NOAA Technical Memorandum NOS CS 57

Global ESTOFS, STOFS-3D-Atlantic and OFS Water Level Skill Assessment Comparisons

Silver Spring, Maryland
August 2023

noaa National Oceanic and Atmospheric Administration

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

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

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ABSTRACT

Over the years, the NOAA National Ocean Service (NOS) has developed about 20 operational nowcast and forecast systems (OFS) for U.S. coastal waters as well as some deep ocean areas. The OFS support marine navigation, emergency response, search and rescue, offshore oil/gas operations, and the environmental management communities. The OFS perform nowcasts and short to long term (0 hr. - 180 hrs.) forecast guidance of pertinent parameters such as water levels, three-dimensional (3-D) water currents, salinity, water temperature. The OFS consist of the automated integration of observing system data streams, hydrodynamic model predictions, product dissemination and continuous quality-control monitoring. State-of-the-art numerical hydrodynamic models driven by real-time data and meteorological, oceanographic, and/or river flow rate forecasts form the core of these end-to-end systems.

The present study represents the first step toward gaining thorough and comprehensive insight into the relative performance between/among various NOS OFS. We focused on investigating five OFS among a total of about twenty operational OFS. The five OFS are, respectively, the San Francisco Bay OFS (SFBOFS), the Chesapeake Bay OFS (CBOFS), the Northern Gulf of Mexico OFS (NGOFS2), the Global Extratropical Surge & Tide OFS (hereafter referred to as ESTOFS), and the 3-D Surge and Tide OFS for the Atlantic Basin (STOFS-3D-Atlantic). These OFSs represent both the NOS port-based OFS (SFBOFS and CBOFS) and bay, region, or global based, larger domain OFS (NGOFS2, ESTOFS and STOFS-3D-Atlantic). Hopefully, the findings may provide technical guidance to various levels of OFS management and/or stakeholders in the planning for the development of the next generation, high-performance OFS.

We calculated the bias and RMSE of the nowcast water levels by comparing the model time series with the observed data at various NOSNational Water Level Observation Network (NWLON) stations during a time span of one to three months periods. Some of the areas are covered by more than one OFS. The ESTOFS and STOFS-3D-Atlantic domains cover broader areas that overlapped both with each other and even encompass the domains of some other OFS. In cases of overlapped domains, the water level bias and RMSE between the concerned OFS are compared and contrasted so as to gain insight into the relative skills. The results may help identify the merits and disadvantages of each OFS.

The study concluded that these five OFS demonstrated similar levels of model skill in terms of bias and RMSE. The model skill represents an integrated balance of multiple factors, such as the system configuration, the model numerical schemes, model grid resolution, the accuracy of the forcing data, etc. The present study reveals that the five OFS demonstrated similar degrees of model performance in terms of the bias and RMSE of the nowcast water level. In certain areas, some OFS may exhibit slightly better skill, i.e., smaller bias or RMSE. However, none of the five OFS demonstrated statistically significantly better overall skill than the others.

This report is organized as follows. Following up to a brief introduction in Section 1, Section 2 describes the configurations of the concerned NOAA/NOS OFS with respect to the employed core hydrodynamic models, forcing data flow, etc. Section 3 is about the project design that details the methods for data processing and statistics analysis. Section 4 shows the model-data comparison results in terms of the model water level bias and RMSE. Section 5 summarizes the study and recommends future work.

1. INTRODUCTION

This research aims to gain insights about relative skills of five National Ocean Service (NOS) operational forecast systems (OFS) by comparing the bias and RMSE of their nowcast water levels. The five OFS refer to the San Francisco Bay OFS (SFBOFS), the Chesapeake Bay OFS (CBOFS), the Northern Gulf of Mexico OFS (NGOFS2), the Global Extratropical Surge & Tide OFS (hereafter referred to as ESTOFS), and the 3-D Surge and Tide OFS for the Atlantic Basin (STOFS-3D-Atlantic), respectively. The results may help identify the merits and disadvantages of each OFS, as well as to provide authoritative data, information and guidance on storm surge, currents, water levels, salinity, and water temperature for the Gulf of Mexico, and the Atlantic and Pacific regions.

We aim to identify ideal models and parameters for a given region by performing skill assessments on several Operational Forecast Systems and the Global Extratropical Surge and Tide Operational Forecast System (Global ESTOFS). Hopefully, the findings may provide technical guidance to various levels of OFS management and/or stakeholders in the planning for the development of the next generation, high-performance OFS.

2. OPERATIONAL FORECAST SYSTEMS

NOAA continues to develop and operate national and regional networks of Operational Nowcast and Forecast Hydrodynamic Modeling Systems (called OFS) to support NOAA's mission goals and priorities. An OFS consists of the automated integration of observing system data streams, hydrodynamic model predictions, product dissemination and continuous quality-control monitoring. State-of-the-art numerical hydrodynamic models driven by real-time data and meteorological, oceanographic, and/or river flow rate forecasts form the core of these end-to-end systems. NOAA’s OFS perform nowcasts and short to long term (0 hr. - 180 hrs.) forecast guidance of pertinent parameters such as water levels, water currents, salinity, water temperature, and waves, and disseminate them to users.

Nowcasts and forecasts provide scientific information about the present and future states of water levels (and possibly currents and other relevant oceanographic variables, such as salinity and water temperature) in a coastal area. These predictions rely on either observed data or forecasts from a numerical model. OFS are being implemented in critical ports, harbors, estuaries, Great Lakes and coastal waters of the United States, and join the National Ocean Service's Precision Marine Navigation Program and other operational oceanographic capabilities to form a national backbone of real-time data, tidal predictions, data management and operational forecast modeling.

An important product of two- and three-dimensional model based forecast guidance systems, such as the Global Extratropical Surge and Tide Operational Forecast System (Global ESTOFS) and regional Operational Forecast Systems (OFS), are to provide accurate and timely information for coastal communities and to support safe and precise marine navigation by providing mariners with reliable data on water levels, surface water currents, and vertical stratification.

Coastal and ocean models like those mentioned above and in Table 1 below are also used for forecasting to support decision-making at all levels. To determine and quantify the performance and capabilities of these models, several metrics and a rigorous set of tests are conducted as part of a skill assessment performed on each model.

Model	Model Core	Model Hydrodynamics	Flood Inundation	NCEP* Model for Surface Forcing	River Forcing / River Discharge
SFBOFS	FVCOM	3-D, baroclinic	no	NAM	USGS: observed data
CBOFS	ROMS	3-D, baroclinic	no	NAM	As above
NGOFS2	FVCOM	3-D, baroclinic	no	NAM	As above
ESTOFS	ADCIRC	2-D, barotropic	yes	GFS	No river forcing
STOFS-3D Atlantic	SCHISM	3-D, baroclinic	yes	GFS & HRRR	NWM forecast

Table 1. List of National Ocean Service Operational Forecast Systems for skill assessment. Listed in column two are the model cores such as the Finite Volume Community Ocean Model (FVCOM), Regional Ocean Modeling System (ROMS), ADvanced CIRCulation (ADCIRC) model, and Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM).

*Note: National Centers for Environmental Prediction (NCEP)

Table 2 contains metrics and additional information on the forcing models used in many of the OFS listed in Table 1. Additionally, the outcomes from the skill assessments will estimate each model's performance and will also identify possible areas for improvement.

Names	Online Sites
NAM	North American Mesoscale Forecast System, 12 km resolution https://www.ncei.noaa.gov/products/weather-climate-models/north-american-mesoscale
GFS	Global Forecast System, 0.25 degree resolution https://www.nco.ncep.noaa.gov/pmb/products/gfs/
HRRR	High-Resolution Rapid Refresh, 3-km resolution https://rapidrefresh.noaa.gov/hrrr/
USGS	United States Geological Survey https://waterdata.usgs.gov/nwis/rt
NWM	National Water Model https://water.noaa.gov/about/nwm

Table 2. Online resources for the forcing data listed in Table 1

3. PROJECT DESIGN

For this project we first chose Global Extratropical Surge and Tide Operational Forecast System (Global ESTOFS), the Chesapeake Bay OFS (CBOFS), the San Francisco Bay OFS (SFBOFS) and the Northern Gulf OFS (NGOFS2) as the main models to evaluate and compare. One of the routine tasks in performing a comparison project of this nature is to identify the stations within each OFS and then to retrieve the data and water level information for the duration of the project.

Global ESTOFS provides a second operational set of forecast guidance in addition to the ET-SURGE (ETSS) model. It has a community-based ADvanced CIRCulation (ADCIRC) model which is used for Global ESTOFS and the Global Forecast System (GFS) model provides the atmospheric forcing. The Global ESTOFS model is run on NOAA's WCOSS supercomputing system four times daily with 6-hour nowcasts and forecast guidance out to 180 hours producing numerical storm surge guidance for extratropical systems. Our comparisons will use 48 stations which contribute to Global ESTOFS.

CBOFS is one of several models that is operated by NOAA’s National Ocean Service. The new higher resolution CBOFS is now based on a three-dimensional ROMS model that runs on NOAA's High Performance Computers (HPC). In addition to providing water level nowcast and forecast guidance, the new CBOFS also provides currents, water temperature and salinity as well as interpolated winds from National Weather Service products. CBOFS runs four times per day and generates 6-hour nowcasts and 48-hour forecast guidance. CBOFS products include time series graphics at station locations and areal animations of the whole Chesapeake Bay for all five parameters (wind, water level, water currents, water temperature and salinity). Our comparison will evaluate 13 stations from the Chesapeake Bay network.

SFBOFS is based on a three-dimensional FVCOM model that also runs on NOAA's High Performance Computing System (HPCS). SFBOFS provides water levels, water currents, water temperature and salinity nowcast and forecast guidance as well as interpolated winds from National Weather Service products for two subdomains: the San Francisco Bay and the San Francisco Bay Entrance. SFBOFS runs four times per day and generates 6-hour nowcasts and 48-hour forecast guidance. SFBOFS products include time series graphics at station locations and areal animations of the San Francisco Bay for all five parameters (winds, water levels, water currents, water temperature and salinity). We will evaluate seven stations from this network as part of our comparison.

NOAA's National Ocean Service (NOS) has also upgraded the existing Northern Gulf of Mexico Operational Forecast System (NGOFS, NEGOFS, and NWGOFS) to the new Northern Gulf of Mexico Operational Forecast System (NGOFS2) which extends the model domain to cover Lower Mississippi River, Barataria Bay, Lake Pontchartrain, Corpus Christi Bay, and Mexican coastal waters without sacrificing model resolution. NGOFS2 is the same hydrodynamic model using three-dimensional FVCOM. NGOFS2 runs four times per day and provides water levels, water currents, water temperature and salinity 6-hour nowcast and forecast guidance out to 48 hours for the northern Gulf of Mexico including nine ports at Matagorda Bay, Galveston Bay, Sabine Neches, Calcasieu/Lake Charles, Gulfport, Pascagoula Bay, Mobile Bay, Corpus Christi Bay, and Lake Pontchartrain. Our comparison will evaluate 49 stations from the northern Gulf region.

To perform the evaluation and analyze the results in a consistent and unbiased manner, a number of steps needed to be taken. The first was to obtain and convert the nowcast netCDF data into appropriate or more manageable forms to work with. Next we had to retrieve the observed water level time series measurements from all of the National Water Level Observation Network (NWLON) stations and plot each time series. We needed to select the criteria for the weekly, monthly, and every two months skill assessments we were to perform. Lastly we needed to identify the skill parameters to report such as root mean square error (RMSE), bias and standard deviation (STD). To estimate RMSE and STD of the model water level, we used the model outputs on the closest model mesh nodes to the observation stations and compared the time series between the model and observations.

4. RESULTS

This section presents the skill assessment results in terms of the model water level bias and the root-mean-square error (RMSE). The time periods for analysis vary for different OFS due to availability of either the model results or the observed data. The periods are March 25 - July 31, 2021 for SFBOFS; March 25 – August 30, 2021 for CBOFS; April 27 – August 31, 2021 for NGOFS2; March 25 – July 31, 2021 for ESTOFS; and July 25-August 23, 2021 for STOFS-3D-Atlantic. The STOFS-3D-Atlantic model data were kindly provided by the SCHISM team of the Virginia Institute of Marine Science, whereas the other model data were retrieved from the NOAA online resources.

To compare the model outputs with the observations, it is necessary to ensure that both data sets are referenced to the same vertical datum, e.g., the mean sea level (MSL) or the North American Vertical Datum of 1988 (NAVD 88). Depending on the characteristics of the OFS configurations, the water level time series of SFBOFS, CBOFS, NGOFS2, and ESTOFS are referenced to MSL, whereas those of STOFS-3D-Atlantic are referenced to NAVD88. In this study, the observed water level time series relative to MSL were retrieved from the NOS NWLON station database. Hence, in assessing the model skill of STOFS-3D-Atlantic, the observed data were first adjusted to be referenced to NAVD88 prior to performing the model-data comparison.

I. Bias and RMSE of the SFBOFS, NGOFS2, and CBOFS Water Levels

For this project, we analyzed water level data collected from 135 stations along the Atlantic, Pacific and Gulf Coasts. The plots in this first section show water level bias and Root Mean Square Error (RMSE) for the San Francisco Bay Operational Forecast System (SFBOFS), Northern Gulf Operational Forecast System (NGOFS2), and the Chesapeake Bay Operational Forecast System (CBOFS). In Fig. I.1 the water level bias for seven stations in the SFBOFS is plotted. The average bias is 0.12 m and ranges from 0.01 m to 0.27 m. The magnitude and standard deviation of the absolute value of the average bias are 0.12 m and 0.09 m, respectively.

