NOAA Technical Memorandum NESDIS NGDC-44

DIGITAL ELEVATION MODELS OF MOBILE, ALABAMA: PROCEDURES, DATA SOURCES AND ANALYSIS

C.J. Amante
M.R. Love
L.A. Taylor
B.W. Eakins

National Geophysical Data Center
Marine Geology and Geophysics Division
Boulder, Colorado
August 2011

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / National Environmental Satellite, Data, and Information Service

NOAA Technical Memorandum NESDIS NGDC-44

DIGITAL ELEVATION MODELS OF MOBILE, ALABAMA: PROCEDURES, DATA SOURCES AND ANALYSIS

Christopher J. Amante[1]
Matthew R. Love[1]
Lisa A. Taylor[2]
Barry W. Eakins[1]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado at Boulder

[2]NOAA, National Geophysical Data Center, Boulder, Colorado

National Geophysical Data Center
Marine Geology and Geophysics Division
Boulder, Colorado
August 2011

UNITED STATES DEPARTMENT OF COMMERCE

Gary Locke
Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Dr. Jane Lubchenco
Under Secretary for Oceans and Atmosphere/Administrator

National Environmental Satellite, Data, and Information Service

Mary E. Kicza
Assistant Administrator

NOTICE

Corresponding project contact:
Lisa A. Taylor
NOAA National Geophysical Data Center
Marine Geology and Geophysics Division
325 Broadway, E/GC 3
Boulder, Colorado 80305
Phone: 303-497-6767
Fax: 303-497-6513
E-mail: Lisa.A.Taylor@noaa.gov
http://www.ngdc.noaa.gov/mgg/inundation/vdatum/vdatum.html

Also available from the National Technical Information Service (NTIS)
(http://www.ntis.gov)

Contents

List of Figures

List of Tables

Digital Elevation Models of Mobile, Alabama: Procedures, Data Sources and Analysis

1. Introduction

The National Geophysical Data Center (NGDC), an office of the National Oceanic and Atmospheric Administration (NOAA), has developed two bathymetric–topographic digital elevation models (DEMs) of Mobile, AL (Fig. 1). The DEMs were developed for NOAA Coast Survey Development Laboratory (CSDL) through the American Recovery and Reinvestment Act (ARRA) of 2009[1] to evaluate the utility of the *Vertical Datum Transformation* tool (*VDatum*), developed jointly by NOAA's Office of Coast Survey (OCS), National Geodetic Survey (NGS), and Center for Operational Oceanographic Products and Services (CO-OPS) (http://vdatum.noaa.gov/).The 1/3 arc-second[2] DEM referenced to North American Vertical Datum of 1988 (NAVD 88) was carefully developed and evaluated. A NAVD 88 to mean high water (MHW) 1/3 arc-second conversion grid derived from *VDatum* projects areas was then created to model the relationship between NAVD 88 and MHW in the Mobile region. NGDC combined the NAVD 88 DEM and the conversion grid to develop a 1/3 arc-second MHW DEM. The NAVD 88 DEM were generated from diverse digital datasets in the region (grid boundary and sources shown in Fig. 5) and the DEMs will be used for storm-surge inundation and sea-level-rise modeling. This report provides a summary of the data sources and methodology used in developing the Mobile DEMs.

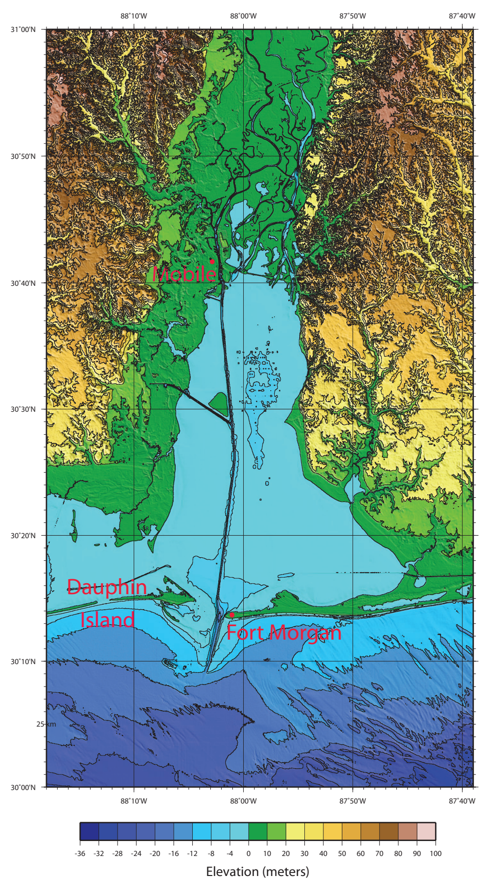

Figure 1. *Shaded-relief image of the Mobile NAVD 88 DEM. Contour interval is 4 meters for bathymetry and 10 meters for topography.*

1. On Feb. 13, 2009, Congress passed the American Recovery and Reinvestment Act of 2009 at the urging of President Obama, who signed it into law four days later. A direct response to the economic crisis, the Recovery Act's three goals are to create new jobs as well as save existing ones, spur economic activity and invest in long-term economic growth and foster unprecedented levels of accountability and transparency in government spending (http://www.recovery.gov/Pages/home.aspx).

