLLW at locations (black circles in Figure 11). The abscissa, Location Index, is counted from A to A' (Figure 11).

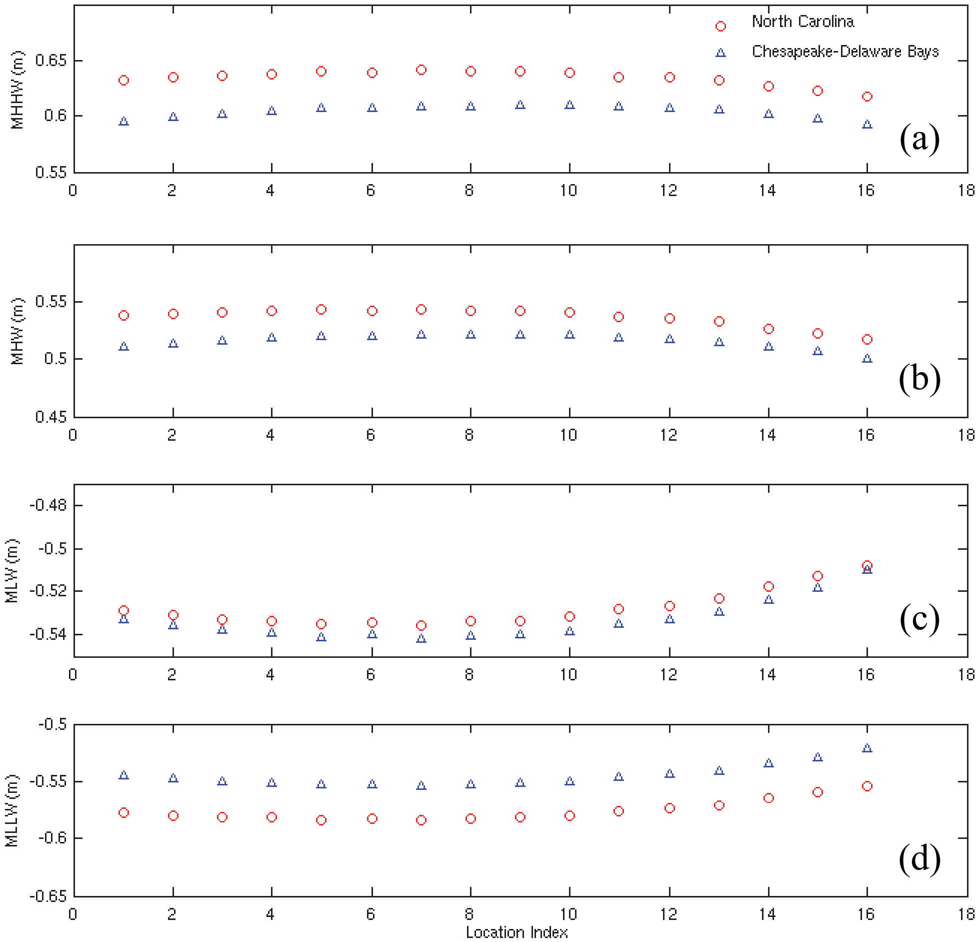


Figure 13. Comparisons of tidal datums along the CB-DB and NC boundary, (a) MHHW, (b) MHW, (c) MLW, and (d) MLLW at locations (red triangles in Figure 11). The abscissa, Location Index, is counted from B to B' (Figure 11).

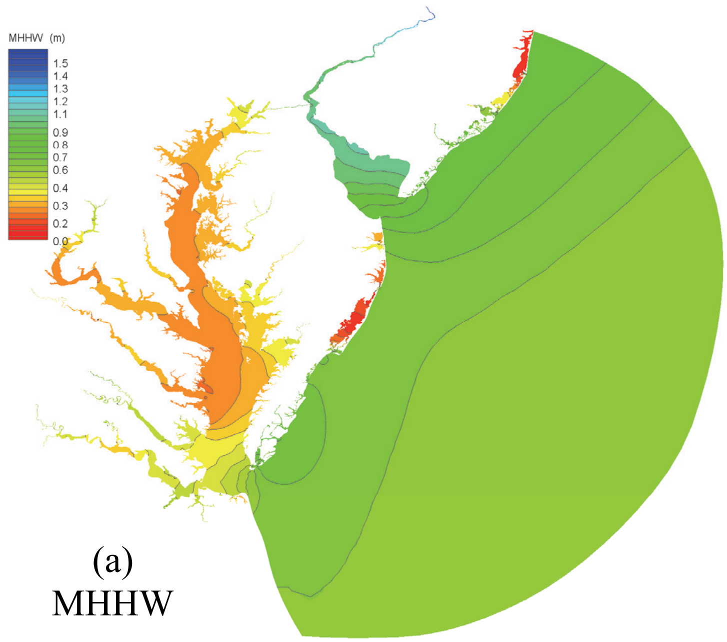
3.6.3. Corrections

Tidal datum corrections are applied to the modeled tidal datums to eliminate model-data differences at observational stations (Section 3.6.1) as well as to diminish datum discrepancies across boundaries of different VDatum domains (Section 3.6.2). This was achieved via the MatLab version of the tidal constituent and residual interpolation (TCARI) technique (Hess, 2002; Hess 2003). TCARI spatially interpolates the error fields defined at a number of individual control stations onto the whole domain by solving Laplace's equation. The technique was implemented for both structured and unstructured model grids at Coastal Servey Development Laboratory (CSDL), and a version of the latter was employed in this study.

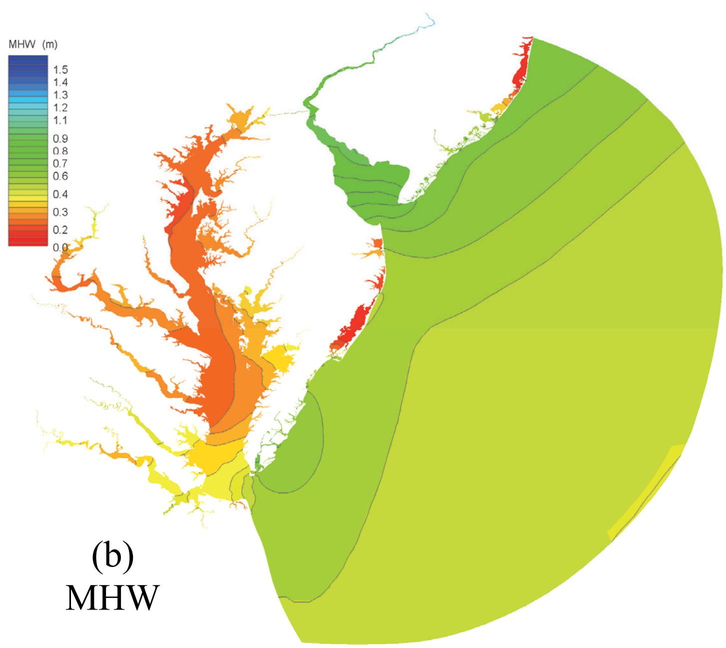
To apply TCARI in the region, both the observational stations and the domain boundary discrepancies are treated equally as control stations. For each tidal datum, both model-data differences at the 298 tidal stations and across-boundary discrepancies at 38 boundary locations (Section 3.6.2) were computed and merged into one dataset as input to TCARI.

After running TCARI, error fields for MHHW, MHW, MLW, and MLLW were derived, which matched the tidal datum differences at the 298 control stations as well as the tidal datums from adjoining VDatum applications. The initial model results (Section 3.5) were then corrected by subtracting the error fields over the entire model grid. Figures 14(a-f) display the corrected datum fields.

Note that the other two tidal datum fields, the MTL and DTL, were produced in a different way. They were derived from the four corrected datums by taking the averages between MHW and MLW and between MHHW and MLLW, respectively.

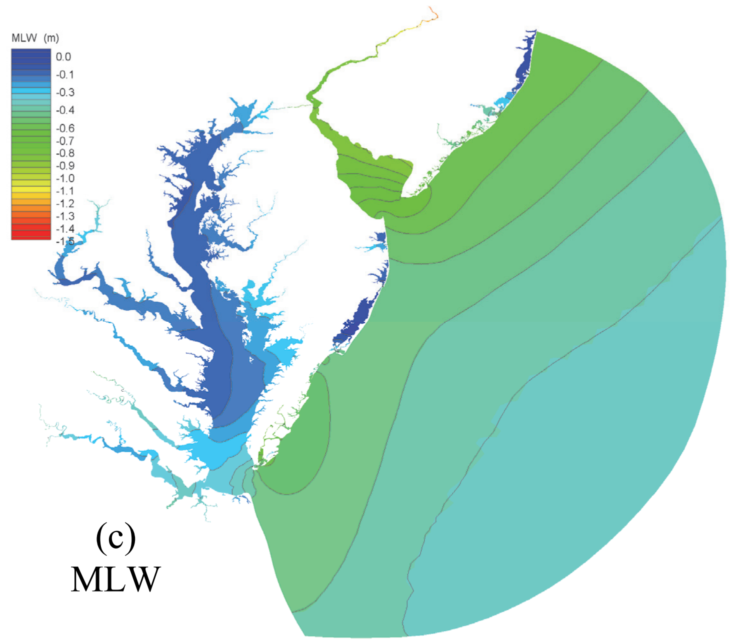


(a)
MHHW

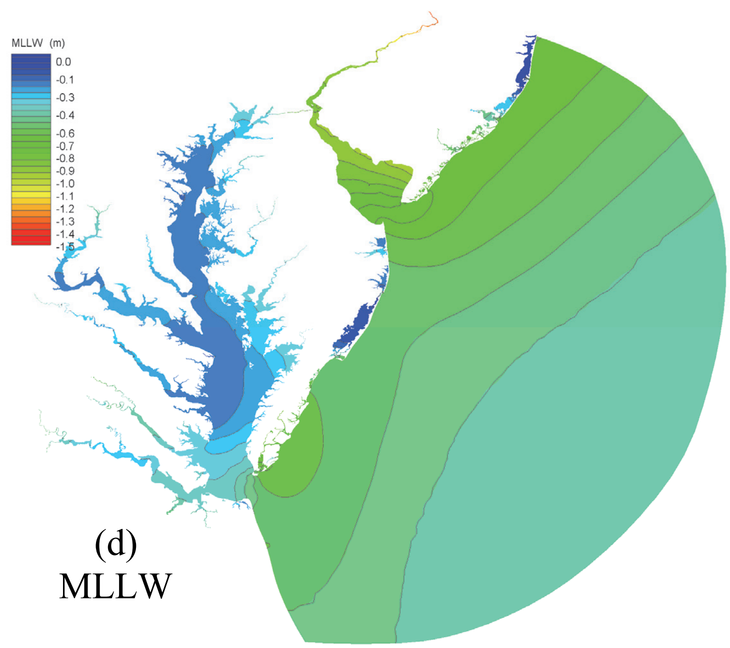


(b)
MHW

Figure 14. Corrected tidal datum fields on the unstructured grid, (a) MHHW, (b) MHW, (c) MLW, (d) MLLW, (e) MTL, and (f) DTL.

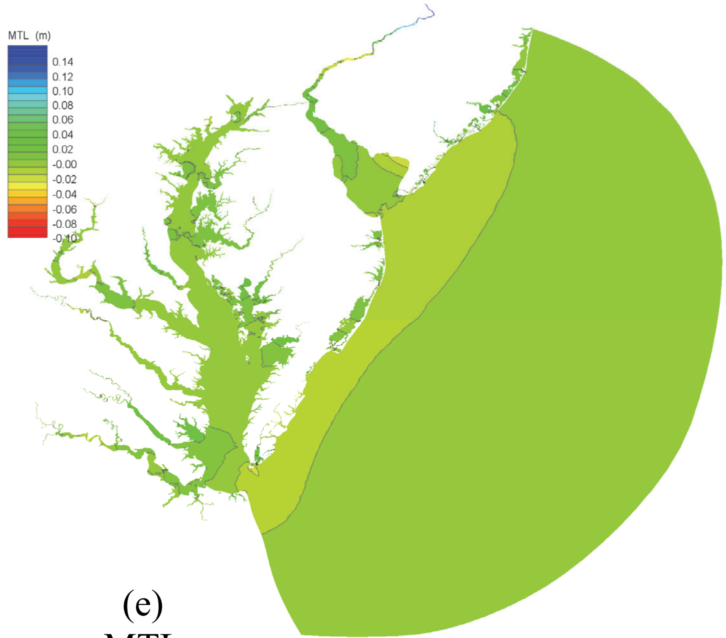


(c)
MLW

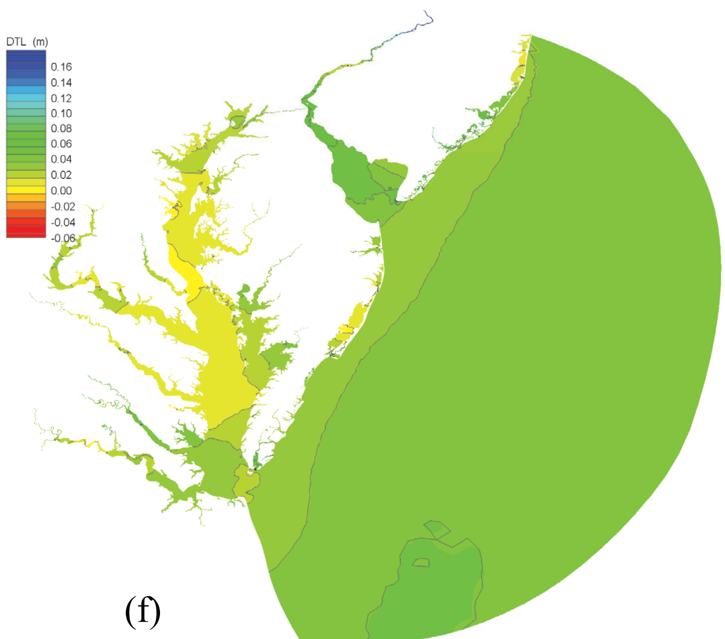


(d)
MLLW

Figure 14. (Continued)



(e)
MTL



(f)
DTL

Figure 14. (Continued)

4. CREATION AND POPULATION OF THE MARINE GRID

4.1. Creation of VDatum Marine Grid

VDatum incorporates the corrected version of the modeled tidal datums through the use of a marine grid. This is a regularly spaced set of data points onto which the corrected model results are interpolated (Hess and White, 2004). Using the high resolution shoreline data, each marine grid point is evaluated as to whether it falls inside (water) or outside (land) this shoreline. A small buffer is also taken into account, such that marine grid points that fall just slightly on the land (within 0.1 nautical miles) may still be assigned a tidal datum value. There may also be areas for which the hydrodynamic model grid does not fully extend through the entire water domain as defined by the shoreline data, and interpolation techniques are used to extend the tidal datums in these regions. The final marine grid of tidal datum fields is provided as input to the VDatum software. A user-supplied longitude/latitude pair to VDatum will thus interpolate from the marine grid the desired tidal datum.

The C&D Bays region includes many embayments along the New Jersey, Delaware, Maryland, and Virginia coasts. These embayments are separated from nearby shelf waters by a series of narrow barrier islands. Thus, the tidal regimes on either side of these islands will be very different. If the width of the barrier islands is less than the marine grid resolution, VDatum may erroneously calculate some user-input locations by averaging datums from both regimes. To avoid this, the two regimes need to be represented by different marine grids.

Hence, the whole study region was divided into five sections each with their own marine grid: Chesapeake Bay, DE-MD-VA embayments, Delaware Bay, New Jersey embayments, and mid-Atlantic Bight shelf (Figure 15). The five sections are delineated with bounding polygons, and the marine grid parameters are listed in Table 2. VDatum points within the bounding polygons and over water or within up to one half of a cell size landward of the coastline are designated as water points, while the others are marked as land points. The water points were populated by the error-corrected tidal datums and MSL-to-NAVD88 (Section 5) conversions. For a given point at the *i*-th row and *j*-th column relative to the point of origin *(longitude*$_0$*, latitude*$_0$*)* of a given section's southwest corner, its location *(longitude_i, latitude_j)* is defined as,

$$\text{Longitude\_i} = \text{longitude}_0 + (\text{i}-1)\times\text{del\_lon},\ \ \text{i}=1, \ldots, \text{N\_lon},$$
$$\text{Latitude\_j} = \text{latitude}_0 + (\text{j}-1)\times\text{del\_lat},\ \text{j}=1, \ldots, \text{N\_lat},$$

where *del_lon*, and *del_lat* denote separation between neighboring points along the meridional and zonal directions, respectively; *N_lon* and *N_lat* represent, respectively, the longitude and latitude dimensions of the raster data set. It is noted that the *del_lon* and *del_lat* are prescribed parameters representing the expected grid resolutions, while *N_lon* and *N_lat* are derived parameters according to

$$\text{N\_lon} = 1 + (\text{longitude}_1 - \text{longitude}_0)/\text{del\_lon}$$

$$N\_lat = 1 + (latitude_1 - latitude_0)/del\_lat$$

where *(longitude₁, latitude₁)* are the coordinate at the raster region's northeast corner. Table 2 lists parameters defining the five marine grids.

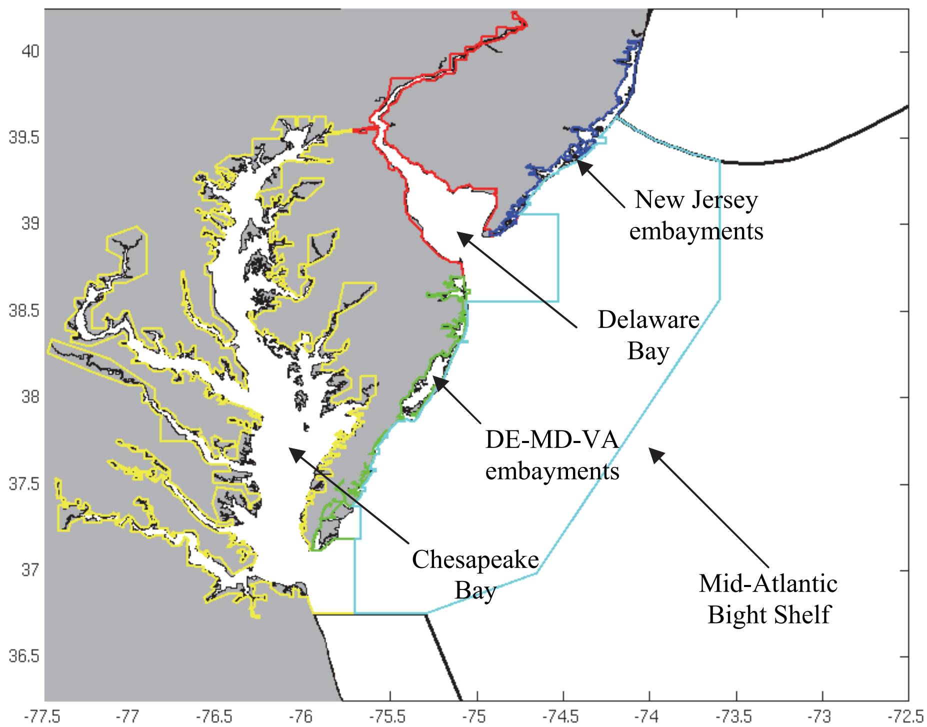


Figure 15. Bounding polygons of the five VDatum regions: (1) Chesapeake Bay (yellow), (2) DE-MD-VA embayments (green), (3) Delaware Bay (red), (4) New Jersey embayments (blue), and the Mid-Atlantic Bight shelf (cyan).

Table 2. Marine grid parameters

Marine Grids	$Longitude_0$ (degrees)	$Latitude_0$ (degrees)	del_lon (degrees)	del_lat (degrees)	N_lon	N_lat
Chesapeake Bay	-77.48	35.95	0.002	0.002	951	1851
DE-MD-VA embayments	-75.96	37.11	0.002	0.002	466	801
Delaware Bay	-75.78	38.5	0.002	0.002	631	876
New Jersey embayments	-74.93	38.92	0.002	0.002	446	576
Mid-Atlantic Bight shelf	-75.73	35.93	0.004	0.004	746	1034

4.2. Population of VDatum Grid with Tidal Datums

Tidal datums on the VDatum marine grid were populated by interpolating TCARI-corrected tidal datums (Section 3.6) according to the algorithm of Hess and White (2004). Datums at each VDatum marine grid point were computed by averaging or linearly interpolating corrected values from the model grid within a user-specified searching radius or the closest user-specified number of points. In the present case, the interpolation was accomplished using a FORTRAN program vpop10.f. It populates marine grid points differently depending on whether the point is inside/outside of the ADCIRC grid elements. If the point is inside an element, datums were calculated using an interpolation of the 3 nodes of the element; if the point is outside any elements, datums were computed using the inverse distance weighting of the closest two node values. Figures D.1-D.5 in Appendix D display the populated tidal datums (MHHW, MHW, MLW, MLLW, MTL, DTL) defined on the five marine grids (Section 4.1): Chesapeake Bay, DE-MD-VA embayments, Delaware Bay, New Jersey embayments, and CB-DB shelf grids.

Two types of verifications were conducted for the tidal datums populated on the marine grids: comparing with observations from the 320 CO-OPS tidal stations and examining matches across its boundaries with the LIS-NY and NC VDatum regimes. For each of the four datums (MHHW, MHW, MLW, and MLLW), the average model-data error is less than 0.1 mm and the rms error is less than 0.38 mm.

Datum fields across the boundaries of different VDatum regimes also demonstrate good consistency. For each of MHHW, MHW, MLW, and MLLW, average difference and rms difference across the CB-DB and LIS-NY boundary are less than 0.1 mm and 0.1 mm, respectively; the corresponding values across the CB-DB and NC boundary are less than 0.1 mm and 0.14 mm, respectively.

5. TOPOGRAPHY OF THE SEA SURFACE

The TSS is defined as the elevation of NAVD 88 relative to MSL. It is created by combining observed datums at NGS benchmarks and CO-OPS water level stations with model results. Figure 16 illustrates the station locations used in this application (see details of the station information at Table F.1 of Appendix F). To create the TSS over the VDatum domain, the TSS values at the observation stations were first derived. They are then interpolated over the whole domain. Afterwards, a quality control procedure was followed and appropriate changes were made to meet certain criteria.

Figure 16. Location of tidal benchmarks and tide stations used to compute the Chesapeake Bay to Barnegat Bay, NJ VDatum TSS fields.

5.1. Derivation of TSS

Two methodologies were used to compute the TSS at the observational stations: an indirect method for the NGS data (see Appendix E) and a direct method for the CO-OPS data (see Appendix F). To derive TSS at the NGS stations, first, residuals (R_{datum}) at every NGS Benchmark location are computed as:

$$R_{datum} = TBM_{navd88} - TBM_{datum} - VD_{datum}$$

where TBM_{navd88} and TBM_{datum} are the observed (NAVD88–MLLW) and (Datum-MLLW) differences, respectively, and VD_{datum} denotes modeled (Datum–MSL) differences. The residual, R_{datum}, represents an estimation of the (MSL-NAVD88) difference.

There are four sets of R_{datum}, corresponding to MHHW, MHW, MLW, and MLLW. Each represents an independent estimation of the quantity MSL–NAVD88 associated with a tidal datum. Tables E.(1-5) list R_{datum}'s at stations located within the five VDatum bounding polygons (Figure 15), respectively. At each station, the four R_{datum}'s are then averaged to produce a mean residual ($\overline{R}_{datum}$). $\overline{R}_{datum}$ represents an overall estimation of MSL–NAVD88 and is used for further development of the TSS grid.

The TSS values at CO-OPS stations were simply derived by calculating orthometric-to-tidal datum relationships. Table F.1 shows the station location inventories and observations of elevation information.

Next, the $\overline{R}_{datum}$ values are merged with TSS values from CO-OPS stations to form a data set for creating a TSS mesh using the gridding software, Surfer©. A grid covering the entire area of benchmarks and water level stations with a spatial resolution similar to that of the VDatum marine grid is created. Breaklines are inserted to represent the influence of land. The Surfer© software's minimum curvature algorithm is employed to create a primary TSS field (TSS_{grid}) that honors the data as closely as possible. It is noted that the TSS_{grid} represents an estimation of the quantity MSL- NAVD88 and still requires further quality control and correction procedures (Section 5.2). Figures 16(a-e) show the final TSS fields for the five VDatum regions (Table 2). In the figures, a positive value specifies that the NAVD 88 reference value is further from the center of the Earth than the local mean sea level surface.

(a)

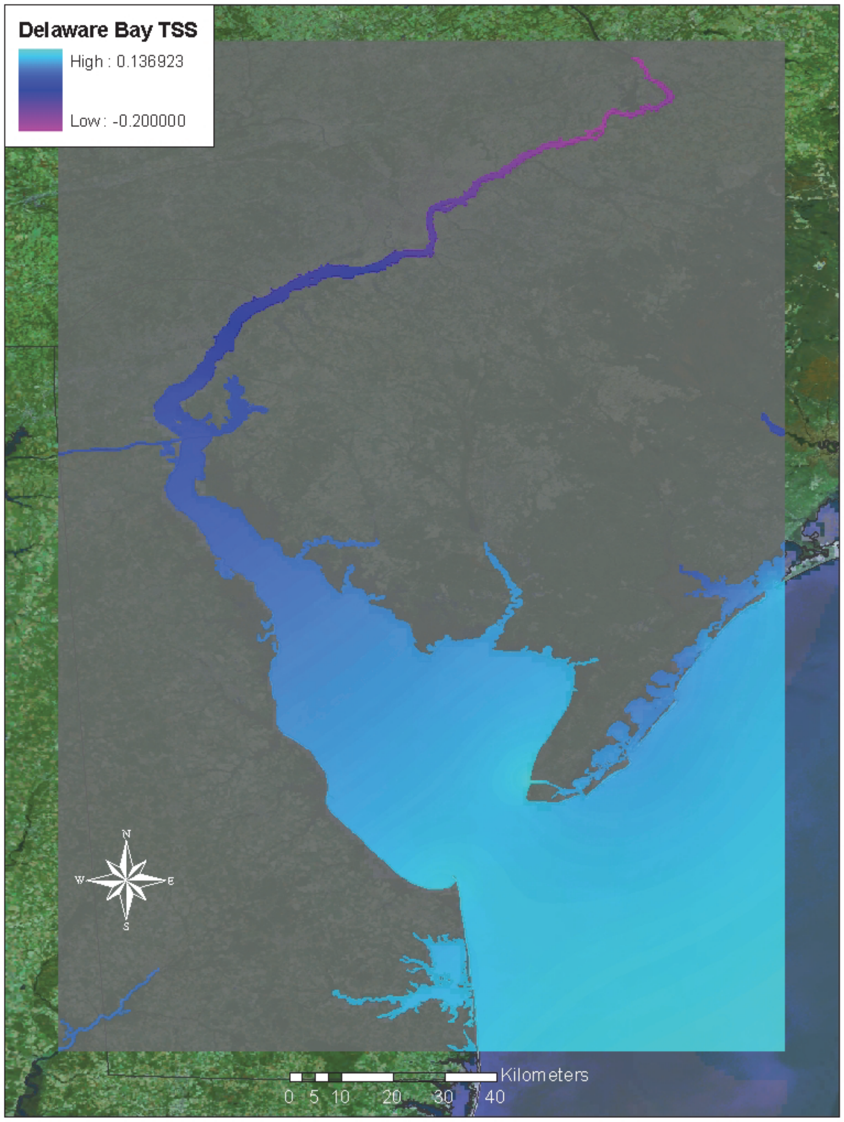


Figure 17. The TSS fields for (a) Delaware Bay, (b) New Jersey coast, (c) Chesapeake Bay, (d) DE-MD-VA coast, and (e) the Mid-Atlantic Bight shelf.

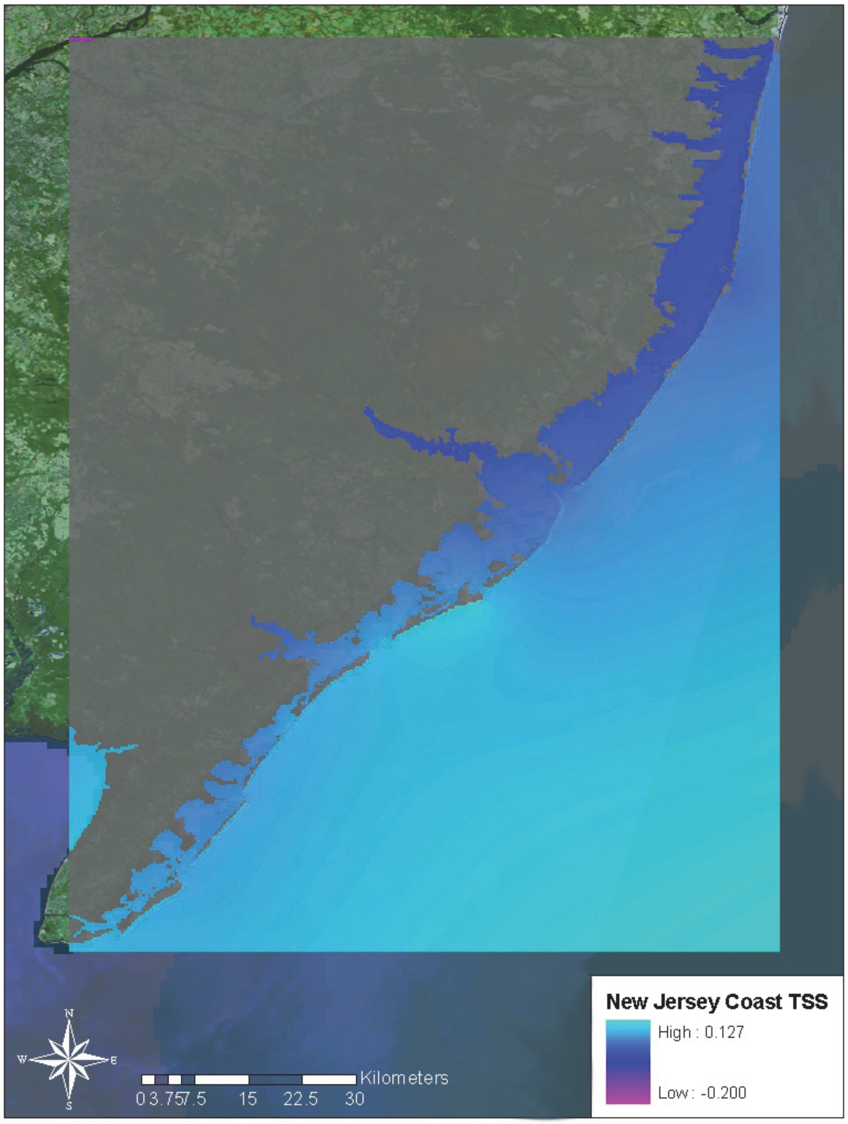


Figure 17. (Continued)

(c)

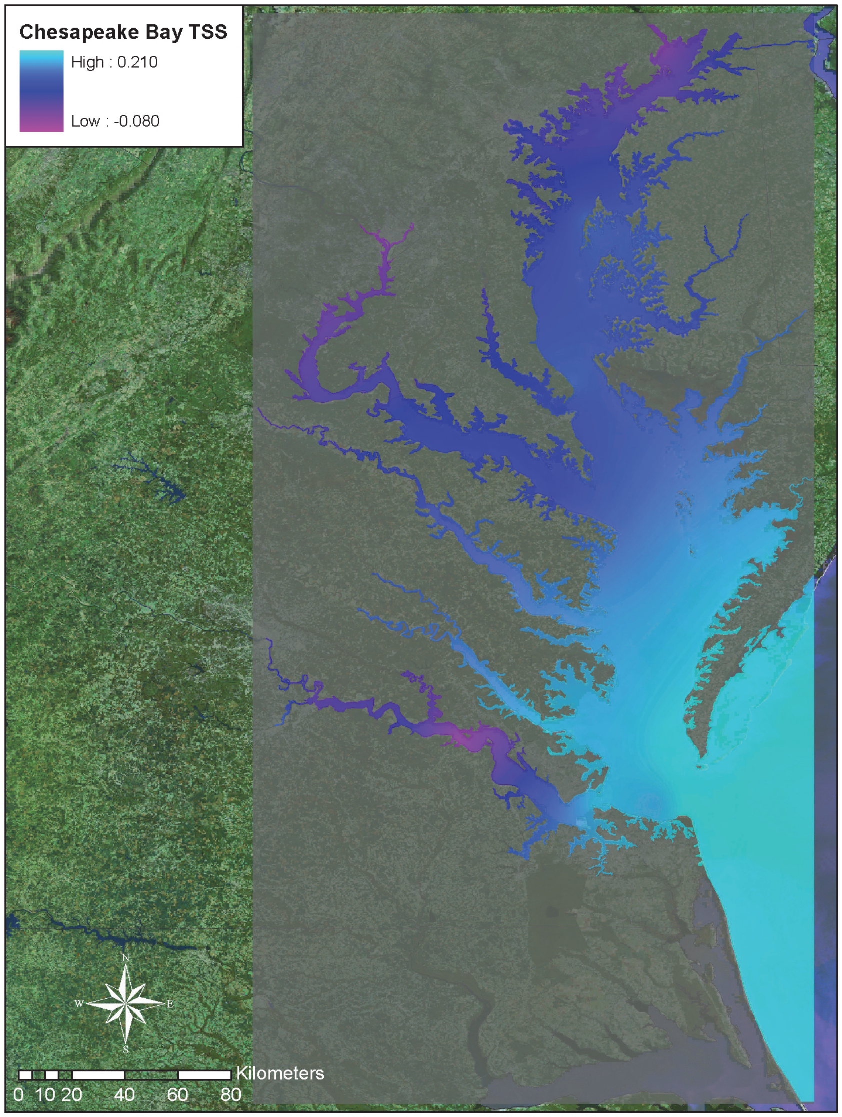


Figure 17. (Continued)

(d)

Figure 17. (Continued)

(e)

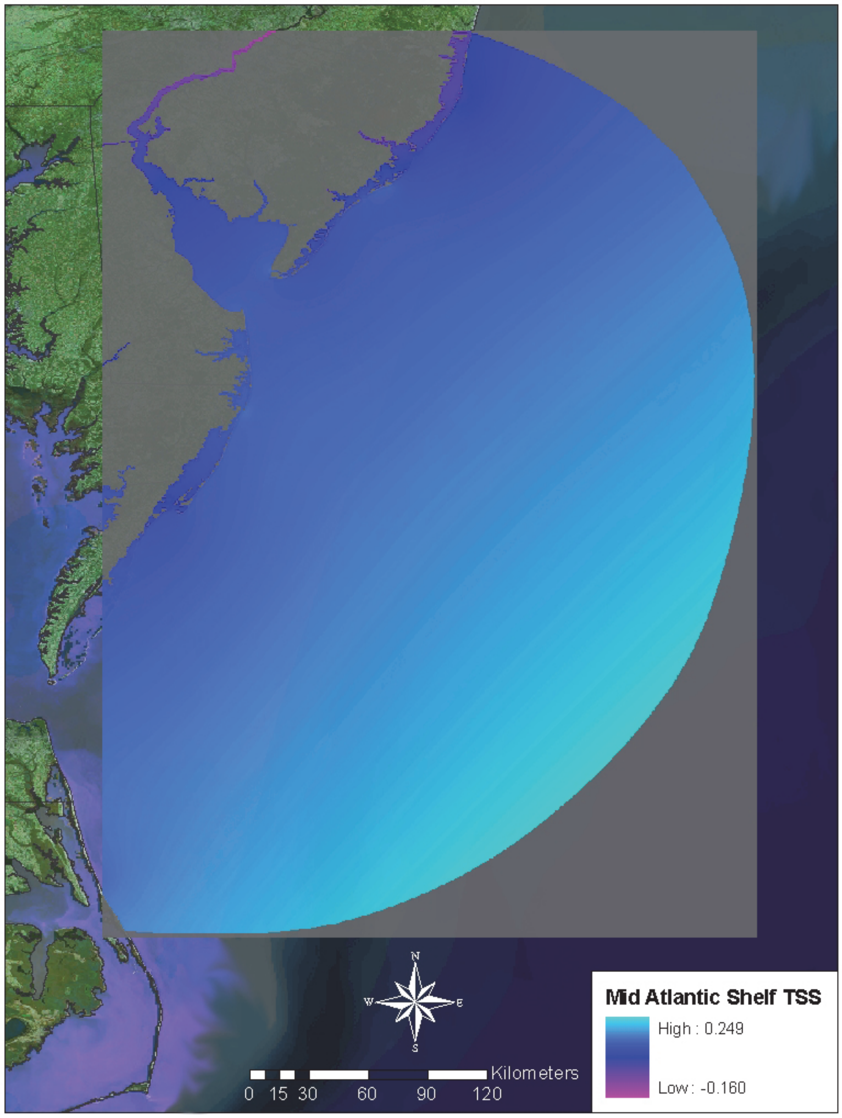


Figure 17. (Continued)

It should be noted that in the Delmarva, Delaware Bay, and Mid Atlantic Shelf VDatum areas, higher than normal standard deviations for NAVD 88 to MSL values were noticed during the indirect method calibration process. This led to further investigation into the reason for the high standard deviations. In the Ocean City, MD vicinity, several benchmark's elevation information are tied to two CO-OPS tide stations. Tide station 8570280 is located on the Atlantic Ocean side of the isle, whereas tide station 8570282 is located on the estuarine side. During the indirect calibration process, when calculating residuals for the estuarine side, benchmark elevation information related with the ocean side tide station will lead to higher than normal standard deviations. It is the opposite scenario when calculating residuals for the ocean side. Another area where a high standard deviation was noticed was tidal benchmark JU0176. This benchmark located in the Barnegat Inlet vicinity, is very close to a breakline. Therefore, high standard deviations arise from hydrodynamic model values being utilized in the calibration process from both the inside tidal regime and the estuarine tidal regime. Two additional NAVD88-to-MSL values were calculated by NGS at CO-OPS tide stations, 8534048 and 8558690. The high residuals reported at these two tide stations can be attributed to the tide stations not being used during the hydrodynamic modeling of the tidal grids.