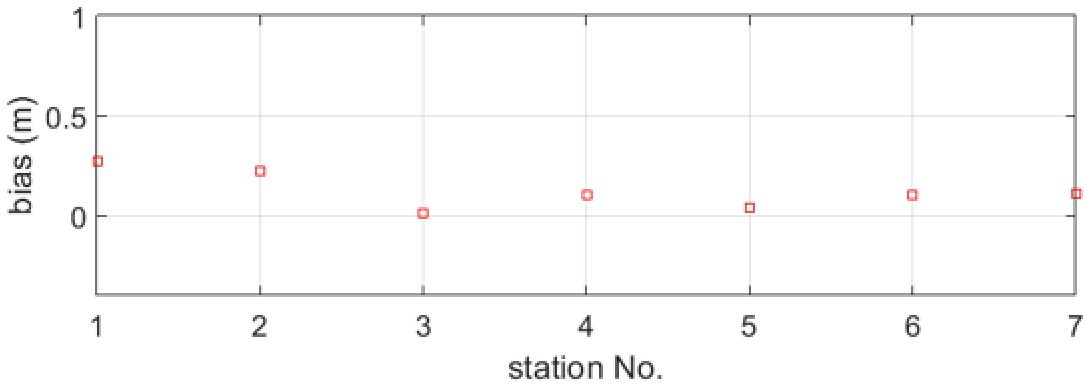

Figure I.1 Bias of the SFBOFS water level

In Fig I.2 the bias is smaller at the stations close to the open coast and becomes gradually greater at the embayment stations. The bias is nearly zero at the open coastal station in the northwest and the station at the bay entrance. It increases to about 0.11 m at the three embayment stations. Bias at the two stations in the northeast is over 0.22 m. The two stations are located in the upstream portion of the river course. It is noted that the two stations are not shown on the CO-OPS SFBOFS website https://tidesandcurrents.noaa.gov/ofs/sfbofs/sfbofs_entrance.html. This indicates that the nowcast/forecast guidance for water levels at the two stations and hence their adjacent areas are not supported by the SFBOFS. The large magnitudes of bias may be attributed to the particular vertical datum that is different from the mean sea level in this region. Additionally, Table A.1 contains the geographic location for all the stations.

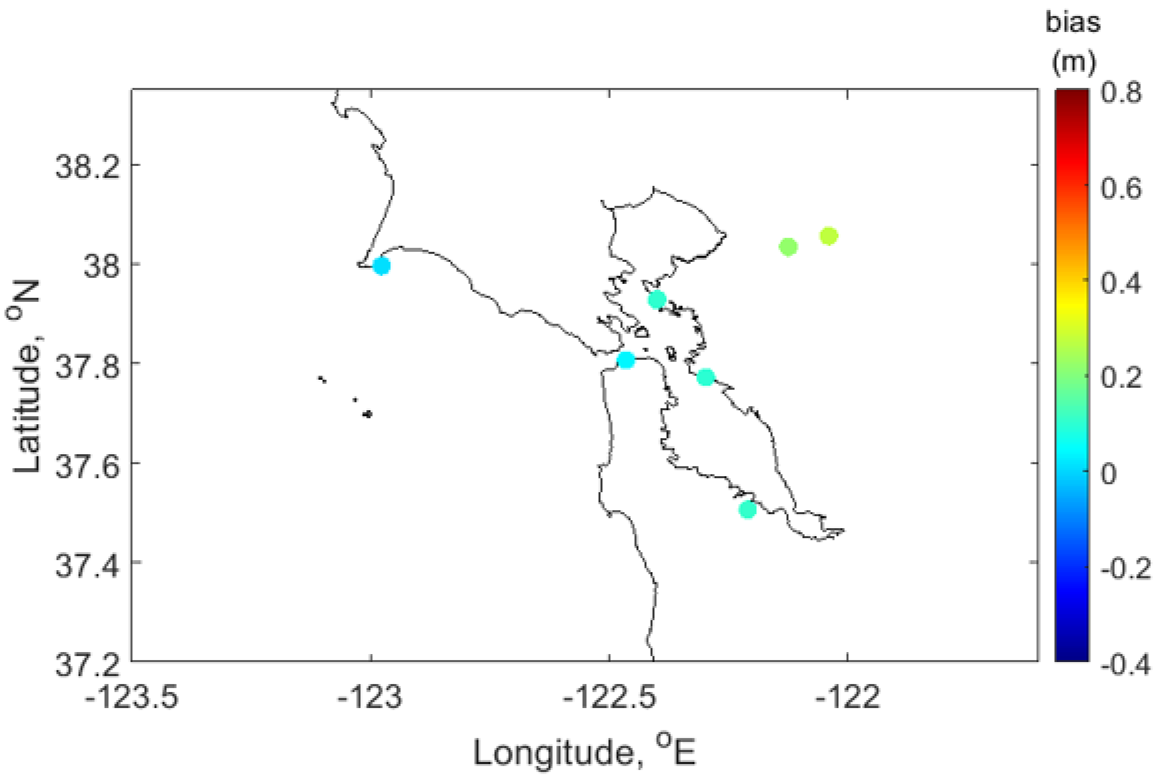

Figure I.2 Color coded map of bias of the SFBOFS water level

Figure I.3 shows the RMSE for the San Francisco Bay area which ranges from 0.14 m to 0.30 m with an average of 0.20 m. The spatial distribution pattern for the RMSE is similar to that of the bias. This indicates that the bias makes up a significant portion of the RMSE at the stations, except at the open coastal station in the northwest and the station at the bay entrance. The RMSE is about 0.14 - 0.15 m at the open coast station in the northwest and the bay entrance station. For the three embayment stations, the RMSE ranges from 0.17 m to 0.23 m and for the two stations in the upper portion of the river, the RMSE is 0.25 m and 0.30 m, respectively.

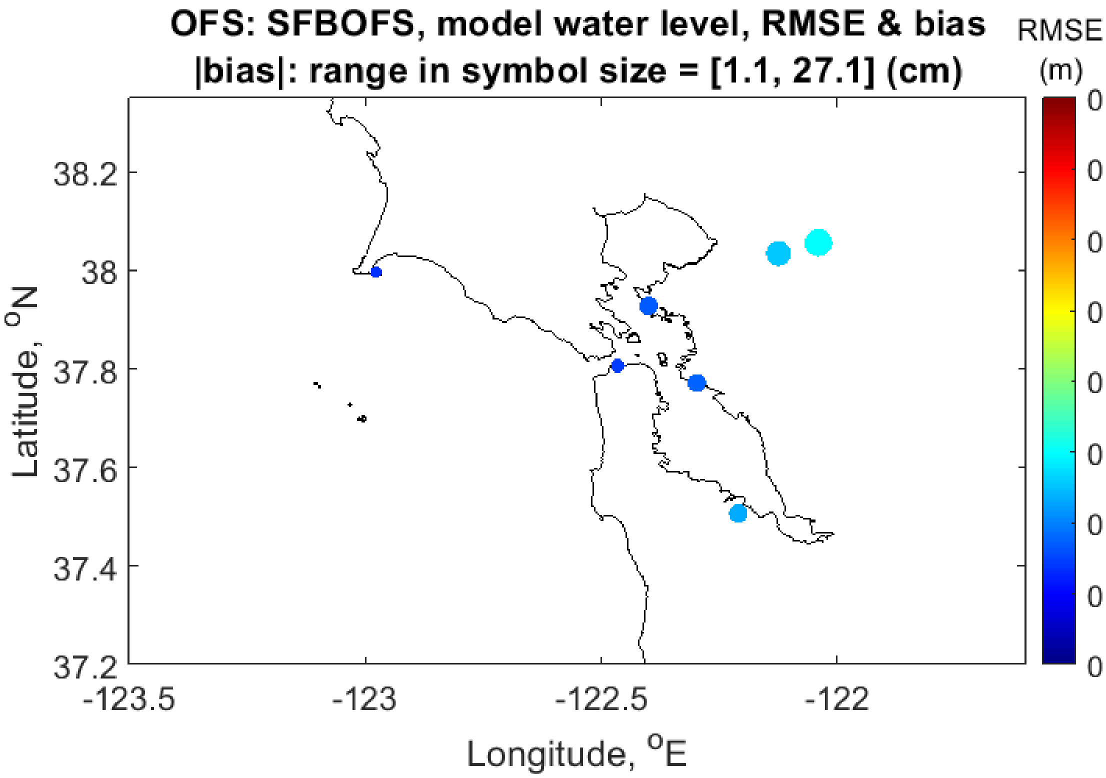

Figure I.3 Color coded map of combined bias and RMSE of the SFBOFS water level

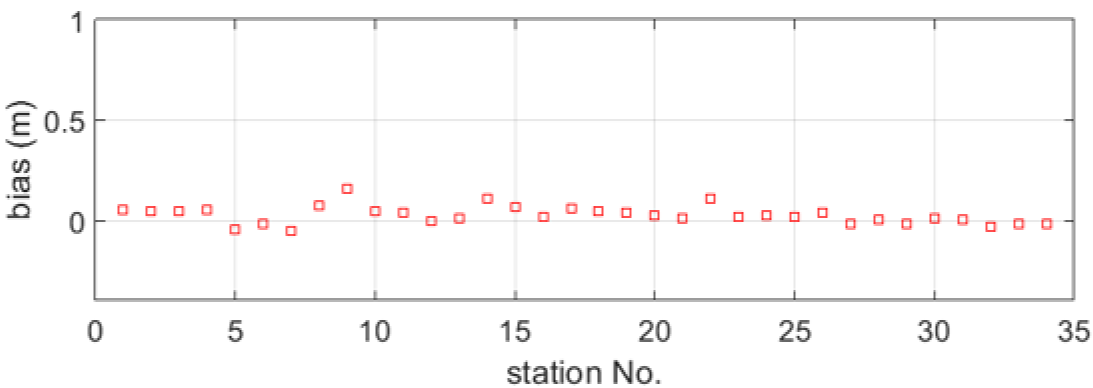

Figure I.4 Bias of the NGOFS2 water level

Figure I.4 shows the NGOFS2 biases for 34 stations that range between -0.05 m and 0.16 m with an average bias of 0.03 m. The magnitude of the average bias is 0.03 m and the standard deviation of the bias is 0.05 m.

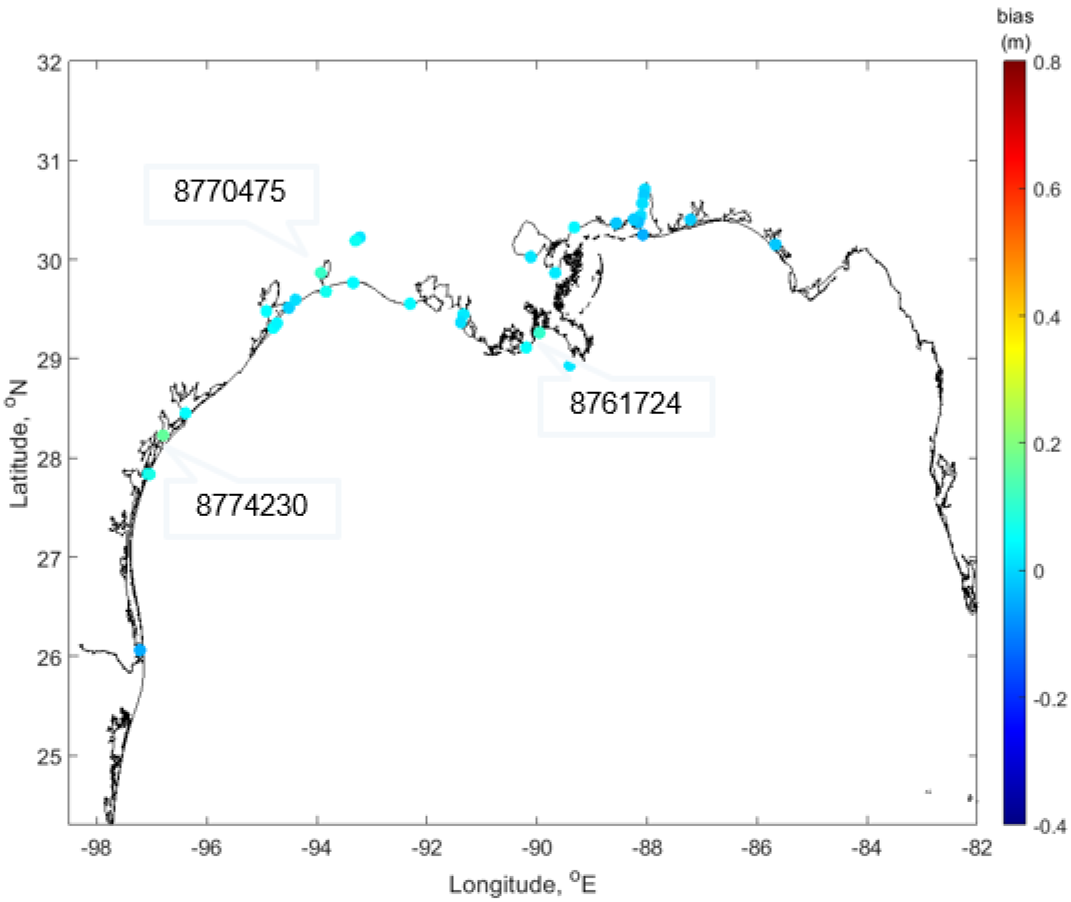

Figure I.5 Color coded map of bias of the NGOFS2 water level

Figure I.5 shows an even distribution of the magnitude of the bias across the NGOFS2 model domain. The biases of three stations (8774230, 8770475, 8761724) in the western domain appear to be most significant. Their corresponding bias values are 0.16 m, 0.11 m and 0.11 m respectively. The remaining 31 stations in the NGOFS2 domain have an average bias of 0.08 m. Additionally, Table A.2 contains the geographic location for all the stations.

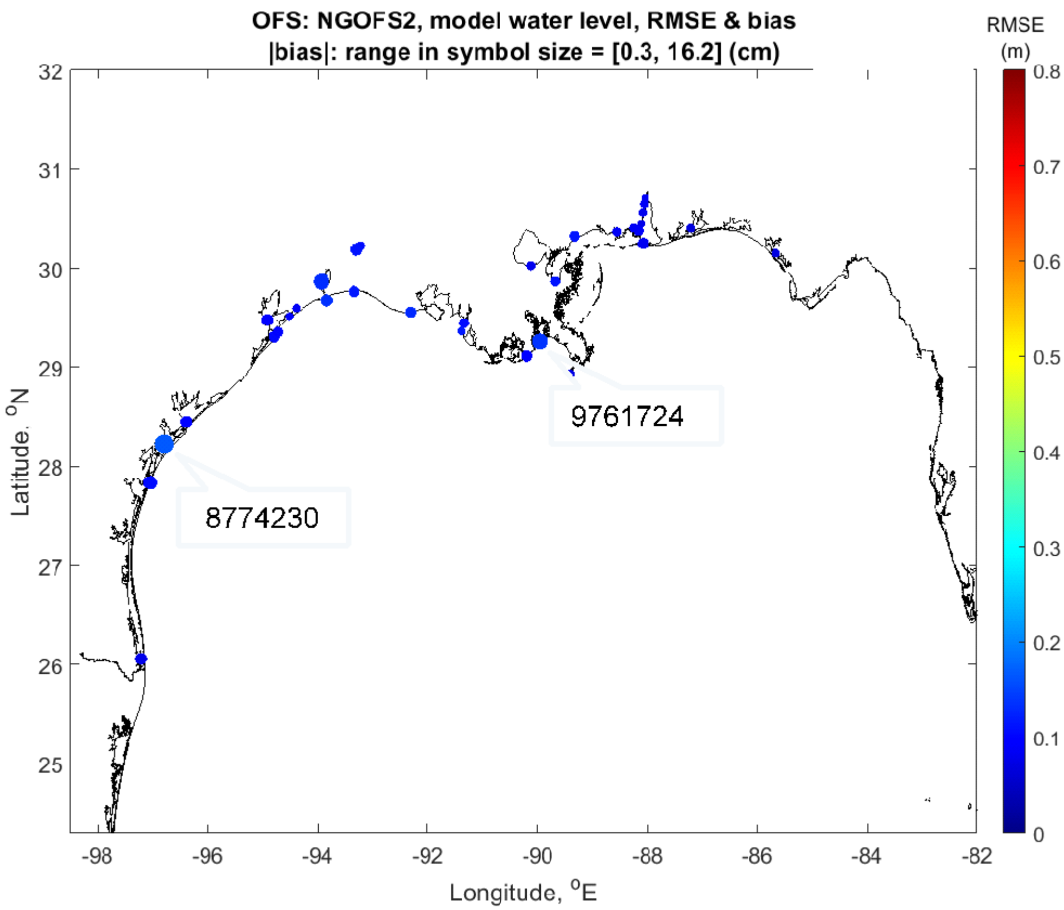

Figure I.6 Color coded map of combined bias and RMSE of the NGOFS2 water level

The color-coded map in Fig. I.6 illustrates the bias and RMSE of the NGOFS2 water level. The range of the RMSE is from 0.07 m to 0.18 m with an average of 0.10 m. The RMSE demonstrates a similar spatial distribution to that of the bias in Fig. I.5. The RMSE is less than 0.10 m at the stations in Mobile Bay and adjacent waters but it does become greater at the stations to the west where it ranges from 0.09 m to 0.17 m. The RMSE appears to be most significant at stations 8774230 and 8761724 with corresponding RMSEs of 0.16 m and 0.14 m, respectively.

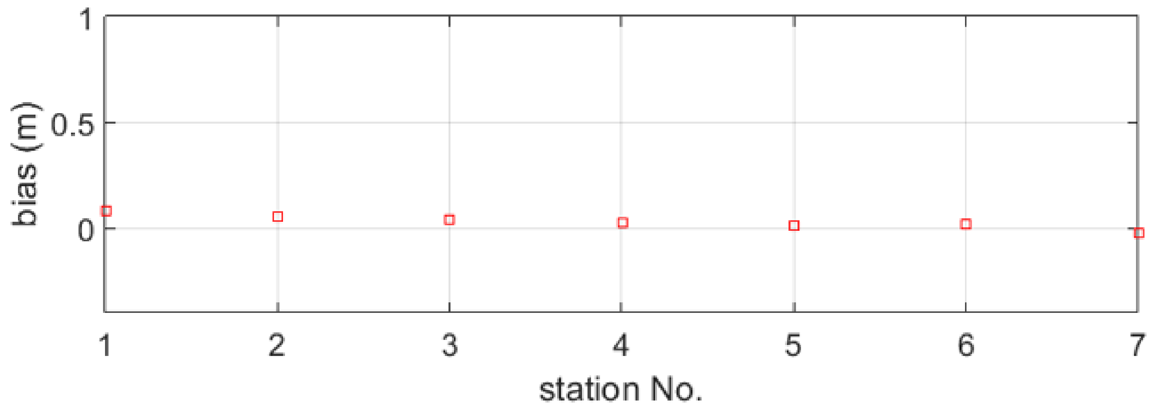

Figure I.7 Bias of the CBOFS water level

Figure I.7 shows the water level bias for seven stations in the CBOFS where the bias ranges from -0.03 m to 0.08 m with an average bias of 0.03 m. The magnitude and standard deviation of the bias are 0.04 m and 0.03 m, respectively.

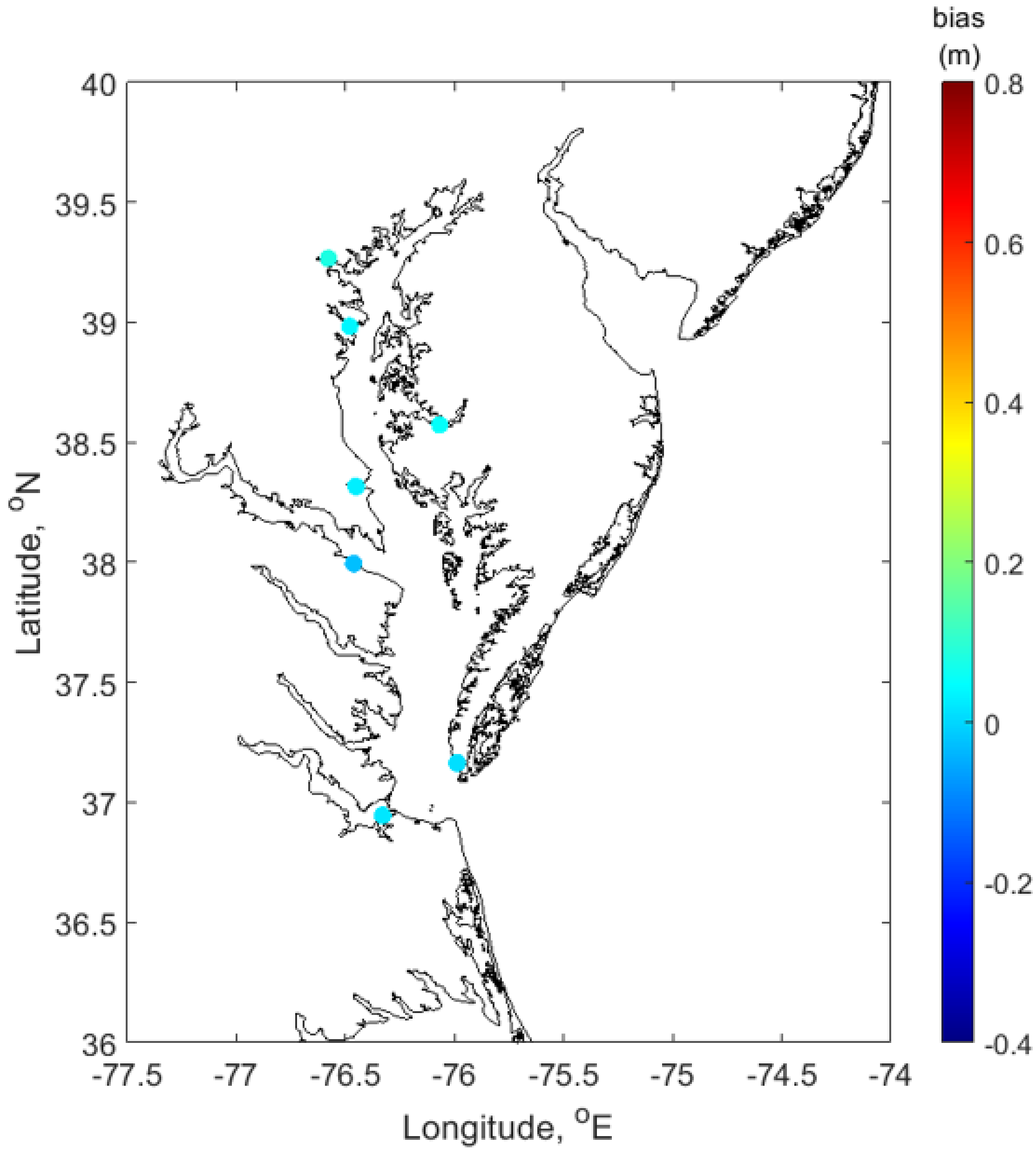

Figure I.8 Color coded map of bias of the CBOFS water level

The color-coded map in Fig. I.8 illustrates the bias of the CBOFS water level. In general the bias appears to be smaller in the lower bay stations that are closer to the open coast than for those at the upper bay stations. The magnitude of the bias at the four lower bay stations is less than 0.02 m, whereas the bias at the upper three bay stations are 0.03 m, 0.05 m and 0.08 m respectively. The far north station (8574680) shows the greatest bias of 0.08 m. Additionally, Table A.3 contains the geographic location for all the stations.

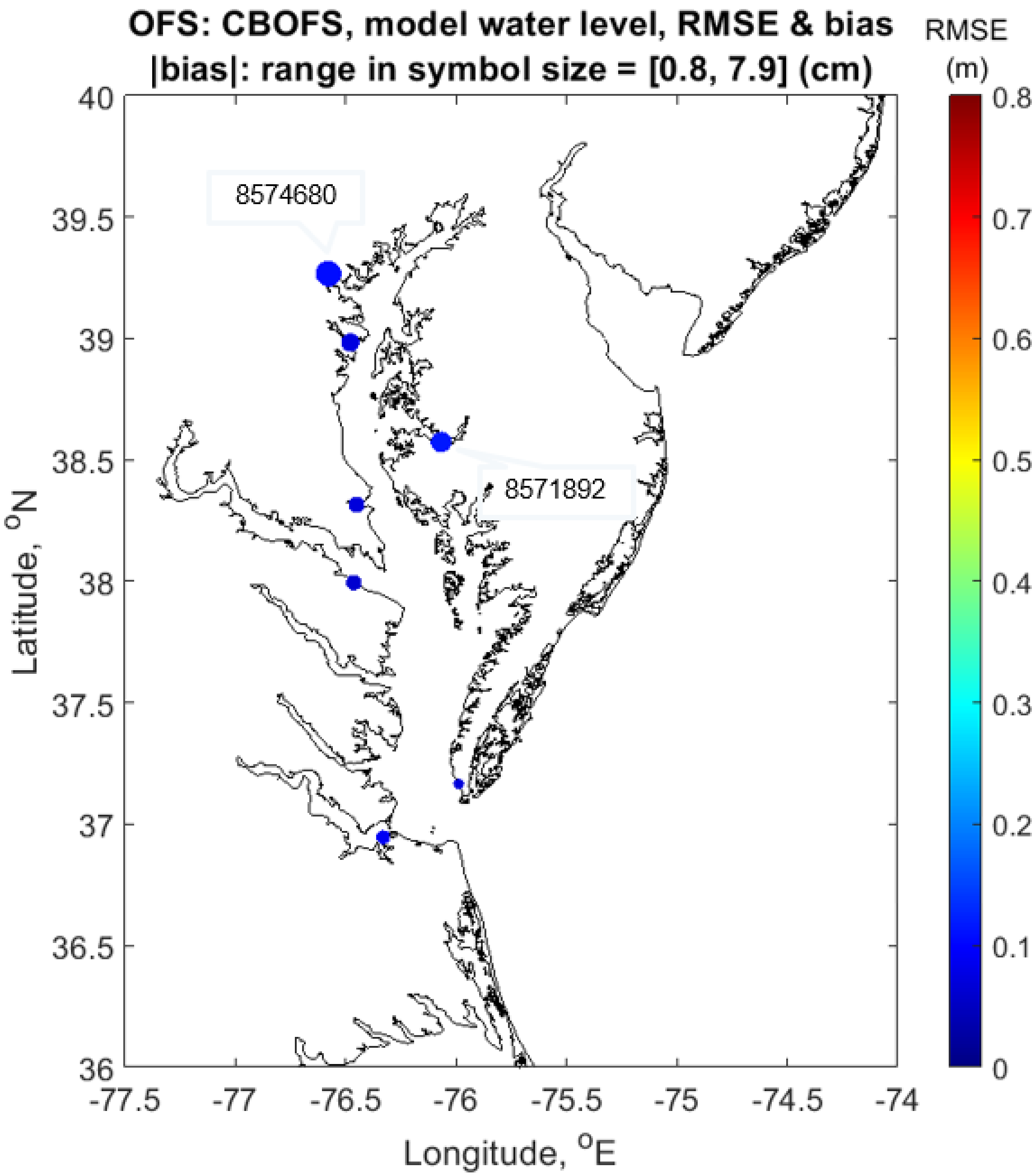

Figure I.9 Color coded map of combined bias and RMSE of the CBOFS water level

In Fig. I.9 the RMSE of the CBOFS water level ranges from 0.06 m to 0.12 m with an average of 0.08 m. The standard deviation of the RMSE is 0.02 m. In general, RMSE is smaller in the lower bay region than in the upper bay region. The corresponding bias also appears to be smaller in the lower bay region. The two stations with the largest RMSE are stations 8574680 and 8571892 and have corresponding RMSEs of 0.11 m and 0.12 m, respectively.