5.2. Quality Control

Quality control is necessary for obtaining a final TSS field. This is facilitated through examining the differences ($\Delta_{R\text{-}TSS}$) between R_{datum} and TSS_{grid} observational stations:

$$\Delta_{R\text{-}TSS} = -(R_{datum} - TSS_{grid})$$

The $\Delta_{R\text{-}TSS}$ approximately represents the difference between the observed tidal datum and the datum as computed by the gridded fields. The mean $\Delta_{R\text{-}TSS}$ at each benchmark should be less than 0.01 m. If it is not, the input data and grids are checked, appropriate changes are made, and the values are recomputed until the criterion is met. This results in a final TSS field. Finally, a land mask is applied to denote the presence of land.

A final quality control was conducted by evaluating mean $\Delta_{R\text{-}TSS}$ over four tidal datums (MHHW, MHW, MLW, and MLLW) at each benchmark station. Note that $\Delta_{R\text{-}TSS}$ represents the difference between the observed and modeled tidal datums. The results give mean ($\Delta_{R\text{-}TSS}$) values that are less than the criteria value of 0.01 m. Tables H.1-H.5 of Appendix H tabulate average mean $\Delta_{R\text{-}TSS}$ values and the corresponding standard deviations over stations in each VDatum grid area. Both values are less than 5×10^{-3} m, thus indicating good model-data agreement.

6. SUMMARY

VDatum fields for an area encompassing Chesapeake Bay, Delaware Bay, and adjacent coastal waters were developed in this study. Creation of VDatum begins with creating tidal datums with numerical tidal simulations using the ADCIRC model. A triangular finite-element grid consisting of 318,860 nodes and 558,718 cells was created. The model was forced with nine tidal constituents (M_2, S_2, N_2, K_2, K_1, P_1, O_1, Q_1, and M_4). Tidal harmonic constants for 37 major tidal constituents were derived from the simulations. They are then used to construct 6-minute time series for the whole National Tidal Datum Epoch of 1983-2001. Various tidal datum fields, including mean lower low water (MLLW), mean low water (MLW), mean high water (MHW), and mean higher high water (MHHW), were computed based on these time series.

A regular VDatum marine grid was created to conform with the VDatum software tool. Tidal datums defined on the unstructured grid were interpolated onto the regular grid to form the final datums as input to the VDatum tool. To compromise with the limitation of the TSS software in handling large-size arrays, the whole VDatum marine grid was divided into four sections. Tidal datum fields for each section were accordingly produced by extracting from those defined on the whole grid.

The TSS fields were created separately for each of the four sections of the marine grid. They were derived using two methodologies: fitting tidal model results to tidal benchmarks leveled in NAVD88 or calculating orthometric-to-tidal datum relationships at NOAA tidal gauges. Results from two methods were coupled to create the final TSS grids and incorporated into the VDatum tool.

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REFERENCES

Gill, S. K., and J. R. Schultz, 2001: Tidal Datums and Their Applications. Silver Spring, Maryland: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Silver Spring, MD. **NOAA Special Publication** NOS CO-OPS 1, 111 pp + appendix.

Hess, K. W, 2001: Generation of Tidal Datum Fields for Tampa Bay and the New York Bight. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Silver Spring, Maryland, **NOAA Technical Report** NOS CS 11, 43 pp.

___, 2002: Spatial interpolation of tidal data in irregularly-shaped coastal regions by numerical solution of Laplace's equation. **Estuarine, Coastal and Shelf Science**, 54(2), 175-192.

___, 2003: Water level simulation in bays by spatial interpolation of tidal constituents, residual water levels, and datums. **Continental Shelf Research**, 23(5), 395-414.

___, D. G. Milbert, S.K. Gill, and D.R. Roman, 2003: Vertical Datum Transformations for Kinematic GPS Hydrographic Surveys. Proceedings, U.S. Hydrographic Conference, March 24 – 27, 2003. Biloxi, MS. 8 pp.

___, and S. K. Gill, 2003: Puget Sound Tidal Datums by Spatial Interpolation. **Proceedings, Fifth Conference on Coastal Atmospheric and Oceanic Prediction and Processes**. Am. Meteorological Soc., Seattle, August 6-8, 2003. Paper 6.1, 108 - 112.

___, and S. A. White, 2004: VDatum for Puget Sound: Generation of the Grid and Population with Tidal Datums and Sea Surface Topography. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Silver Spring, Maryland, **NOAA Technical Memorandum** NOS CS 4, 27 pp.

Hess, K.W., E. A. Spargo, A. Wong, S. A. White, and S. K. Gill, 2005 : "VDatum for Central Coastal North Carolina: Tidal Datums, Marine Grids, and Sea Surface Topography." U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Silver Spring, Maryland, *NOAA Technical Report* NOS CS 21, 46 pp.

Leuttich, Jr., R. A., J. L. Hench, C. W. Fulcher, F. E. Werner, B. O. Blanton, and J. H. Churchill, 1999: Barotropic tidal and wind driven larval transport in the vicinity of a barrier island inlet. **Fisheries Oceanography,** 33 (April), 913 – 932.

Milbert, D. G. and K. W. Hess, 2001: Combination of Topography and Bathymetry Through Application of Calibrated Vertical Datum Transformations in the Tampa Bay Region. **Preceedings of the 2nd Biennial Coastal GeoTools Conferences**, Charleston, SC.

Milbert, D.G., 2002: Documentation for VDatum (and VDatum Tutorial); Vertical datum transformation software. Ver. 1.06 (nauticalcharts.noaa.gov/bathytopo/vdatum.htm).

Mukai, A. Y., J. J. Westerink, R. A. Luettich Jr., and D. Mark, 2002, Eastcoast 2001: A tidal constituent database for the western North Atlantic, Gulf of Mexico and Caribbean Sea, US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Technical Report, ERDC/CHL TR-02-24, September 2002, 201p.

Myers, E.P., Wong, A., Hess, K., White. S., Spargo, E., Feyen, J., Yang, Z., Richardson, P., Auer, C., Sellars, J., Woolard, J., Roman, D., Gill, S., Zervas, C. and K. Tronvig, 2005: "Development of a National VDatum, and its Application to Sea Level Rise in North Carolina." *Proceedings of the 2005 Hydro Conference*, San Diego, CA.

Myers, E.P., unpublished manuscript: "Tidal Datum Inversion Model of the Eastcoast of the United States."

Parker, B. P., 2002: The integration of bathymetry, topography, and shoreline, and the vertical datum transformations behind it. **International Hydrographic Review** (3) 3 (November 2002).

Parker, B., K. W. Hess, D. Milbert, and S. K. Gill, 2003: A national vertical datum transformation tool. **Sea Technology**, v. 44. no. 9 (Sept. 2003), 10 - 15.

Spargo, E. A., and J. W. Woolard, 2005. VDatum for the Calcasieu River from Lake Charles to the Gulf of Mexico, Louisiana: Tidal Datum Modeling and Population of the Grid**. NOS Technical Report** NOS CS 19, 26 pp**.**

Spargo, E.A., K.H. Hess, and S.A. White, 2006: "VDatum for the San Juan Islands and Juan de Fuca Strait with Updates for Southern Puget Sound: Tidal Datum Modeling and Population of the VDatum Marine Grids." U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Silver Spring, Maryland, *NOAA Technical Report* NOS CS 25, 50 pp.

Spargo, E.A., Hess, K.H., Myers, E.P., Yang, Z., and A.Wong, 2006: "Tidal Datum Modeling in support of NOAA's Vertical Datum Transformation Tool." *Proceedings of the 9th International Conference on Estuarine and Coastal Modeling*, October 31-November 2, 2005, Charleston, SC. p. 523-536.

Westerink, J.J., R. A. Luettich, and J. C. Muccino, 1993: An Advanced Three-Dimensional Circulation Model for Shelves, Coasts, and Estuaries, Report 3: Development of a Tidal Constituent Database for the Western North Atlantic and Gulf of Mexico, **Technical Report DRP-92-6**, U.S. ACE Waterways Experiment Station, Vicksburg, MS.

Yang, Z., Hess, K.H., Myers, E.P., Spargo, E.A., Wong, A., and J. Feyen, 2006: "Numerical Simulation of Tidal Datum Fields for the Long Island Sound, New York Bight, and Narragansett Bay Area." *Proceedings of the 9th International Conference on Estuarine and Coastal Modeling*, October 31-November 2, 2005, Charleston, SC. p. 548-567.

APPENDIX A. HORIZONTAL AND VERTICAL ACCURACY STANDARDS FOR NOAA BATHYMETRY SURVEY

Table A.1. The required horizontal and vertical accuracy standards for NOAA surveys. Accuracy requirements before 1957 were prescribed for survey projects.

Survey Year*	Horizontal Accuracy	Vertical Accuracy	Standard
1998 – present	**Order 1** 1 – 100 m depth: 5.0 m + 5% of depth **Order 2** 100 – 200 m depth: 20 m + 5% of depth **Order 3** 100 – 200 m depth: 150 m + 5% of depth	**Order 1** 1 – 100 m depth: 0.5 – 1.4 m **Order 2** 100 – 200 m depth: 2.5 – 4.7 m **Order 3** > 100 m depth: same as Order 2	IHO S-44 [1] and NOAA [2]
1988 – 1998	95% probability that the true position lies within a circle of radius 1.5 mm, at the scale of the survey	0 – 30 m depth: 0.3 m > 30 m depth: 1% of depth	IHO S-44 [1] and NOAA [2]
1982 – 1988	probable error shall seldom exceed twice the plottable error (1.0 mm) at the scale of the survey	0 – 20 m depth: 0.3 m 20 – 100 m depth: 1.0 m > 100 m depth: 1% of depth	IHO S-44 [1] and NOAA [2]
1957 – 1982	maximum error of plotted positions shall seldom exceed 1.5 mm at the scale of the survey	0 – 20 m depth: 0.3 m 20 – 100 m depth: 1.0 m > 100 m depth: 1% of depth	IHC [3] NOAA [2] and IHO S-44 [1]
before 1957	undetermined	undetermined	undocumented

* end of field collection

[1] International Hydrographic Organization (IHO) Standards for Hydrographic Surveys, Special Publication 44, (First Edition, 1968; Second Edition, 1982; Third Edition, 1987; Fourth Edition, 1998).

[2] U.S. Department of Commerce Coast and Geodetic Survey Hydrographic Manual (1931, 1942, 1960, 1976) NOAA NOS Office of Coast Survey Specifications and Deliverables, 1999 – 2006. NOAA was established in 1970.

[3] International Hydrographic Conference, 1957.

APPENDIX B. NAMES AND SPEEDS OF 37 TIDAL CONSTITUENTS FOR HARMONIC ANALYSIS

Table B.1. List of names and speeds of 37 tidal constituents.

No.	Names	Speeds (rad/s)
1	MN	0.000002639
2	SM	0.000004925
3	K1	0.000072921
4	O1	0.000067598
5	P1	0.000072523
6	Q1	0.000064959
7	SO1	0.000002639
8	MNS2	0.000132955
9	2MS2	0.000135594
10	N2	0.000137880
11	M2	0.000140519
12	2MN2	0.000143158
13	S2	0.000145444
14	K2	0.000145842
15	MSN2	0.000148083
16	2SM2	0.000150369
17	MO3	0.000208117
18	SO3/MK3	0.000213042
19	SK3	0.000218365
20	N4	0.000275759
21	3MS4	0.000276113
22	MN4	0.000278399
23	M4	0.000281038
24	3MN4	0.000283677
25	MS4	0.000285963
26	2MSN4	0.000288602
27	2NM6	0.000416278
28	2MN6	0.000418918
29	M6	0.000421557
30	MSN6	0.000423843
31	2MS6	0.000426482
32	2SM6	0.000431407
33	2(MN)8	0.000556797
34	3MN8	0.000559436
35	M8	0.000562076
36	2MSN8	0.000564362
37	3MS8	0.000567001

APPENDIX C. WATER LEVEL STATION DATA

Table C.1. NOS Water Level Station Names

No.	Station ID	Station Name
1	8651376	CURRITUCK SOUND NO 2 NC
2	8651372	DUCK WLTS (OUTSIDE) NC
3	8651371	DUCK (INSHORE) NC
4	8639834	FALSE CAPE U S G S #165 VA
5	8639428	SANDBRIDGE
6	8639414	DEEP CREEK ENTRANCE
7	8639208	VIRGINIA BEACHRUDEE INLET
8	8638999	CAPE HENRY
9	8638978	CAVALIER YACHT CLUB LINKHORN BAY VA
10	8638942	CARTERS POINT #1 VA
11	8638923	BROAD BAY CANAL EAST VA
12	8638922	BROWN COVE LYNNHAVEN BAY VA
13	8638916	LONG CREEK LYNNHAVEN BAY VA
14	8638912	BROCK COVE VA
15	8638905	LYNNHAVEN FISHING PIER VA
16	8638888	VA PILOTS DOCK LYNNHAVEN INLET VA
17	8638863	CHESAPEAKE BAY BRIDGE TUNNEL
18	8638854	BUCHANAN CR ENT (KEMPSVILLE) VA
19	8638776	LITTLE CREEK VA
20	8638610	SEWELLS POINTHAMPTON ROADS
21	8638514	PIG POINT NANSEMOND RIVER ENT VA
22	8638495	RICHMOND RIVER LOCKS JAMES RIVER VA
23	8638491	VEPCO PLANT CHESTER JAMES R VA
24	8638489	PUDDLEDOCK SAND & GRAVEL APPOMATTOX R.
25	8638486	MEADOWVILLE VA
26	8638483	CURLES NECK WHARF (1 MILE N OF) VA
27	8638481	CITY POINT HOPEWELL
28	8638478	HAXALL TURKEY IS CR JAMES R VA
29	8638476	JORDAN POINT JAMES RIVER VA
30	8638464	WILLCOX WHARF CHARLES CITY VA
31	8638455	STURGEON POINT JAMES RIVER VA
32	8638449	CLAREMONTJAMES RIVER
33	8638442	CHICKAHOMINY RIVER BRIDGE VA
34	8638441	SHIPYARD LANDING VA
35	8638433	SCOTLANDJAMES RIVER
36	8638432	CHURCH PT JAMESTOWN IS JAMES R VA
37	8638424	KINGSMILLJAMES RIVER
38	8638422	HOMEWOOD LIGHT HOG ISLAND VA
39	8638421	BURWELL BAY JAMES RIVER VA
40	8638419	FORT EUSTIS JAMES RIVER VA
41	8638409	KINGS HIGHWAY BRIDGE VA
42	8638407	MENCHVILLE DEEP CR ENTR VA
43	8638406	OLD NIX CLUBHSE SITE NANSEMOND R VA
44	8638405	CHUCKATUCK CREEK ENTRANCE VA VA
45	8638401	HUNTINGTON PARK JAMES R BR VA
46	8638379	NEWPORT NEWS JAMES R ENT VA
47	8638288	OLD POINT COMFORT FORT MONROE VA
48	8638252	SOLDIER'S HOME WHARF PHOEBUS VA

49	8638051	MESSICK POINT BACK RIVER VA
50	8638013	MAGOTHY TO CHESAPEAKE BAY CUT VA
51	8637689	YORKTOWN USCG TRAINING CENTERYORK R.
52	8637686	YORKTOWN YORK RIVER VA
53	8637663	TUE MARSHES LIGHTHOUSE YORK R VA
54	8637624	GLOUCESTER POINTYORK RIVER
55	8637556	PERRIN RIVER SEDGER CREEK YORK RIVER VA
56	8637472	CHEATHAM ANNEX (NAVAL SUPPLY DEOT VA
57	8637444	BROWNS BAY MOBJACK BAY VA
58	8637288	CLAY BANK AND VICINITY VA
59	8637199	MOBJACK EAST RIVER VA
60	8637144	WOLF TRAP LIGHTHOUSE VA
61	8637072	BELLEVILLE NORTH RIVER VA
62	8637044	AUBURN WHARF NORTH RIVER VA
63	8636969	ROANE POINT YORK RIVER VA
64	8636831	DIXIE (WILTON FERRY LANDING) VA
65	8636769	WEST POINT YORK RIVER VA
66	8636749	FISHING BAY VA
67	8636735	DELTAVILLE JACKSON CREEK VA
68	8636654	NEW MILL CREEK (GREYS POINT) VA
69	8636653	LESTER MANOR VA
70	8636580	WINDMILL POINTRAPPAHANNOCK RIVER
71	8636522	URBANNA RAPPAHANNOCK RIVER VA
72	8636261	BAYPORT RAPPAHANNOCK RIVER VA
73	8636046	GLEBE PT HIGHWAY BRIDGE VA
74	8635985	WARES WHARF RAPPAHANNOCK RIVER VA
75	8635961	SMITH POINT VA
76	8635881	TAPPAHANNOCK RAPPAHANNOCK RIVER VA
77	8635762	TRAVIS POINT POTOMAC RIVER VA
78	8635750	LEWISETTAPOTOMAC RIVER
79	8635554	SAUNDERS WHARF RAPPAHANNOCK R VA
80	8635485	COLES NECK RAGGED PT VA
81	8635409	MOUNT HOLLY NOMINI CREEK VA
82	8635171	HOPYARD LANDING RAPPAHANNOCK R VA
83	8635154	MASSAPONAX SAND & GRAVEL RAPPA R VA
84	8635150	COLONIAL BEACHPOTOMAC RIVER
85	8635064	FREDERICKSBURG RAPPAHANNOCK RIVER VA
86	8635027	DAHLGREN (NAVAL PROVING GROUND) VA
87	8634892	MATHIAS POINT POTOMAC RIVER VA
88	8634858	AQUIA CREEK POTOMAC RIVER VA
89	8634689	QUANTICO POTOMAC RIVER VA
90	8634489	WHITESTONE PT GUNSTON COVE VA
91	8634437	MOUNT VERNON POTOMAC RIVER VA
92	8633596	GUARDSHORE VA
93	8633532	TANGIER ISLANDCHESAPEAKE BAY
94	8633451	WATTS ISLAND CHESAPEAKE BAY VA
95	8633362	SCHOONER BAY
96	8633214	ONANCOCK ONANCOCK CREEK VA
97	8633091	HARBOR `TONPUNGOTEAGUE CREEK
98	8632869	GASKINS PT OCCOHANNOCK CREEK VA
99	8632599	MATTAWOMAN CREEK VA
100	8632200	KIPTOPEKECHESAPEAKE BAY
101	8632085	FISHERMANS ISLAND VA
102	8631874	SMITH IS COAST GUARD STA VA

103	8631742	UPPER MAGOTHY BAY VA
104	8631542	SAND SHOAL INLETCOBB ISLAND
105	8631486	GULL MARSH VA
106	8631103	WACHAPREAGUE INLET VA
107	8631023	BURTONS BAY VA
108	8630901	METOMKIN INLET INSIDE VA
109	8630705	WIRE PASSAGE VA
110	8630641	GARGATHY INLET VA
111	8630441	WALLOPS ISLAND VA
112	8630413	ASSATEAGUE BEACH CGS VA
113	8630316	HARBOR OF REFUGECHINCOTEAGUE
114	8630315	SOUTHERN CHINCOTEAGUE IS VA
115	8630308	CHINCOTEAGUE CHANNELSOUTH END
116	8630249	CHINCOTEAGUEUSCG STATION
117	8630229	LEWIS CREEK VA
118	8630194	BLAKE COVE VA
119	8630111	JESTERS ISLAND
120	8594900	WASHINGTONPOTOMAC RIVER
121	8593545	KINGMAN LAKE ANACOSTIA RIVER DC
122	8593005	WASHINGTON NAVY YARD D C DC
123	8579997	BLADENSBURGANACOSTIA RIVER
124	8579629	MARSHALL HALL POTOMAC RIVER MD
125	8579542	LOWER MARLBOROPATUXENT RIVER
126	8579381	INDIAN HEAD POTOMAC RIVER MD
127	8578853	RIVERSIDE POTOMAC RIVER MD
128	8578769	PORT TOBACCO POTOMAC RIVER MD
129	8578240	PINEY POINT POTOMAC RIVER MD
130	8578002	POINT LOOKOUT POTOMAC RIVER MD
131	8577940	CORNFIELD HARBOR POTOMAC RIVER MD
132	8577385	NAVY SEAPLANE BASIN BOATHOUSE MD
133	8577381	CEDAR POINT MD
134	8577330	SOLOMONS ISLANDPATUXENT RIVER
135	8577188	COVE POINT
136	8577123	BROOMES ISLAND PATUXENT RIVER MD
137	8577004	LONG BEACHCHESAPEAKE BAY
138	8575787	RHODE RIVER MD
139	8575550	GINGERVILLE CREEK SOUTH RIVER MD
140	8575512	U.S. NAVAL ACADEMYSEVERN R.CHES. BAY
141	8575510	ANNAPOLIS NAVAL RADIO STATION MD
142	8575109	CORNFIELD CREEKMAGOTHY RIVER
143	8574931	STONY CREEK
144	8574878	CURTIS CREEK POINT PLEASANT MD
145	8574857	NORTH POINT MD
146	8574821	HAWKINS POINTPATAPSCO RIVER
147	8574726	BEAR CREEK MARINA MD
148	8574686	POWER STATION MIDDLE BRANCH MD
149	8574683	FORT MCHENRY MARSHPATAPSCO RIVER
150	8574680	BALTIMOREFORT MCHENRYPATAPSCO RIVER
151	8574459	POND POINT (ABERDEEN P.G.)BUSH RIVER
152	8574070	HAVRE DE GRACECHESAPEAKE BAY
153	8574008	PORT DEPOSIT MD
154	8573968	CHARLESTOWN NORTHEAST RIVER MD
155	8573927	CHESAPEAKE CITY
156	8573903	TOWN POINT WHARF

157	8573704	BETTERTONSASSAFRAS RIVER
158	8573364	TOLCHESTER BEACHCHESAPEAKE BAY
159	8573349	CRUMPTONCHESTER RIVER
160	8573343	CHESTERTOWN CHESTER RIVER MD
161	8573137	CLIFF'S WHARF MD
162	8572955	LOVE POINT PIERKENT ISLAND
163	8572770	MATAPEAKE
164	8572669	HILLSBOROTUCKAHOE CREEK
165	8572467	KENT POINTCHESAPEAKE BAY
166	8572342	ST MICHAELS MILES RIVER MD
167	8571979	TILGHMAN ISLAND FERRY COVE MD
168	8571944	DOVER BRIDGE CHOPTANK RIVER MD
169	8571901	AVALON TILGANAN ISLAND MD
170	8571892	CAMBRIDGECHOPTANK RIVER
171	8571890	CAMBRIDGE MD
172	8571773	VIENNANANICOKE RIVER
173	8571752	TAYLORS ISLAND MD
174	8571579	BARREN ISLANDCHESAPEAKE BAY
175	8571559	MCCREADYS CREEKFISHING BAY
176	8571519	MIDDLE HOOPERS ISLAND MD
177	8571485	WHITEHAVEN WICOMICO RIVER MD
178	8571477	NANTICOKE MD
179	8571421	BISHOPS HEADHOOPERS STRAIT
180	8571402	HOOPER STRAIT LIGHTHOUSE MD
181	8571351	CHANCE NANTICOKE RIVER MD
182	8571266	RUMBLEY MANOKIN RIVER MD
183	8571214	HOLLAND BAR LIGHT MD
184	8571181	COLBOURN CREEK BIG ANNEMESSEX R MD
185	8571117	EWELLSMITH ISLAND
186	8571091	CRISFIELD
187	8570649	PUBLIC LANDINGCHINCOTEAGUE BAY
188	8570536	SOUTH POINT
189	8570283	OCEAN CITY INLET
190	8570282	OCEAN CITYISLE OF WIGHT
191	8570280	OCEAN CITYFISHING PIER
192	8570255	KEYDASHISLE OF WIGHT BAY
193	8558690	INDIAN RIVER INLET
194	8557380	LEWESFT. MILES
195	8557125	HARBOR OF REFUGE LIGHT DE
196	8556198	MISPILLION RIVER ENTRANCE DE
197	8555889	BRANDYWINE SHOAL LIGHTDELAWARE BAY
198	8555461	FOURTEEN FOOT BANK LIGHT DE
199	8555388	MURDERKILL RIVER ENTRANCE DE
200	8554399	MAHON RIVER ENTRANCEDELAWARE BAY
201	8551973	ST GEORGES DE
202	8551910	REEDY POINTC&D CANAL
203	8551762	DELAWARE CITYDELAWARE RIVER
204	8551702	PEA PATCH ISLAND DE
205	8551201	NEW CASTLE DE
206	8550714	WILMINGTON CHRISTINA R ENT DE
207	8550438	EDGEMOOR DE
208	8549424	MEENAN PA
209	8548989	NEWBOLDDELAWARE RIVER
210	8547333	CORNWELLS HEIGHTS PA

211	8546252	BRIDESBURG PA
212	8545530	PHILADELPHIA (PIER 11 NORTH)DEL. RIVER
213	8545240	PHILADELPHIA (USCG STA.)DELAWARE RIVER
214	8540433	MARCUS HOOK
215	8539993	TRENTON MARINE TERMINAL
216	8539487	FIELDSBORODELAWARE RIVER
217	8539094	BURLINGTONDELAWARE RIVER
218	8538886	TACONY-PALMYRA BRIDGE
219	8538552	BILLINGSPORT NJ
220	8538548	WOODBURY CREEK NJ
221	8538231	DEEPWATER DELAWARE RIVER NJ
222	8537961	SINNICKSON LANDING SALEM R NJ
223	8537614	ARTIFICIAL IS NJ
224	8537121	SHIP JOHN SHOALDELAWARE RIVER
225	8537116	BACK CREEK DEL BAY NJ
226	8537101	CEDAR CREEK NJ
227	8537052	MONEY ISLAND NJ
228	8536915	FORTESCUEDELAWARE BAY
229	8536849	LOWER DIVIDING CREEK NJ
230	8536848	FISHING CREEK NJ
231	8536780	EAST POINT NJ
232	8536581	BIDWELL CREEK ENTRANCEDELAWARE BAY
233	8536271	VILLAS-JACKSON PIER NJ
234	8536110	CAPE MAYCAPE MAY CANALDELAWARE BAY
235	8536021	CAPE MAY POINT NJ
236	8535962	CAPE MAY ATLANTIC OCEAN NJ
237	8535902	CAPE ISLAND CREEK NJ
238	8535901	CAPE MAY HARBOR NJ
239	8535838	SUNSET LAKE NJ
240	8535835	WILDWOOD CREST
241	8535805	SWAIN CHANNEL NJ
242	8535726	WEST WILDWOOD GRASSY SOUND NJ
243	8535721	GRASSY SOUND HEREFORD INLET NJ
244	8535695	OLD TURTLE RICHARDSON SOUND NJ
245	8535661	NUMMY IS GRASSY SND CH NJ
246	8535581	STONE HARBOR GREAT CHANNEL NJ
247	8535511	GULL ISLAND GREAT SOUND NJ
248	8535451	LONGREACH NJ
249	8535419	INGRAM THOROFARE NJ
250	8535375	TOWNSEND INLET NJ
251	8535357	STITES SOUND NJ
252	8535291	SEA ISLE CITY ATLANTIC OCEAN NJ
253	8535278	SEA ISLE CITY INSIDE NJ
254	8535221	LUDLAM BAY
255	8535163	STRATHMERESTRATHMERE BAY
256	8535101	CORSON INLET
257	8534975	GREAT EGG HARBOR BAY NJ
258	8534836	LONGPORTRISELY CHANNEL
259	8534770	VENTNOR CITYFISHING PIER
260	8534739	DOCK THOROFARE
261	8534720	ATLANTIC CITYATLANTIC OCEAN
262	8534670	ATLANTIC CITY COAST GUARD STA NJ
263	8534657	PLEASANTVILLELAKES BAY
264	8534638	ABSECON CHANNAL NJ

265	8534596	MAIN CHANNEL NJ
266	8534496	BRIGANTINE CHANNEL
267	8534393	MAIN MARSH THOROFARE
268	8534348	LITTLE EGG L S S LITTLE EGG HBR NJ
269	8534244	GRAVELING POINT
270	8534208	BEACH HAVEN CG STATION
271	8534139	TUCKERTON LITTLE EGG HARBOR NJ
272	8534048	BEACH HAVEN CREST (INSIDE)
273	8534044	LONG POINTLITTLE EGG HARBOR
274	8533935	MANAHAWKIN DRAWBRIDGE NJ
275	8533909	MANAHAWKIN CREEK NJ
276	8533862	NORTH BEACH MANAHAWKIN BAY NJ
277	8533738	LOVELADIES NJ
278	8533651	BARNEGAT LANDING DOUBLE CREEK NJ
279	8533631	HIGH BAR BARNEGAT BAY NJ
280	8533615	BARNEGAT INLET (INSIDE)
281	8533541	WARETOWN BARNEGAT BAY NJ
282	8533535	ISLAND BEACH SEDGE ISLANDS NJ
283	8533345	ISLAND BEACH BARNEGAT BAY NJ
284	8533141	BARNEGAT PIER BARNEGAT BAY NJ
285	8533135	SEASIDE PARK NJ
286	8533055	COATES POINT BARNEGAT BAY NJ
287	8532885	OCEAN BEACH BARNEGAT BAY NJ
288	8532835	KETTLE CREEK NJ
289	8532786	MANTOLOKING BARNEGAT BAY NJ
290	8532721	TALL PINES CAMP METEDECONK R NJ
291	8532715	BEAVER DAM CREEK
292	8532705	BAYHEAD METEDECONK RIVER ENT NJ
293	6530005	Waretown NJ
294	6530004	Ship Bottom NJ
295	6530003	Little Egg Inlet NJ
296	6530001	Atlantic City CG Station (USGS) NJ
297	8638660	PORTSMOUTH NORFOLK NAVAL SHIPYRD
298	8639348	MONEY POINTS. BR. ELIZABETH RIVER

Table C.2. Tidal datums (meters) relative to mean sea level. NAVD88 is relative to MLLW. The 'N/A's in the table denote missing values.