II. Bias and RMSE of the ESTOFS Water Levels

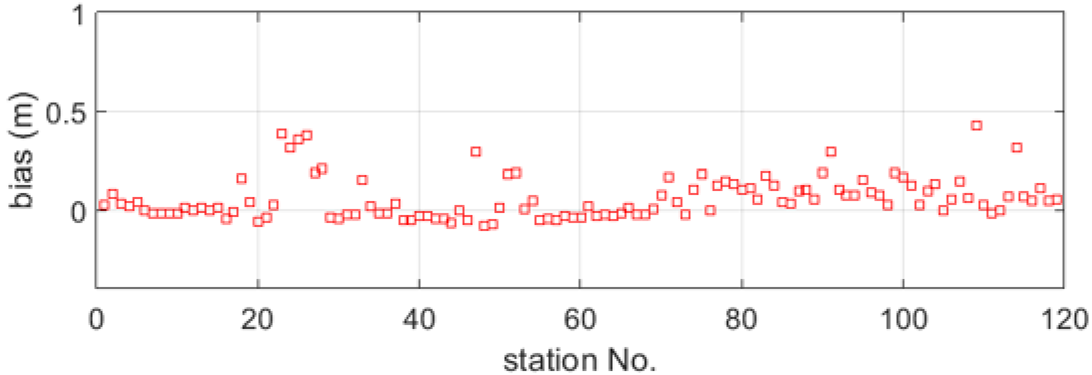

Figure II.1 Bias of the ESTOFS water level

Figure II.1 illustrates the bias for 119 stations for the ESTOFS water level model. The biases range from -0.08 m to 0.43 m with an average bias of 0.06 m. The magnitude and standard deviation of the bias are 0.08 m and 0.11 m, respectively.

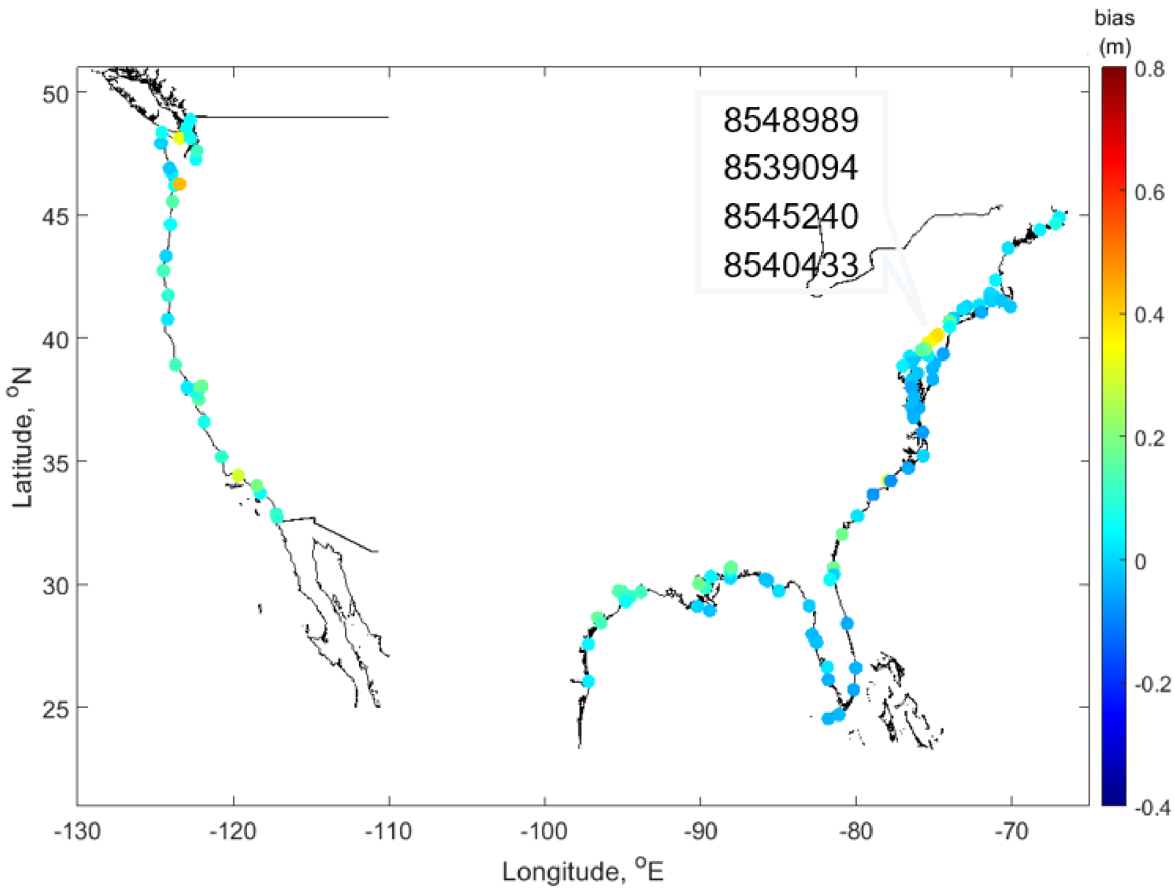

Figure II.2 Color coded map of bias of the ESTOFS water level

Figure II.2 shows the bias for 119 stations along the U.S. east and west coasts. The east coast has 86 stations where the bias ranges from -0.08 m to 0.38 m with an average bias of 0.04 m and an absolute value of bias average of 0.07 m. The west coast has 33 stations where the bias ranges from -0.01 m to 0.43 m with an average bias of 0.11 m and an absolute value of bias average of 0.11 m. The standard deviation of the biases along the east and west coasts are 0.10 m and 0.09 m, respectively. On average, the west coast stations demonstrate slightly greater magnitude of bias than the east coast stations, 0.11 m vs. 0.07 m. The magnitude of bias appears to be greater than 0.30 m at stations 8540433, 8545240, 8548989, and 8539094 with bias equal to 0.32 m, 0.36 m, 0.37 m, and 0.38 m, respectively. The four stations are aligned from south to north in the upper stream of the Delaware River (Figure II.2). Later versions of ESTOFS (later called STOFS) have resolved some wetting and drying issues that were found to occur which may have resulted in higher biases, including in these upper reaches of the Delaware River. Additionally, Table A.4 contains the geographic location for all the stations.

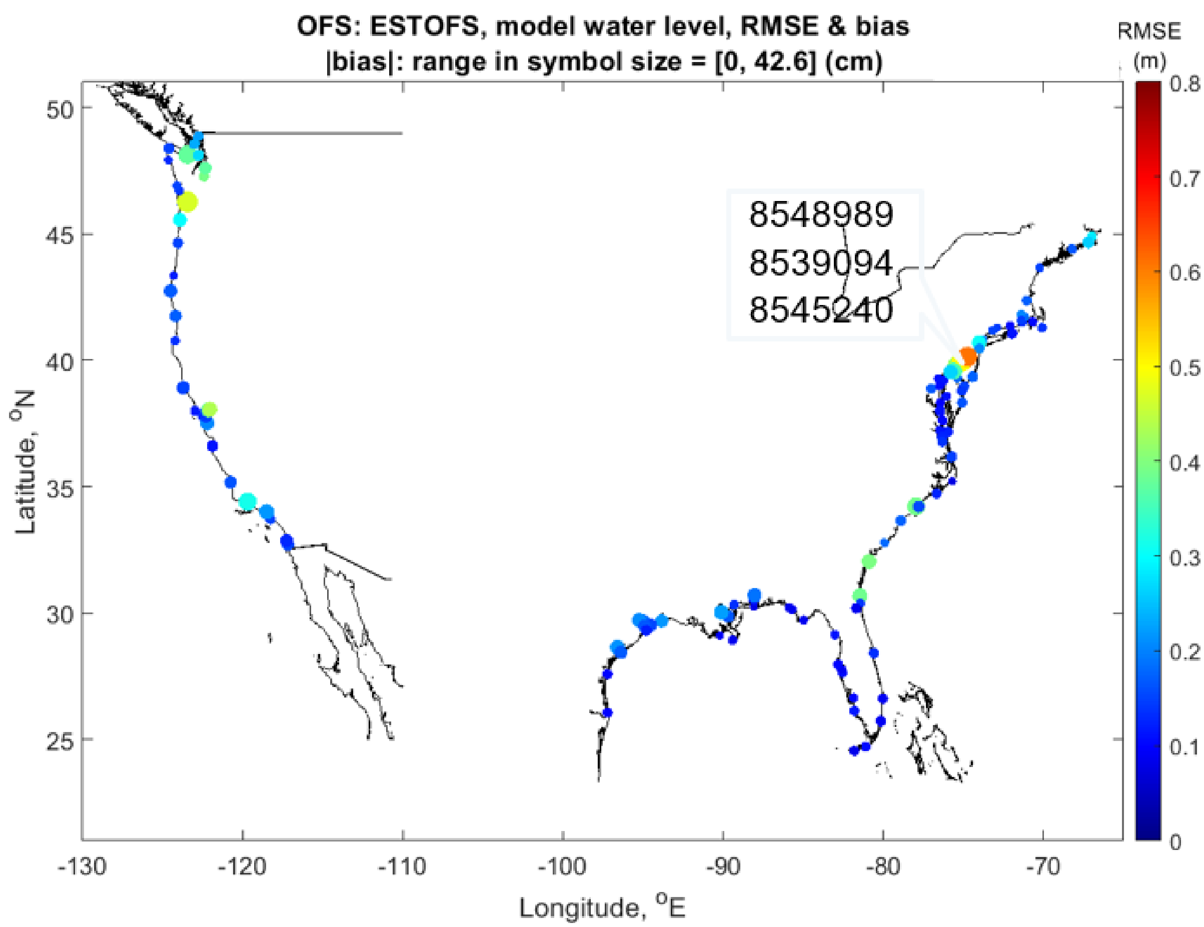

Figure II.3 Color coded map of combined bias and RMSE of the ESTOFS water level

Figure II.3 shows the RMSE for 119 stations along the U.S. east and west coasts. There are 86 stations along the east coast where the RMSE ranges from 0.08 m to 0.61 m with an average RMSE of 0.18 m and a standard deviation of RMSE of 0.11 m. The west coast has 33 stations where the RMSE ranges from 0.12 m to 0.47 m and has an average RMSE of 0.21 m and a standard deviation of RMSE of 0.10 m. On average, the west coast stations demonstrate slightly greater RMSE than the east coast stations, 0.21 m vs. 0.18 m. The RMSE appears to be greater than 0.50 m at stations 8545240, 8539094, and 8548989 with RMSE equal to 0.51 m, 0.59 m, and 0.61 m, respectively. These three stations are aligned from south to north in the upper stream of the Delaware River (Figure II.3). Again, later versions of ESTOFS (later called STOFS) have resolved some of the sources of high bias and RMSE, including in the Delaware River.

III. Comparison of Bias and RMSE Between ESTOFS and SFBOFS / NGOFS2 / CBOFS

Figure III.1 shows the bias of the common stations (total of 29 stations) between ESTOFS and SFBOFS, or NGOFS2, or CBOFS. They include seven stations between ESTOFS and SFBOFS, 15 stations between ESTOFS and NGOFS2, and seven stations between ESTOFS and CBOFS. Overall, the bias points are scattered symmetrically around the black diagonal line (which represents the equal bias location). This indicates the model skill in terms of bias is similar between ESTOFS and SFBOFS / NGOFS2 / CBOFS.

For ESTOFS vs. SFBOFS (Red squares), both models demonstrate similar values of bias at the five open coast and embayment stations (Figure I.2). At the two upper river stations, SFBOFS exhibits greater bias than ESTOFS.

For ESTOFS vs. CBOFS, all the black triangles ride above the diagonal line. This means that the magnitude of the bias of CBOFS is greater than that of ESTOFS and hence, indicates a less satisfactory performance for CBOFS than ESTOFS.

For ESTOFS vs. NGOFS2, most of the blue circles are scattered below the diagonal line. This indicates that the magnitude of the bias of NGOFS2 is in general smaller than that of ESTOFS and hence, demonstrates a more satisfactory skill for NGOFS2 than ESTOFS.

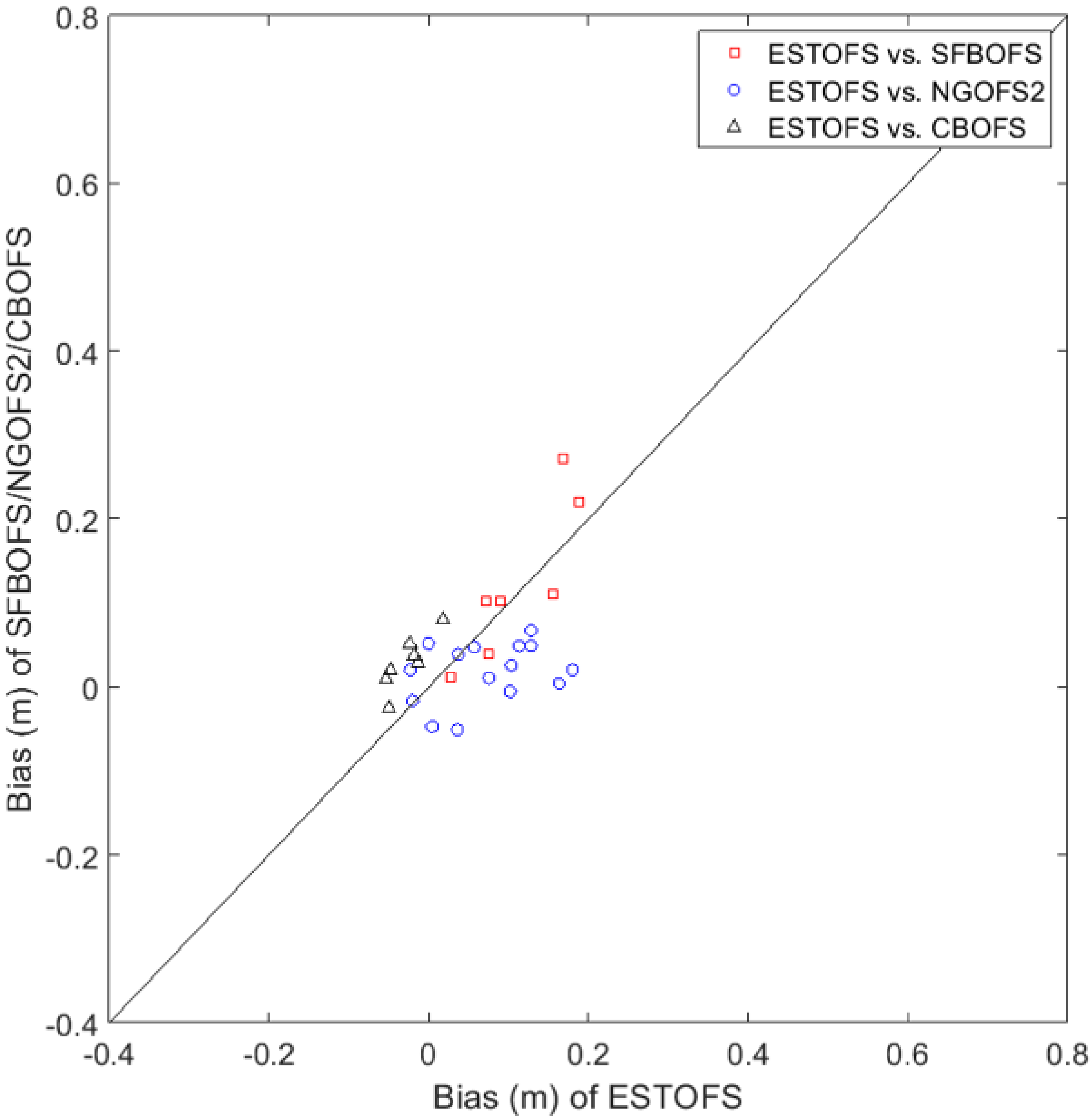

Figure III.1 Comparison of bias between the ESTOFS water level and SFBOFS/NGOFS2/CBOFS.

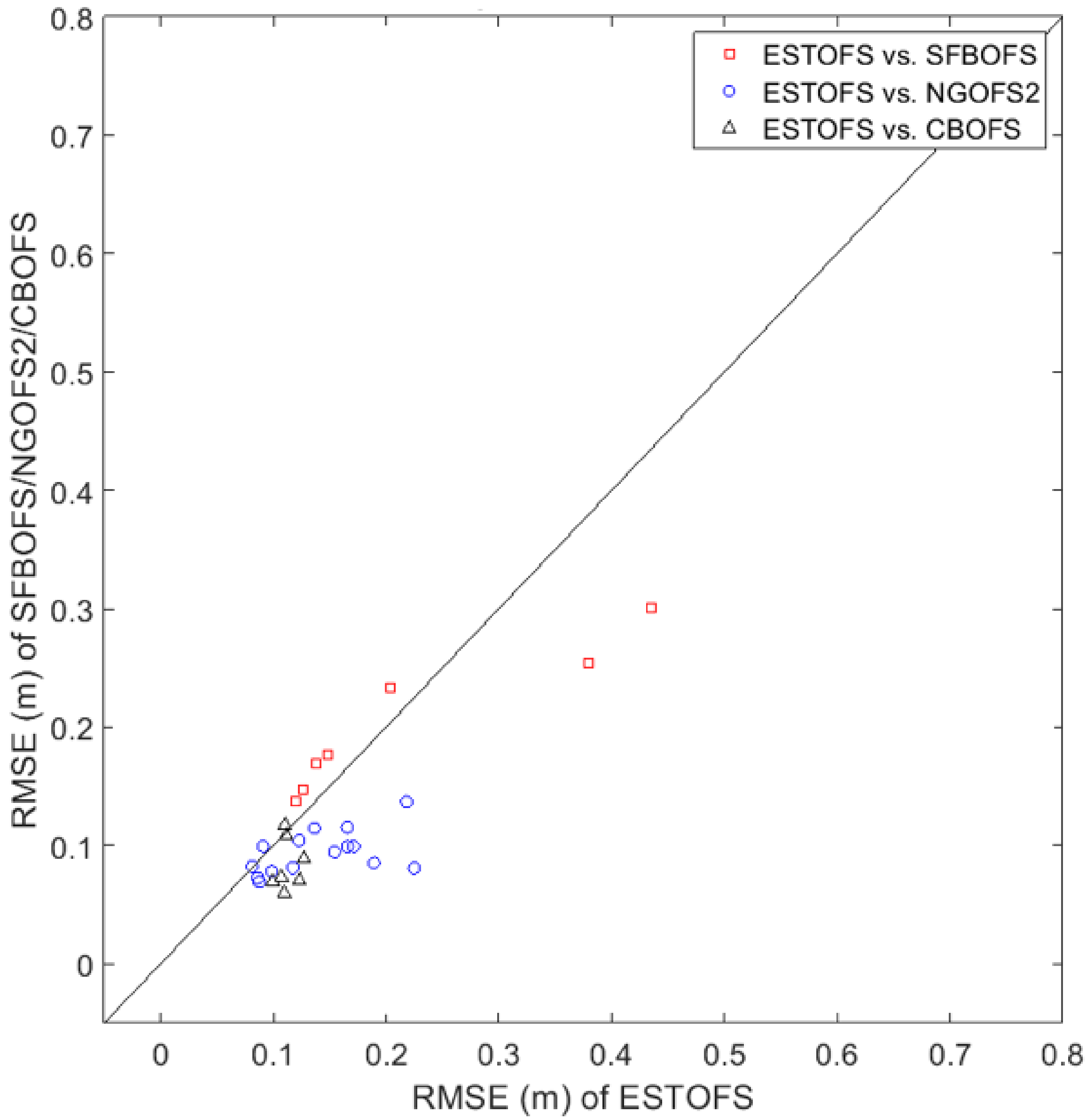

Figure III.2 Comparison of RMSE between the ESTOFS water level and SFBOFS/NGOFS2/CBOFS

Figure III.2 shows the RMSE of the common stations (total of 29 stations) between ESTOFS and SFBOFS, or NGOFS2, or CBOFS. They include seven stations between ESTOFS and SFBOFS, 15 stations between ESTOFS and NGOFS2, and seven stations between ESTOFS and CBOFS. Overall, the RMSE points are scattered below the diagonal line (which represents the equal RMSE location). This means that in general, the RMSE of ESTOFS is larger than that of SFBOFS/NGOFS2/CBOFS. This demonstrates that ESTOFS performs slightly worse in terms of RMSE than the other OFS.

For ESTOFS vs. SFBOFS, and similar to the case of bias, both models demonstrate similar RMSE at the five open coast and embayment stations, with ESTOFS slightly better than SFBOFS for RMSE (Figure I.2). However, at the two upper river stations, ESTOFS exhibits greater RMSE than SFBOFS, i.e., 0.25 m vs. 0.38 m and 0.30 m vs. 0.44 m.

For ESTOFS vs. NGOFS2, nearly all the blue circles scatter below the diagonal line. This indicates that the RMSE of NGOFS2 is smaller than that of ESTOFS and hence, demonstrates a more satisfactory performance for NGOFS2 than ESTOFS.

For ESTOFS vs. CBOFS, nearly all the black triangles scatter below the diagonal line. This means that RMSE of CBOFS is slightly less than that of ESTOFS and hence, indicates a slightly more satisfactory performance for CBOFS than ESTOFS.

IV. Comparison of Bias and RMSE Between STOFS-3D-Atlantic and NGOFS2 / CBOFS / ESTOFS

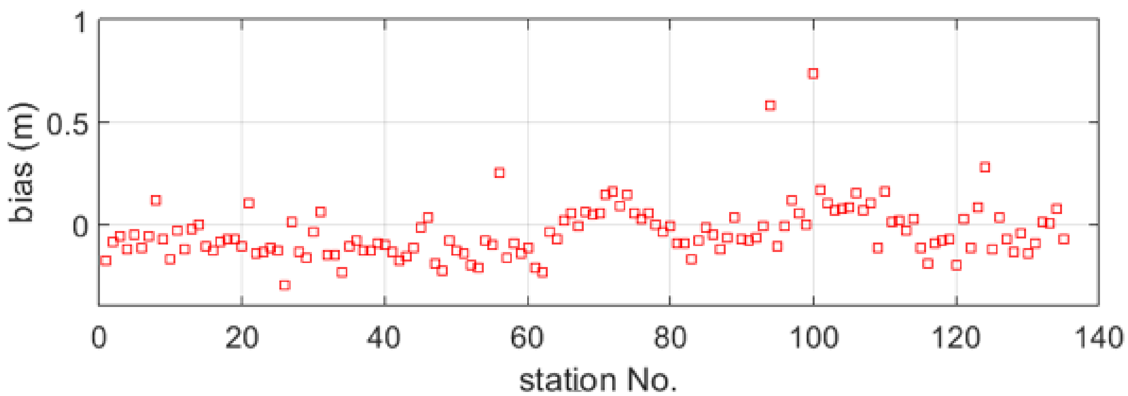

Figure IV.1 Bias of the STOFS-3D-Atlant water level

There are a total of 135 stations (Table A.5) in Fig. IV.1 with biases ranging from -0.03 m to 0.74 m with an average bias of -0.04 m and a standard deviation of bias of 0.14 m. The magnitude of the bias is 0.11 m.

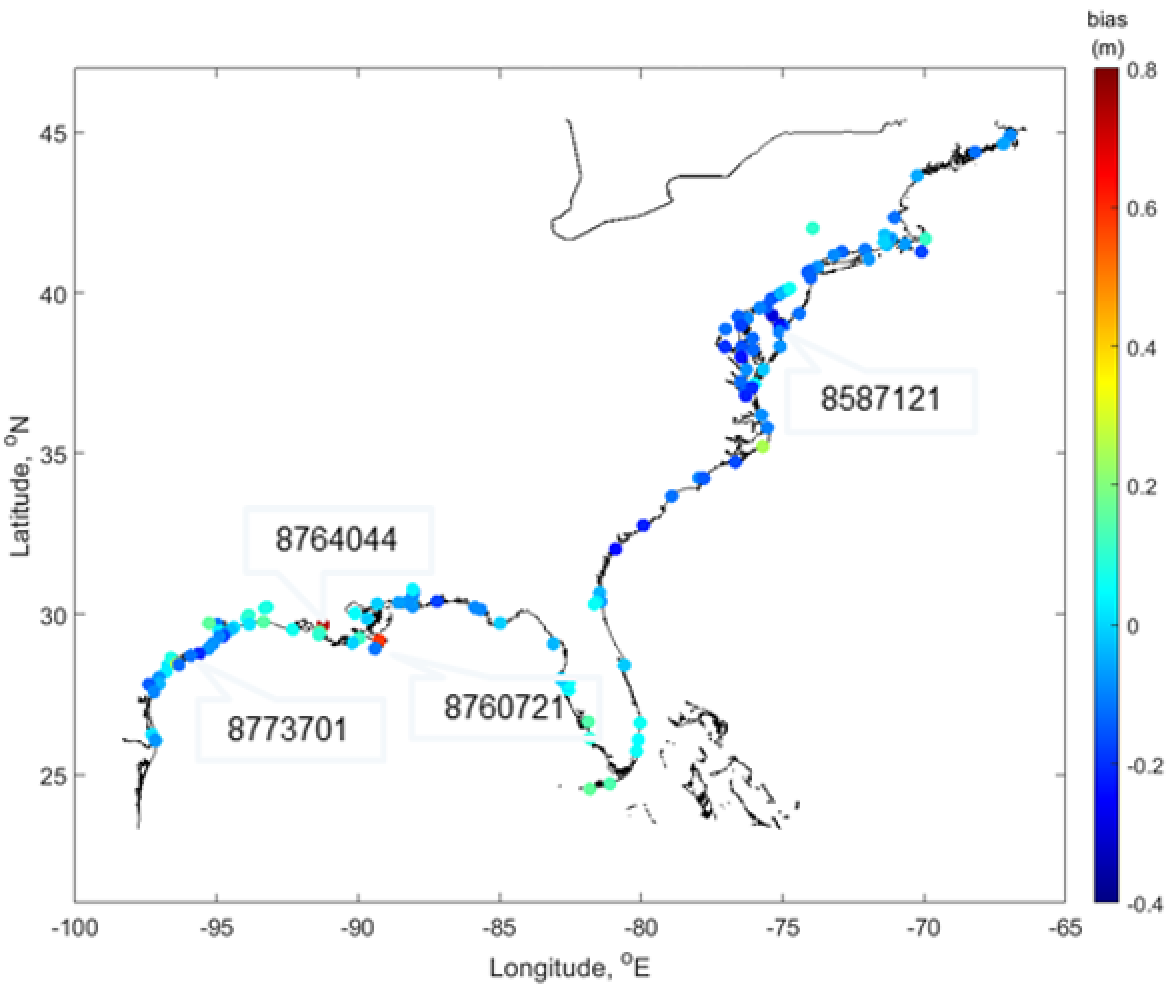

Figure IV.2 Color coded map of bias of the STOFS-3D-Atlantic water level

In general, the biases at the stations along the Florida coast appear to be smaller in magnitude than those at the stations along the Gulf of Mexico or along the Mid-Atlantic Bight (MAB) coast. The stations along the Gulf coast exhibit a smaller magnitude of the bias than the MAB stations. The majority of stations along the MAB coast exhibit negative bias with the maximum magnitude up to 0.30 m. The magnitude of the bias is the greatest at stations 8537121, 8773701, 8760721, and 8764044. The corresponding biases are -0.30 m, 0.28 m, 0.58 m, and 0.74 m, respectively.