No.	Station ID	Longitude (degree)	Latitude (degree)	MHHW (m)	MHW (m)	MLW (m)	MLLW (m)	NAVD88 (m)	Epoch
1	8651376	-75.7583	36.1817	0.591	0.493	-0.506	-0.552	N/A	1960-1978
2	8651372	-75.7467	36.1833	0.591	0.493	-0.506	-0.552	N/A	1960-1978
3	8651371	-75.75	36.1817	0.591	0.493	-0.506	-0.552	N/A	1960-1978
4	8639834	-75.8817	36.6033	0.64	0.548	-0.549	-0.61	N/A	N/A
5	8639428	-75.92	36.6917	0.6	0.506	-0.516	-0.568	N/A	1960-1978
6	8639414	-76.2933	36.755	0.509	0.443	-0.446	-0.491	N/A	1960-1978
7	8639208	-75.9683	36.8317	0.573	0.487	-0.514	-0.551	0.757	1983-2001
8	8638999	-76.0067	36.93	0.547	0.469	-0.481	-0.519	N/A	1983-2001
9	8638978	-76.005	36.8683	0.277	0.216	-0.216	-0.253	N/A	1960-1978
10	8638942	-76.0367	36.905	0.271	0.21	-0.211	-0.241	N/A	1960-1978
11	8638923	-76.0617	36.9017	0.268	0.21	-0.21	-0.244	N/A	1960-1978
12	8638922	-76.0617	36.875	0.305	0.275	-0.244	-0.274	N/A	N/A
13	8638916	-76.07	36.9033	0.32	0.256	-0.256	-0.296	N/A	1960-1978
14	8638912	-76.08	36.8917	0.366	0.305	-0.305	-0.335	N/A	N/A
15	8638905	-76.0783	36.9167	0.494	0.418	-0.42	-0.457	N/A	1960-1978
16	8638888	-76.09	36.9067	0.427	0.338	-0.338	-0.378	N/A	1960-1978
17	8638863	-76.1133	36.9667	0.453	0.383	-0.394	-0.431	N/A	1983-2001
18	8638854	-76.115	36.8617	0.366	0.305	-0.275	-0.305	N/A	N/A
19	8638776	-76.1767	36.9117	0.46	0.393	-0.39	-0.433	0.637	1960-1978
20	8638610	-76.33	36.9467	0.429	0.366	-0.374	-0.412	0.501	1983-2001
21	8638514	-76.435	36.9167	0.488	0.427	-0.427	-0.457	N/A	N/A
22	8638495	-77.42	37.525	0.579	0.487	-0.488	-0.549	N/A	1941-1959
23	8638491	-77.3783	37.3833	0.46	0.399	-0.485	-0.515	N/A	N/A
24	8638489	-77.3717	37.2667	0.443	0.376	-0.476	-0.523	0.56	1983-2001
25	8638486	-77.3233	37.3783	0.488	0.427	-0.457	-0.518	N/A	N/A
26	8638483	-77.295	37.3967	0.548	0.426	-0.427	-0.488	N/A	N/A
27	8638481	-77.27	37.3133	0.411	0.338	-0.392	-0.437	N/A	1983-2001
28	8638478	-77.2433	37.3733	0.457	0.396	-0.427	-0.488	N/A	N/A
29	8638476	-77.2233	37.3133	0.457	0.396	-0.366	-0.396	N/A	N/A
30	8638464	-77.0983	37.315	0.402	0.341	-0.33	-0.36	N/A	N/A
31	8638455	-77.0067	37.3067	0.397	0.336	-0.305	-0.335	N/A	N/A
32	8638449	-76.9483	37.2317	0.313	0.255	-0.289	-0.334	N/A	1983-2001
33	8638442	-76.8767	37.2633	0.345	0.284	-0.296	-0.326	N/A	N/A
34	8638441	-76.875	37.345	0.396	0.335	-0.336	-0.366	N/A	N/A
35	8638433	-76.7833	37.185	0.329	0.276	-0.286	-0.327	N/A	1983-2001
36	8638432	-76.7783	37.2067	0.366	0.305	-0.305	-0.335	N/A	N/A
37	8638424	-76.6633	37.22	0.408	0.343	-0.345	-0.393	N/A	1983-2001
38	8638422	-76.6783	37.1933	0.397	0.336	-0.305	-0.335	N/A	N/A
39	8638421	-76.6683	37.0567	0.427	0.369	-0.368	-0.411	N/A	1960-1978
40	8638419	-76.6333	37.1367	0.427	0.366	-0.366	-0.396	N/A	N/A
41	8638409	-76.55	36.8383	0.552	0.46	-0.454	-0.515	N/A	N/A
42	8638407	-76.525	37.0817	0.457	0.396	-0.397	-0.427	N/A	N/A
43	8638406	-76.5083	36.8833	0.548	0.457	-0.458	-0.488	N/A	N/A
44	8638405	-76.4983	36.9133	0.488	0.427	-0.427	-0.457	N/A	N/A
45	8638401	-76.4583	37.0133	0.433	0.372	-0.421	-0.451	N/A	N/A
46	8638379	-76.4333	36.9733	0.457	0.396	-0.397	-0.427	N/A	N/A
47	8638288	-76.315	37.0033	0.429	0.368	-0.394	-0.424	N/A	N/A
48	8638252	-76.34	37.0167	0.457	0.396	-0.397	-0.427	N/A	N/A

49	8638051	-76.3183	37.1067	0.391	0.351	-0.35	-0.405	N/A	1960-1978
50	8638013	-75.95	37.1267	0.616	0.537	-0.536	-0.588	N/A	1960-1978
51	8637689	-76.4783	37.2267	0.419	0.356	-0.343	-0.382	N/A	1983-2001
52	8637686	-76.4383	37.2217	0.384	0.345	-0.344	-0.396	N/A	1960-1978
53	8637663	-76.385	37.235	0.405	0.344	-0.327	-0.357	N/A	N/A
54	8637624	-76.5	37.2467	0.426	0.366	-0.359	-0.394	0.487	1983-2001
55	8637556	-76.425	37.2667	0.426	0.366	-0.336	-0.366	N/A	N/A
56	8637472	-76.5867	37.2917	0.451	0.39	-0.372	-0.402	N/A	N/A
57	8637444	-76.4033	37.3017	0.397	0.354	-0.353	-0.411	N/A	1960-1978
58	8637288	-76.6133	37.3467	0.488	0.427	-0.396	-0.457	N/A	N/A
59	8637199	-76.3467	37.3733	0.427	0.366	-0.366	-0.396	N/A	N/A
60	8637144	-76.19	37.39	0.275	0.244	-0.244	-0.274	N/A	N/A
61	8637072	-76.4383	37.4117	0.448	0.387	-0.375	-0.405	N/A	N/A
62	8637044	-76.4367	37.42	0.448	0.387	-0.375	-0.405	N/A	N/A
63	8636969	-76.7083	37.4467	0.479	0.418	-0.436	-0.466	N/A	N/A
64	8636831	-76.4167	37.5067	0.228	0.198	-0.199	-0.229	N/A	N/A
65	8636769	-76.7933	37.535	0.488	0.427	-0.427	-0.457	N/A	N/A
66	8636749	-76.3333	37.5417	0.214	0.183	-0.183	-0.213	N/A	N/A
67	8636735	-76.3317	37.5483	0.214	0.183	-0.183	-0.213	N/A	N/A
68	8636654	-76.4183	37.5833	0.241	0.211	-0.186	-0.216	N/A	N/A
69	8636653	-76.99	37.5833	0.488	0.427	-0.427	-0.457	N/A	N/A
70	8636580	-76.29	37.615	0.21	0.17	-0.184	-0.214	0.289	1983-2001
71	8636522	-76.575	37.65	0.241	0.21	-0.217	-0.247	N/A	N/A
72	8636261	-76.6733	37.755	0.269	0.238	-0.25	-0.28	N/A	N/A
73	8636046	-76.3683	37.8467	0.214	0.183	-0.183	-0.213	N/A	N/A
74	8635985	-76.7833	37.8733	0.338	0.277	-0.272	-0.302	N/A	N/A
75	8635961	-76.2417	37.8883	0.173	0.14	-0.138	-0.165	N/A	1960-1978
76	8635881	-76.8567	37.93	0.28	0.25	-0.269	-0.299	N/A	N/A
77	8635762	-76.4667	37.9967	0.214	0.183	-0.183	-0.213	N/A	N/A
78	8635750	-76.465	37.995	0.228	0.185	-0.194	-0.23	0.253	1983-2001
79	8635554	-77.0333	38.09	0.241	0.211	-0.247	-0.277	N/A	N/A
80	8635485	-76.6133	38.1417	0.253	0.223	-0.235	-0.265	N/A	N/A
81	8635409	-76.735	38.0983	0.274	0.244	-0.214	-0.244	N/A	N/A
82	8635171	-77.2267	38.2433	0.345	0.284	-0.357	-0.387	N/A	N/A
83	8635154	-77.41	38.255	0.399	0.338	-0.393	-0.454	N/A	N/A
84	8635150	-76.96	38.2517	0.298	0.248	-0.25	-0.293	0.301	1983-2001
85	8635064	-77.4533	38.2983	0.487	0.426	-0.427	-0.488	N/A	N/A
86	8635027	-77.0367	38.32	0.266	0.235	-0.253	-0.283	N/A	1941-1959
87	8634892	-77.0533	38.3983	0.214	0.183	-0.183	-0.213	N/A	N/A
88	8634858	-77.3533	38.4183	0.228	0.198	-0.199	-0.229	N/A	N/A
89	8634689	-77.2867	38.52	0.229	0.198	-0.229	-0.259	N/A	N/A
90	8634489	-77.135	38.6767	0.366	0.305	-0.305	-0.335	N/A	N/A
91	8634437	-77.0883	38.705	0.396	0.335	-0.336	-0.366	N/A	N/A
92	8633596	-75.7	37.85	0.405	0.345	-0.357	-0.387	N/A	N/A
93	8633532	-75.9933	37.8283	0.276	0.227	-0.232	-0.26	N/A	1983-2001
94	8633451	-75.8967	37.7983	0.275	0.244	-0.244	-0.274	N/A	N/A
95	8633362	-75.7733	37.7633	0.348	0.294	-0.297	-0.342	N/A	1960-1978
96	8633214	-75.7567	37.7117	0.335	0.274	-0.275	-0.305	N/A	N/A
97	8633091	-75.8333	37.6667	0.319	0.263	-0.273	-0.303	N/A	1960-1978
98	8632869	-75.9167	37.5567	0.317	0.265	-0.263	-0.293	N/A	1960-1978
99	8632599	-75.9633	37.3883	0.354	0.296	-0.295	-0.329	N/A	1960-1978
100	8632200	-75.9883	37.1667	0.462	0.393	-0.401	-0.434	0.58	1983-2001
101	8632085	-75.9833	37.0967	0.533	0.46	-0.46	-0.506	N/A	1960-1978
102	8631874	-75.9117	37.1233	0.61	0.549	-0.518	-0.579	N/A	N/A

103	8631742	-75.9183	37.205	0.786	0.695	-0.692	-0.759	N/A	1960-1978
104	8631542	-75.7783	37.3017	0.719	0.618	-0.601	-0.65	N/A	1983-2001
105	8631486	-75.8217	37.35	0.747	0.64	-0.64	-0.683	N/A	1960-1978
106	8631103	-75.6183	37.5733	0.673	0.576	-0.576	-0.628	N/A	1960-1978
107	8631023	-75.6467	37.62	0.707	0.607	-0.606	-0.652	N/A	1960-1978
108	8630901	-75.595	37.6717	0.64	0.548	-0.549	-0.61	N/A	N/A
109	8630705	-75.5667	37.7383	0.573	0.485	-0.487	-0.533	N/A	1960-1978
110	8630641	-75.5367	37.775	0.558	0.473	-0.469	-0.524	N/A	1960-1978
111	8630441	-75.4783	37.8417	0.674	0.558	-0.561	-0.576	N/A	1960-1978
112	8630413	-75.3683	37.865	0.64	0.548	-0.549	-0.61	N/A	N/A
113	8630316	-75.4067	37.9033	0.444	0.371	-0.37	-0.411	0.469	1983-2001
114	8630315	-75.41	37.9033	0.457	0.396	-0.366	-0.396	N/A	N/A
115	8630308	-75.405	37.9067	0.399	0.332	-0.326	-0.359	0.401	1983-2001
116	8630249	-75.3833	37.9317	0.292	0.242	-0.241	-0.269	0.322	1983-2001
117	8630229	-75.3733	37.9383	0.237	0.201	-0.202	-0.232	N/A	1960-1978
118	8630194	-75.355	37.9517	0.173	0.137	-0.135	-0.162	N/A	1960-1978
119	8630111	-75.3017	37.9817	0.142	0.116	-0.115	-0.145	N/A	1983-2001
120	8594900	-77.0217	38.8733	0.493	0.424	-0.425	-0.472	0.425	1983-2001
121	8593545	-76.9683	38.895	0.511	0.439	-0.428	-0.481	N/A	1960-1978
122	8593005	-76.995	38.8717	0.501	0.427	-0.425	-0.479	N/A	1960-1978
123	8579997	-76.9383	38.9333	0.524	0.455	-0.444	-0.495	N/A	1983-2001
124	8579629	-77.1017	38.6867	0.405	0.345	-0.344	-0.387	N/A	N/A
125	8579542	-76.6833	38.655	0.282	0.247	-0.272	-0.319	N/A	N/A
126	8579381	-77.185	38.6017	0.317	0.256	-0.289	-0.323	N/A	N/A
127	8578853	-77.145	38.3867	0.231	0.201	-0.202	-0.226	N/A	N/A
128	8578769	-77.0533	38.4533	0.265	0.235	-0.226	-0.253	N/A	N/A
129	8578240	-76.5333	38.1333	0.244	0.213	-0.214	-0.244	N/A	N/A
130	8578002	-76.3233	38.04	0.231	0.186	-0.186	-0.238	N/A	1960-1978
131	8577940	-76.3567	38.0617	0.219	0.189	-0.214	-0.238	N/A	N/A
132	8577385	-76.3967	38.2717	0.22	0.171	-0.17	-0.219	N/A	1960-1978
133	8577381	-76.37	38.2983	0.275	0.183	-0.183	-0.274	N/A	N/A
134	8577330	-76.4517	38.3167	0.219	0.174	-0.182	-0.23	0.259	1983-2001
135	8577188	-76.3983	38.3917	0.229	0.153	-0.163	-0.191	N/A	1983-2001
136	8577123	-76.545	38.415	0.323	0.201	-0.196	-0.287	N/A	N/A
137	8577004	-76.4733	38.465	0.201	0.151	-0.157	-0.208	N/A	1983-2001
138	8575787	-76.54	38.8867	0.244	0.153	-0.146	-0.213	N/A	N/A
139	8575550	-76.555	38.9583	0.225	0.155	-0.159	-0.226	N/A	1960-1978
140	8575512	-76.48	38.9833	0.219	0.145	-0.152	-0.219	0.235	1983-2001
141	8575510	-76.4567	38.975	0.183	0.122	-0.131	-0.183	N/A	N/A
142	8575109	-76.445	39.1	0.232	0.148	-0.156	-0.221	N/A	N/A
143	8574931	-76.5267	39.1633	0.253	0.163	-0.169	-0.231	N/A	1960-1978
144	8574878	-76.5767	39.195	0.256	0.161	-0.162	-0.238	N/A	1960-1978
145	8574857	-76.4467	39.1967	0.253	0.158	-0.156	-0.229	N/A	1960-1978
146	8574821	-76.5333	39.2083	0.274	0.175	-0.187	-0.25	N/A	1983-2001
147	8574726	-76.49	39.25	0.262	0.164	-0.165	-0.232	N/A	1960-1978
148	8574686	-76.6267	39.2667	0.275	0.153	-0.146	-0.213	N/A	N/A
149	8574683	-76.585	39.2617	0.263	0.171	-0.176	-0.242	N/A	1983-2001
150	8574680	-76.5783	39.2667	0.262	0.171	-0.177	-0.244	0.254	1983-2001
151	8574459	-76.255	39.3883	0.277	0.169	-0.211	-0.269	N/A	1983-2001
152	8574070	-76.09	39.5367	0.385	0.281	-0.297	-0.361	0.315	1983-2001
153	8574008	-76.1133	39.6033	0.384	0.274	-0.278	-0.354	N/A	1960-1978
154	8573968	-75.97	39.5733	0.457	0.305	-0.271	-0.396	N/A	N/A
155	8573927	-75.81	39.5267	0.518	0.454	-0.418	-0.487	0.5	1983-2001
156	8573903	-75.9167	39.5033	0.434	0.338	-0.324	-0.383	N/A	1983-2001

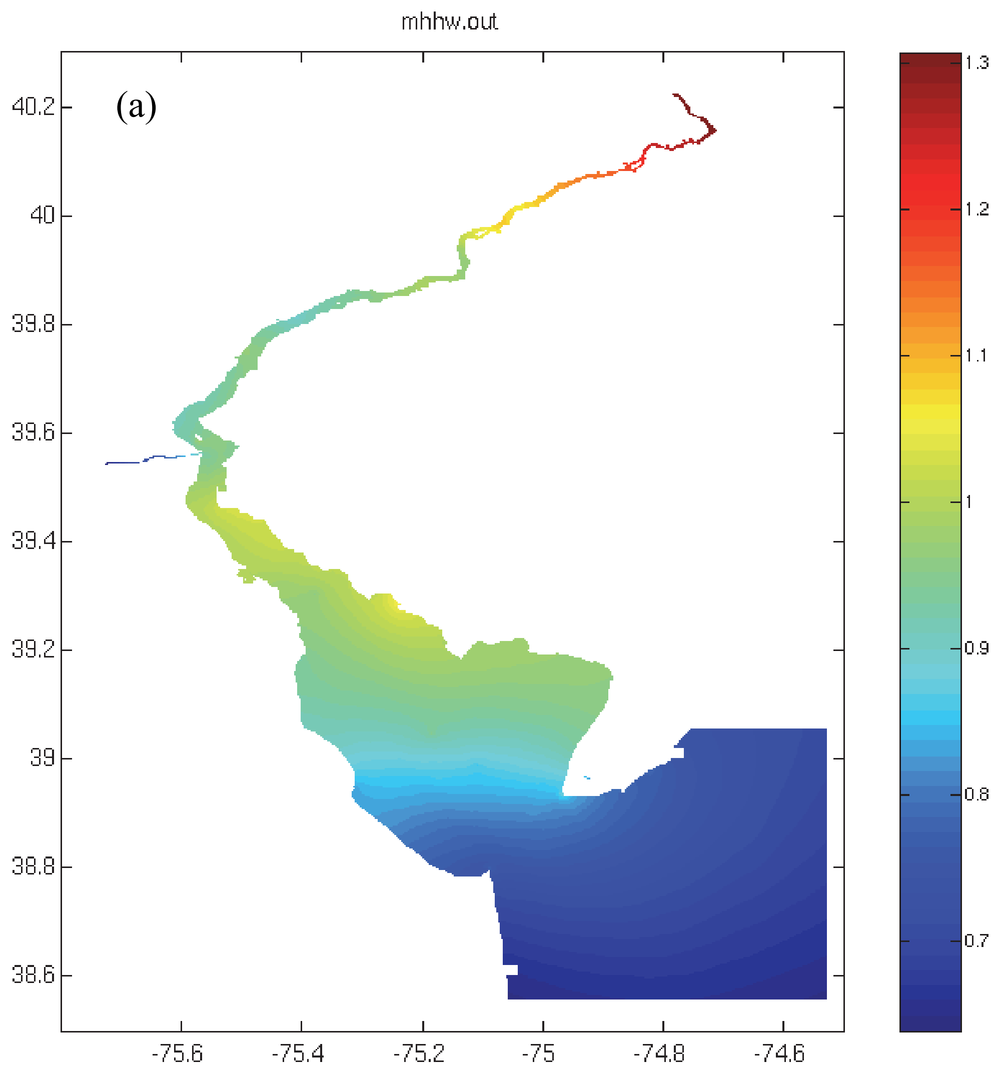
157	8573704	-76.0633	39.3717	0.342	0.239	-0.249	-0.315	N/A	1983-2001
158	8573364	-76.245	39.2133	0.273	0.177	-0.19	-0.254	N/A	1983-2001
159	8573349	-75.925	39.245	0.424	0.34	-0.356	-0.416	N/A	1983-2001
160	8573343	-76.0633	39.2067	0.418	0.266	-0.286	-0.405	N/A	N/A
161	8573137	-76.1383	39.11	0.335	0.232	-0.235	-0.32	N/A	1960-1978
162	8572955	-76.3017	39.0317	0.266	0.179	-0.183	-0.248	N/A	1983-2001
163	8572770	-76.355	38.9567	0.228	0.151	-0.161	-0.224	0.272	1983-2001
164	8572669	-75.945	38.9167	0.363	0.312	-0.389	-0.448	N/A	1983-2001
165	8572467	-76.3733	38.8367	0.239	0.167	-0.17	-0.234	N/A	1960-1978
166	8572342	-76.2217	38.7867	0.286	0.213	-0.214	-0.293	N/A	1960-1978
167	8571979	-76.325	38.7667	0.247	0.167	-0.171	-0.238	N/A	1960-1978
168	8571944	-75.9983	38.7567	0.411	0.259	-0.268	-0.381	N/A	N/A
169	8571901	-76.335	38.71	0.271	0.204	-0.201	-0.265	N/A	1960-1978
170	8571892	-76.0683	38.5733	0.313	0.249	-0.246	-0.309	0.349	1983-2001
171	8571890	-76.0717	38.575	0.314	0.241	-0.238	-0.311	N/A	1960-1978
172	8571773	-75.8183	38.4833	0.313	0.261	-0.331	-0.379	N/A	N/A
173	8571752	-76.295	38.4667	0.275	0.183	-0.195	-0.274	N/A	N/A
174	8571579	-76.265	38.3417	0.232	0.18	-0.193	-0.24	0.37	1983-2001
175	8571559	-76.0067	38.3	0.364	0.314	-0.312	-0.354	N/A	1983-2001
176	8571519	-76.205	38.2967	0.333	0.211	-0.237	-0.338	N/A	N/A
177	8571485	-75.7883	38.2683	0.427	0.366	-0.359	-0.396	N/A	N/A
178	8571477	-75.9133	38.27	0.347	0.32	-0.32	-0.366	N/A	1960-1978
179	8571421	-76.0383	38.22	0.309	0.261	-0.265	-0.305	N/A	1983-2001
180	8571402	-76.0767	38.2267	0.305	0.275	-0.25	-0.274	N/A	N/A
181	8571351	-75.9467	38.17	0.326	0.296	-0.295	-0.338	N/A	1960-1978
182	8571266	-75.8617	38.0917	0.323	0.293	-0.292	-0.335	N/A	1960-1978
183	8571214	-76.0967	38.0683	0.244	0.213	-0.223	-0.244	N/A	N/A
184	8571181	-75.8033	38.0483	0.326	0.296	-0.295	-0.338	N/A	1960-1978
185	8571117	-76.0317	37.995	0.278	0.227	-0.238	-0.274	N/A	1983-2001
186	8571091	-75.8633	37.9767	0.351	0.3	-0.268	-0.305	N/A	1960-1978
187	8570649	-75.285	38.1483	0.101	0.077	-0.084	-0.115	N/A	1983-2001
188	8570536	-75.1917	38.215	0.093	0.068	-0.073	-0.105	N/A	1983-2001
189	8570283	-75.0917	38.3283	0.383	0.309	-0.357	-0.393	N/A	1983-2001
190	8570282	-75.09	38.3317	0.389	0.321	-0.349	-0.395	0.521	1983-2001
191	8570280	-75.0833	38.3267	0.62	0.506	-0.519	-0.567	0.707	1983-2001
192	8570255	-75.085	38.3417	0.274	0.221	-0.244	-0.284	N/A	1983-2001
193	8558690	-75.07	38.61	0.443	0.361	-0.405	-0.452	N/A	1983-2001
194	8557380	-75.12	38.7817	0.738	0.61	-0.632	-0.68	0.801	1983-2001
195	8557125	-75.0833	38.8	0.762	0.64	-0.61	-0.671	N/A	N/A
196	8556198	-75.3133	38.945	0.832	0.704	-0.707	-0.756	N/A	1960-1978
197	8555889	-75.1133	38.9867	0.857	0.719	-0.725	-0.776	N/A	N/A
198	8555461	-75.1833	39.0483	0.945	0.793	-0.792	-0.853	N/A	N/A
199	8555388	-75.3967	39.0583	0.908	0.78	-0.78	-0.826	N/A	1960-1978
200	8554399	-75.4	39.185	0.929	0.797	-0.827	-0.882	N/A	1983-2001
201	8551973	-75.6483	39.555	0.738	0.671	-0.673	-0.728	N/A	1960-1978
202	8551910	-75.5733	39.5583	0.89	0.793	-0.835	-0.89	0.905	1983-2001
203	8551762	-75.5883	39.5817	0.909	0.787	-0.822	-0.877	N/A	1983-2001
204	8551702	-75.5733	39.5833	0.973	0.857	-0.856	-0.911	N/A	1960-1978
205	8551201	-75.5617	39.6567	0.918	0.796	-0.792	-0.847	N/A	1960-1978
206	8550714	-75.52	39.7183	0.926	0.804	-0.802	-0.863	N/A	1960-1978
207	8550438	-75.4933	39.75	0.973	0.842	-0.841	-0.905	N/A	1960-1978
208	8549424	-74.8233	40.1283	1.247	1.125	-1.204	-1.274	N/A	1960-1978
209	8548989	-74.7517	40.1367	1.258	1.143	-1.254	-1.314	N/A	1983-2001
210	8547333	-74.9383	40.0683	1.14	1.037	-1.103	-1.164	N/A	1960-1978

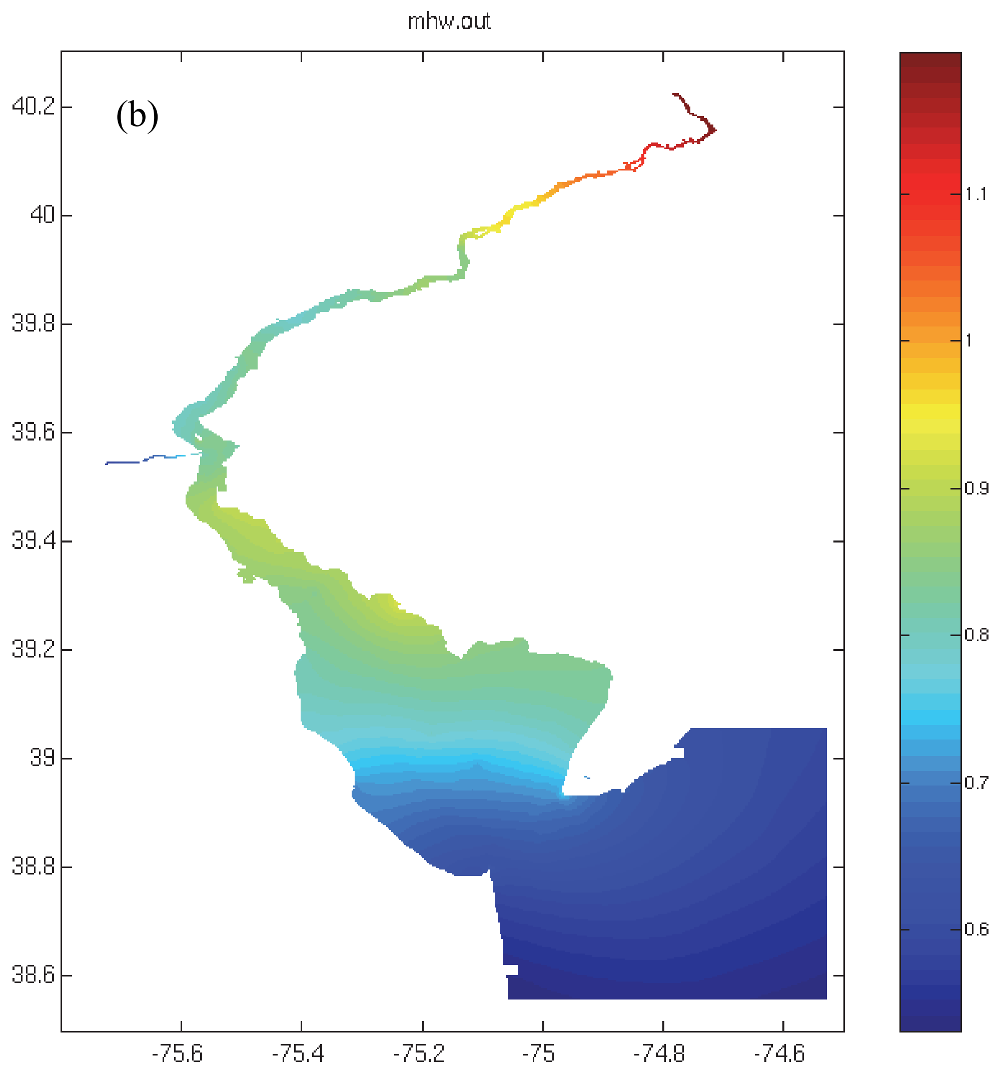
211	8546252	-75.0683	39.9833	1.091	0.973	-0.972	-1.033	N/A	1960-1978
212	8545530	-75.1383	39.9533	1.011	0.893	-1.01	-1.069	0.987	1983-2001
213	8545240	-75.1417	39.9333	0.964	0.836	-0.991	-1.051	0.96	1983-2001
214	8540433	-75.41	39.8117	0.896	0.78	-0.882	-0.94	N/A	N/A
215	8539993	-74.755	40.1883	1.3	1.19	-1.302	-1.363	1.175	1983-2001
216	8539487	-74.7367	40.1367	1.29	1.179	-1.23	-1.291	1.14	1983-2001
217	8539094	-74.8733	40.08	1.16	1.046	-1.134	-1.196	N/A	1983-2001
218	8538886	-75.0433	40.0117	1.053	0.934	-1.032	-1.094	N/A	1983-2001
219	8538552	-75.25	39.85	0.973	0.851	-0.853	-0.911	N/A	1960-1978
220	8538548	-75.1867	39.86	0.996	0.875	-0.878	-0.936	N/A	1960-1978
221	8538231	-75.51	39.6833	0.957	0.841	-0.841	-0.896	N/A	1960-1978
222	8537961	-75.4983	39.57	0.932	0.81	-0.811	-0.863	N/A	1960-1978
223	8537614	-75.5333	39.4617	1.03	0.902	-0.905	-0.963	N/A	1960-1978
224	8537121	-75.375	39.305	0.959	0.835	-0.872	-0.92	N/A	N/A
225	8537116	-75.2783	39.305	1.009	0.893	-0.908	-0.954	N/A	1960-1978
226	8537101	-75.2483	39.2983	1.043	0.909	-0.908	-0.966	N/A	1960-1978
227	8537052	-75.2383	39.285	1.058	0.927	-0.923	-0.978	N/A	1960-1978
228	8536915	-75.1733	39.2367	1.01	0.883	-0.942	-0.998	N/A	1960-1978
229	8536849	-75.1033	39.2167	0.981	0.844	-0.869	-0.924	N/A	1960-1978
230	8536848	-75.1583	39.2167	0.991	0.854	-0.862	-0.917	N/A	1960-1978
231	8536780	-75.02	39.2	0.979	0.842	-0.911	-0.975	N/A	1960-1978
232	8536581	-74.8917	39.1283	0.956	0.825	-0.904	-0.962	N/A	1983-2001
233	8536271	-74.9533	39.0183	0.93	0.793	-0.804	-0.853	N/A	1960-1978
234	8536110	-74.96	38.9683	0.876	0.743	-0.734	-0.783	0.92	1983-2001
235	8536021	-74.9717	38.9467	0.86	0.729	-0.734	-0.783	N/A	1960-1978
236	8535962	-74.935	38.93	0.826	0.695	-0.704	-0.756	N/A	1960-1978
237	8535902	-74.9133	38.9467	0.808	0.68	-0.695	-0.753	N/A	1960-1978
238	8535901	-74.8917	38.9483	0.801	0.673	-0.695	-0.747	N/A	1960-1978
239	8535838	-74.8367	38.9783	0.792	0.667	-0.704	-0.756	N/A	1960-1978
240	8535835	-74.8233	38.975	0.783	0.649	-0.664	-0.719	N/A	1983-2001
241	8535805	-74.8633	38.98	0.795	0.67	-0.689	-0.741	N/A	1960-1978
242	8535726	-74.8267	39.005	0.747	0.625	-0.676	-0.725	N/A	1960-1978
243	8535721	-74.8133	39.0283	0.731	0.64	-0.61	-0.671	N/A	N/A
244	8535695	-74.8417	39.0183	0.758	0.637	-0.683	-0.732	N/A	1960-1978
245	8535661	-74.8017	39.0283	0.746	0.618	-0.628	-0.677	N/A	1960-1978
246	8535581	-74.765	39.0567	0.722	0.6	-0.625	-0.674	N/A	1960-1978
247	8535511	-74.785	39.0883	0.731	0.64	-0.61	-0.671	N/A	N/A
248	8535451	-74.755	39.1017	0.671	0.579	-0.579	-0.64	N/A	N/A
249	8535419	-74.7383	39.11	0.704	0.589	-0.609	-0.658	N/A	1960-1978
250	8535375	-74.7167	39.1217	0.704	0.585	-0.597	-0.649	N/A	1960-1978
251	8535357	-74.755	39.12	0.701	0.585	-0.628	-0.677	N/A	1960-1978
252	8535291	-74.69	39.1533	0.731	0.64	-0.61	-0.671	N/A	N/A
253	8535278	-74.7	39.1567	0.671	0.579	-0.579	-0.64	N/A	N/A
254	8535221	-74.71	39.1767	0.706	0.59	-0.612	-0.66	N/A	1960-1978
255	8535163	-74.6567	39.2	0.682	0.562	-0.597	-0.648	0.735	1983-2001
256	8535101	-74.6483	39.215	0.69	0.572	-0.585	-0.635	0.723	1983-2001
257	8534975	-74.6283	39.2883	0.653	0.543	-0.539	-0.588	N/A	1960-1978
258	8534836	-74.5333	39.3083	0.701	0.578	-0.574	-0.619	N/A	1983-2001
259	8534770	-74.4767	39.335	0.733	0.605	-0.625	-0.678	0.797	1983-2001
260	8534739	-74.54	39.3517	0.706	0.587	-0.608	-0.658	N/A	1960-1978
261	8534720	-74.4183	39.355	0.728	0.601	-0.624	-0.675	0.797	1983-2001
262	8534670	-74.425	39.3783	0.707	0.592	-0.597	-0.652	N/A	1960-1978
263	8534657	-74.5183	39.3817	0.716	0.598	-0.61	-0.652	N/A	1960-1978
264	8534638	-74.425	39.385	0.71	0.595	-0.594	-0.649	N/A	1960-1978