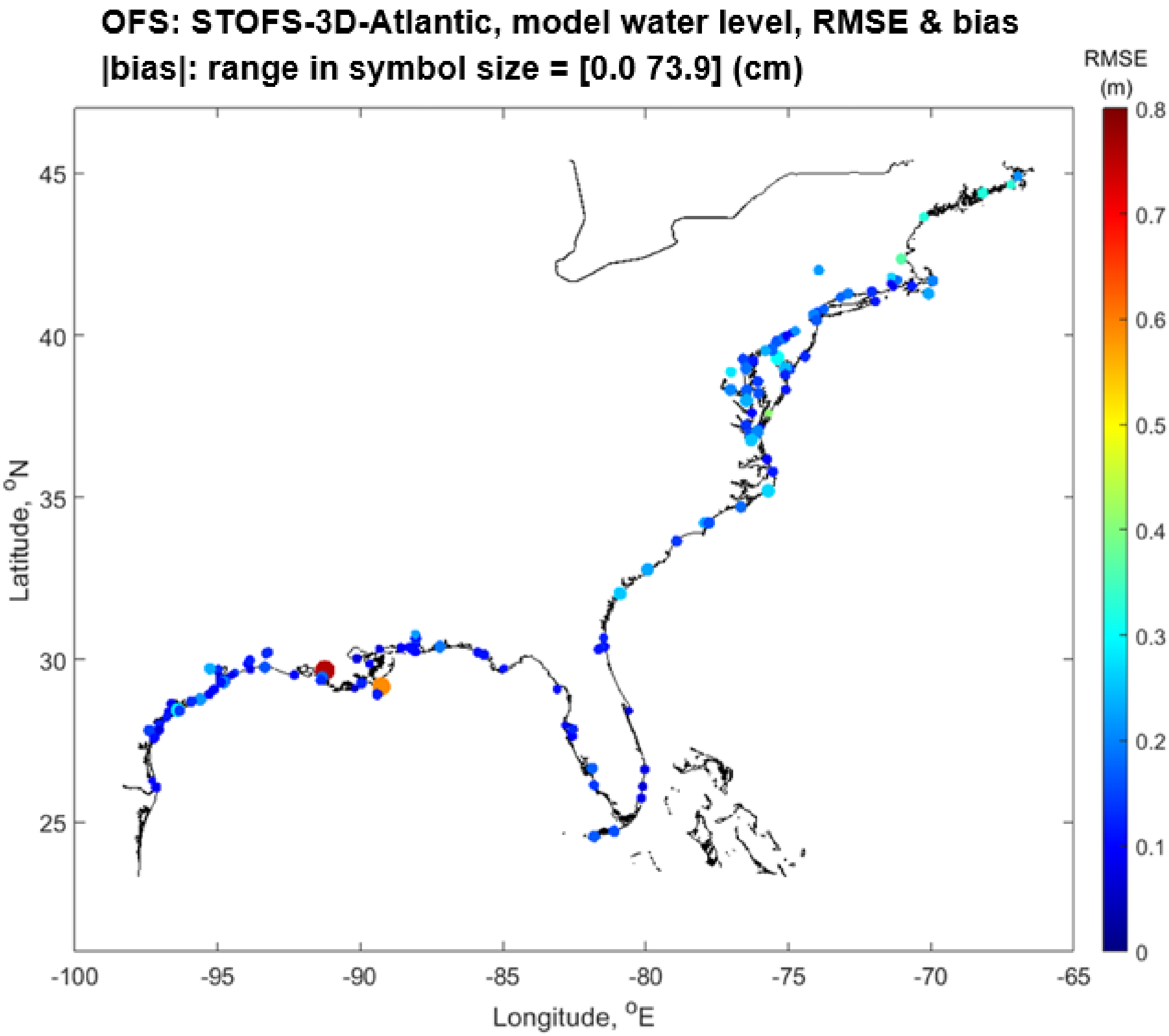

Figure IV.3 Color coded map of combined bias and RMSE of the STOFS-3D-Atlantic water level

In Fig. IV.3, the RMSE ranges from 0.04 m to 0.76 m with an average RMSE of 0.16 m and a standard deviation of the RMSE of 0.09 m. The RMSE demonstrates a similar spatial pattern to that of bias (Figure IV.2). In general, the stations in the Gulf of Maine display the largest RMSEs over the entire STOFS-3D-Atlantic model domain. The stations along the MAB exhibit larger RMSE than those along the Florida and the Gulf of Mexico coasts. Two stations (8760721 and 8764044) in the Gulf of Mexico exhibit significantly greater RMSE than the remaining 133 stations. The corresponding RMSEs are 0.59 m and 0.76 m, respectively.

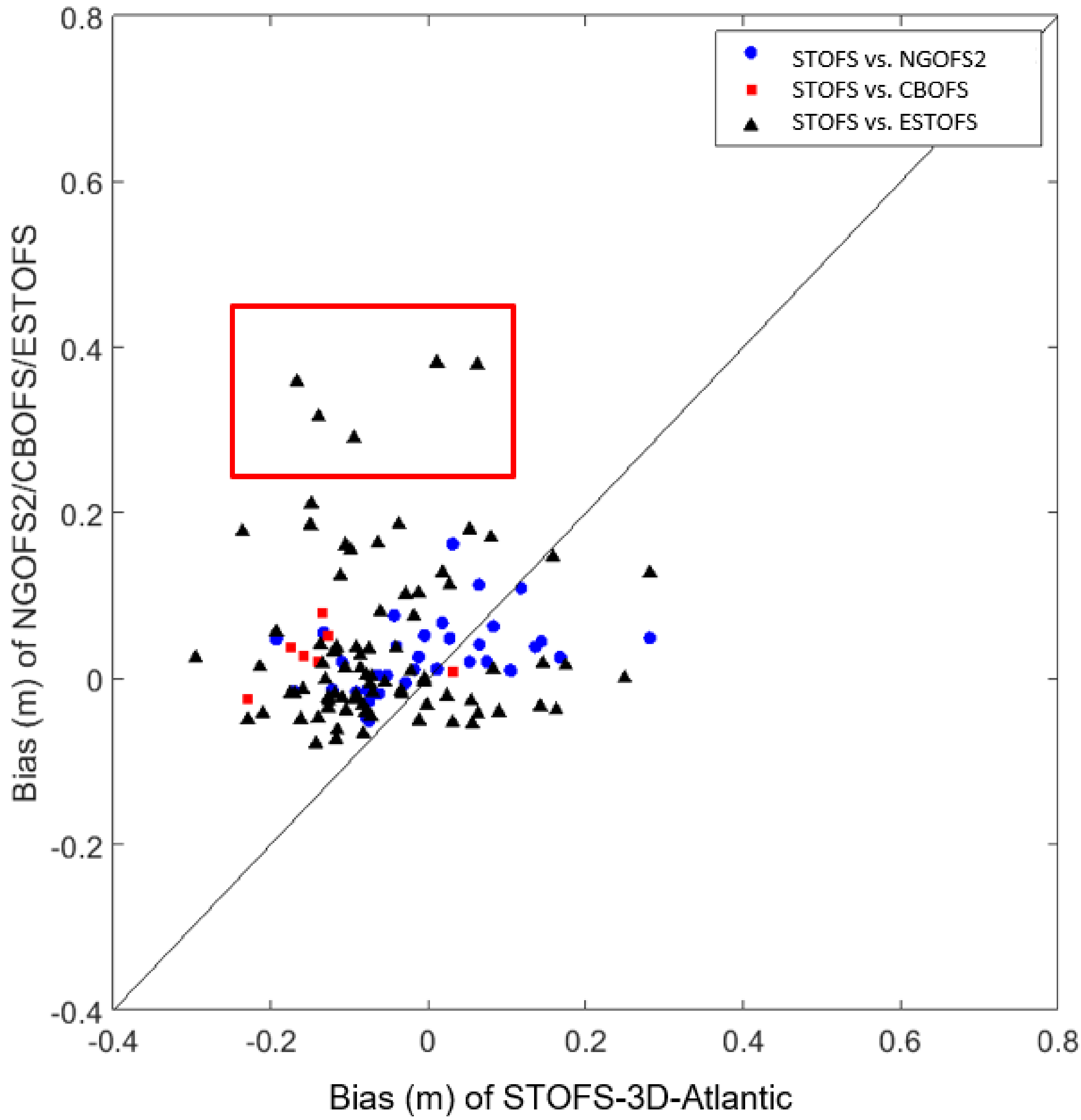

Figure IV.4 Comparison of bias and RMSE of the STOFS-3D-Atlantic w water level and the NGOFS2 / CBOFS / ESTOFS water levels

Shown on the plot are biases of the common stations (total of 126 stations) between STOFS-3D-Atlantic and NGOFS2, or CBOFS, or ESTOFS. They include 34 stations between STOFS-3D-Atlantic and NGOFS2, seven stations between STOFS-3D-Atlantic and CBOFS, and 85 stations between STOFS-3D-Atlantic and ESTOFS. Except for the five stations (outlined by the red rectangle on the plot), data points are scattered symmetrically around the black diagonal line. This indicates that in general, STOFS-

3D-Atlantic demonstrates a similar model skill of bias to the combined NGOFS2 / CBOFS / ESTOFS.

The five outlier stations (red rectangles) are stations 8539094, 8540433, 8545240, 8548989, and 8658120. The corresponding biases for these stations are 0.01 m, -0.14 m, -0.17 m, 0.06 m, and -0.09 m for STOFS-3D-Atlantic and are 0.38 m, 0.32 m, 0.36 m, 0.38 m, and 0.29 m for ESTOFS.

For STOFS-3D-Atlantic vs. NGOFS2 (blue circles), the NGOFS2 stations demonstrate a narrower range of bias that ranges from -0.05 m to 0.16 m compared with that of STOFS-3D-Atlantic that ranges from -0.19 m to 0.28 m.

For STOFS-3D-Atlantic vs. CBOFS (red squares), nearly all points are located above the diagonal line which reflects that the biases of CBOFS are greater than those of STOFS-3D-Atlantic. The bias of CBOFS ranges from -0.03 m to 0.08 m, whereas the bias of STOFS-3D-Atlantic ranges from -0.23 m to 0.03 m.

For STOFS-3D-Atlantic vs. ESTOFS (black triangles), most data points are located above the diagonal line which reflects that the biases of ESTOFS are greater than those of STOFS-3D-Atlantic. The bias of ESTOFS ranges from -0.08 m to 0.38 m, whereas the bias of STOFS-3D-Atlantic ranges from -0.30 m to 0.28 m.

Similar to Figure IV.4, shown on the plot are the RMSE of the common stations (total of 126 stations) between STOFS-3D-Atlantic and NGOFS2, or CBOFS, or ESTOFS. They include 34 stations between STOFS-3D-Atlantic and NGOFS2, seven stations between STOFS-3D-Atlantic and CBOFS, and 85 stations between STOFS-3D-Atlantic and ESTOFS. With the exception of the three stations (outlined by the red rectangle), the data points are scattered symmetrically around the black diagonal line. This indicates that in general, STOFS-3D-Atlantic demonstrates similar model skill of RMSE to the combined NGOFS2 / CBOFS / ESTOFS. The three outlier stations (outlined by the red rectangle) are stations 8539094, 8545240, and 8548989. The corresponding RMSEs for these stations are 0.10 m, 0.19 m, 0.21 m for STOFS-3D-Atlantic and are 0.50 m, 0.59 m, and 0.61 m for ESTOFS.

For STOFS-3D-Atlantic vs. NGOFS2 (blue circles), the NGOFS2 stations demonstrate a narrower range of RMSE that is between 0.07 m and 0.18 m compared with that of STOFS-3D-Atlantic that is between 0.06 m and 0.28 m.

For STOFS-3D-Atlantic vs. CBOFS (red squares), the CBOFS stations demonstrate a narrower range of RMSE that is between 0.06 m and 0.12 m compared with that of STOFS-3D-Atlantic that is between 0.06 m and 0.24 m.

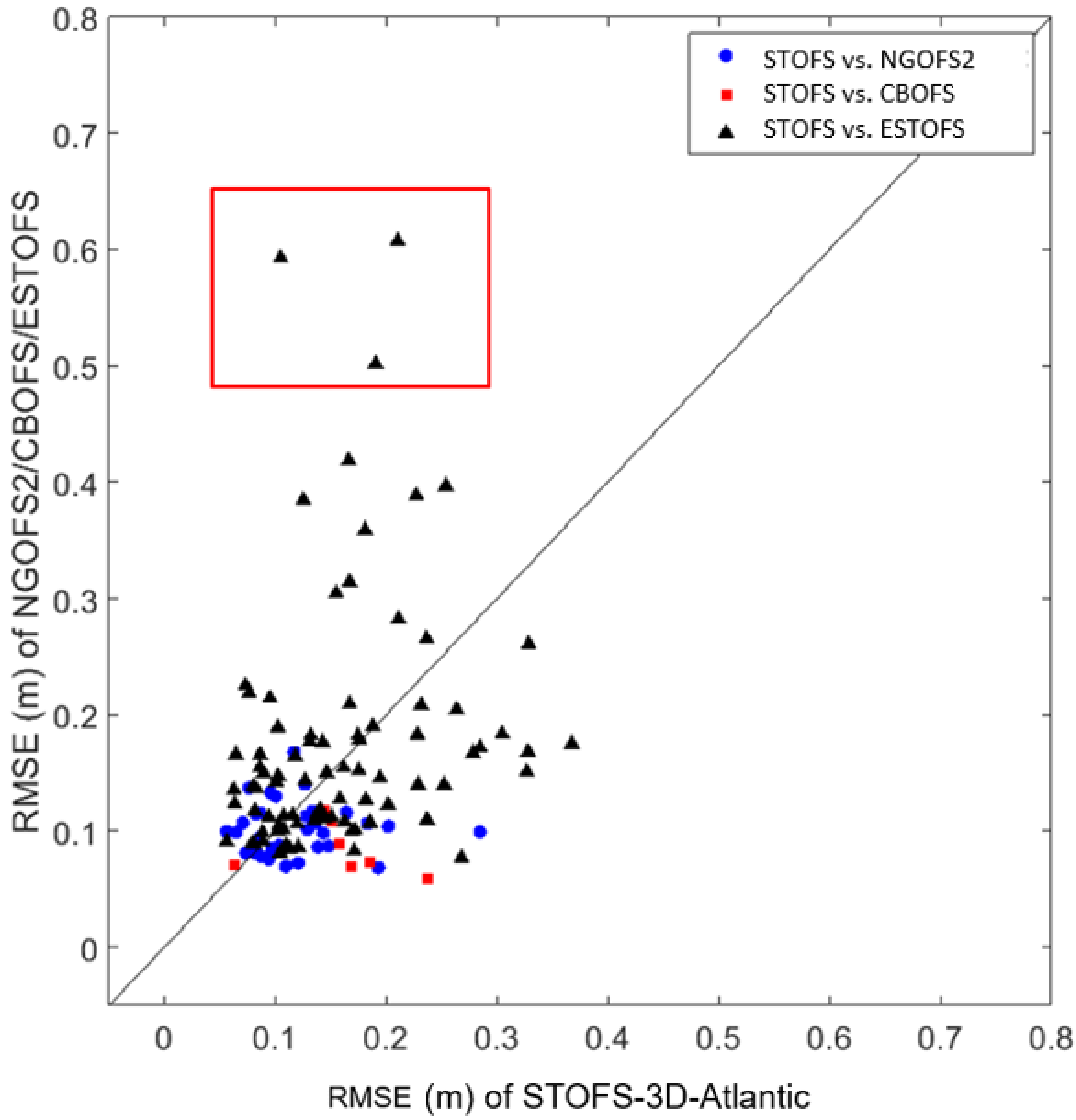

Figure IV.5 Comparison of RMSE between the STOFS-3D-Atlantic water level and the NGOFS2/CBOFS/ESTOFS water levels

For STOFS-3D-Atlantic vs. ESTOFS (black triangles), and except for the three stations described in the above, the vast majority of the data points are rather evenly distributed around the diagonal line. This indicates both STOFS-3D-Atlantic and ESTOFS demonstrate similar degree of skill. Excluding the three outlier stations, the RMSE of

ESTOFS ranges from 0.08 m to 0.42 m, whereas the RMSE of STOFS-3D-Atlantic ranges from 0.06 m to 0.37 m.

5. CONCLUDING REMARKS

The present study aims to compare the model water level skills of five NOS OFSs and, if possible, to identify the OFS which may demonstrate significantly better skills than the others. We selected five characteristic NOS OFSs (SFBOFS, CBOFS, NGOFS2, ESTOFS, and STOFS-3D-Atlantic) that represent either eastern, or western U.S. coastal waters, or both to investigate the skills of the model simulated water levels. These OFSs represent both the NOS port based OFS (SFBOFS and CBOFS) and bay or region based, larger domain OFS (NGOFS2, ESTOFS and STOFS-3D-Atlantic).

For this research, we calculated the bias and RMSE of the nowcast water levels by comparing the model time series with the observed data at various NOS NWLON stations. We also compared the model performance between/among the five OFSs by contrasting the water level bias and RMSE to gain insights into the relative model skills compared with each other. The study concluded that these five OFSs mentioned above demonstrated similar levels of model skills in terms of bias and RMSE. The model skill represents an integrated balance of multiple factors, such as the system configuration, the model numerical schemes, model grid resolution, the accuracy (skills) of the forcing data, etc. Of the five OFS, they each simultaneously have their merits and disadvantages compared with each other. The present study reveals that the five OFS demonstrated similar degrees of model performance in terms of the bias and RMSE of the nowcast water level. In certain areas, some OFS may exhibit slightly better skills, i.e., smaller bias or RMSE. However, none of the five OFS demonstrated statistically significantly better skills than the others.

The present study represents the first step toward gaining a thorough and comprehensive insight into the relative performance between/among various NOS OFS. We focused on investigating these five OFSs mentioned above among a total of over ten operational OFS during a time span of one to three months period. The to-do list for the next steps may include the following two tasks:

- Include other NOS OFSs in the skill assessment and an inter-OFS model skill comparison. This may help gain a thorough understanding of the overall model skills of the NOS OFS currently in operations.
- Extend the period of skill assessment to one year or even multiple years. This may help reveal the monthly, seasonal, and even the interannual variability of the model performance.

Except for the five OFSs discussed in the present study, there are many other NOS OFSs that are worth investigation. They are

- Delaware Bay Operational Forecast System (DBOFS).
- Gulf of Maine Operational Forecast System (GoMOFS).
- New York and New Jersey Operational Forecast System (NYOFS).
- St. John's River Operational Forecast System (SJROFS).
- Tampa Bay Operational Forecast System (TBOFS).
- Columbia River Estuary Operational Forecast System (CREOFS).
- Cook Inlet Operational Forecast System (CIOFS).
- West Coast Operational Forecast System (WCOFS).

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APPENDIX STATION METADATA FOR EACH OPERATIONAL FORECAST SYSTEM

Table A.1 Station IDs, names, and geographical locations of the SFBOFS stations

No.	ID	Name	Longitude (ºE)	Latitude (ºN)
001	9415144	PORTCHICAGO	-122.04	38.056
002	9415102	MARTINEZ-AMORCOPIER	-122.1248	38.0342
003	9415020	POINTREYES	-122.977	37.9961
004	9414863	RICHMOND	-122.4	37.9283
005	9414290	SANFRANCISCO	-122.465	37.8067
006	9414750	ALAMEDA	-122.298	37.7717
007	9414523	REDWOODCITY	-122.21	37.5067

Table A.2 Station IDs, names, and geographical locations of the NGOFS2 stations

No.	ID	Name	Longitude (ºE)	Latitude (ºN)
001	8775237	Port Aransas, TX	-97.0733	27.8383
002	8773701	Port O'Connor, TX	-96.3883	28.4517
003	8771013	Eagle Point, TX	-94.9183	29.48
004	8762075	Port Fourchon, LA	-90.1983	29.1133
005	8735180	Dauphin Island, AL	-88.075	30.25
006	8729840	Pensacola, AL	-87.2117	30.4033
007	8779770	Port Isabel, TX	-97.215	26.061
008	8775241	Aransas Pass, TX	-97.0383	27.8367
009	8774230	Aransas Wildlife Refuge, TX	-96.795	28.2283
010	8771450	Galveston Pier 21, TX	-94.7933	29.31
011	8771341	Galveston Bay Entrance, TX	-94.7233	29.3567
012	8770971	Rollover Pass, TX	-94.5133	29.515
013	8770808	High Island, TX	-94.39	29.595
014	8770475	Port Arthur, TX	-93.93	29.8667
015	8770822	Texas Point, TX	-93.8367	29.6767
016	8767816	Lake Charles, TX	-93.2217	30.2233
017	8767961	Bulk Terminal, TX	-93.3	30.19
018	8768094	Calcasieu Pass, TX	-93.3417	29.7667
019	8766072	Freshwater Canal, LA	-92.305	29.555
020	8764227	Atchafalaya Delta, LA	-91.3367	29.4483
021	8764314	Eugene Island, LA	-91.3833	29.3667
022	8761724	Grand Isle, LA	-89.9567	29.2633
023	8760922	Pilots Station, LA	-89.4067	28.9317
024	8761305	Shell Beach, LA	-89.6717	29.8667
025	8761927	New Canal Station, LA	-90.1133	30.0267
026	8747437	Bay Waveland, MS	-89.325	30.325
027	8741533	Pascagoula NOAA Lab, MS	-88.5617	30.3667
028	8737048	Mobile State Docks, AL	-88.0433	30.7083
029	8736897	USCG Sector Mobile, AL	-88.0583	30.6483
030	8735391	Dog River Bridge, AL	-88.0867	30.565
031	8735523	E Fow l River Bridge, AL	-88.1133	30.4433
032	8738043	W Fow l River Bridge, AL	-88.1583	30.3767
033	8739803	Bayou La Batre Bridge, AL	-88.2467	30.405
034	8729108	Panama City, AL	-85.6667	30.1517

Table A.3 Station IDs, names, and geographical locations of the CBOFS stations

No.	ID	Name	Longitude (ºE)	Latitude (ºN)
001	8574680	Baltimore	-76.5783	39.2667
002	8571892	Cambridge	-76.0683	38.5733
003	8575512	Annapolis	-76.48	38.9833
004	8577330	Solomons	-76.4517	38.3167
005	8632200	Kiptopeke	-75.9883	37.165
006	8638610	Sewells	-76.33	36.9467
007	8635750	Lewisetta	-76.4633	37.995

Table A.4 Station IDs, names, and geographical locations of the ESTOFS stations

No.	ID	Name	Longitude (ºE)	Latitude (ºN)
001	2695535	Bermuda Biological Station	-64.695	32.37
002	8410140	Eastport	-66.962	44.916
003	8411060	Cutler Farris Wharf	-67.1986	44.6523
004	8413320	Bar Harbor	-68.1997	44.3936
005	8418150	Portland	-70.2467	43.6567
006	8443970	Boston	-71.0503	42.3539
007	8447386	Fall River	-71.1663	41.7066
008	8447435	Chatham, Lydia Cove	-69.9505	41.6886
009	8447930	Woods Hole	-70.6711	41.5236
010	8449130	Nantucket Island	-70.0964	41.2853
011	8452660	Newport	-71.3267	41.505
012	8452944	Conimicut Light	-71.3433	41.7167
013	8454000	Providence	-71.3992	41.8067
014	8454049	Quonset Point	-71.411	41.5868
015	8461490	New London, Thames River	-72.0867	41.355
016	8465705	New Haven	-72.9083	41.2833
017	8467150	Bridgeport	-73.1841	41.175
018	8510560	Montauk	-71.9594	41.0483
019	8516945	Kings Point	-73.765	40.8103
020	8518750	The Battery	-74.0148	40.6995
021	8518962	Turkey Point Hudson River NERRS	-73.9389	42.0138
022	8519483	Bergen Point West Reach	-74.1177	40.6438
023	8531680	Sandy Hook	-74.0094	40.4669
024	8534720	Atlantic City	-74.4183	39.355
025	8536110	Cape May	-74.9597	38.9678
026	8537121	Ship John Shoal	-75.375	39.305
027	8539094	Burlington, Delaware River	-74.8733	40.08
028	8540433	Marcus Hook	-75.4094	39.8117
029	8545240	Philadelphia	-75.1402	39.9332
030	8546252	Bridesburg	-75.075	39.9833
031	8548989	Newbold	-74.7519	40.1373
032	8551762	Delaware City	-75.5883	39.5817
033	8551910	Reedy Point	-75.5733	39.5597
034	8555889	Brandywine Shoal Light	-75.1133	38.9867
035	8557380	Lewes	-75.1192	38.7828
036	8570283	Ocean City Inlet	-75.091	38.3278
037	8571421	Bishops Head	-76.0387	38.2204
038	8571892	Cambridge	-76.0694	38.5804
039	8573364	Tolchester Beach	-76.245	39.2133
040	8573927	Chesapeake City	-75.8126	39.529

No.	ID	Name	Longitude (ºE)	Latitude (ºN)
041	8574680	Baltimore, Fort McHenry, Patapsco River	-76.5783	39.2667
042	8575512	Annapolis	-76.4741	38.9805
043	8577330	Solomons Island	-76.4508	38.3172
044	8594900	Washington	-77.0217	38.8733
045	8631044	Wachapreague	-75.6858	37.6078
046	8632200	Kiptopeke	-75.9884	37.1652
047	8635027	Dahlgren	-77.0366	38.3197
048	8635750	Lewisetta	-76.4646	37.9954
049	8636580	Windmill Point	-76.2806	37.6073
050	8637689	Yorktown USCG Training Center	-76.4788	37.2265
051	8638610	Sewells Point	-76.33	36.9467
052	8638901	CBBT, Chesapeake Channel	-76.0833	37.0329
053	8639348	Money Point	-76.3017	36.7783
054	8651370	Duck	-75.7467	36.1833
055	8652587	Oregon Inlet Marina	-75.5481	35.795
056	8654467	USCG Station Hatteras	-75.7042	35.2086
057	8656483	Beaufort, Duke Marine Lab	-76.67	34.72
058	8658120	Wilmington	-77.9536	34.2275
059	8658163	Wrightsville Beach	-77.7867	34.2133
060	8661070	Springmaid Pier	-78.9183	33.655
061	8665530	Charleston, Cooper River Entrance	-79.9236	32.7808
062	8670870	Fort Pulaski	-80.9017	32.0367
063	8720030	Fernandina Beach	-81.4658	30.6714
064	8720218	Mayport, Bar Pilots Dock	-81.4279	30.3982
065	8720219	Dames Point	-81.5583	30.3867
066	8720226	Southbank Riverwalk, St Johns River	-81.6581	30.3209
067	8721604	Trident Pier, Port Canaveral	-80.5934	28.4157
068	8722670	Lake Worth Pier, Atlantic Ocean	-80.0342	26.6128
069	8722956	South Port Everglades	-80.1008	26.0889
070	8723214	Virginia Key, Biscayne Bay	-80.1618	25.7314
071	8723970	Vaca Key, Florida Bay	-81.1065	24.711
072	8724580	Key West	-81.8081	24.5508
073	8725110	Naples, Gulf of Mexico	-81.8075	26.1317
074	8725520	Fort Myers, Caloosahatchee River	-81.8712	26.6477
075	8726384	Port Manatee	-82.5625	27.6383
076	8726520	St. Petersburg, Tampa Bay	-82.6269	27.7606
077	8726607	Old Port Tampa	-82.5528	27.8578
078	8726724	Clearwater Beach	-82.8317	27.9783
079	8727520	Cedar Key	-83.102	29.0851
080	8728690	Apalachicola	-84.9817	29.7267