265	8534596	-74.435	39.405	0.579	0.518	-0.519	-0.549	N/A	N/A
266	8534496	-74.3633	39.435	0.652	0.541	-0.564	-0.61	N/A	1960-1978
267	8534393	-74.3833	39.4783	0.602	0.497	-0.481	-0.521	N/A	1983-2001
268	8534348	-74.305	39.5033	0.67	0.579	-0.549	-0.61	N/A	N/A
269	8534208	-74.2567	39.5483	0.412	0.327	-0.328	-0.362	N/A	1960-1978
270	8534139	-74.3317	39.5767	0.402	0.323	-0.321	-0.351	N/A	1960-1978
271	8534048	-74.21	39.6133	0.349	0.266	-0.284	-0.301	N/A	1983-2001
272	8534044	-74.2633	39.6133	0.384	0.308	-0.294	-0.32	N/A	1983-2001
273	8533935	-74.185	39.6533	0.265	0.207	-0.177	-0.198	N/A	1960-1978
274	8533909	-74.215	39.6667	0.262	0.21	-0.171	-0.192	N/A	1960-1978
275	8533862	-74.16	39.675	0.223	0.174	-0.137	-0.158	N/A	1960-1978
276	8533738	-74.1367	39.725	0.113	0.077	-0.064	-0.085	N/A	1960-1978
277	8533651	-74.1883	39.7517	0.097	0.052	-0.043	-0.052	N/A	1960-1978
278	8533631	-74.1283	39.7567	0.094	0.079	-0.085	-0.122	N/A	1960-1978
279	8533615	-74.1117	39.7617	0.41	0.339	-0.318	-0.355	0.36	1983-2001
280	8533541	-74.1817	39.7917	0.079	0.052	-0.052	-0.073	N/A	1960-1978
281	8533535	-74.0983	39.7883	0.101	0.061	-0.043	-0.064	N/A	1960-1978
282	8533345	-74.0883	39.8517	0.076	0.052	-0.055	-0.073	N/A	1960-1978
283	8533141	-74.11	39.9183	0.082	0.052	-0.058	-0.073	N/A	1960-1978
284	8533135	-74.0833	39.9217	0.089	0.058	-0.058	-0.076	N/A	1960-1978
285	8533055	-74.115	39.9483	0.095	0.058	-0.055	-0.073	N/A	1960-1978
286	8532885	-74.0683	39.9883	0.095	0.055	-0.058	-0.082	N/A	1960-1978
287	8532835	-74.1133	40.0133	0.095	0.055	-0.061	-0.088	N/A	1960-1978
288	8532786	-74.0533	40.0367	0.089	0.049	-0.052	-0.076	N/A	1960-1978
289	8532721	-74.1167	40.0583	0.089	0.043	-0.049	-0.073	N/A	1960-1978
290	8532715	-74.0617	40.0617	0.082	0.025	-0.066	-0.086	N/A	1960-1978
291	8532705	-74.0517	40.065	0.089	0.046	-0.046	-0.073	N/A	1960-1978
292	6530005	-74.1817	39.7917	0.079	0.052	-0.052	-0.073	N/A	1960-1978
293	6530004	-74.1867	39.6533	0.265	0.207	-0.177	-0.198	N/A	1960-1978
294	6530003	-74.325	39.5083	0.64	0.527	-0.506	-0.549	N/A	1960-1978
295	6530001	-74.4233	39.3783	0.707	0.592	-0.597	-0.652	N/A	1960-1978
297	8638660	-76.2933	36.8217	0.482	0.418	-0.422	-0.464	0.546	1983-2001
298	8639348	-76.3017	36.7783	0.5	0.435	-0.437	-0.479	0.557	1983-2001

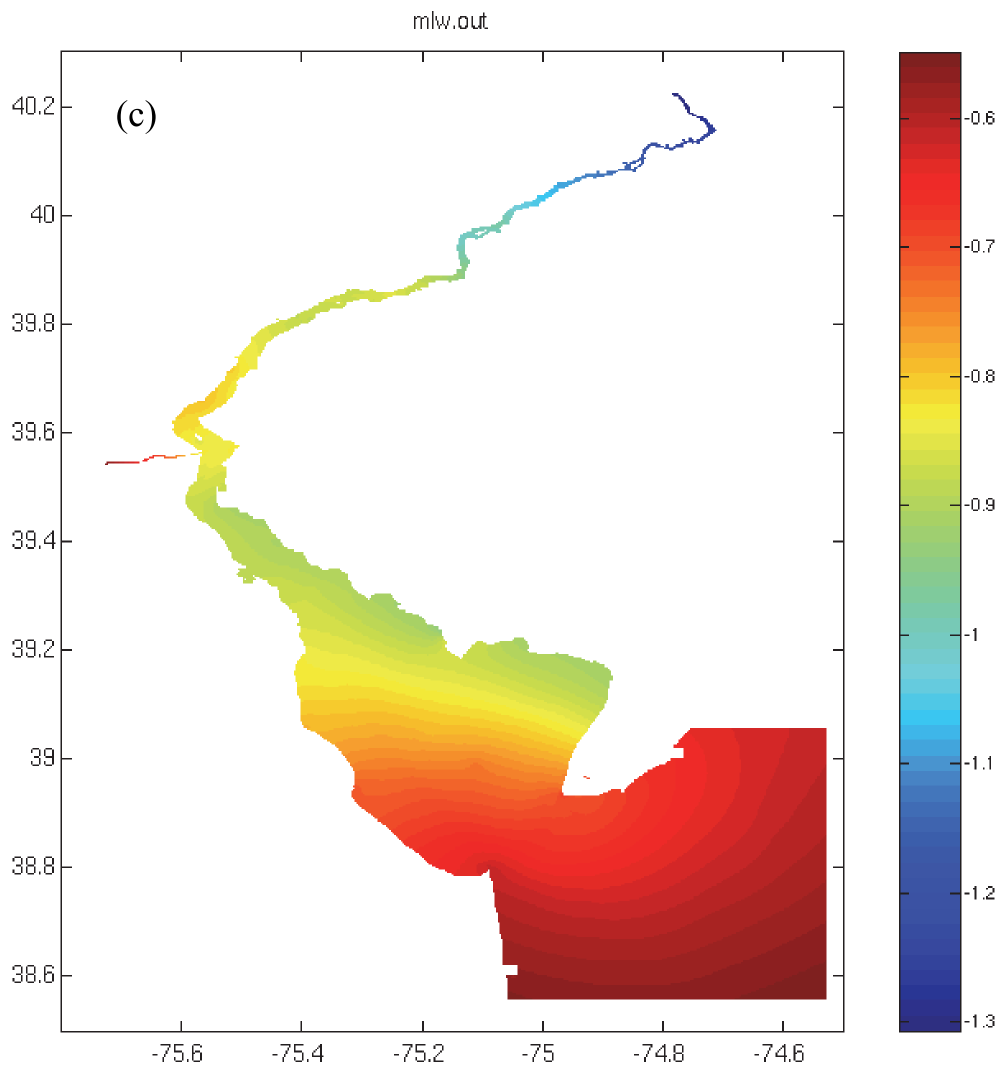
APPENDIX D. CORRECTED TIDAL DATUMS ON MARINE GRID

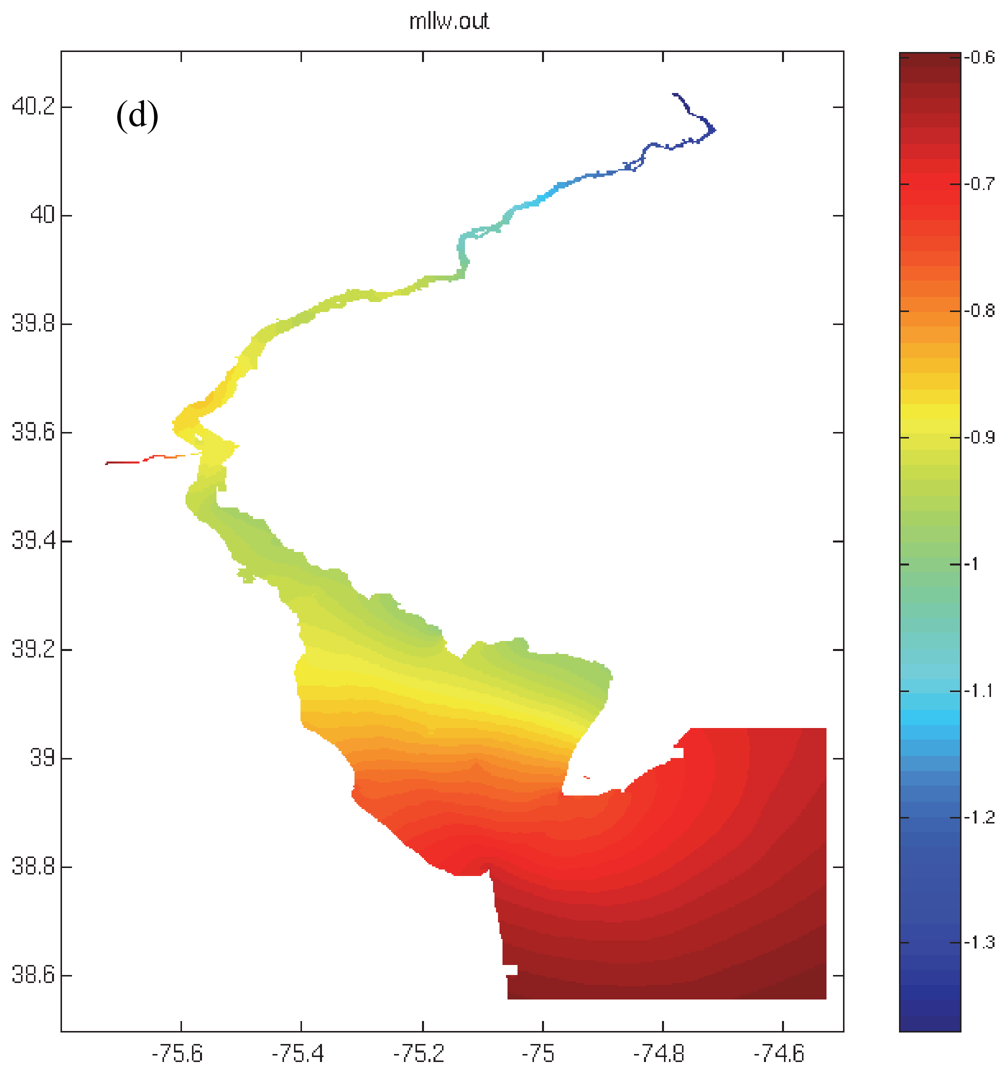
Figure D.1. Tidal datums on Delaware Bay marine grid, (a) MHHW, (b) MHW, (c) MLW, (d) MLLW, (e) MTL, and (f) DTL. Color bars are in meters.

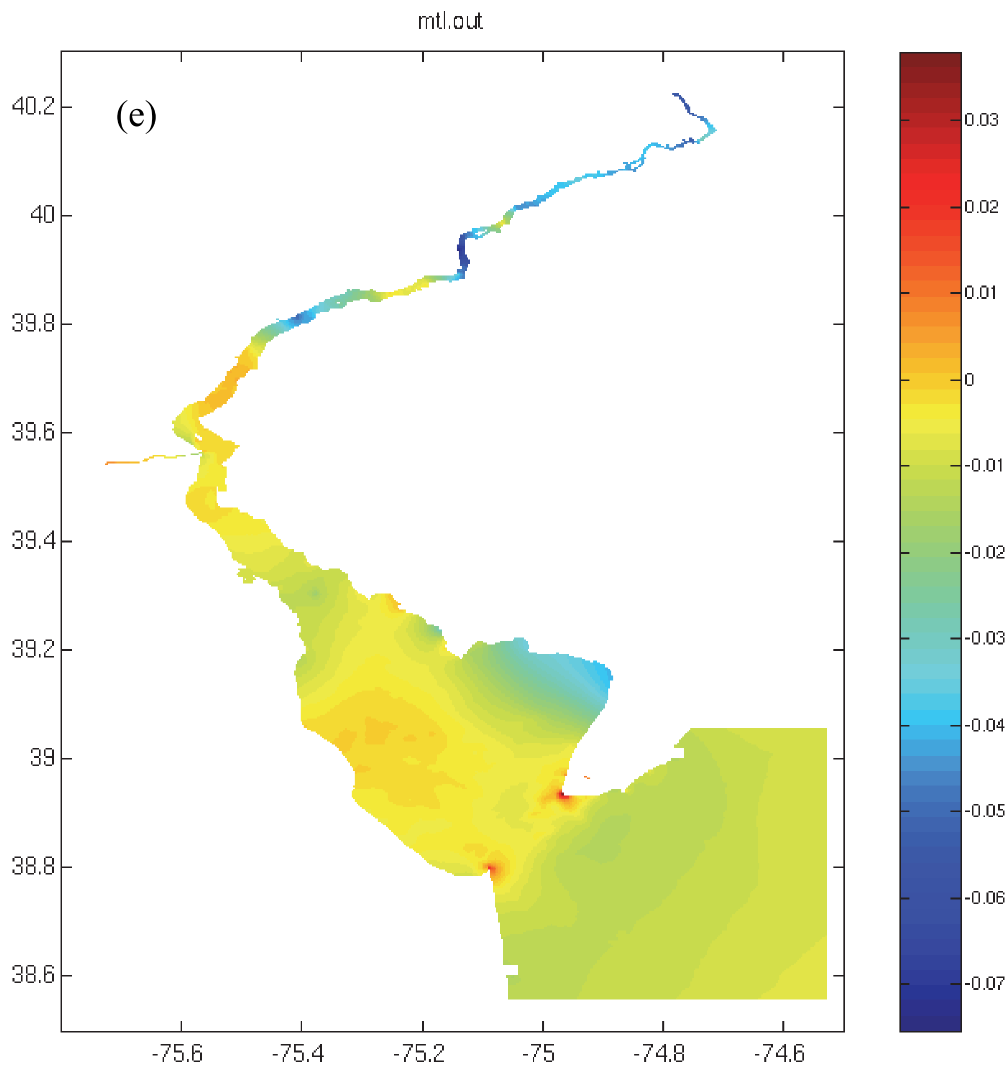




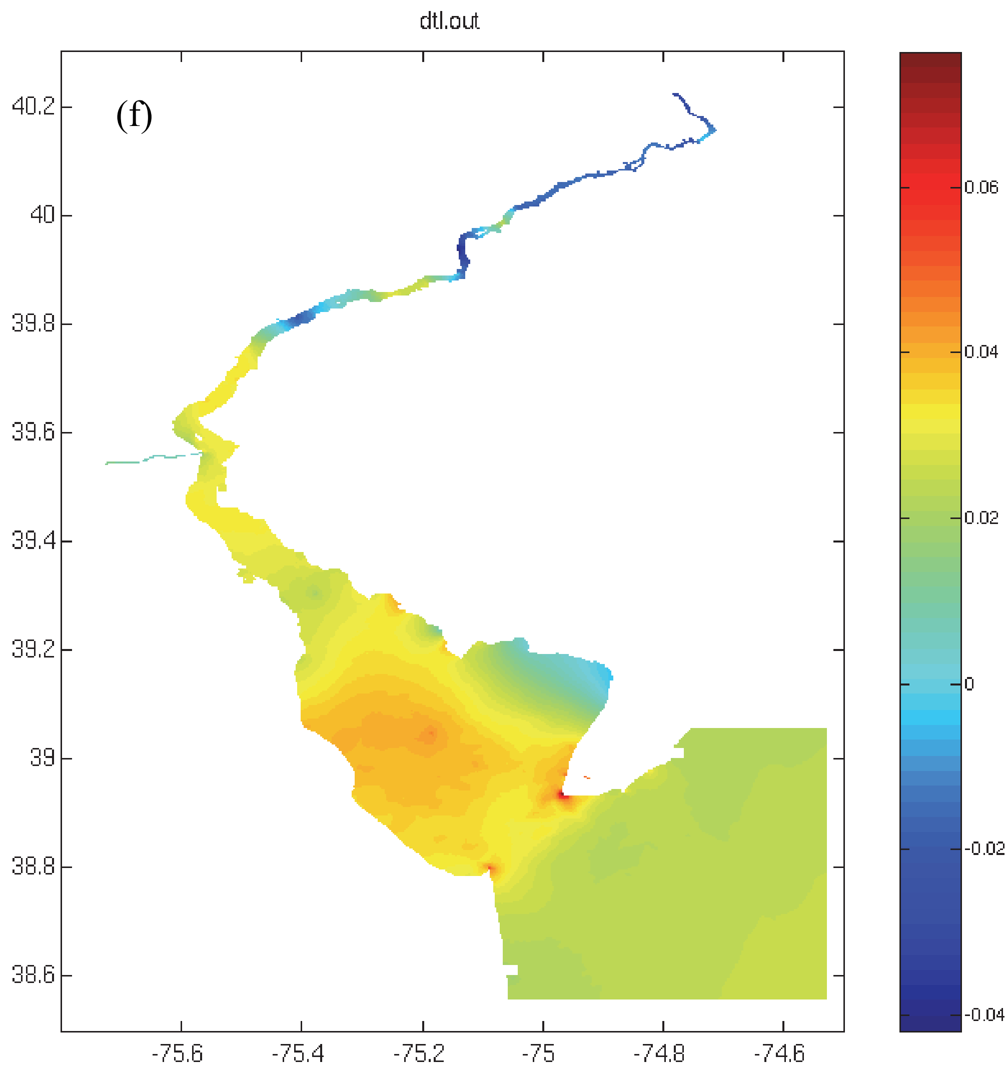
mhw.out
(b)
40.2
40
39.8
39.6
39.4
39.2
39
38.8
38.6
-75.6
-75.4
-75.2
-75
-74.8
-74.6
1.1
1
0.9
0.8
0.7
0.6


mlw.out
(c)
40.2
40
39.8
39.6
39.4
39.2
39
38.8
38.6
-75.6
-75.4
-75.2
-75
-74.8
-74.6
-0.6
-0.7
-0.8
-0.9
-1
-1.1
-1.2
-1.3


mllw.out
(d)
40.2
40
39.8
39.6
39.4
39.2
39
38.8
38.6
-75.6
-75.4
-75.2
-75
-74.8
-74.6
-0.6
-0.7
-0.8
-0.9
-1
-1.1
-1.2
-1.3

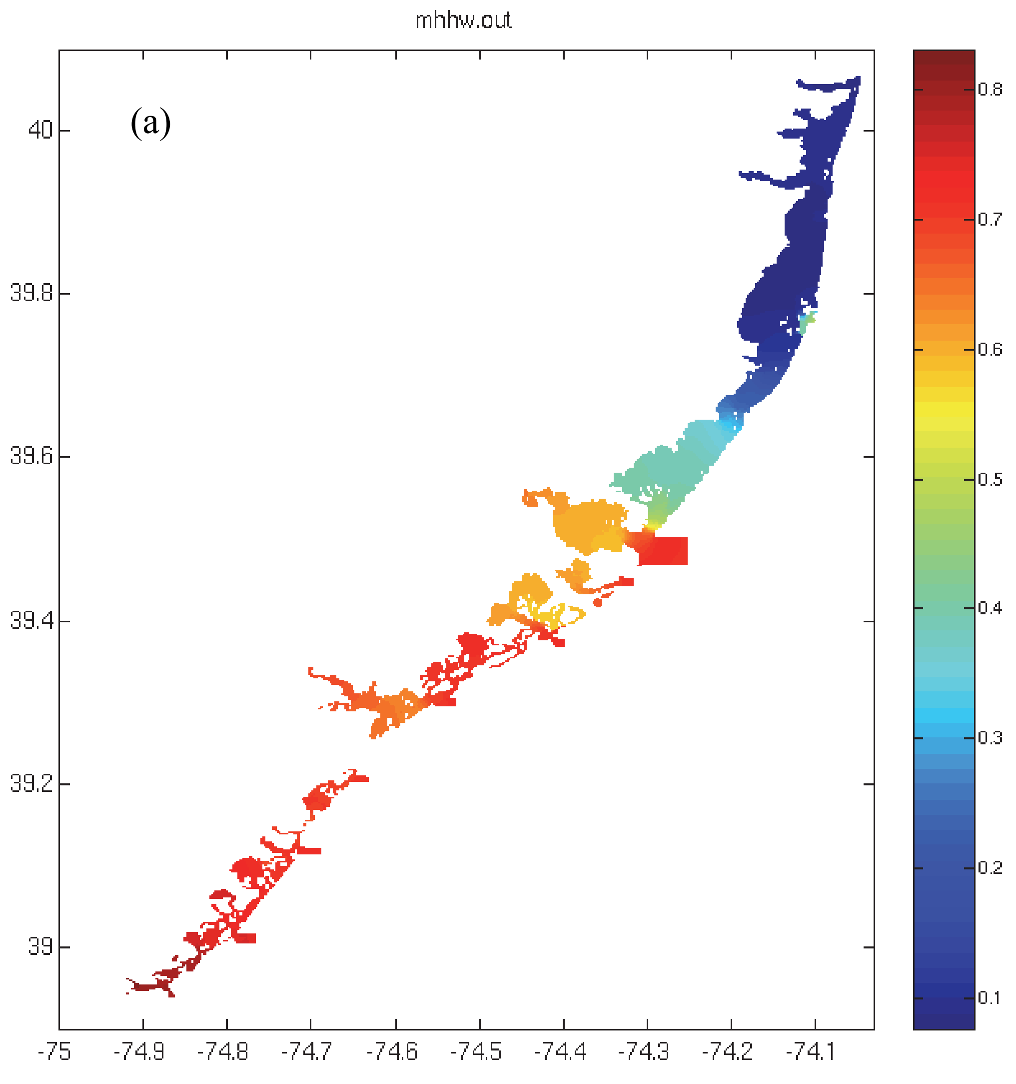


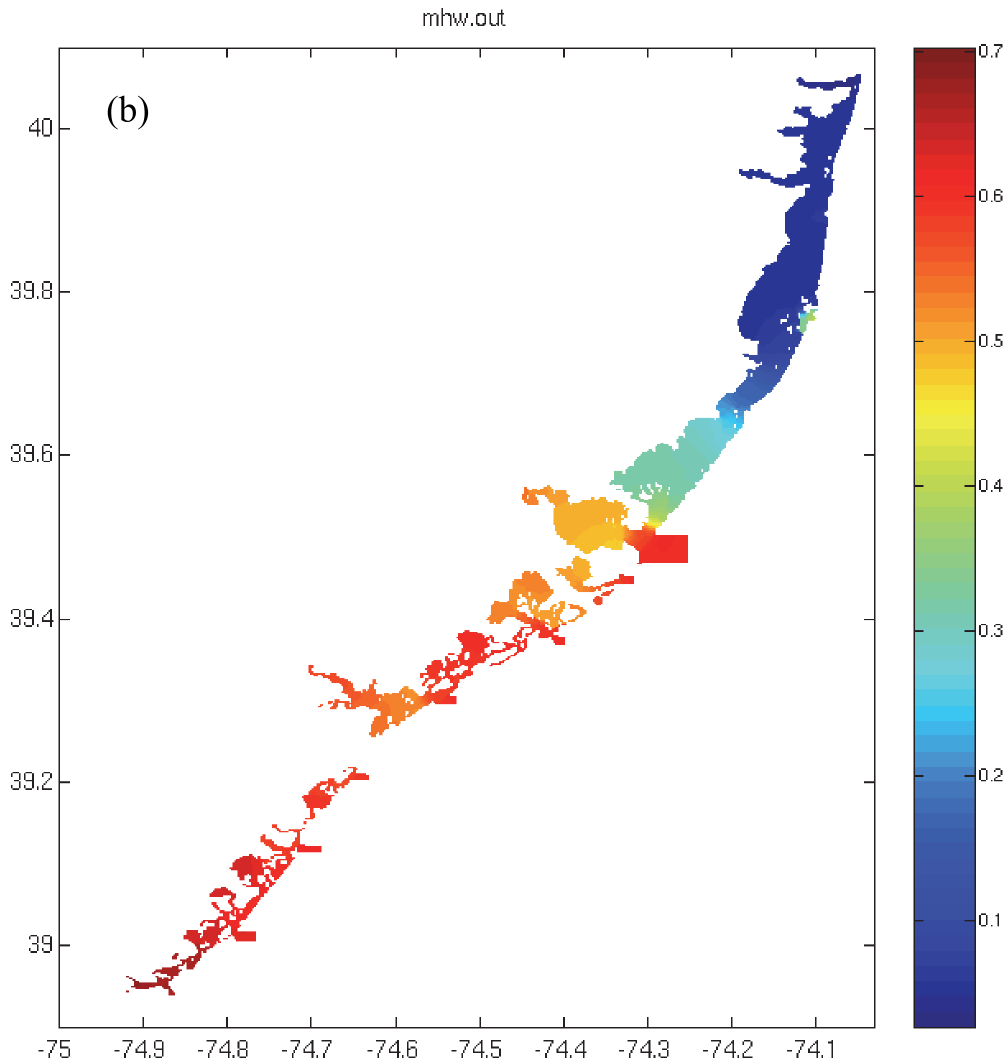
mtl.out
(e)
40.2
40
39.8
39.6
39.4
39.2
39
38.8
38.6
-75.6
-75.4
-75.2
-75
-74.8
-74.6
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07

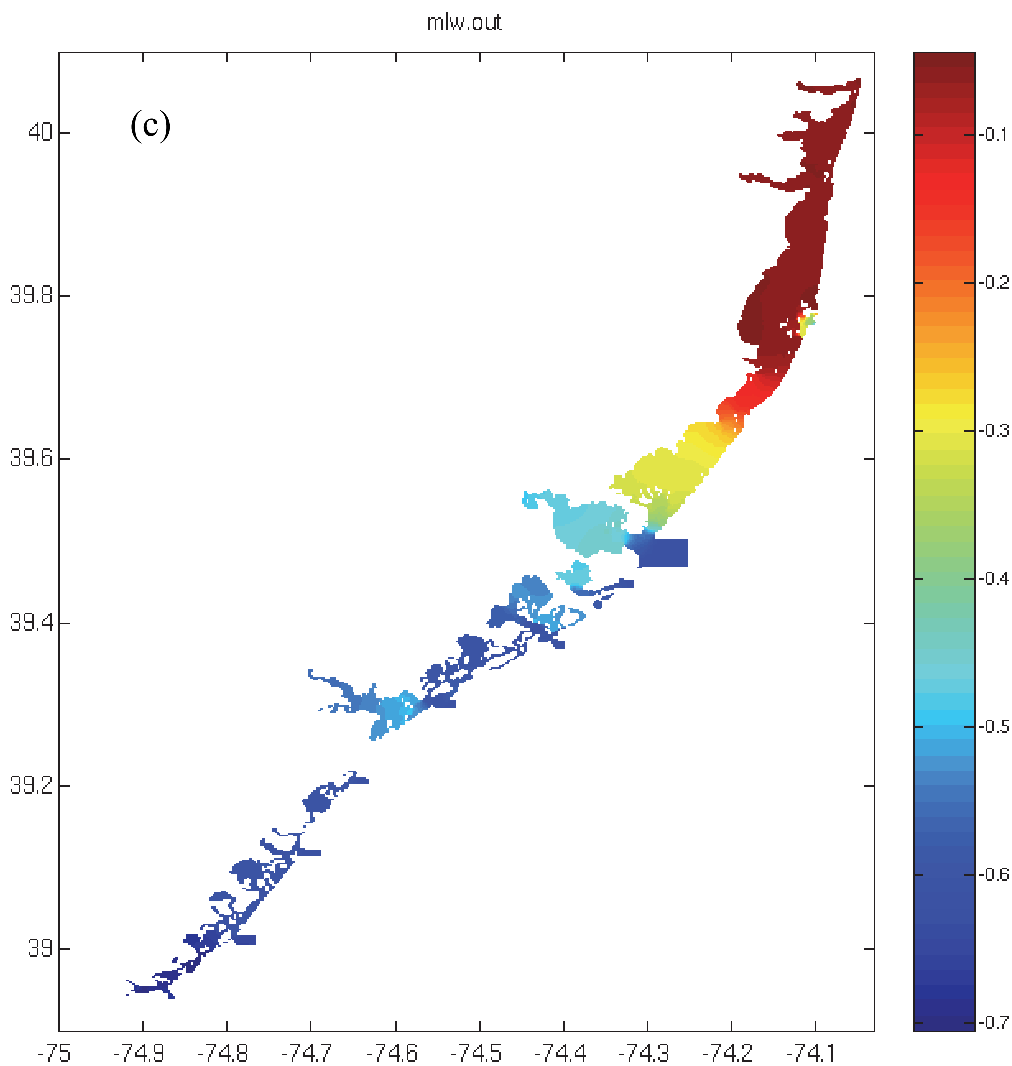


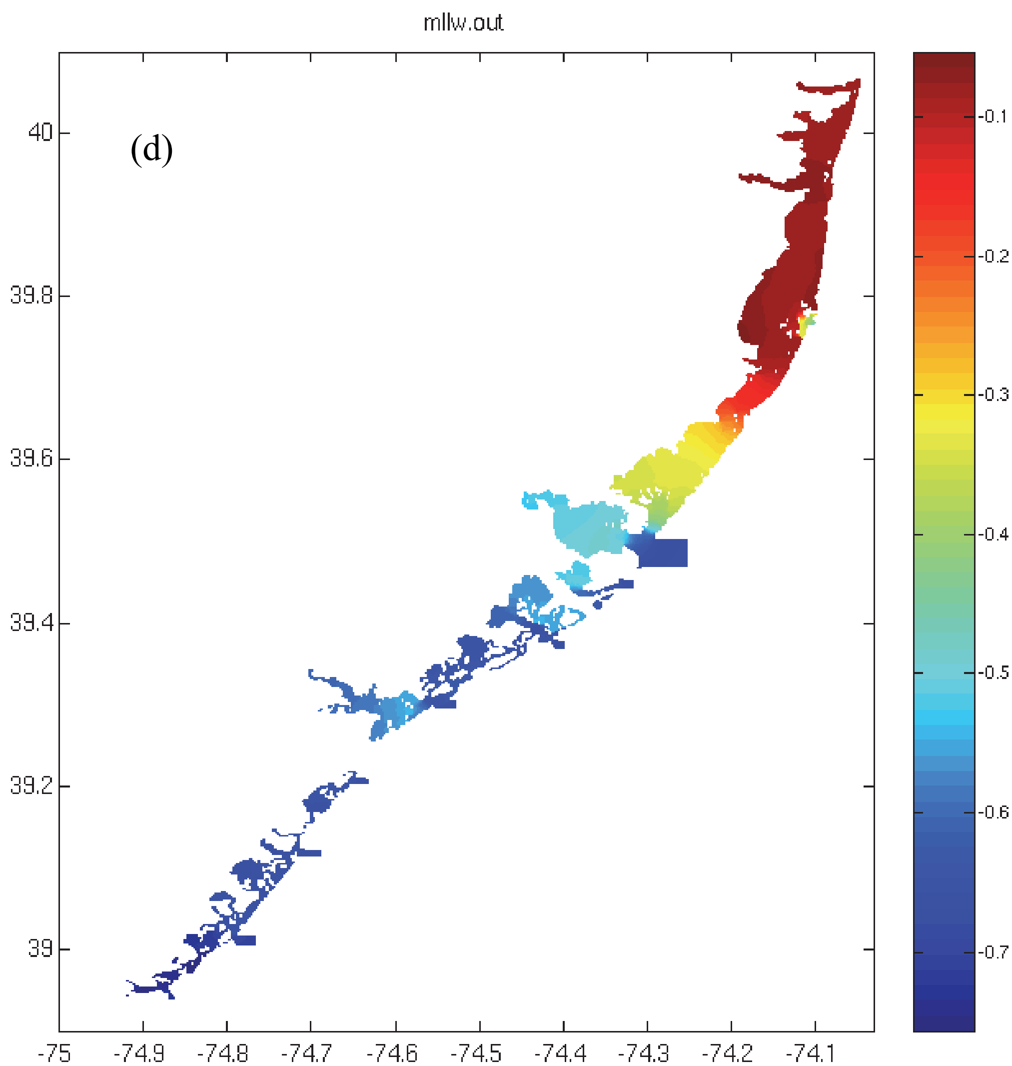
dtl.out
(f)
40.2
40
39.8
39.6
39.4
39.2
39
38.8
38.6
-75.6
-75.4
-75.2
-75
-74.8
-74.6
0.06
0.04
0.02
0
-0.02
-0.04

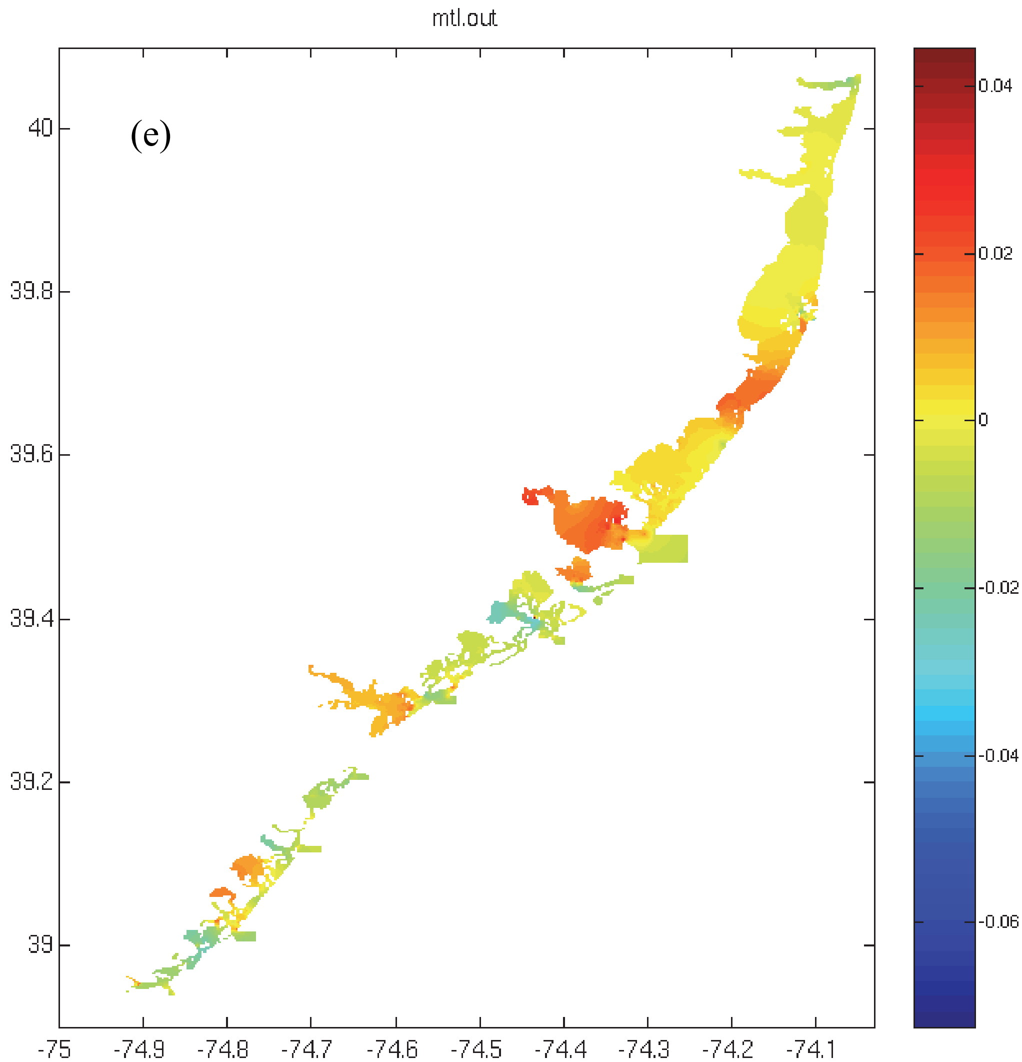
Figure D.2. Tidal datums on the New Jersey coast embayment marine grid, (a) MHHW, (b) MHW, (c) MLW, (d) MLLW, (e) MTL, and (f) DTL. Color bars are in meters.