No.	ID	Name	Longitude (ºE)	Latitude (ºN)
081	8729108	Panama City	-85.6669	30.1523
082	8729210	Panama City Beach	-85.8783	30.2133
083	8729840	Pensacola	-87.2112	30.4044
084	8735180	Dauphin Island	-88.075	30.25
085	8735391	Dog River Bridge	-88.08	30.5639
086	8735523	East Fowl River Bridge	-88.109	30.4463
087	8736897	Coast Guard Sector Mobile	-88.0556	30.648
088	8737048	Mobile State Docks	-88.0433	30.7083
089	8737138	Chickasaw Creek	-88.0736	30.7819
090	8738043	West Fowl River Bridge	-88.1594	30.3749
091	8739803	Bayou La Batre Bridge	-88.2733	30.3765
092	8741533	Pascagoula NOAA Lab	-88.5655	30.3679
093	8747437	Bay Waveland Yacht Club	-89.325	30.325
094	8760721	Pilottown	-89.2583	29.1783
095	8760922	Pilots Station East, S.W. Pass	-89.4075	28.9322
096	8761305	Shell Beach	-89.6732	29.8681
097	8761724	Grand Isle	-89.9575	29.2679
098	8761927	New Canal Station	-90.112	30.0303
099	8762075	Port Fourchon, Belle Pass	-90.1993	29.1142
100	8764044	Berwick, Atchafalaya River	-91.2376	29.6675
101	8764227	Atchafalaya Delta, LA	-91.3459	29.456
102	8764314	Eugene Island, North of, Gulf of Mexico	-91.3839	29.3675
103	8766072	Freshwater Canal Locks	-92.3092	29.5266
104	8767816	Lake Charles	-93.2243	30.2241
105	8767961	Bulk Terminal	-93.3008	30.1902
106	8768094	Calcasieu Pass	-93.3429	29.7682
107	8770475	Port Arthur	-93.931	29.8671
108	8770520	Rainbow Bridge	-93.8642	29.9793
109	8770613	Morgans Point, Barbours Cut	-94.985	29.6817
110	8770777	Manchester	-95.2658	29.7262
111	8770808	High Island	-94.3903	29.5947
112	8770822	Texas Point, Sabine Pass	-93.8408	29.6897
113	8770971	Rollover Pass	-94.5106	29.5156
114	8771013	Eagle Point, Galveston Bay	-94.9183	29.48
115	8771341	Galveston Bay Entrance, North Jetty	-94.7248	29.3573
116	8771450	Galveston Pier 21	-94.7933	29.31
117	8771486	Galveston Railroad Bridge	-94.8971	29.3026
118	8771972	San Luis Pass	-95.1313	29.081
119	8772471	Freeport SPIP, Freeport Harbor	-95.2942	28.9357
120	8772985	Sargent	-95.6172	28.7714

No.	ID	Name	Longitude (ºE)	Latitude (ºN)
121	8773037	Seadrift	-96.7319	28.3891
122	8773146	Matagorda City	-95.914	28.7101
123	8773259	Port Lavaca	-96.6098	28.6406
124	8773701	Port O.Connor	-96.3956	28.4459
125	8773767	Matagorda Bay Entrance Channel	-96.3301	28.4269
126	8774230	Aransas Wildlife Refuge	-96.7816	28.2199
127	8774770	Rockport	-97.0403	28.0187
128	8775237	Port Aransas	-97.0725	27.8397
129	8775241	Aransas, Aransas Pass	-97.0391	27.8366
130	8775296	USS Lexington, Corpus Christi Bay	-97.3892	27.8149
131	8775870	Bob Hall Pier, Corpus Christi	-97.2167	27.58
132	8779280	Realitos Peninsula	-97.2853	26.2624
133	8779748	South Padre Island CG Station	-97.1675	26.0731
134	8779749	SPI Brazos Santiago	-97.1548	26.0674
135	8779770	Port Isabel	-97.166	26.0649

Table A.5 Station IDs, names, and geographical locations of the STOFS-3D-Atlantic stations

No.	ID	Name	Longitude (ºE)	Latitude (ºN)
001	2695535	Bermuda Biological Station	-64.695	32.37
002	8410140	Eastport	-66.962	44.916
003	8411060	Cutler Farris Wharf	-67.1986	44.6523
004	8413320	Bar Harbor	-68.1997	44.3936
005	8418150	Portland	-70.2467	43.6567
006	8443970	Boston	-71.0503	42.3539
007	8447386	Fall River	-71.1663	41.7066
008	8447435	Chatham, Lydia Cove	-69.9505	41.6886
009	8447930	Woods Hole	-70.6711	41.5236
010	8449130	Nantucket Island	-70.0964	41.2853
011	8452660	Newport	-71.3267	41.505
012	8452944	Conimicut Light	-71.3433	41.7167
013	8454000	Providence	-71.3992	41.8067
014	8454049	Quonset Point	-71.411	41.5868
015	8461490	New London, Thames River	-72.0867	41.355
016	8465705	New Haven	-72.9083	41.2833
017	8467150	Bridgeport	-73.1841	41.175
018	8510560	Montauk	-71.9594	41.0483
019	8516945	Kings Point	-73.765	40.8103
020	8518750	The Battery	-74.0148	40.6995
021	8518962	Turkey Point Hudson River NERRS	-73.9389	42.0138
022	8519483	Bergen Point West Reach	-74.1177	40.6438
023	8531680	Sandy Hook	-74.0094	40.4669
024	8534720	Atlantic City	-74.4183	39.355
025	8536110	Cape May	-74.9597	38.9678
026	8537121	Ship John Shoal	-75.375	39.305
027	8539094	Burlington, Delaware River	-74.8733	40.08
028	8540433	Marcus Hook	-75.4094	39.8117
029	8545240	Philadelphia	-75.1402	39.9332
030	8546252	Bridesburg	-75.075	39.9833
031	8548989	Newbold	-74.7519	40.1373
032	8551762	Delaware City	-75.5883	39.5817
033	8551910	Reedy Point	-75.5733	39.5597
034	8555889	Brandywine Shoal Light	-75.1133	38.9867
035	8557380	Lewes	-75.1192	38.7828
036	8570283	Ocean City Inlet	-75.091	38.3278
037	8571421	Bishops Head	-76.0387	38.2204
038	8571892	Cambridge	-76.0694	38.5804
039	8573364	Tolchester Beach	-76.245	39.2133
040	8573927	Chesapeake City	-75.8126	39.529
041	8574680	Baltimore, Fort McHenry, Patapsco River	-76.5783	39.2667
042	8575512	Annapolis	-76.4741	38.9805
043	8577330	Solomons Island	-76.4508	38.3172
044	8594900	Washington	-77.0217	38.8733

No.	ID	Name	Longitude (ºE)	Latitude (ºN)
045	8631044	Wachapreague	-75.6858	37.6078
046	8632200	Kiptopeke	-75.9884	37.1652
047	8635027	Dahlgren	-77.0366	38.3197
048	8635750	Lewisetta	-76.4646	37.9954
049	8636580	Windmill Point	-76.2806	37.6073
050	8637689	Yorktown USCG Training Center	-76.4788	37.2265
051	8638610	Sewells Point	-76.33	36.9467
052	8638901	CBBT, Chesapeake Channel	-76.0833	37.0329
053	8639348	Money Point	-76.3017	36.7783
054	8651370	Duck	-75.7467	36.1833
055	8652587	Oregon Inlet Marina	-75.5481	35.795
056	8654467	USCG Station Hatteras	-75.7042	35.2086
057	8656483	Beaufort, Duke Marine Lab	-76.67	34.72
058	8658120	Wilmington	-77.9536	34.2275
059	8658163	Wrightsville Beach	-77.7867	34.2133
060	8661070	Springmaid Pier	-78.9183	33.655
061	8665530	Charleston, Cooper River Entrance	-79.9236	32.7808
062	8670870	Fort Pulaski	-80.9017	32.0367
063	8720030	Fernandina Beach	-81.4658	30.6714
064	8720218	Mayport, Bar Pilots Dock	-81.4279	30.3982
065	8720219	Dames Point	-81.5583	30.3867
066	8720226	Southbank Riverwalk, St Johns River	-81.6581	30.3209
067	8721604	Trident Pier, Port Canaveral	-80.5934	28.4157
068	8722670	Lake Worth Pier, Atlantic Ocean	-80.0342	26.6128
069	8722956	South Port Everglades	-80.1008	26.0889
070	8723214	Virginia Key, Biscayne Bay	-80.1618	25.7314
071	8723970	Vaca Key, Florida Bay	-81.1065	24.711
072	8724580	Key West	-81.8081	24.5508
073	8725110	Naples, Gulf of Mexico	-81.8075	26.1317
074	8725520	Fort Myers, Caloosahatchee River	-81.8712	26.6477
075	8726384	Port Manatee	-82.5625	27.6383
076	8726520	St. Petersburg, Tampa Bay	-82.6269	27.7606
077	8726607	Old Port Tampa	-82.5528	27.8578
078	8726724	Clearwater Beach	-82.8317	27.9783
079	8727520	Cedar Key	-83.102	29.0851
080	8728690	Apalachicola	-84.9817	29.7267
081	8729108	Panama City	-85.6669	30.1523
082	8729210	Panama City Beach	-85.8783	30.2133
083	8729840	Pensacola	-87.2112	30.4044
084	8735180	Dauphin Island	-88.075	30.25
085	8735391	Dog River Bridge	-88.08	30.5639
086	8735523	East Fowl River Bridge	-88.109	30.4463
087	8736897	Coast Guard Sector Mobile	-88.0556	30.648
088	8737048	Mobile State Docks	-88.0433	30.7083
089	8737138	Chickasaw Creek	-88.0736	30.7819
090	8738043	West Fowl River Bridge	-88.1594	30.3749
091	8739803	Bayou La Batre Bridge	-88.2733	30.3765

No.	ID	Name	Longitude (ºE)	Latitude (ºN)
092	8741533	Pascagoula NOAA Lab	-88.5655	30.3679
093	8747437	Bay Waveland Yacht Club	-89.325	30.325
094	8760721	Pilottown	-89.2583	29.1783
095	8760922	Pilots Station East, S.W. Pass	-89.4075	28.9322
096	8761305	Shell Beach	-89.6732	29.8681
097	8761724	Grand Isle	-89.9575	29.2679
098	8761927	New Canal Station	-90.112	30.0303
099	8762075	Port Fourchon, Belle Pass	-90.1993	29.1142
100	8764044	Berwick, Atchafalaya River	-91.2376	29.6675
101	8764227	Atchafalaya Delta, LA	-91.3459	29.456
102	8764314	Eugene Island, North of, Gulf of Mexico	-91.3839	29.3675
103	8766072	Freshwater Canal Locks	-92.3092	29.5266
104	8767816	Lake Charles	-93.2243	30.2241
105	8767961	Bulk Terminal	-93.3008	30.1902
106	8768094	Calcasieu Pass	-93.3429	29.7682
107	8770475	Port Arthur	-93.931	29.8671
108	8770520	Rainbow Bridge	-93.8642	29.9793
109	8770613	Morgans Point, Barbours Cut	-94.985	29.6817
110	8770777	Manchester	-95.2658	29.7262
111	8770808	High Island	-94.3903	29.5947
112	8770822	Texas Point, Sabine Pass	-93.8408	29.6897
113	8770971	Rollover Pass	-94.5106	29.5156
114	8771013	Eagle Point, Galveston Bay	-94.9183	29.48
115	8771341	Galveston Bay Entrance, North Jetty	-94.7248	29.3573
116	8771450	Galveston Pier 21	-94.7933	29.31
117	8771486	Galveston Railroad Bridge	-94.8971	29.3026
118	8771972	San Luis Pass	-95.1313	29.081
119	8772471	Freeport SPIP, Freeport Harbor	-95.2942	28.9357
120	8772985	Sargent	-95.6172	28.7714
121	8773037	Seadrift	-96.7319	28.3891
122	8773146	Matagorda City	-95.914	28.7101
123	8773259	Port Lavaca	-96.6098	28.6406
124	8773701	Port O.Connor	-96.3956	28.4459
125	8773767	Matagorda Bay Entrance Channel	-96.3301	28.4269
126	8774230	Aransas Wildlife Refuge	-96.7816	28.2199
127	8774770	Rockport	-97.0403	28.0187
128	8775237	Port Aransas	-97.0725	27.8397
129	8775241	Aransas, Aransas Pass	-97.0391	27.8366
130	8775296	USS Lexington, Corpus Christi Bay	-97.3892	27.8149
131	8775870	Bob Hall Pier, Corpus Christi	-97.2167	27.58
132	8779280	Realitos Peninsula	-97.2853	26.2624
133	8779748	South Padre Island CG Station	-97.1675	26.0731
134	8779749	SPI Brazos Santiago	-97.1548	26.0674
135	8779770	Port Isabel	-97.166	26.0649