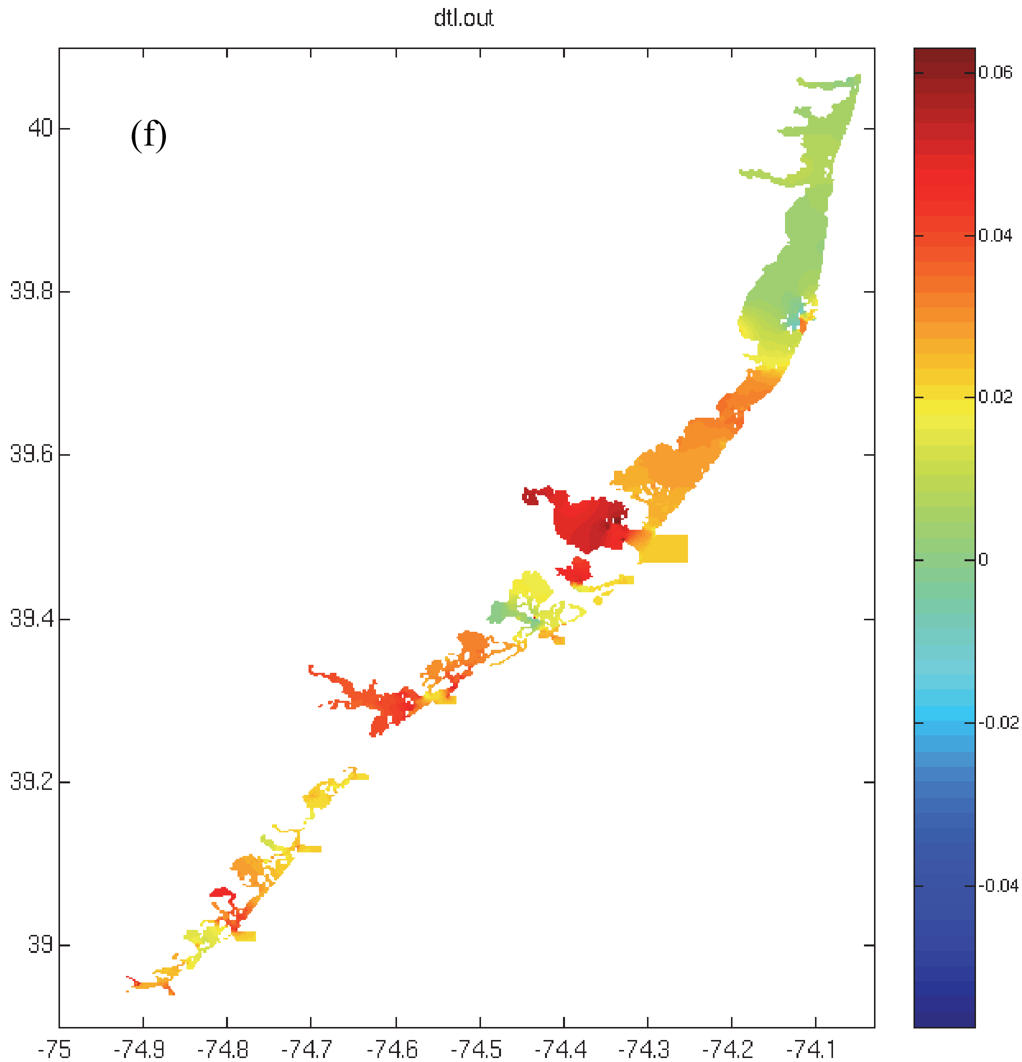



mhw.out
(b)
40
39.8
39.6
39.4
39.2
39
-75
-74.9
-74.8
-74.7
-74.6
-74.5
-74.4
-74.3
-74.2
-74.1
0.7
0.6
0.5
0.4
0.3
0.2
0.1


mlw.out
(c)
40
39.8
39.6
39.4
39.2
39
-75
-74.9
-74.8
-74.7
-74.6
-74.5
-74.4
-74.3
-74.2
-74.1
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7

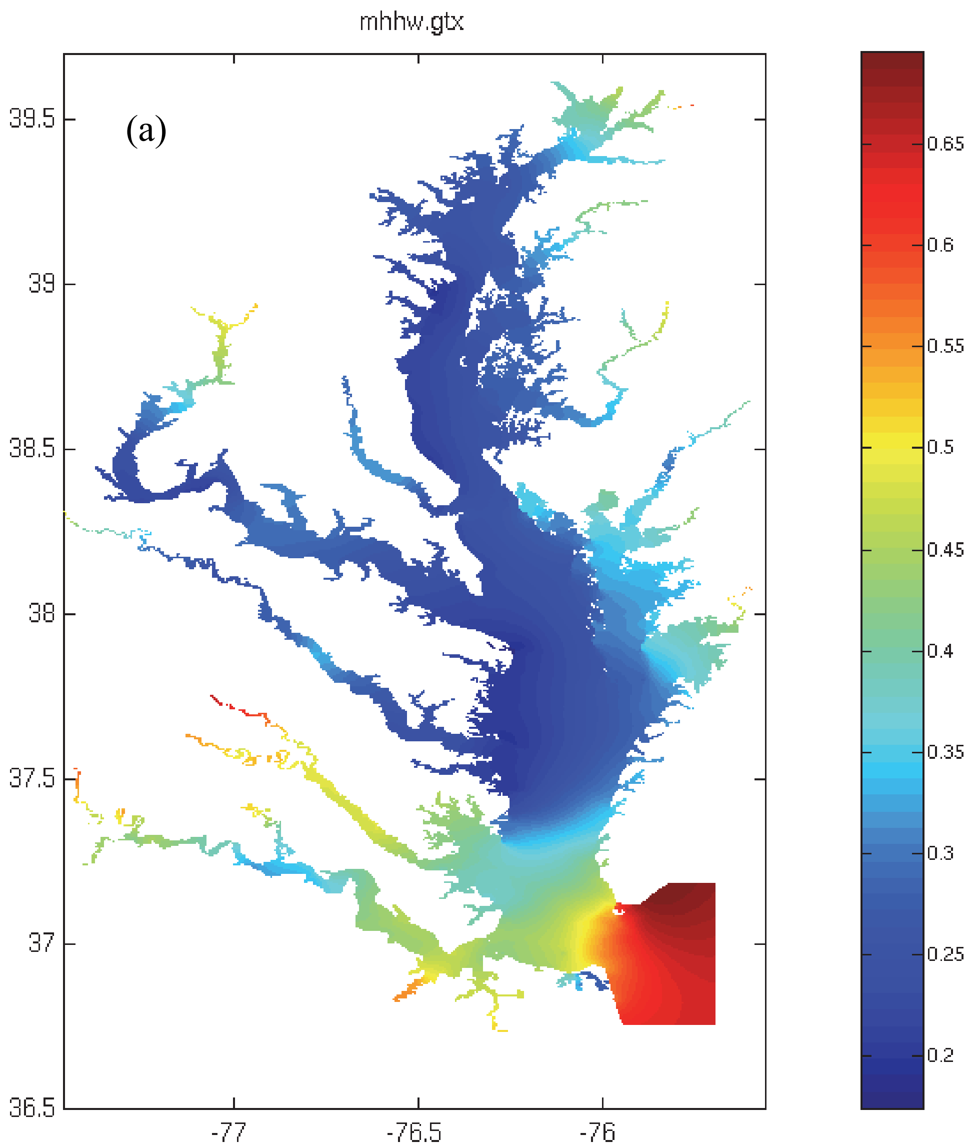

mllw.out
(d)
40
39.8
39.6
39.4
39.2
39
-75
-74.9
-74.8
-74.7
-74.6
-74.5
-74.4
-74.3
-74.2
-74.1
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7

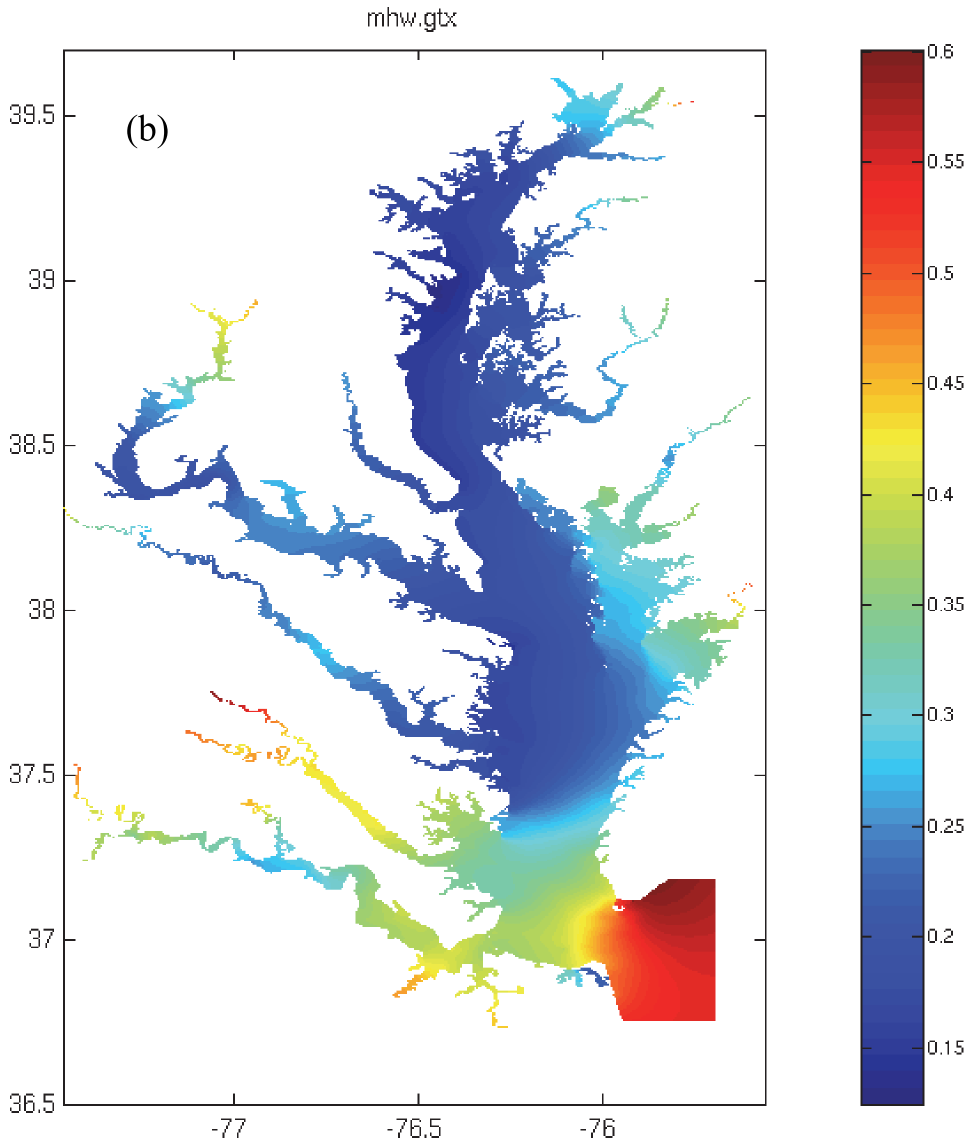

mtl.out
(e)
40
39.8
39.6
39.4
39.2
39
-75
-74.9
-74.8
-74.7
-74.6
-74.5
-74.4
-74.3
-74.2
-74.1
0.04
0.02
0
-0.02
-0.04
-0.06

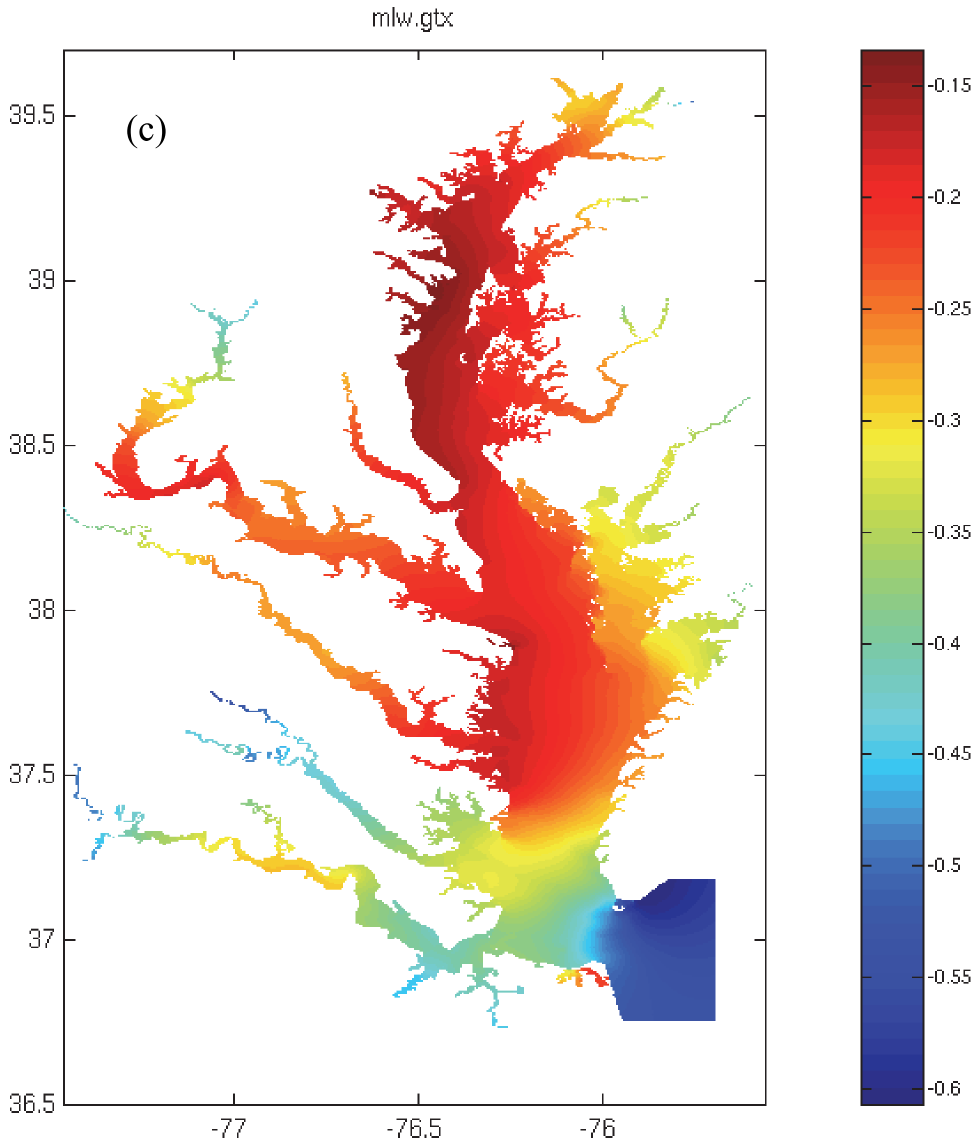


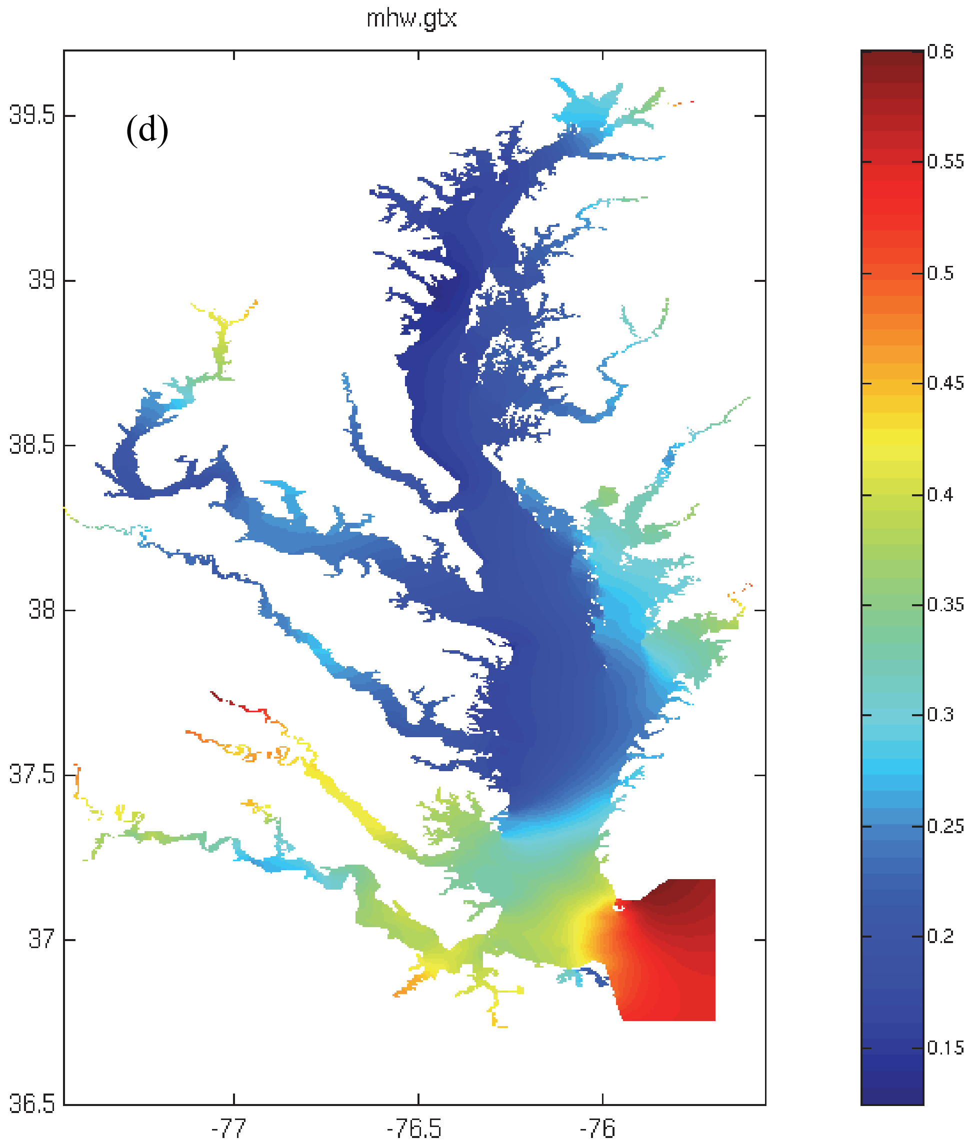
dtl.out
(f)
40
39.8
39.6
39.4
39.2
39
-75
-74.9
-74.8
-74.7
-74.6
-74.5
-74.4
-74.3
-74.2
-74.1
0.06
0.04
0.02
0
-0.02
-0.04

Figure D.3. Tidal datums on Chesapeake Bay marine grid, (a) MHHW, (b) MHW, (c) MLW, (d) MLLW, (e) MTL, and (f) DTL. Color bars are in meters.

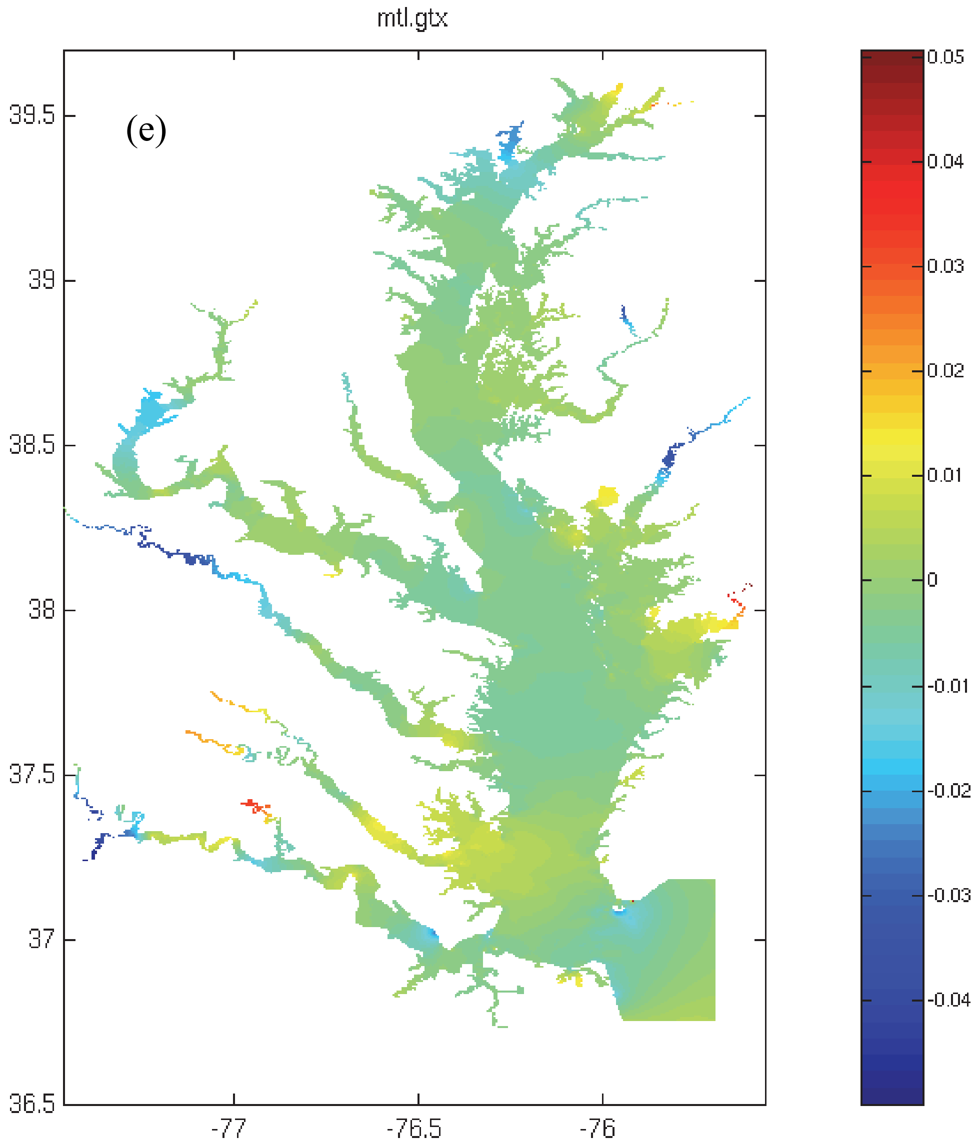



mhw.gtx
(b)
39.5
39
38.5
38
37.5
37
36.5
-77
-76.5
-76
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15


mlw.gtx
(c)
39.5
39
38.5
38
37.5
37
36.5
-77
-76.5
-76
-0.15
-0.2
-0.25
-0.3
-0.35
-0.4
-0.45
-0.5
-0.55
-0.6



mhw.gtx
(d)
39.5
39
38.5
38
37.5
37
36.5
-77
-76.5
-76
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15


mtl.gtx
(e)
39.5
39
38.5
38
37.5
37
36.5
-77
-76.5
-76
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04

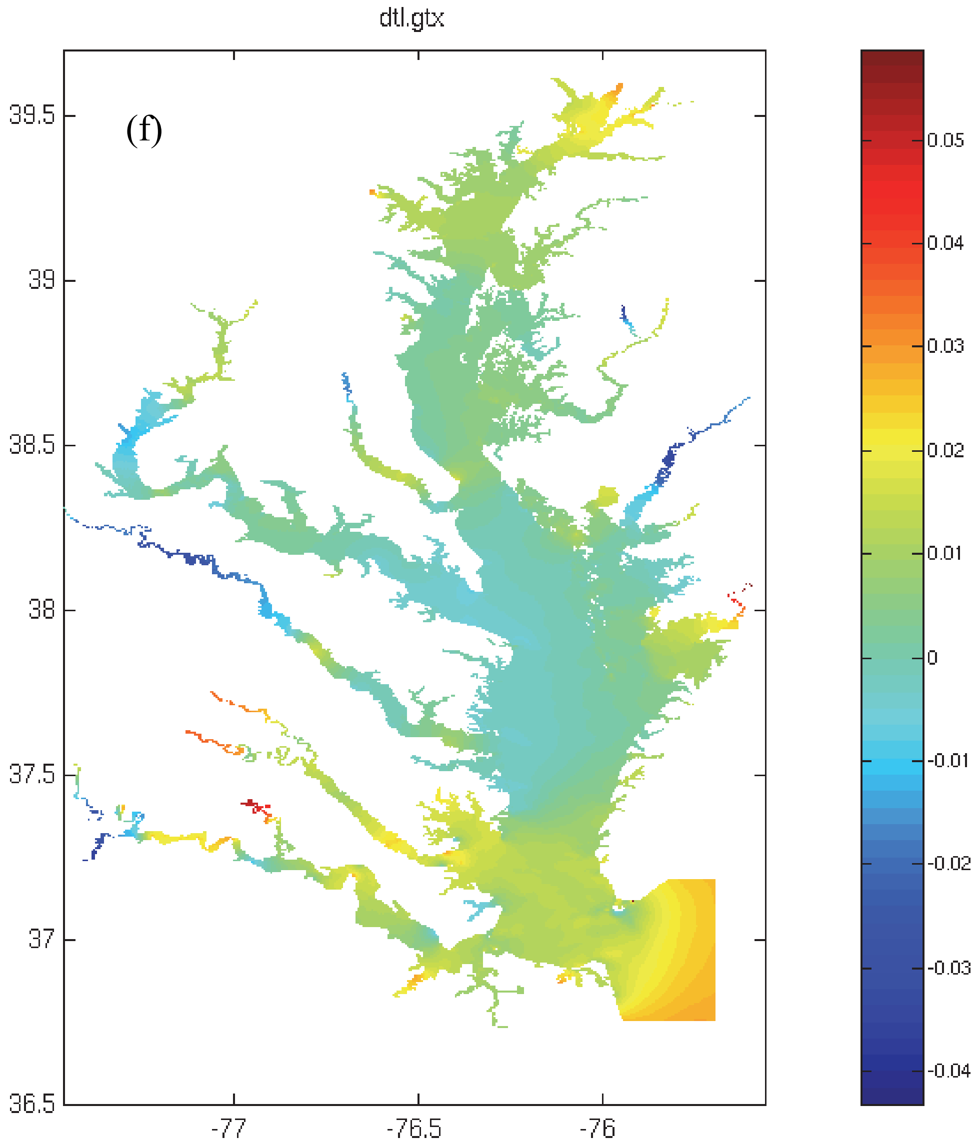
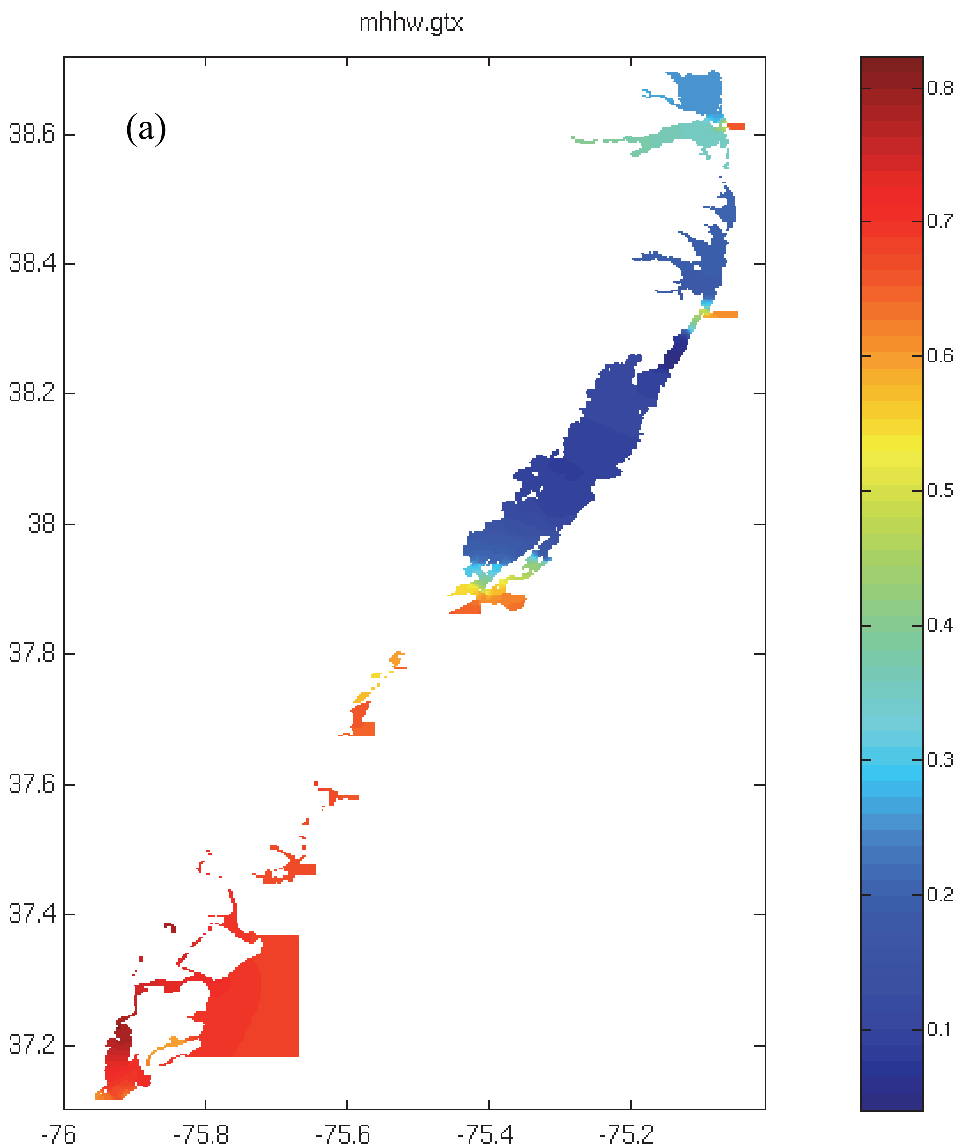
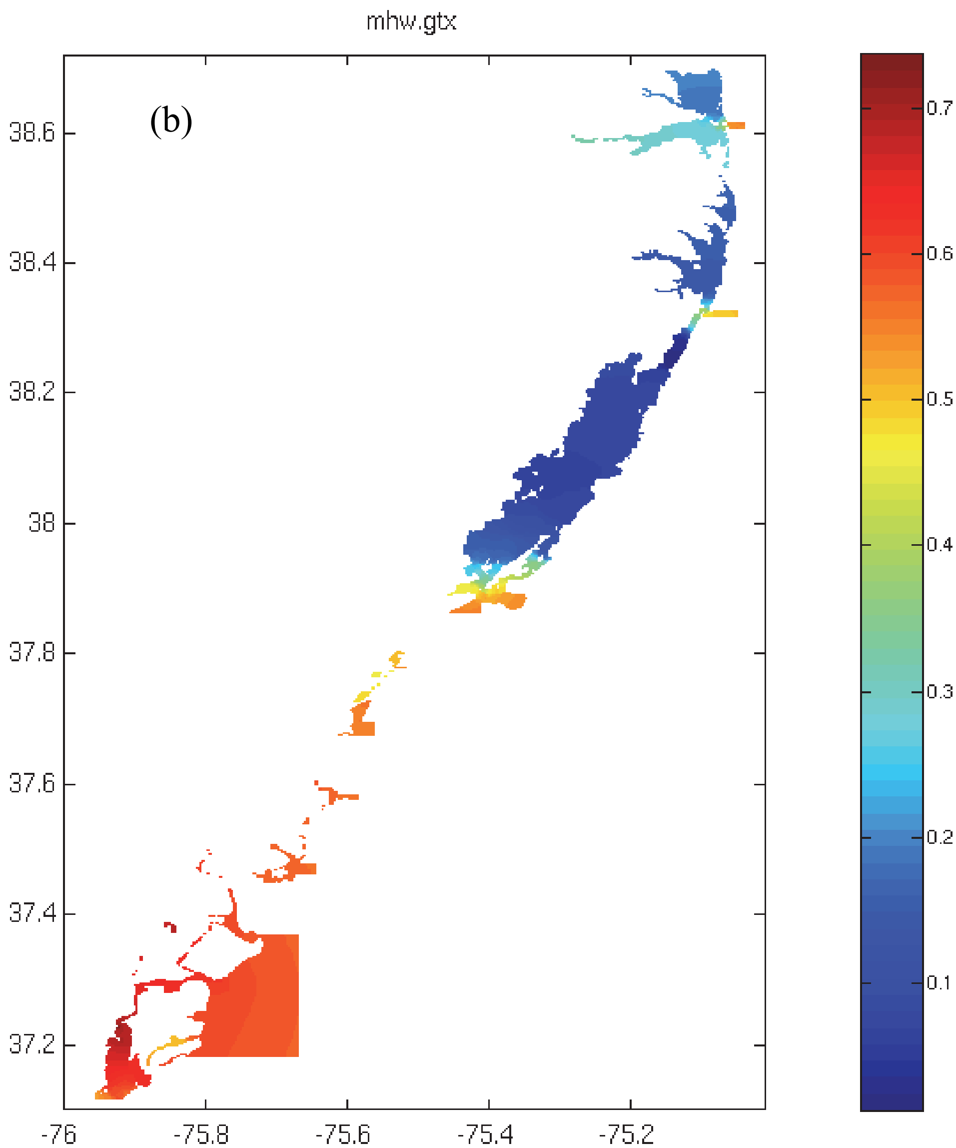
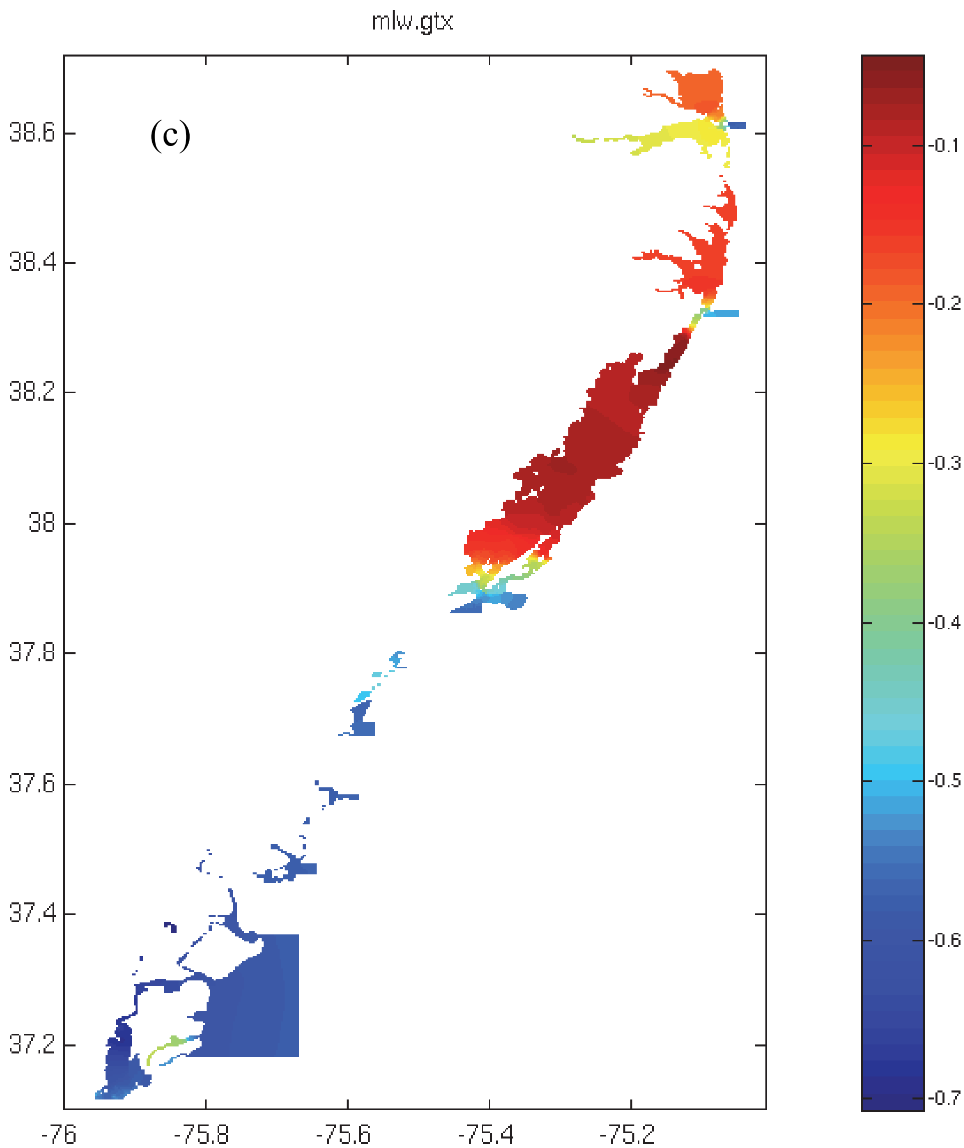
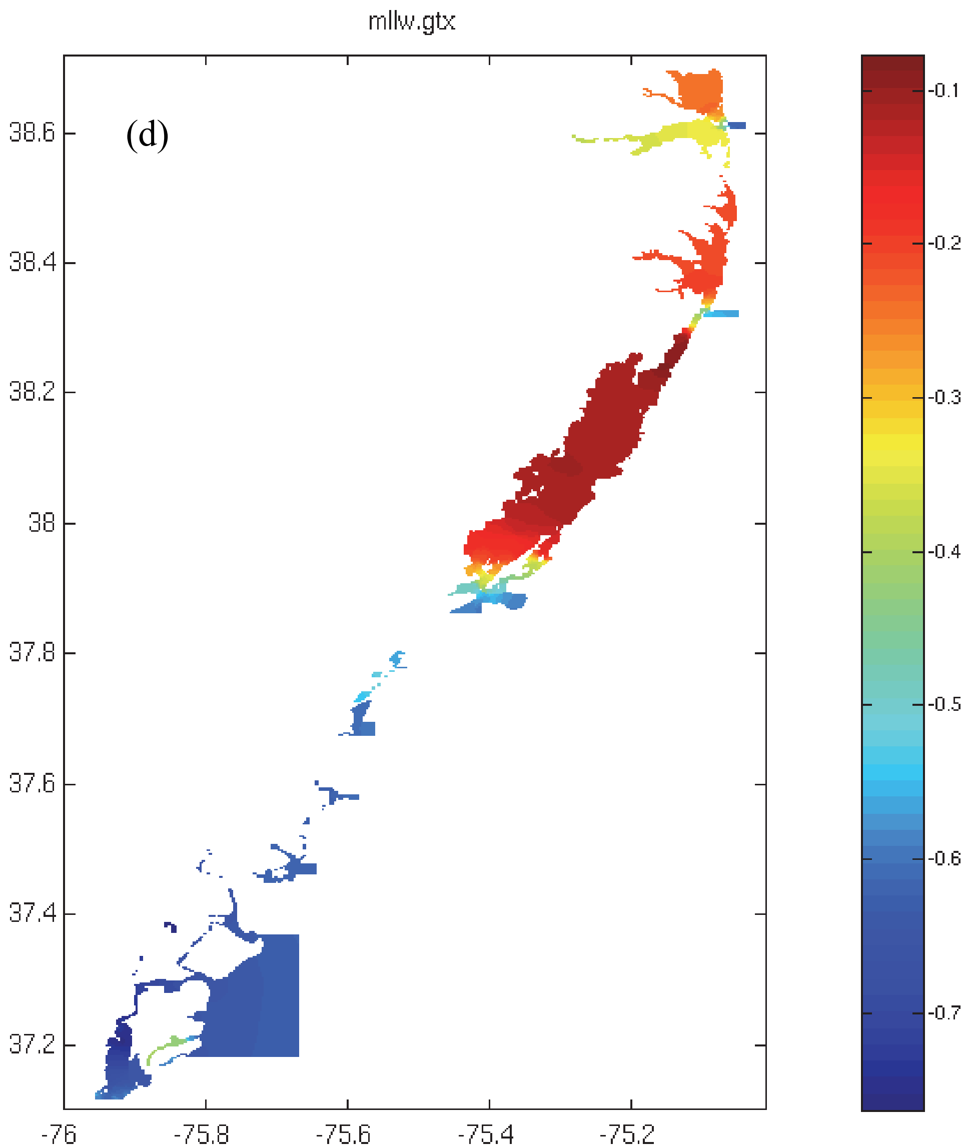

dtl.gtx
(f)
39.5
39
38.5
38
37.5
37
36.5
-77
-76.5
-76
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04

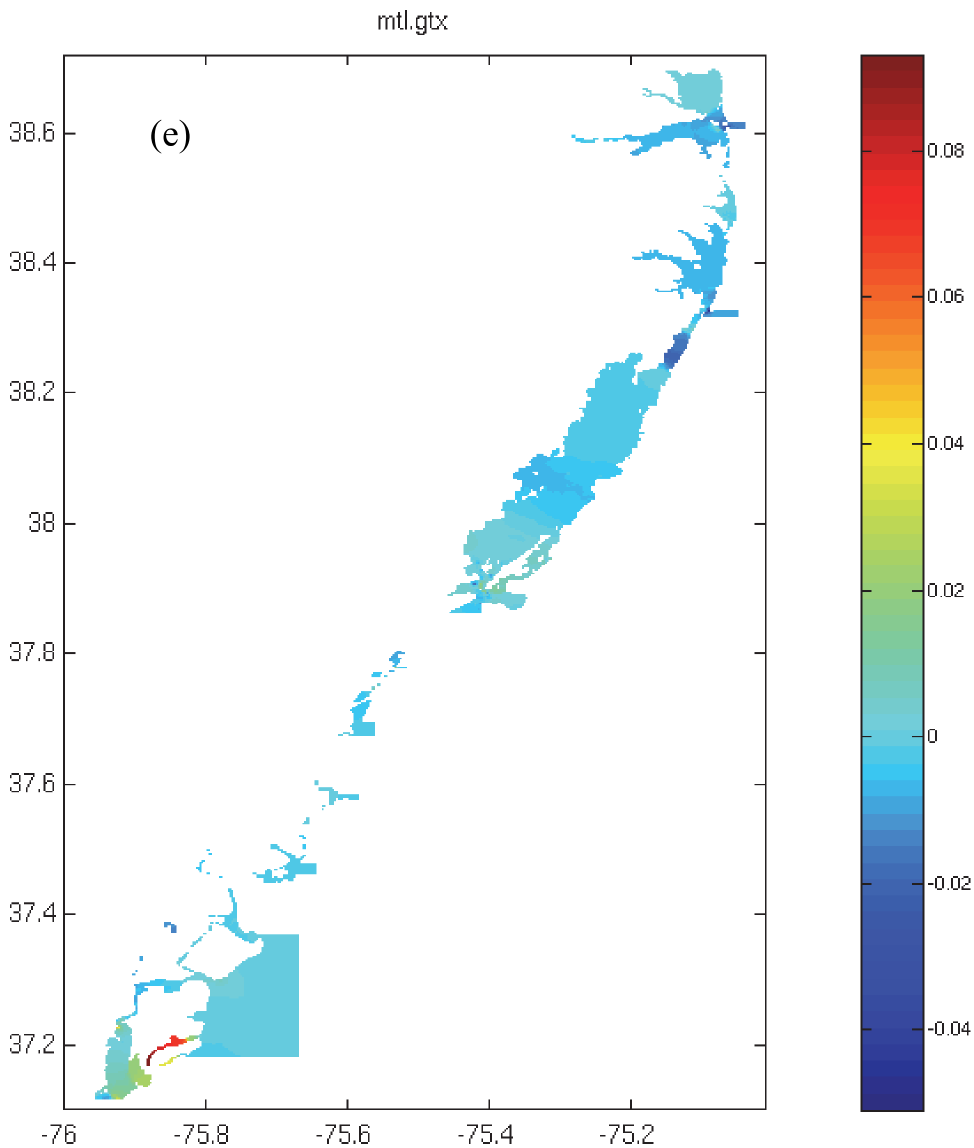
Figure D.4. **Tidal datums on DE-MD-VA embayment marine grid, (a) MHHW, (b) MHW, (c) MLW, (d) MLLW, (e) MTL, and (f) DTL. Color bars are in meters.**




mhw.gtx
(b)
38.6
38.4
38.2
38
37.8
37.6
37.4
37.2
-76
-75.8
-75.6
-75.4
-75.2
0.7
0.6
0.5
0.4
0.3
0.2
0.1


mlw.gtx
(c)
38.6
38.4
38.2
38
37.8
37.6
37.4
37.2
-76
-75.8
-75.6
-75.4
-75.2
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7


mllw.gtx
(d)
38.6
38.4
38.2
38
37.8
37.6
37.4
37.2
-76
-75.8
-75.6
-75.4
-75.2
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7


mtl.gtx
(e)
38.6
38.4
38.2
38
37.8
37.6
37.4
37.2
-76
-75.8
-75.6
-75.4
-75.2
0.08
0.06
0.04
0.02
0
-0.02
-0.04

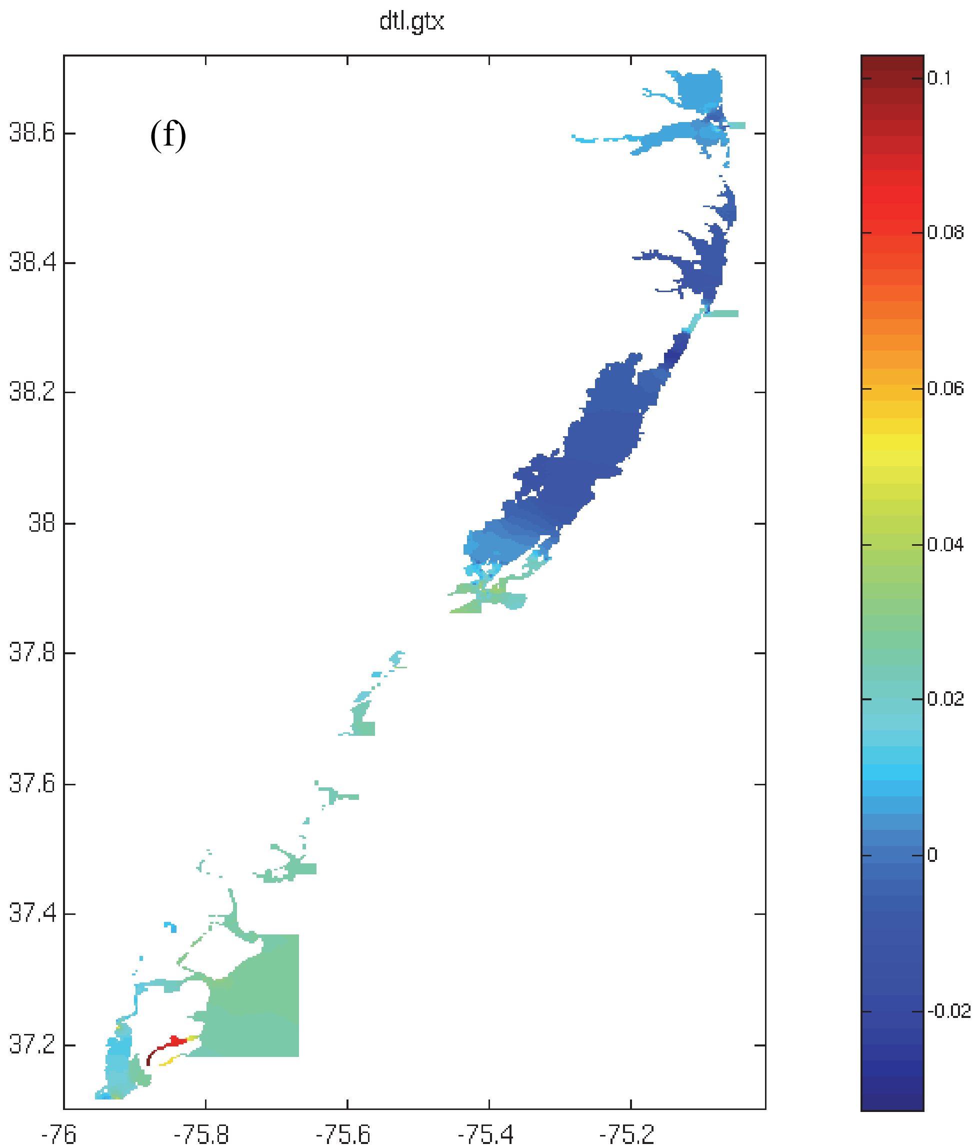
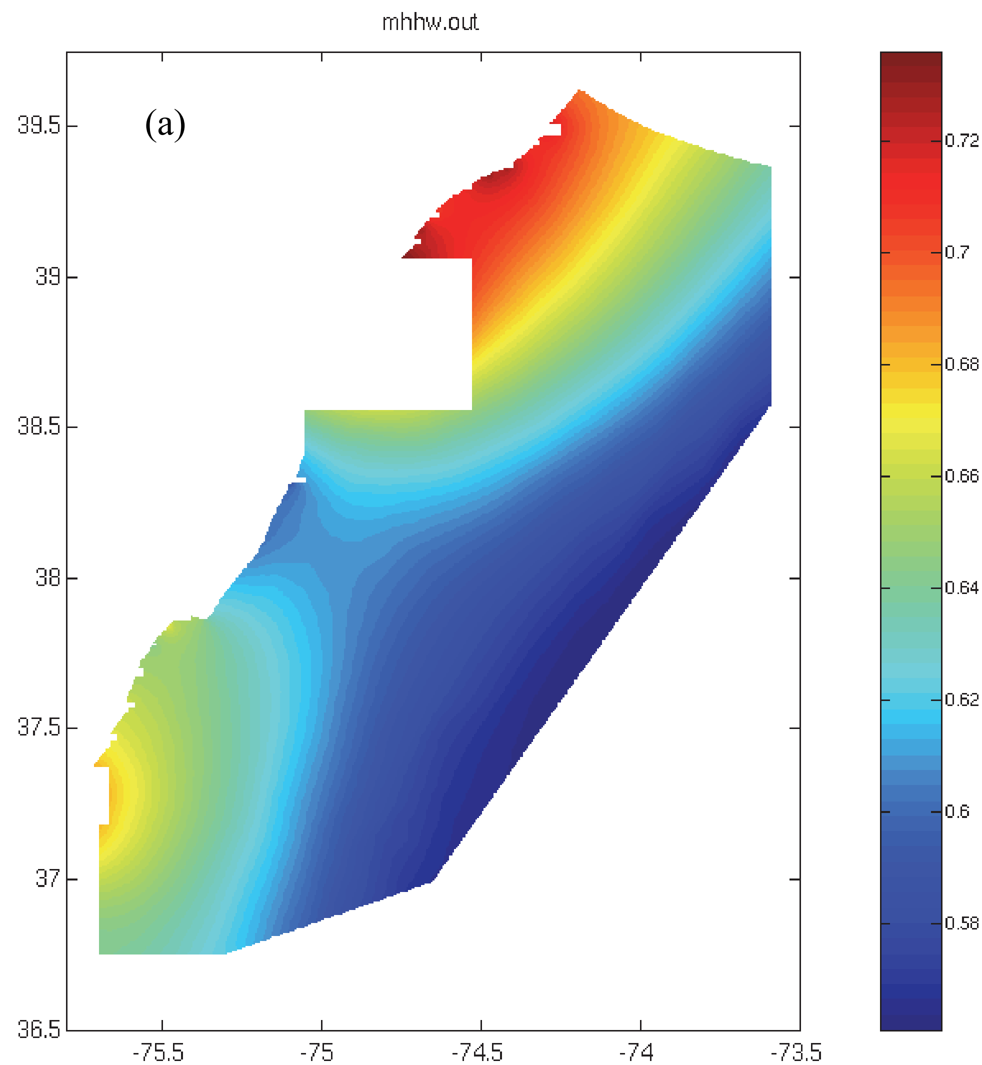
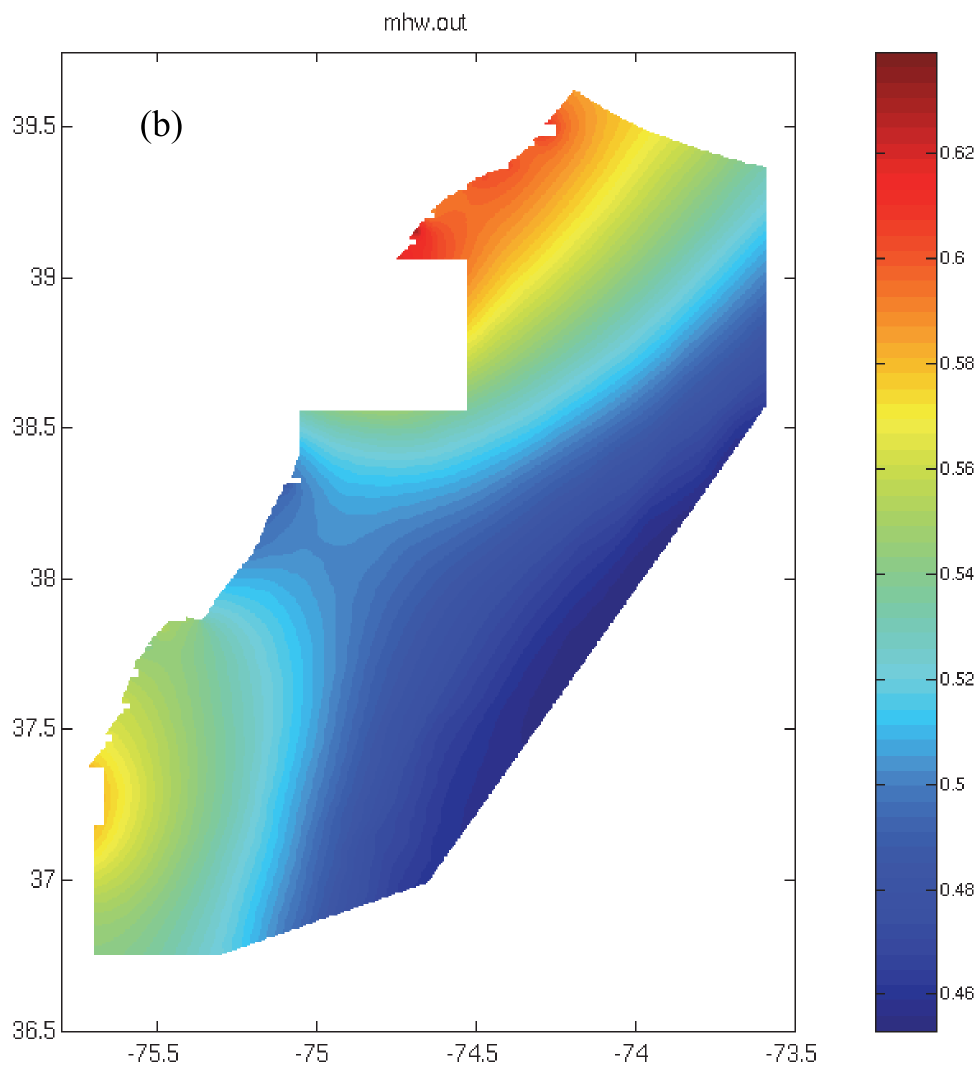
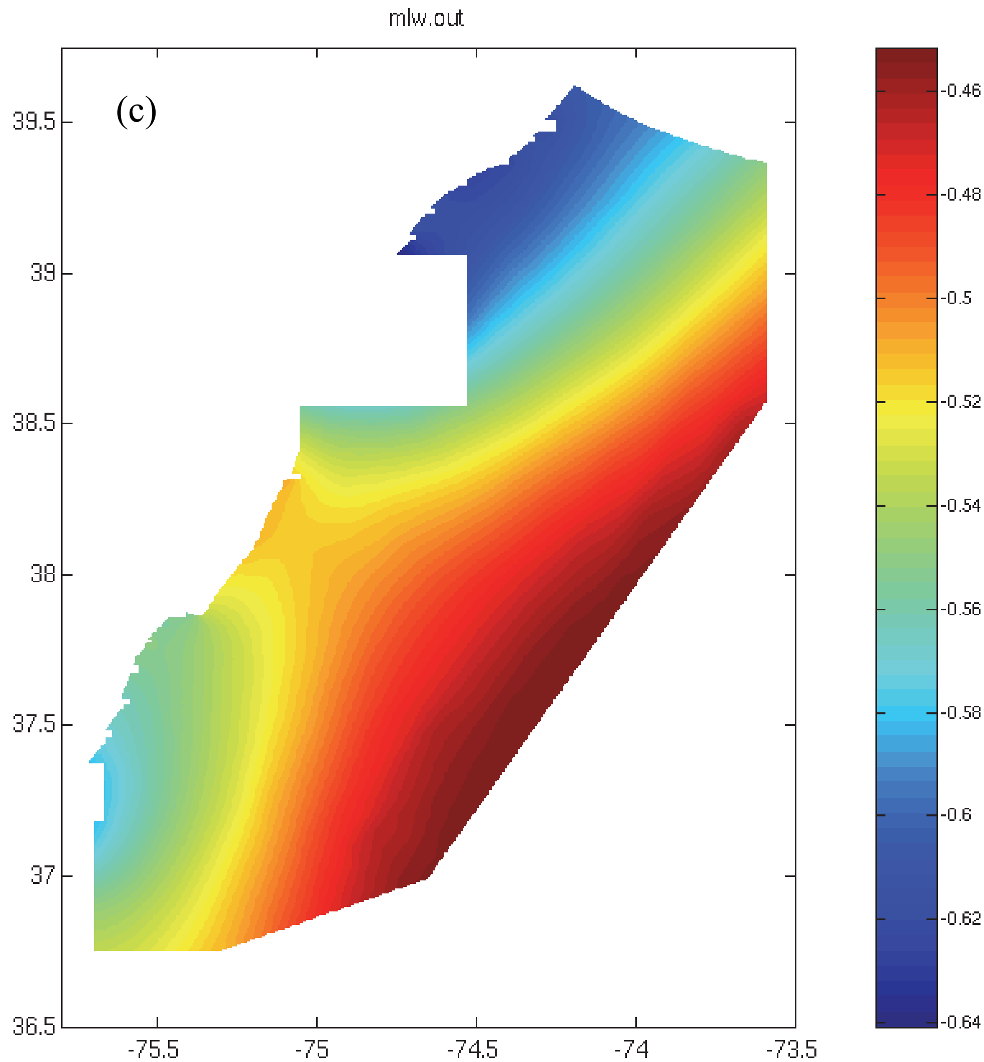
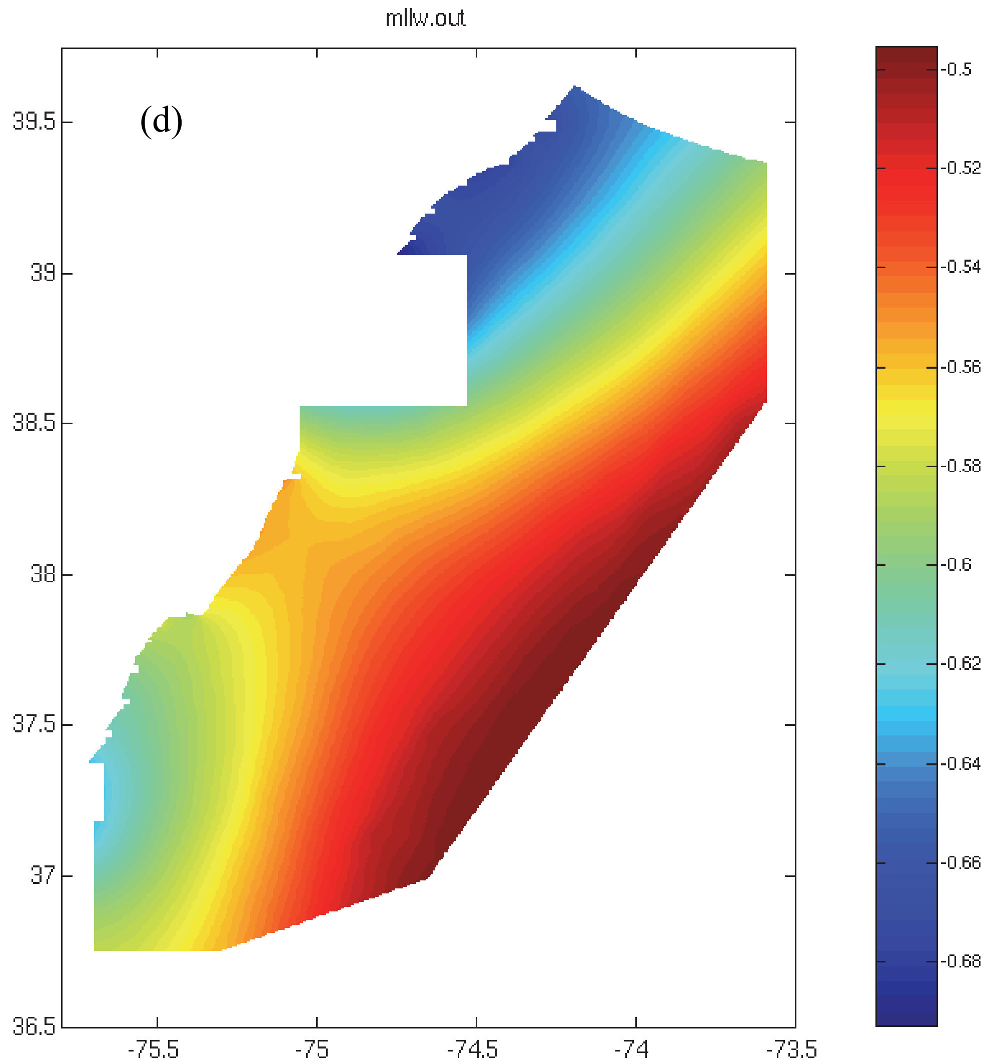

dtl.gtx
(f)
38.6
38.4
38.2
38
37.8
37.6
37.4
37.2
-76
-75.8
-75.6
-75.4
-75.2
0.1
0.08
0.06
0.04
0.02
0
-0.02

Figure D.5 Tidal datums over the mid-Atlantic Bight shelf marine grid, (a) MHHW, (b) MHW, (c) MLW, (d) MLLW, (e) MTL, and (f) DTL. Color bars are in meters.

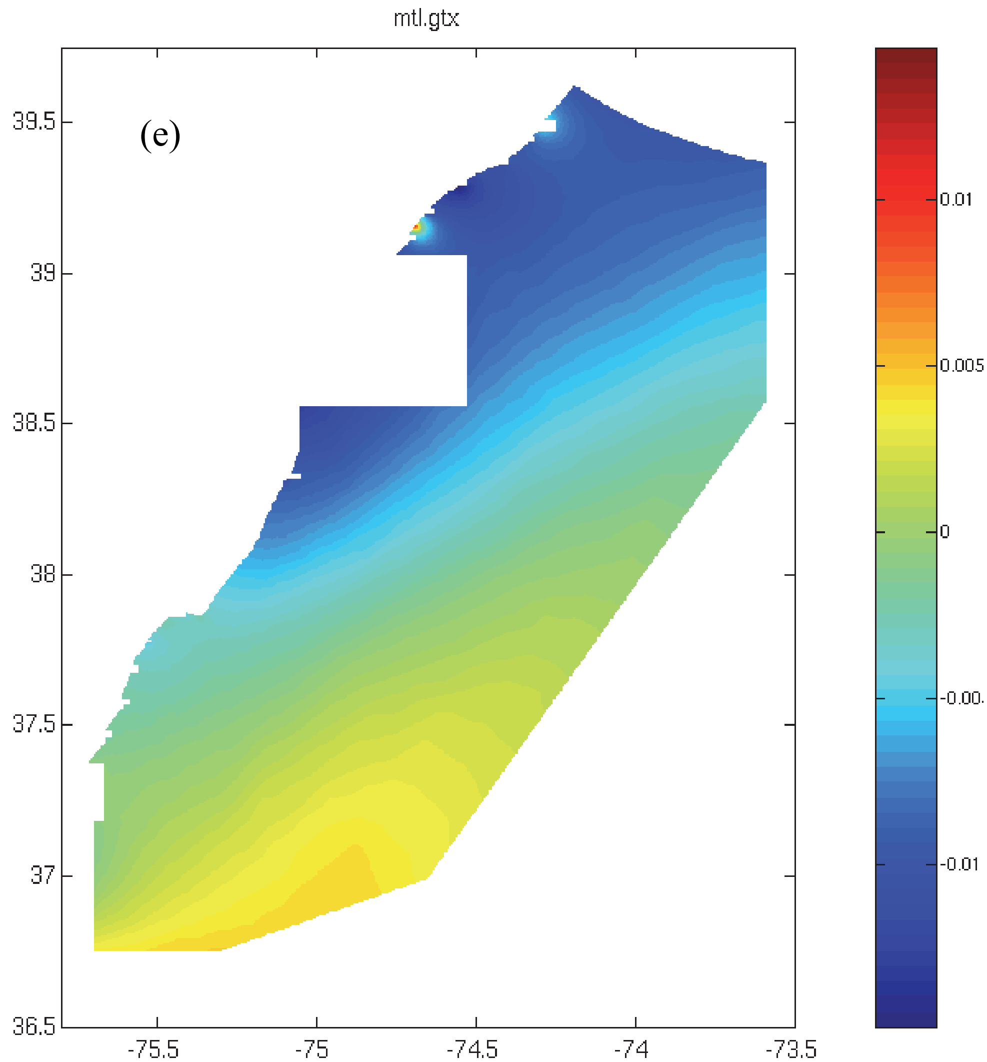


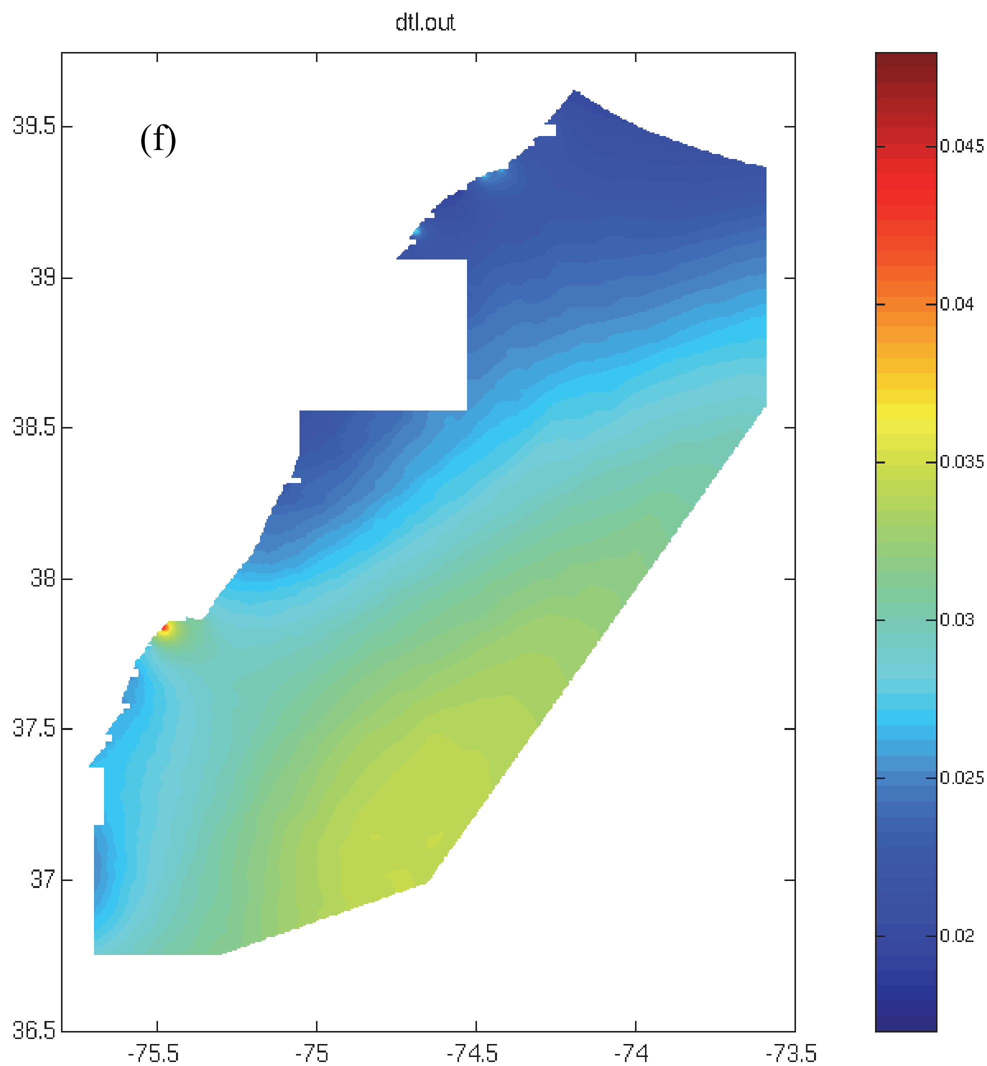

mhw.out
(b)
39.5
39
38.5
38
37.5
37
36.5
-75.5
-75
-74.5
-74
-73.5
0.62
0.6
0.58
0.56
0.54
0.52
0.5
0.48
0.46


mlw.out
(c)
39.5
39
38.5
38
37.5
37
36.5
-75.5
-75
-74.5
-74
-73.5
-0.46
-0.48
-0.5
-0.52
-0.54
-0.56
-0.58
-0.6
-0.62
-0.64



mllw.out
(d)
39.5
39
38.5
38
37.5
37
36.5
-75.5
-75
-74.5
-74
-73.5
-0.5
-0.52
-0.54
-0.56
-0.58
-0.6
-0.62
-0.64
-0.66
-0.68


mtl.gtx
(e)
39.5
39
38.5
38
37.5
37
36.5
-75.5
-75
-74.5
-74
-73.5
0.01
0.005
0
-0.00.
-0.01


dtl.out
(f)
39.5
39
38.5
38
37.5
37
36.5
-75.5
-75
-74.5
-74
-73.5
0.045
0.04
0.035
0.03
0.025
0.02

APPENDIX E. NAVD 88-TO-MSL VALUES AT NGS BENCHMARKS

Table E.1. Stations for Delaware Bay Grid

PID	Latitude (deg)	Longitude (deg)	MHHW Deltas (m)	MHW Deltas (m)	MLW Deltas (m)	MLLW Deltas (m)	Avg. (m)	Std. Dev. (m)
HU0108	38.61138	-75.06388	-0.144	-0.143	0.134	0.155	0.001	0.167
HU0087	38.78111	-75.12000	-0.001	-0.001	0.003	0.003	0.001	0.002
HU1194	38.96833	-74.95972	-0.004	-0.004	-0.004	-0.002	-0.004	0.001
HU1196	38.96833	-74.96055	0.002	0.003	0.004	0.006	0.004	0.002
HU1197	38.97000	-74.96194	-0.012	-0.011	0.011	0.012	0.000	0.013
JU2186	39.55611	-75.58166	0.016	0.017	-0.016	-0.018	0.000	0.020
JU2188	39.55694	-75.57638	0.010	0.010	-0.006	-0.006	0.002	0.010
JU2187	39.55722	-75.58222	0.020	0.020	-0.018	-0.021	0.000	0.023
JU2189	39.55805	-75.57388	0.001	0.001	-0.002	-0.001	0.000	0.001
JU0724	39.95166	-75.14194	0.006	0.007	-0.005	-0.001	0.002	0.006
JU0730	39.95250	-75.13861	0.002	0.003	-0.005	-0.001	0.000	0.004
JU0722	39.95305	-75.14000	-0.007	-0.006	-0.012	-0.009	-0.008	0.003
JU0721	39.95361	-75.14055	0.000	0.002	-0.003	0.000	0.000	0.002
JU2225	39.95361	-75.14000	0.008	0.009	0.005	0.007	0.007	0.002
KV5987	40.13500	-74.73694	-0.004	-0.004	-0.004	-0.006	-0.005	0.001
KV1079	40.18861	-74.75500	-0.018	-0.017	-0.018	-0.018	-0.018	0.001
KV1081	40.18888	-74.75555	0.021	0.021	0.021	0.021	0.021	0.000
KV6014	40.19027	-74.75555	-0.001	0.000	0.000	0.000	0.000	0.000
KV6013	40.19166	-74.75583	-0.003	-0.003	-0.001	-0.001	-0.002	0.001
KV6012	40.19194	-74.75611	0.001	0.001	0.003	0.003	0.002	0.001
KV6016	40.19194	-74.75500	0.002	0.002	0.003	0.003	0.002	0.001

Table E.2. Stations for New Jersey Coast Grid

PID	Latitude (deg)	Longitude (deg)	MHHW Deltas (m)	MHW Deltas (m)	MLW Deltas (m)	MLLW Deltas (m)	Avg. (m)	Std. Dev. (m)
JU2402	39.19777	-74.65472	-0.003	-0.004	0.001	0.002	-0.001	0.003
JU0394	39.19861	-74.65611	-0.002	-0.003	0.003	0.003	0.000	0.003
JU2401	39.19861	-74.65611	-0.002	-0.003	0.003	0.003	0.000	0.003
JU2400	39.19888	-74.65583	-0.002	-0.003	0.002	0.003	0.000	0.003
JU0393	39.19916	-74.65666	-0.001	-0.002	0.004	0.004	0.001	0.003
JU2403	39.19944	-74.65500	-0.002	-0.003	0.002	0.003	0.000	0.003
JU0392	39.20138	-74.65722	-0.004	-0.005	0.005	0.005	0.000	0.006
JU2404	39.21694	-74.64722	-0.002	-0.001	0.005	0.003	0.001	0.003
JU2405	39.21777	-74.64611	-0.005	-0.004	0.002	0.001	-0.002	0.004
JU4236	39.30777	-74.53305	-0.002	-0.002	0.004	0.004	0.001	0.004
JU0180	39.76250	-74.10694	-0.048	-0.051	0.043	0.046	-0.003	0.054
JU0178	39.76277	-74.10833	-0.024	-0.027	0.022	0.023	-0.001	0.028
JU2476	39.76277	-74.10833	-0.021	-0.024	0.025	0.026	0.002	0.028
JU2475	39.76277	-74.10777	-0.039	-0.043	0.043	0.046	0.002	0.049

Table E.3. Stations for Chesapeake Bay Grid

PID	Latitude (deg)	Longitude (deg)	MHHW Deltas (m)	MHW Deltas (m)	MLW Deltas (m)	MLLW Deltas (m)	Avg. (m)	Std. Dev. (m)
FW0688	36.18194	-75.75138	-0.006	-0.004	0.010	0.009	0.002	0.008
FW0693	36.18194	-75.75138	-0.006	-0.004	0.010	0.009	0.002	0.008
FW0687	36.18250	-75.75138	-0.011	-0.008	0.006	0.005	-0.002	0.008
FW0689	36.18250	-75.75138	-0.007	-0.004	0.010	0.009	0.002	0.008
FW0690	36.18250	-75.75138	-0.011	-0.008	0.006	0.005	-0.002	0.008
FW0692	36.18250	-75.75138	-0.011	-0.008	0.006	0.005	-0.002	0.008
FW0691	36.18277	-75.75166	-0.010	-0.007	0.006	0.005	-0.002	0.008
FX0345	36.77555	-76.29388	-0.002	-0.003	0.002	0.003	0.000	0.003
FX0346	36.77555	-76.29388	0.004	0.003	0.008	0.009	0.006	0.003
FX0170	36.81944	-76.29527	-0.002	-0.003	0.001	0.001	-0.001	0.002
FX0171	36.82027	-76.29333	0.001	0.000	0.003	0.003	0.002	0.002
FX2219	36.82111	-76.29277	0.001	0.000	0.002	0.002	0.002	0.001
FX0172	36.82194	-76.29388	0.000	-0.001	0.001	0.001	0.000	0.001
FX0173	36.82194	-76.29277	-0.007	-0.008	-0.006	-0.006	-0.007	0.001
FW0085	36.83055	-75.97277	0.007	0.001	-0.012	-0.029	-0.008	0.016
FW0085	36.83055	-75.97277	0.028	0.019	-0.012	-0.030	0.001	0.027
FW0083	36.83555	-75.97166	0.003	0.004	0.004	0.004	0.004	0.000
FX0093	36.94555	-76.32888	-0.007	-0.006	-0.003	-0.004	-0.005	0.002
FX4422	36.95638	-76.32722	-0.004	-0.005	0.006	0.004	0.000	0.006
FX4418	36.95694	-76.33138	-0.007	-0.008	0.005	0.003	-0.002	0.007
FX4419	36.95722	-76.33138	-0.004	-0.006	0.008	0.006	0.001	0.007
FX4420	36.95722	-76.33111	-0.004	-0.006	0.008	0.006	0.001	0.007
FW0304	37.16805	-75.98555	-0.001	-0.001	0.001	0.000	0.000	0.001
FW0303	37.16833	-75.98500	0.002	0.001	0.003	0.001	0.002	0.001
GV0759	37.18388	-76.78583	-0.001	-0.001	-0.001	0.002	0.000	0.002
GV0447	37.23055	-76.95250	-0.002	-0.003	0.002	0.002	0.000	0.003
GV0449	37.23055	-76.95000	-0.001	-0.003	0.000	0.000	-0.001	0.001
GV0448	37.23083	-76.95055	-0.005	-0.006	-0.003	-0.003	-0.004	0.002
GV1855	37.23222	-77.39638	-0.003	-0.003	0.003	0.004	0.000	0.004
GV3523	37.24611	-76.50361	-0.001	-0.001	-0.001	-0.003	-0.002	0.001
GV0598	37.24805	-76.50250	0.000	-0.002	0.001	0.000	0.000	0.001
GV0595	37.24833	-76.50138	0.001	-0.001	0.002	0.001	0.001	0.001
GV0596	37.24833	-76.50138	-0.008	-0.010	-0.007	-0.008	-0.008	0.001
GV0597	37.24833	-76.50138	0.001	-0.001	0.002	0.001	0.001	0.001
GV0088	37.61638	-76.29083	0.001	0.001	0.001	0.000	0.001	0.001
GV0156	37.99583	-76.46361	0.007	0.004	0.003	0.000	0.003	0.003
GV0157	37.99638	-76.46444	-0.006	-0.010	-0.013	-0.016	-0.011	0.004
GV0155	37.99666	-76.46388	0.010	0.007	0.006	0.003	0.007	0.003
HV8244	38.24972	-76.96194	0.005	0.005	0.004	0.000	0.003	0.002
HV8242	38.25083	-76.96138	0.006	0.005	0.005	0.003	0.005	0.001
HV8248	38.25222	-76.96222	0.001	0.000	0.001	-0.002	0.000	0.001
HV0367	38.31805	-76.45416	-0.002	-0.001	-0.001	0.004	0.000	0.003
HV0369	38.31833	-76.45361	-0.001	-0.001	-0.001	0.003	0.000	0.002
HV0371	38.31916	-76.45361	-0.001	-0.001	-0.001	0.003	0.000	0.002
HV0379	38.38472	-76.38250	-0.013	0.002	0.008	0.002	0.000	0.009
HV0237	38.57527	-76.07388	0.005	0.012	0.000	0.007	0.006	0.005
HV0239	38.57527	-76.07222	-0.009	-0.002	-0.014	-0.007	-0.008	0.005
HV1983	38.87388	-77.02083	-0.001	0.001	-0.001	-0.002	-0.001	0.001
HV1980	38.87472	-77.02138	0.002	0.003	0.002	0.001	0.002	0.001
HV9069	38.87500	-77.02138	-0.001	0.001	-0.001	-0.002	-0.001	0.001
HV9068	38.87527	-77.02138	0.000	0.001	-0.001	-0.002	-0.001	0.001

HV0186	38.95583	-76.35472	-0.001	-0.002	-0.002	-0.001	-0.001	0.001
HV0208	38.98250	-76.48055	-0.004	-0.005	-0.007	-0.010	-0.007	0.003
HV0207	38.98277	-76.48111	-0.002	-0.004	-0.006	-0.009	-0.005	0.003
JV0540	39.03222	-76.30638	-0.023	-0.021	-0.029	-0.030	-0.026	0.004
JV0541	39.03250	-76.30555	0.029	0.031	0.023	0.022	0.026	0.004
JV0579	39.26305	-76.57972	0.000	-0.001	-0.003	-0.001	-0.001	0.001
JV0580	39.26361	-76.57833	0.002	0.001	0.000	0.002	0.001	0.001
JV0578	39.26416	-76.58138	0.001	0.000	-0.002	0.000	0.000	0.001
JV0576	39.26555	-76.58416	0.002	0.001	-0.002	0.000	0.000	0.001
JV0582	39.26583	-76.57916	-0.003	-0.003	-0.003	-0.003	-0.003	0.000
JV0584	39.26583	-76.57944	0.001	0.001	0.000	0.001	0.001	0.000
JV0585	39.26638	-76.58138	0.000	0.000	0.000	0.001	0.000	0.000
JV0586	39.26694	-76.58083	0.001	0.001	0.000	0.001	0.001	0.000
JV0549	39.37027	-76.06250	0.001	0.000	-0.001	0.000	0.000	0.001
JU1847	39.50166	-75.91527	0.002	0.003	-0.003	-0.002	0.000	0.003
JU1833	39.52722	-75.80722	-0.006	-0.008	0.008	0.008	0.001	0.008
JU1835	39.52750	-75.80444	-0.011	-0.014	0.011	0.012	0.000	0.014
JV0011	39.53777	-76.08944	-0.003	-0.001	-0.003	-0.002	-0.002	0.001
JV0013	39.53833	-76.08972	0.000	0.002	0.000	0.001	0.001	0.001
JV6256	39.53861	-76.09027	0.000	0.001	-0.001	0.000	0.000	0.001
JV6255	39.53916	-76.09166	0.001	0.002	0.000	0.001	0.001	0.001
JV0016	39.55222	-76.09361	-0.005	0.003	-0.003	0.003	-0.001	0.004
JV0015	39.55250	-76.09361	-0.005	0.003	-0.003	0.003	-0.001	0.004

Table E.4. Stations for the DE-MD-VA Grid

PID	Latitude (deg)	Longitude (deg)	MHHW Deltas (m)	MHW Deltas (m)	MLW Deltas (m)	MLLW Deltas (m)	Avg. (m)	Std. Dev. (m)
FW0142	37.90416	-75.40750	-0.039	-0.041	0.035	0.028	-0.004	0.041
FW0142	37.90416	-75.40750	0.032	0.023	0.014	0.001	0.017	0.013
FW0143	37.90500	-75.40750	-0.029	-0.031	0.025	0.020	-0.004	0.031
FW0143	37.90500	-75.40750	0.038	0.030	0.001	-0.010	0.015	0.023
FW0139	37.92250	-75.39083	-0.026	-0.023	0.023	0.027	0.000	0.028
FW0135	37.93055	-75.38166	0.005	0.006	-0.006	-0.007	0.000	0.007
FW0613	37.93055	-75.38194	0.005	0.006	-0.006	-0.007	0.000	0.007
FW0136	37.93138	-75.38222	0.004	0.006	-0.005	-0.006	0.000	0.006
HU0268	38.32833	-75.08805	0.007	-0.001	-0.009	-0.003	-0.002	0.007
HU0366	38.32944	-75.08888	0.194	0.185	-0.178	-0.218	-0.004	0.224
HU0366	38.32944	-75.08888	0.011	0.005	-0.004	0.003	0.003	0.006
HU2732	38.32944	-75.08888	0.029	0.023	0.014	0.021	0.021	0.006
HU0367	38.33138	-75.08805	0.007	0.005	-0.005	-0.002	0.002	0.006
HU0108	38.61138	-75.06388	-0.144	-0.143	0.134	0.155	0.001	0.167

Table E.5. Stations for the mid-Atlantic Bight Shelf Grid

PID	Latitude (deg)	Longitude (deg)	MHHW Deltas (m)	MHW Deltas (m)	MLW Deltas (m)	MLLW Deltas (m)	Avg. (m)	Std. Dev. (m)
HU0268	38.32833	-75.08805	-0.168	-0.168	0.178	0.223	0.016	0.214
HU0366	38.32944	-75.08888	0.016	0.013	0.005	0.004	0.010	0.006
HU0366	38.32944	-75.08888	-0.167	-0.167	0.179	0.224	0.017	0.214
HU2732	38.32944	-75.08888	-0.149	-0.149	0.197	0.242	0.035	0.214
HU1172	38.34500	-75.08111	-0.295	-0.290	0.261	0.320	-0.001	0.338
JU2402	39.19777	-74.65472	-0.021	-0.021	0.032	0.026	0.004	0.029
JU0394	39.19861	-74.65611	-0.020	-0.020	0.033	0.027	0.005	0.029
JU2401	39.19861	-74.65611	-0.020	-0.020	0.033	0.027	0.005	0.029
JU2400	39.19888	-74.65583	-0.020	-0.020	0.033	0.027	0.005	0.029
JU0393	39.19916	-74.65666	-0.020	-0.019	0.034	0.028	0.006	0.029
JU2403	39.19944	-74.65500	-0.021	-0.020	0.033	0.027	0.005	0.029
JU0392	39.20138	-74.65722	-0.022	-0.022	0.031	0.025	0.003	0.029
JU4236	39.30777	-74.53305	-0.049	-0.045	0.023	0.021	-0.012	0.040
JU0326	39.33777	-74.47944	0.003	0.003	0.002	0.001	0.002	0.001
JU0325	39.34083	-74.47305	0.001	0.002	-0.002	-0.004	-0.001	0.003
JU4072	39.35805	-74.42166	0.001	0.000	-0.001	0.000	0.000	0.001
AC7255	39.61138	-74.20472	-0.352	-0.322	0.323	0.349	-0.001	0.389

APPENDIX F. LOCATION AND ELEVATION INFORMATION OF CO-OPS TIDAL STATIONS

Table F.1. **Location and elevation information of CO-OPS Stations used for creating TSS fields. Tidal datums are relative to MLLW. Station numbers marked with an asterisk have NAVD 88 elevations computed from NGS.**

Station ID	Latitude (deg)	Longitude (deg)	MLLW (m)	MLW (m)	MSL (m)	MHW (m)	MHHW (m)	NAVD88 (m)
8531991	40.30333	-73.97667	0.000	0.058	0.744	1.399	1.504	0.819
8533615	39.76167	-74.11167	0.000	0.037	0.355	0.694	0.765	0.360
8533987	39.63167	-74.29667	0.000	0.027	0.340	0.661	0.742	0.344
8534048*	39.61333	-74.21000	0.000	0.017	0.301	0.567	0.650	0.329
8534049*	39.61667	-74.31000	0.000	0.027	0.344	0.663	0.739	0.360
8534212	39.54833	-74.46167	0.000	0.047	0.530	0.943	1.024	0.522
8534540	39.42333	-74.50000	0.000	0.048	0.676	1.226	1.337	0.732
8534691	39.36833	-74.71667	0.000	0.050	0.647	1.109	1.195	0.645
8534720	39.35500	-74.41833	0.000	0.051	0.675	1.276	1.403	0.797
8534770	39.33500	-74.47667	0.000	0.053	0.678	1.283	1.411	0.797
8535101	39.21500	-74.64833	0.000	0.050	0.635	1.207	1.325	0.723
8535101	39.21500	-74.64833	0.000	0.050	0.635	1.207	1.325	0.723
8535163	39.20000	-74.65667	0.000	0.051	0.648	1.210	1.330	0.735
8536110	38.96833	-74.96000	0.000	0.049	0.783	1.526	1.659	0.920
8538449*	39.80667	-75.35500	0.000	0.061	0.964	1.714	1.815	0.916
8538512	39.83500	-75.23833	0.000	0.056	0.994	1.775	1.885	0.963
8538875	40.01333	-75.00833	0.000	0.032	1.020	1.979	2.085	0.888
8539058	40.07333	-74.84833	0.000	0.051	1.094	2.108	2.205	0.903
8539487	40.13667	-74.73667	0.000	0.061	1.291	2.470	2.581	1.140
8539993	40.18833	-74.75500	0.000	0.061	1.363	2.553	2.663	1.175
8545240	39.93333	-75.14167	0.000	0.060	1.051	1.887	2.015	0.960
8545530	39.95333	-75.13833	0.000	0.059	1.069	1.962	2.080	0.987
8551910	39.55833	-75.57333	0.000	0.055	0.890	1.683	1.780	0.905
8557380	38.78167	-75.12000	0.000	0.048	0.680	1.290	1.418	0.801
8558690*	38.61000	-75.07000	0.000	0.047	0.452	0.813	0.895	0.556
8570280	38.32667	-75.08333	0.000	0.048	0.567	1.073	1.187	0.707
8570280	38.32667	-75.08333	0.000	0.048	0.567	1.073	1.187	0.707
8570282	38.33167	-75.09000	0.000	0.046	0.395	0.716	0.784	0.521
8571892*	38.57333	-76.06833	0.000	0.063	0.309	0.558	0.622	0.328
8572770	38.95667	-76.35500	0.000	0.063	0.224	0.375	0.452	0.272
8572955*	39.03167	-76.30167	0.000	0.065	0.248	0.427	0.514	0.270
8573704*	39.37167	-76.06333	0.000	0.066	0.315	0.554	0.657	0.300
8573903*	39.50333	-75.91667	0.000	0.059	0.383	0.721	0.817	0.389
8573927	39.52667	-75.81000	0.000	0.069	0.487	0.941	1.005	0.500
8574070	39.53667	-76.09000	0.000	0.064	0.361	0.642	0.746	0.315
8574680	39.26667	-76.57833	0.000	0.067	0.244	0.415	0.506	0.254
8575512	38.98333	-76.48000	0.000	0.067	0.219	0.364	0.438	0.235
8577188*	38.39167	-76.39833	0.000	0.028	0.191	0.344	0.420	0.240
8577330	38.31667	-76.45167	0.000	0.048	0.230	0.404	0.449	0.259
8594900	38.87333	-77.02167	0.000	0.047	0.472	0.896	0.965	0.425
8630249	37.93167	-75.38333	0.000	0.028	0.269	0.511	0.561	0.322
8630308	37.90667	-75.40500	0.000	0.033	0.359	0.691	0.758	0.401
8630316	37.90333	-75.40667	0.000	0.041	0.411	0.782	0.855	0.469
8632200	37.16667	-75.98833	0.000	0.033	0.434	0.827	0.896	0.580
8632200	37.16667	-75.98833	0.000	0.033	0.434	0.827	0.896	0.580
8633532*	37.82833	-75.99333	0.000	0.027	0.242	0.459	0.513	0.322
8635150	38.25167	-76.96000	0.000	0.043	0.293	0.541	0.591	0.301

8635750	37.99500	-76.46500	0.000	0.036	0.230	0.415	0.458	0.253
8636580	37.61500	-76.29000	0.000	0.030	0.214	0.384	0.424	0.289
8637624	37.24667	-76.50000	0.000	0.035	0.394	0.760	0.820	0.487
8638433*	37.18500	-76.78333	0.000	0.041	0.327	0.603	0.656	0.265
8638449*	37.23167	-76.94833	0.000	0.045	0.334	0.589	0.647	0.331
8638481*	37.31333	-77.27000	0.000	0.045	0.437	0.775	0.848	0.416
8638489	37.26667	-77.37167	0.000	0.047	0.523	0.899	0.966	0.560
8638610	36.94667	-76.33000	0.000	0.038	0.412	0.778	0.841	0.501
8638660	36.82167	-76.29333	0.000	0.042	0.464	0.882	0.946	0.546
8638863*	36.96667	-76.11333	0.000	0.037	0.431	0.814	0.884	0.510
8639208	36.83167	-75.96833	0.000	0.037	0.551	1.038	1.124	0.757
8639214	36.82500	-75.97500	0.000	0.044	0.557	1.058	1.161	0.691
8639219	36.82500	-75.98167	0.000	0.046	0.569	1.079	1.182	0.711
8639348	36.77833	-76.30167	0.000	0.042	0.479	0.914	0.979	0.557
8651370	36.18333	-75.74667	0.000	0.044	0.539	1.026	1.124	0.667
8654400	35.22333	-75.63500	0.000	0.036	0.492	0.947	1.056	0.627
8534836*	39.30833	-74.53333	0.000	0.045	0.619	1.197	1.320	0.725
8534393*	39.47833	-74.38333	0.000	0.040	0.521	1.018	1.123	0.556
8534049*	39.61667	-74.31000	0.000	0.027	0.344	0.663	0.739	0.360
8534048*	39.61333	-74.21000	0.000	0.017	0.301	0.567	0.650	0.330

APPENDIX G. QA/QC Deltas at Stations for TSS Grids

Table G.1. Values for Delaware Bay TSS Grid.

PID	Latitude (deg)	Longitude (deg)	MHHW Deltas (m)	MHW Deltas (m)	MLW Deltas (m)	MLLW Deltas (m)	Avg. (m)	Std. Dev. (m)
HU0108	38.61138	-75.06388	-0.144	-0.143	0.134	0.155	0.001	0.167
HU0087	38.78111	-75.12000	-0.001	-0.001	0.003	0.003	0.001	0.002
HU1194	38.96833	-74.95972	-0.004	-0.004	-0.004	-0.002	-0.004	0.001
HU1196	38.96833	-74.96055	0.002	0.003	0.004	0.006	0.004	0.002
HU1197	38.97000	-74.96194	-0.012	-0.011	0.011	0.012	0.000	0.013
JU2186	39.55611	-75.58166	0.016	0.017	-0.016	-0.018	0.000	0.020
JU2188	39.55694	-75.57638	0.010	0.010	-0.006	-0.006	0.002	0.010
JU2187	39.55722	-75.58222	0.020	0.020	-0.018	-0.021	0.000	0.023
JU2189	39.55805	-75.57388	0.001	0.001	-0.002	-0.001	0.000	0.001
JU0724	39.95166	-75.14194	0.006	0.007	-0.005	-0.001	0.002	0.006
JU0730	39.95250	-75.13861	0.002	0.003	-0.005	-0.001	0.000	0.004
JU0722	39.95305	-75.14000	-0.007	-0.006	-0.012	-0.009	-0.008	0.003
JU0721	39.95361	-75.14055	0.000	0.002	-0.003	0.000	0.000	0.002
JU2225	39.95361	-75.14000	0.008	0.009	0.005	0.007	0.007	0.002
KV5987	40.13500	-74.73694	-0.004	-0.004	-0.004	-0.006	-0.005	0.001
KV1079	40.18861	-74.75500	-0.018	-0.017	-0.018	-0.018	-0.018	0.001
KV1081	40.18888	-74.75555	0.021	0.021	0.021	0.021	0.021	0.000
KV6014	40.19027	-74.75555	-0.001	0.000	0.000	0.000	0.000	0.000
KV6013	40.19166	-74.75583	-0.003	-0.003	-0.001	-0.001	-0.002	0.001
KV6012	40.19194	-74.75611	0.001	0.001	0.003	0.003	0.002	0.001
KV6016	40.19194	-74.75500	0.002	0.002	0.003	0.003	0.002	0.001

Table G.2. Values for the New Jersey Coast TSS Grid.

PID	Latitude (deg)	Longitude (deg)	MHHW Deltas (m)	MHW Deltas (m)	MLW Deltas (m)	MLLW Deltas (m)	Avg. (m)	Std. Dev. (m)
JU2402	39.19777	-74.65472	-0.003	-0.004	0.001	0.002	-0.001	0.003
JU0394	39.19861	-74.65611	-0.002	-0.003	0.003	0.003	0.000	0.003
JU2401	39.19861	-74.65611	-0.002	-0.003	0.003	0.003	0.000	0.003
JU2400	39.19888	-74.65583	-0.002	-0.003	0.002	0.003	0.000	0.003
JU0393	39.19916	-74.65666	-0.001	-0.002	0.004	0.004	0.001	0.003
JU2403	39.19944	-74.65500	-0.002	-0.003	0.002	0.003	0.000	0.003
JU0392	39.20138	-74.65722	-0.004	-0.005	0.005	0.005	0.000	0.006
JU2404	39.21694	-74.64722	-0.002	-0.001	0.005	0.003	0.001	0.003
JU2405	39.21777	-74.64611	-0.005	-0.004	0.002	0.001	-0.002	0.004
JU4236	39.30777	-74.53305	-0.002	-0.002	0.004	0.004	0.001	0.004
JU0180	39.76250	-74.10694	-0.048	-0.051	0.043	0.046	-0.003	0.054
JU0178	39.76277	-74.10833	-0.024	-0.027	0.022	0.023	-0.001	0.028
JU2476	39.76277	-74.10833	-0.021	-0.024	0.025	0.026	0.002	0.028
JU2475	39.76277	-74.10777	-0.039	-0.043	0.043	0.046	0.002	0.049

Table G.3. Values for the Chesapeake Bay TSS Grid.

PID	Latitude (deg)	Longitude (deg)	MHHW Deltas (m)	MHW Deltas (m)	MLW Deltas (m)	MLLW Deltas (m)	Avg. (m)	Std. Dev. (m)
FW0688	36.18194	-75.75138	-0.006	-0.004	0.010	0.009	0.002	0.008
FW0693	36.18194	-75.75138	-0.006	-0.004	0.010	0.009	0.002	0.008
FW0687	36.18250	-75.75138	-0.011	-0.008	0.006	0.005	-0.002	0.008
FW0689	36.18250	-75.75138	-0.007	-0.004	0.010	0.009	0.002	0.008
FW0690	36.18250	-75.75138	-0.011	-0.008	0.006	0.005	-0.002	0.008
FW0692	36.18250	-75.75138	-0.011	-0.008	0.006	0.005	-0.002	0.008
FW0691	36.18277	-75.75166	-0.010	-0.007	0.006	0.005	-0.002	0.008
FX0345	36.77555	-76.29388	-0.002	-0.003	0.002	0.003	0.000	0.003
FX0346	36.77555	-76.29388	0.004	0.003	0.008	0.009	0.006	0.003
FX0170	36.81944	-76.29527	-0.002	-0.003	0.001	0.001	-0.001	0.002
FX0171	36.82027	-76.29333	0.001	0.000	0.003	0.003	0.002	0.002
FX2219	36.82111	-76.29277	0.001	0.000	0.002	0.002	0.002	0.001
FX0172	36.82194	-76.29388	0.000	-0.001	0.001	0.001	0.000	0.001
FX0173	36.82194	-76.29277	-0.007	-0.008	-0.006	-0.006	-0.007	0.001
FW0085	36.83055	-75.97277	0.007	0.001	-0.012	-0.029	-0.008	0.016
FW0085	36.83055	-75.97277	0.028	0.019	-0.012	-0.030	0.001	0.027
FW0083	36.83555	-75.97166	0.003	0.004	0.004	0.004	0.004	0.000
FX0093	36.94555	-76.32888	-0.007	-0.006	-0.003	-0.004	-0.005	0.002
FX4422	36.95638	-76.32722	-0.004	-0.005	0.006	0.004	0.000	0.006
FX4418	36.95694	-76.33138	-0.007	-0.008	0.005	0.003	-0.002	0.007
FX4419	36.95722	-76.33138	-0.004	-0.006	0.008	0.006	0.001	0.007
FX4420	36.95722	-76.33111	-0.004	-0.006	0.008	0.006	0.001	0.007
FW0304	37.16805	-75.98555	-0.001	-0.001	0.001	0.000	0.000	0.001
FW0303	37.16833	-75.98500	0.002	0.001	0.003	0.001	0.002	0.001
GV0759	37.18388	-76.78583	-0.001	-0.001	-0.001	0.002	0.000	0.002
GV0447	37.23055	-76.95250	-0.002	-0.003	0.002	0.002	0.000	0.003
GV0449	37.23055	-76.95000	-0.001	-0.003	0.000	0.000	-0.001	0.001
GV0448	37.23083	-76.95055	-0.005	-0.006	-0.003	-0.003	-0.004	0.002
GV1855	37.23222	-77.39638	-0.003	-0.003	0.003	0.004	0.000	0.004
GV3523	37.24611	-76.50361	-0.001	-0.001	-0.001	-0.003	-0.002	0.001
GV0598	37.24805	-76.50250	0.000	-0.002	0.001	0.000	0.000	0.001
GV0595	37.24833	-76.50138	0.001	-0.001	0.002	0.001	0.001	0.001
GV0596	37.24833	-76.50138	-0.008	-0.010	-0.007	-0.008	-0.008	0.001
GV0597	37.24833	-76.50138	0.001	-0.001	0.002	0.001	0.001	0.001
GV0088	37.61638	-76.29083	0.001	0.001	0.001	0.000	0.001	0.001
GV0156	37.99583	-76.46361	0.007	0.004	0.003	0.000	0.003	0.003
GV0157	37.99638	-76.46444	-0.006	-0.010	-0.013	-0.016	-0.011	0.004
GV0155	37.99666	-76.46388	0.010	0.007	0.006	0.003	0.007	0.003
HV8244	38.24972	-76.96194	0.005	0.005	0.004	0.000	0.003	0.002
HV8242	38.25083	-76.96138	0.006	0.005	0.005	0.003	0.005	0.001
HV8248	38.25222	-76.96222	0.001	0.000	0.001	-0.002	0.000	0.001
HV0367	38.31805	-76.45416	-0.002	-0.001	-0.001	0.004	0.000	0.003
HV0369	38.31833	-76.45361	-0.001	-0.001	-0.001	0.003	0.000	0.002
HV0371	38.31916	-76.45361	-0.001	-0.001	-0.001	0.003	0.000	0.002
HV0379	38.38472	-76.38250	-0.013	0.002	0.008	0.002	0.000	0.009
HV0237	38.57527	-76.07388	0.005	0.012	0.000	0.007	0.006	0.005
HV0239	38.57527	-76.07222	-0.009	-0.002	-0.014	-0.007	-0.008	0.005
HV1983	38.87388	-77.02083	-0.001	0.001	-0.001	-0.002	-0.001	0.001
HV1980	38.87472	-77.02138	0.002	0.003	0.002	0.001	0.002	0.001
HV9069	38.87500	-77.02138	-0.001	0.001	-0.001	-0.002	-0.001	0.001

HV9068	38.87527	-77.02138	0.000	0.001	-0.001	-0.002	-0.001	0.001
HV0186	38.95583	-76.35472	-0.001	-0.002	-0.002	-0.001	-0.001	0.001
HV0208	38.98250	-76.48055	-0.004	-0.005	-0.007	-0.010	-0.007	0.003
HV0207	38.98277	-76.48111	-0.002	-0.004	-0.006	-0.009	-0.005	0.003
JV0540	39.03222	-76.30638	-0.023	-0.021	-0.029	-0.030	-0.026	0.004
JV0541	39.03250	-76.30555	0.029	0.031	0.023	0.022	0.026	0.004
JV0579	39.26305	-76.57972	0.000	-0.001	-0.003	-0.001	-0.001	0.001
JV0580	39.26361	-76.57833	0.002	0.001	0.000	0.002	0.001	0.001
JV0578	39.26416	-76.58138	0.001	0.000	-0.002	0.000	0.000	0.001
JV0576	39.26555	-76.58416	0.002	0.001	-0.002	0.000	0.000	0.001
JV0582	39.26583	-76.57916	-0.003	-0.003	-0.003	-0.003	-0.003	0.000
JV0584	39.26583	-76.57944	0.001	0.001	0.000	0.001	0.001	0.000
JV0585	39.26638	-76.58138	0.000	0.000	0.000	0.001	0.000	0.000
JV0586	39.26694	-76.58083	0.001	0.001	0.000	0.001	0.001	0.000
JV0549	39.37027	-76.06250	0.001	0.000	-0.001	0.000	0.000	0.001
JU1847	39.50166	-75.91527	0.002	0.003	-0.003	-0.002	0.000	0.003
JU1833	39.52722	-75.80722	-0.006	-0.008	0.008	0.008	0.001	0.008
JU1835	39.52750	-75.80444	-0.011	-0.014	0.011	0.012	0.000	0.014
JV0011	39.53777	-76.08944	-0.003	-0.001	-0.003	-0.002	-0.002	0.001
JV0013	39.53833	-76.08972	0.000	0.002	0.000	0.001	0.001	0.001
JV6256	39.53861	-76.09027	0.000	0.001	-0.001	0.000	0.000	0.001
JV6255	39.53916	-76.09166	0.001	0.002	0.000	0.001	0.001	0.001
JV0016	39.55222	-76.09361	-0.005	0.003	-0.003	0.003	-0.001	0.004
JV0015	39.55250	-76.09361	-0.005	0.003	-0.003	0.003	-0.001	0.004

Table G.4. Values for the DE-MD-VA Coast TSS Grid.

PID	Latitude (deg)	Longitude (deg)	MHHW Deltas (m)	MHW Deltas (m)	MLW Deltas (m)	MLLW Deltas (m)	Avg. (m)	Std. Dev. (m)
FW0142	37.90416	-75.40750	-0.039	-0.041	0.035	0.028	-0.004	0.041
FW0142	37.90416	-75.40750	0.032	0.023	0.014	0.001	0.017	0.013
FW0143	37.90500	-75.40750	-0.029	-0.031	0.025	0.020	-0.004	0.031
FW0143	37.90500	-75.40750	0.038	0.030	0.001	-0.010	0.015	0.023
FW0139	37.92250	-75.39083	-0.026	-0.023	0.023	0.027	0.000	0.028
FW0135	37.93055	-75.38166	0.005	0.006	-0.006	-0.007	0.000	0.007
FW0613	37.93055	-75.38194	0.005	0.006	-0.006	-0.007	0.000	0.007
FW0136	37.93138	-75.38222	0.004	0.006	-0.005	-0.006	0.000	0.006
HU0268	38.32833	-75.08805	0.007	-0.001	-0.009	-0.003	-0.002	0.007
HU0366	38.32944	-75.08888	0.194	0.185	-0.178	-0.218	-0.004	0.224
HU0366	38.32944	-75.08888	0.011	0.005	-0.004	0.003	0.003	0.006
HU2732	38.32944	-75.08888	0.029	0.023	0.014	0.021	0.021	0.006
HU0367	38.33138	-75.08805	0.007	0.005	-0.005	-0.002	0.002	0.006
HU0108	38.61138	-75.06388	-0.144	-0.143	0.134	0.155	0.001	0.167

Table G.5. Values for the DE-MD-VA Coast TSS Grid.

PID	Latitude (deg)	Longitude (deg)	MHHW Deltas (m)	MHW Deltas (m)	MLW Deltas (m)	MLLW Deltas (m)	Avg. (m)	Std. Dev. (m)
HU0268	38.32833	-75.08805	-0.168	-0.168	0.178	0.223	0.016	0.214
HU0366	38.32944	-75.08888	0.016	0.013	0.005	0.004	0.010	0.006
HU0366	38.32944	-75.08888	-0.167	-0.167	0.179	0.224	0.017	0.214
HU2732	38.32944	-75.08888	-0.149	-0.149	0.197	0.242	0.035	0.214
HU1172	38.34500	-75.08111	-0.295	-0.290	0.261	0.320	-0.001	0.338
JU2402	39.19777	-74.65472	-0.021	-0.021	0.032	0.026	0.004	0.029
JU0394	39.19861	-74.65611	-0.020	-0.020	0.033	0.027	0.005	0.029
JU2401	39.19861	-74.65611	-0.020	-0.020	0.033	0.027	0.005	0.029
JU2400	39.19888	-74.65583	-0.020	-0.020	0.033	0.027	0.005	0.029
JU0393	39.19916	-74.65666	-0.020	-0.019	0.034	0.028	0.006	0.029
JU2403	39.19944	-74.65500	-0.021	-0.020	0.033	0.027	0.005	0.029
JU0392	39.20138	-74.65722	-0.022	-0.022	0.031	0.025	0.003	0.029
JU4236	39.30777	-74.53305	-0.049	-0.045	0.023	0.021	-0.012	0.040
JU0326	39.33777	-74.47944	0.003	0.003	0.002	0.001	0.002	0.001
JU0325	39.34083	-74.47305	0.001	0.002	-0.002	-0.004	-0.001	0.003
JU4072	39.35805	-74.42166	0.001	0.000	-0.001	0.000	0.000	0.001
AC7255	39.61138	-74.20472	-0.352	-0.322	0.323	0.349	-0.001	0.389

APPENDIX H. COMPARISONS OF DERIVED TSS WITH OBSERVATIONS FOR FIVE VDATUM GRIDS

Table H.1. Model-Data Differences for the Delaware Bay Grid.

PID	Latitude (deg)	Longitude (deg)	NAVD 88 to MSL (m)	TSS Derived Value (m)	Delta (m)
HU0108	38.61138	-75.06388	0.109	0.108	0.001
HU0108	38.61138	-75.06388	0.109	0.108	0.001
HU0087	38.78111	-75.12000	0.123	0.122	0.001
HU1194	38.96833	-74.95972	0.133	0.137	-0.003
HU1196	38.96833	-74.96055	0.141	0.137	0.004
HU1197	38.97000	-74.96194	0.136	0.136	0.000
JU2186	39.55611	-75.58166	0.019	0.020	0.000
JU2188	39.55694	-75.57638	0.020	0.018	0.002
JU2187	39.55722	-75.58222	0.020	0.019	0.000
JU2189	39.55805	-75.57388	0.015	0.015	0.000
JU0724	39.95166	-75.14194	-0.085	-0.087	0.002
JU0730	39.95250	-75.13861	-0.086	-0.086	0.000
JU0722	39.95305	-75.14000	-0.097	-0.088	-0.008
JU0721	39.95361	-75.14055	-0.089	-0.089	0.000
JU2225	39.95361	-75.14000	-0.082	-0.089	0.007
KV5987	40.13500	-74.73694	-0.158	-0.154	-0.005
KV1079	40.18861	-74.75500	-0.190	-0.172	-0.018
KV1081	40.18888	-74.75555	-0.147	-0.168	0.021
KV6014	40.19027	-74.75555	-0.190	-0.190	0.000
KV6013	40.19166	-74.75583	-0.190	-0.188	-0.002
KV6012	40.19194	-74.75611	-0.186	-0.188	0.002
KV6016	40.19194	-74.75500	-0.186	-0.188	0.002
JU2402	39.19777	-74.65472	0.088	0.089	-0.001
JU0394	39.19861	-74.65611	0.088	0.088	0.000
JU2401	39.19861	-74.65611	0.088	0.088	0.000
JU2400	39.19888	-74.65583	0.088	0.088	0.000
JU0393	39.19916	-74.65666	0.089	0.087	0.001
JU2403	39.19944	-74.65500	0.088	0.088	0.000
JU0392	39.20138	-74.65722	0.087	0.087	0.000
JU2404	39.21694	-74.64722	0.089	0.087	0.001
JU2405	39.21777	-74.64611	0.086	0.087	-0.002
JU4236	39.30777	-74.53305	0.104	0.103	0.001
JU2402	39.19777	-74.65472	0.093	0.089	0.004
JU0394	39.19861	-74.65611	0.093	0.088	0.005
JU2401	39.19861	-74.65611	0.093	0.088	0.005
JU2400	39.19888	-74.65583	0.093	0.088	0.005
JU0393	39.19916	-74.65666	0.093	0.087	0.006
JU2403	39.19944	-74.65500	0.093	0.088	0.005
JU0392	39.20138	-74.65722	0.090	0.087	0.003
JU4236	39.30777	-74.53305	0.091	0.103	-0.012
8535101	39.21500	-74.64833	0.088	0.088	0.000
8535101	39.21500	-74.64833	0.088	0.088	0.000
8535163	39.20000	-74.65667	0.087	0.087	0.000
8536110	38.96833	-74.96000	0.137	0.137	0.000
8538875	40.01333	-75.00833	-0.132	-0.132	0.000
8539487	40.13667	-74.73667	-0.151	-0.152	0.001
8539993	40.18833	-74.75500	-0.188	-0.171	-0.017
8545240	39.93333	-75.14167	-0.091	-0.091	0.000

8545530	39.95333	-75.13833	-0.082	-0.084	0.002
8551910	39.55833	-75.57333	0.015	0.015	0.000
8557380	38.78167	-75.12000	0.121	0.122	-0.001
8558690	38.61000	-75.07000	0.104	0.104	0.000
8534836	39.30833	-74.53333	0.106	0.103	0.003

Table H.2. Model-Data Differences for New Jersey Coast Grid.

PID	Latitude (deg)	Longitude (deg)	NAVD 88 to MSL (m)	TSS Derived Value (m)	Delta (m)
JU2402	39.19777	-74.65472	0.088	0.089	-0.001
JU0394	39.19861	-74.65611	0.088	0.088	0.000
JU2401	39.19861	-74.65611	0.088	0.088	0.000
JU2400	39.19888	-74.65583	0.088	0.088	0.000
JU0393	39.19916	-74.65666	0.089	0.087	0.001
JU2403	39.19944	-74.65500	0.088	0.088	0.000
JU0392	39.20138	-74.65722	0.087	0.087	0.000
JU2404	39.21694	-74.64722	0.089	0.087	0.001
JU2405	39.21777	-74.64611	0.086	0.087	-0.002
JU4236	39.30777	-74.53305	0.104	0.103	0.001
JU0180	39.76250	-74.10694	0.002	0.005	-0.003
JU0178	39.76277	-74.10833	0.006	0.008	-0.002
JU2476	39.76277	-74.10833	0.009	0.008	0.002
JU2475	39.76277	-74.10777	0.009	0.007	0.002
JU2402	39.19777	-74.65472	0.093	0.089	0.004
JU0394	39.19861	-74.65611	0.093	0.088	0.005
JU2401	39.19861	-74.65611	0.093	0.088	0.005
JU2400	39.19888	-74.65583	0.093	0.088	0.005
JU0393	39.19916	-74.65666	0.093	0.087	0.006
JU2403	39.19944	-74.65500	0.093	0.088	0.005
JU0392	39.20138	-74.65722	0.090	0.087	0.003
JU4236	39.30777	-74.53305	0.091	0.103	-0.012
JU0326	39.33777	-74.47944	0.121	0.119	0.002
JU0325	39.34083	-74.47305	0.113	0.114	-0.001
JU4072	39.35805	-74.42166	0.124	0.123	0.000
AC7255	39.61138	-74.20472	0.026	0.026	-0.001
8533615	39.76167	-74.11167	0.005	0.001	0.004
8534048	39.61333	-74.21000	0.028	0.028	0.000
8534212	39.54833	-74.46167	-0.008	-0.008	0.000
8534720	39.35500	-74.41833	0.122	0.122	0.000
8534770	39.33500	-74.47667	0.119	0.119	0.001
8535101	39.21500	-74.64833	0.088	0.088	0.000
8535101	39.21500	-74.64833	0.088	0.088	0.000
8535163	39.20000	-74.65667	0.087	0.087	0.000
8534836	39.30833	-74.53333	0.106	0.103	0.003
8534393	39.47833	-74.38333	0.035	0.035	0.000
8534048	39.61333	-74.21000	0.029	0.028	0.001

Table H.3. Model-Data Differences for Chesapeake Bay Grid.

PID	Latitude (deg)	Longitude (deg)	NAVD 88 to MSL (m)	TSS Derived Value (m)	Delta (m)
FW0688	36.18194	-75.75138	0.127	0.124	0.002
FW0693	36.18194	-75.75138	0.127	0.124	0.002
FW0687	36.18250	-75.75138	0.123	0.124	-0.002
FW0689	36.18250	-75.75138	0.127	0.124	0.002
FW0690	36.18250	-75.75138	0.123	0.124	-0.002
FW0692	36.18250	-75.75138	0.123	0.124	-0.002
FW0691	36.18277	-75.75166	0.123	0.124	-0.002
FX0345	36.77555	-76.29388	0.076	0.076	0.000
FX0346	36.77555	-76.29388	0.082	0.076	0.006
FX0170	36.81944	-76.29527	0.082	0.083	-0.001
FX0171	36.82027	-76.29333	0.085	0.084	0.002
FX2219	36.82111	-76.29277	0.082	0.081	0.002
FX0172	36.82194	-76.29388	0.082	0.082	0.000
FX0173	36.82194	-76.29277	0.072	0.079	-0.007
FW0085	36.83055	-75.97277	0.123	0.131	-0.008
FW0085	36.83055	-75.97277	0.132	0.131	0.001
FW0083	36.83555	-75.97166	0.202	0.199	0.004
FX0093	36.94555	-76.32888	0.077	0.082	-0.005
FX4422	36.95638	-76.32722	0.090	0.090	0.000
FX4418	36.95694	-76.33138	0.087	0.089	-0.002
FX4419	36.95722	-76.33138	0.090	0.089	0.001
FX4420	36.95722	-76.33111	0.090	0.089	0.001
FW0304	37.16805	-75.98555	0.146	0.146	0.000
FW0303	37.16833	-75.98500	0.149	0.147	0.002
GV0759	37.18388	-76.78583	-0.061	-0.061	0.000
GV0447	37.23055	-76.95250	0.000	0.000	0.000
GV0449	37.23055	-76.95000	-0.001	0.000	-0.001
GV0448	37.23083	-76.95055	-0.004	0.000	-0.004
GV1855	37.23222	-77.39638	0.039	0.039	0.000
GV3523	37.24611	-76.50361	0.082	0.084	-0.002
GV0598	37.24805	-76.50250	0.092	0.092	0.000
GV0595	37.24833	-76.50138	0.094	0.093	0.001
GV0596	37.24833	-76.50138	0.085	0.093	-0.008
GV0597	37.24833	-76.50138	0.094	0.093	0.001
GV0088	37.61638	-76.29083	0.077	0.076	0.001
GV0156	37.99583	-76.46361	0.021	0.017	0.003
GV0157	37.99638	-76.46444	0.006	0.017	-0.011
GV0155	37.99666	-76.46388	0.023	0.017	0.007
HV8244	38.24972	-76.96194	0.028	0.025	0.003
HV8242	38.25083	-76.96138	0.022	0.017	0.005
HV8248	38.25222	-76.96222	0.010	0.010	0.000
HV0367	38.31805	-76.45416	0.029	0.029	0.000
HV0369	38.31833	-76.45361	0.029	0.029	0.000
HV0371	38.31916	-76.45361	0.029	0.029	0.000
HV0379	38.38472	-76.38250	0.044	0.044	0.000
HV0237	38.57527	-76.07388	0.048	0.041	0.006
HV0239	38.57527	-76.07222	0.002	0.009	-0.008
HV1983	38.87388	-77.02083	-0.048	-0.047	-0.001
HV1980	38.87472	-77.02138	-0.045	-0.047	0.002
HV9069	38.87500	-77.02138	-0.048	-0.047	-0.001
HV9068	38.87527	-77.02138	-0.048	-0.048	-0.001

HV0186	38.95583	-76.35472	0.044	0.046	-0.001
HV0208	38.98250	-76.48055	-0.003	0.004	-0.007
HV0207	38.98277	-76.48111	0.000	0.005	-0.005
JV0540	39.03222	-76.30638	-0.004	0.022	-0.026
JV0541	39.03250	-76.30555	0.048	0.022	0.026
JV0579	39.26305	-76.57972	0.007	0.008	-0.001
JV0580	39.26361	-76.57833	0.013	0.012	0.001
JV0578	39.26416	-76.58138	0.007	0.007	0.000
JV0576	39.26555	-76.58416	0.007	0.007	0.000
JV0582	39.26583	-76.57916	0.006	0.009	-0.003
JV0584	39.26583	-76.57944	0.009	0.009	0.001
JV0585	39.26638	-76.58138	0.009	0.009	0.000
JV0586	39.26694	-76.58083	0.009	0.009	0.001
JV0549	39.37027	-76.06250	-0.017	-0.016	0.000
JU1847	39.50166	-75.91527	0.008	0.008	0.000
JU1833	39.52722	-75.80722	0.012	0.011	0.001
JU1835	39.52750	-75.80444	0.008	0.009	0.000
JV0011	39.53777	-76.08944	-0.050	-0.048	-0.002
JV0013	39.53833	-76.08972	-0.047	-0.048	0.001
JV6256	39.53861	-76.09027	-0.047	-0.047	0.000
JV6255	39.53916	-76.09166	-0.044	-0.045	0.001
JV0016	39.55222	-76.09361	-0.044	-0.044	-0.001
JV0015	39.55250	-76.09361	-0.044	-0.044	-0.001
JU2186	39.55611	-75.58166	0.019	0.020	0.000
JU2187	39.55722	-75.58222	0.020	0.019	0.000
8571892	38.57333	-76.06833	0.019	0.019	0.000
8572770	38.95667	-76.35500	0.048	0.046	0.002
8572955	39.03167	-76.30167	0.022	0.022	0.000
8573704	39.37167	-76.06333	-0.015	-0.015	0.000
8573903	39.50333	-75.91667	0.006	0.006	0.000
8573927	39.52667	-75.81000	0.013	0.013	0.000
8574070	39.53667	-76.09000	-0.046	-0.047	0.001
8574680	39.26667	-76.57833	0.010	0.010	0.001
8575512	38.98333	-76.48000	0.016	0.011	0.005
8577188	38.39167	-76.39833	0.049	0.049	0.000
8577330	38.31667	-76.45167	0.029	0.029	0.000
8594900	38.87333	-77.02167	-0.047	-0.046	-0.001
8632200	37.16667	-75.98833	0.146	0.146	0.000
8632200	37.16667	-75.98833	0.146	0.146	0.000
8633532	37.82833	-75.99333	0.080	0.080	0.000
8635150	38.25167	-76.96000	0.008	0.010	-0.002
8635750	37.99500	-76.46500	0.023	0.020	0.003
8636580	37.61500	-76.29000	0.075	0.076	-0.001
8637624	37.24667	-76.50000	0.093	0.094	-0.001
8638433	37.18500	-76.78333	-0.062	-0.062	0.000
8638449	37.23167	-76.94833	-0.003	0.000	-0.003
8638481	37.31333	-77.27000	-0.022	-0.022	0.000
8638489	37.26667	-77.37167	0.037	0.037	0.000
8638610	36.94667	-76.33000	0.089	0.089	0.000
8638660	36.82167	-76.29333	0.082	0.081	0.001
8638863	36.96667	-76.11333	0.079	0.079	0.000
8639208	36.83167	-75.96833	0.206	0.198	0.008
8639214	36.82500	-75.97500	0.134	0.134	0.000
8639219	36.82500	-75.98167	0.142	0.142	0.001
8639348	36.77833	-76.30167	0.078	0.078	0.000
8651370	36.18333	-75.74667	0.128	0.128	0.000

Table H.4. Model-Data Differences for the DE-MD-VA Grid.

PID	Latitude (deg)	Longitude (deg)	NAVD 88 to MSL (m)	TSS Derived Value (m)	Delta (m)
FW0142	37.90416	-75.40750	0.040	0.045	-0.004
FW0142	37.90416	-75.40750	0.062	0.045	0.017
FW0143	37.90500	-75.40750	0.039	0.043	-0.004
FW0143	37.90500	-75.40750	0.058	0.043	0.015
FW0139	37.92250	-75.39083	0.056	0.056	0.000
FW0135	37.93055	-75.38166	0.052	0.053	0.000
FW0613	37.93055	-75.38194	0.052	0.053	0.000
FW0136	37.93138	-75.38222	0.053	0.053	0.000
HU0268	38.32833	-75.08805	0.126	0.127	-0.002
HU0366	38.32944	-75.08888	0.122	0.126	-0.004
HU0366	38.32944	-75.08888	0.130	0.126	0.003
HU2732	38.32944	-75.08888	0.148	0.126	0.021
HU0367	38.33138	-75.08805	0.127	0.126	0.002
HU0108	38.61138	-75.06388	0.109	0.108	0.001
HU0108	38.61138	-75.06388	0.109	0.108	0.001
HU0268	38.32833	-75.08805	0.144	0.127	0.016
HU0366	38.32944	-75.08888	0.136	0.126	0.010
HU0366	38.32944	-75.08888	0.144	0.126	0.017
HU2732	38.32944	-75.08888	0.162	0.126	0.035
HU1172	38.34500	-75.08111	0.106	0.107	-0.001
8558690	38.61000	-75.07000	0.104	0.104	0.000
8570280	38.32667	-75.08333	0.140	0.139	0.001
8570280	38.32667	-75.08333	0.140	0.139	0.001
8570282	38.33167	-75.09000	0.126	0.126	0.000
8630249	37.93167	-75.38333	0.053	0.053	0.000
8630308	37.90667	-75.40500	0.042	0.043	-0.001
8630316	37.90333	-75.40667	0.058	0.053	0.005

Table H.5. Model-Data Differences for the mid-Atlantic Bight Shelf Grid.

PID	Latitude (deg)	Longitude (deg)	NAVD 88 to MSL (m)	TSS Derived Value (m)	Delta (m)
FW0142	37.90416	-75.40750	0.040	0.045	-0.004
FW0142	37.90416	-75.40750	0.062	0.045	0.017
FW0143	37.90500	-75.40750	0.039	0.043	-0.004
FW0143	37.90500	-75.40750	0.058	0.043	0.015
FW0139	37.92250	-75.39083	0.056	0.056	0.000
FW0135	37.93055	-75.38166	0.052	0.053	0.000
FW0613	37.93055	-75.38194	0.052	0.053	0.000
FW0136	37.93138	-75.38222	0.053	0.053	0.000
HU0268	38.32833	-75.08805	0.126	0.127	-0.002
HU0366	38.32944	-75.08888	0.122	0.126	-0.004
HU0366	38.32944	-75.08888	0.130	0.126	0.003
HU2732	38.32944	-75.08888	0.148	0.126	0.021
HU0367	38.33138	-75.08805	0.127	0.126	0.002
HU0108	38.61138	-75.06388	0.109	0.108	0.001
HU0108	38.61138	-75.06388	0.109	0.108	0.001
HU0087	38.78111	-75.12000	0.123	0.122	0.001
HU1194	38.96833	-74.95972	0.133	0.137	-0.003

HU1196	38.96833	-74.96055	0.141	0.137	0.004
HU1197	38.97000	-74.96194	0.136	0.136	0.000
JU2186	39.55611	-75.58166	0.019	0.020	0.000
JU2188	39.55694	-75.57638	0.020	0.018	0.002
JU2187	39.55722	-75.58222	0.020	0.019	0.000
JU2189	39.55805	-75.57388	0.015	0.015	0.000
JU0724	39.95166	-75.14194	-0.085	-0.087	0.002
JU0730	39.95250	-75.13861	-0.086	-0.086	0.000
JU0722	39.95305	-75.14000	-0.097	-0.088	-0.008
JU0721	39.95361	-75.14055	-0.089	-0.089	0.000
JU2225	39.95361	-75.14000	-0.082	-0.089	0.007
JU2402	39.19777	-74.65472	0.088	0.089	-0.001
JU0394	39.19861	-74.65611	0.088	0.088	0.000
JU2401	39.19861	-74.65611	0.088	0.088	0.000
JU2400	39.19888	-74.65583	0.088	0.088	0.000
JU0393	39.19916	-74.65666	0.089	0.087	0.001
JU2403	39.19944	-74.65500	0.088	0.088	0.000
JU0392	39.20138	-74.65722	0.087	0.087	0.000
JU2404	39.21694	-74.64722	0.089	0.087	0.001
JU2405	39.21777	-74.64611	0.086	0.087	-0.002
JU4236	39.30777	-74.53305	0.104	0.103	0.001
JU0180	39.76250	-74.10694	0.002	0.005	-0.003
JU0178	39.76277	-74.10833	0.006	0.008	-0.002
JU2476	39.76277	-74.10833	0.009	0.008	0.002
JU2475	39.76277	-74.10777	0.009	0.007	0.002
HU0268	38.32833	-75.08805	0.144	0.127	0.016
HU0366	38.32944	-75.08888	0.136	0.126	0.010
HU0366	38.32944	-75.08888	0.144	0.126	0.017
HU2732	38.32944	-75.08888	0.162	0.126	0.035
HU1172	38.34500	-75.08111	0.106	0.107	-0.001
JU2402	39.19777	-74.65472	0.093	0.089	0.004
JU0394	39.19861	-74.65611	0.093	0.088	0.005
JU2401	39.19861	-74.65611	0.093	0.088	0.005
JU2400	39.19888	-74.65583	0.093	0.088	0.005
JU0393	39.19916	-74.65666	0.093	0.087	0.006
JU2403	39.19944	-74.65500	0.093	0.088	0.005
JU0392	39.20138	-74.65722	0.090	0.087	0.003
JU4236	39.30777	-74.53305	0.091	0.103	-0.012
JU0326	39.33777	-74.47944	0.121	0.119	0.002
JU0325	39.34083	-74.47305	0.113	0.114	-0.001
JU4072	39.35805	-74.42166	0.124	0.123	0.000
AC7255	39.61138	-74.20472	0.026	0.026	-0.001
8533615	39.76167	-74.11167	0.005	0.001	0.004
8534048	39.61333	-74.21000	0.028	0.028	0.000
8534212	39.54833	-74.46167	-0.008	-0.008	0.000
8534720	39.35500	-74.41833	0.122	0.122	0.000
8534770	39.33500	-74.47667	0.119	0.119	0.001
8535101	39.21500	-74.64833	0.088	0.088	0.000
8535101	39.21500	-74.64833	0.088	0.088	0.000
8535163	39.20000	-74.65667	0.087	0.087	0.000
8536110	38.96833	-74.96000	0.137	0.137	0.000
8538875	40.01333	-75.00833	-0.132	-0.132	0.000
8545240	39.93333	-75.14167	-0.091	-0.091	0.000
8545530	39.95333	-75.13833	-0.082	-0.084	0.002
8551910	39.55833	-75.57333	0.015	0.015	0.000
8557380	38.78167	-75.12000	0.121	0.122	-0.001

8558690	38.61000	-75.07000	0.104	0.104	0.000
8570280	38.32667	-75.08333	0.140	0.139	0.001
8570280	38.32667	-75.08333	0.140	0.139	0.001
8570282	38.33167	-75.09000	0.126	0.126	0.000
8630249	37.93167	-75.38333	0.053	0.053	0.000
8630308	37.90667	-75.40500	0.042	0.043	-0.001
8630316	37.90333	-75.40667	0.058	0.053	0.005
8534836	39.30833	-74.53333	0.106	0.103	0.003
8534393	39.47833	-74.38333	0.035	0.035	0.000
8534048	39.61333	-74.21000	0.029	0.028	0.001