2. The Mobile DEM is built upon a grid of cells that are square in geographic coordinates (latitude and longitude), however, the cells are not square when converted to projected coordinate systems, such as UTM zones (in meters). At the latitude of Mobile, AL (30°40'46" N, 88°6'12" W) 1/3 arc-second of latitude is equivalent to 10.27 meters; 1/3 arc-second of longitude equals 8.87 meters.

2. Study Area

The Mobile DEMs cover the southern coast of Alabama including the city of Mobile and the Mobile Bay estuary. Mobile Bay is enclosed by the Mobile River delta to the north and the Fort Morgan Peninsula and the dynamic barrier island, Dauphin Island, to the south (Fig. 2). Barrier islands are unstable environments with constant erosion, deposition, and migration of sediment under wave action (Figs. 3, 4). Along with sediment transportation issues, rising sea level is another concern for coastal managers and property owners. There are approximately 1,300 permanent residents on Dauphin Island, in addition to being a popular vacation destination (http://townofdauphinisland.org).

Geologically, Mobile Bay originated as an incised fluvial valley that flooded after the last postglacial sea-level rise. Over the past 4,000 years, the mouth of the Mobile River has alternatively incised and flooded due to sea-level fluctuations of as much as 90 feet. The periods of incision and flooding caused the Mobile River valley to fill with estuarine mud, in addition to the formation of sandy shoals and barrier islands such as Dauphin Island. Today, Mobile Bay continues to fill with sediment from fluvial and marine sources (Kindinger 2004).

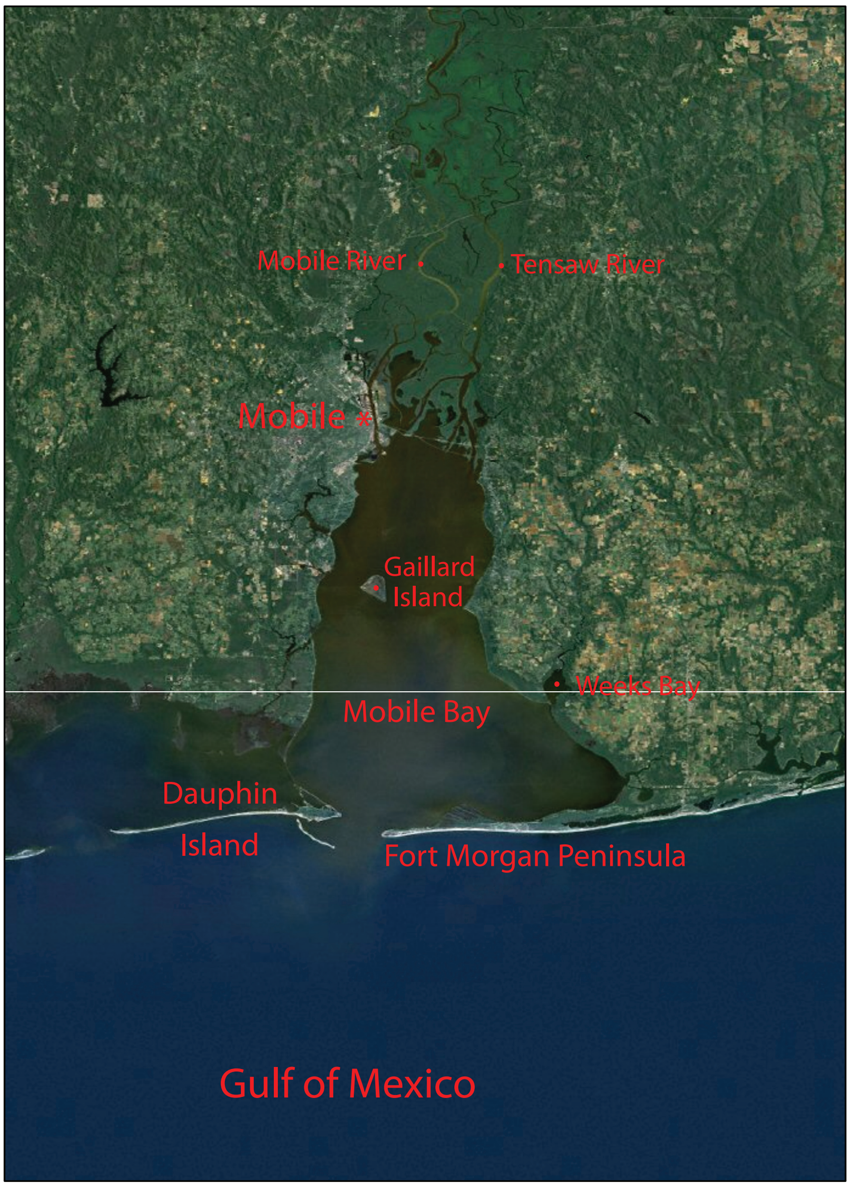

Figure 2. *ESRI World 2D imagery of the Mobile area.*

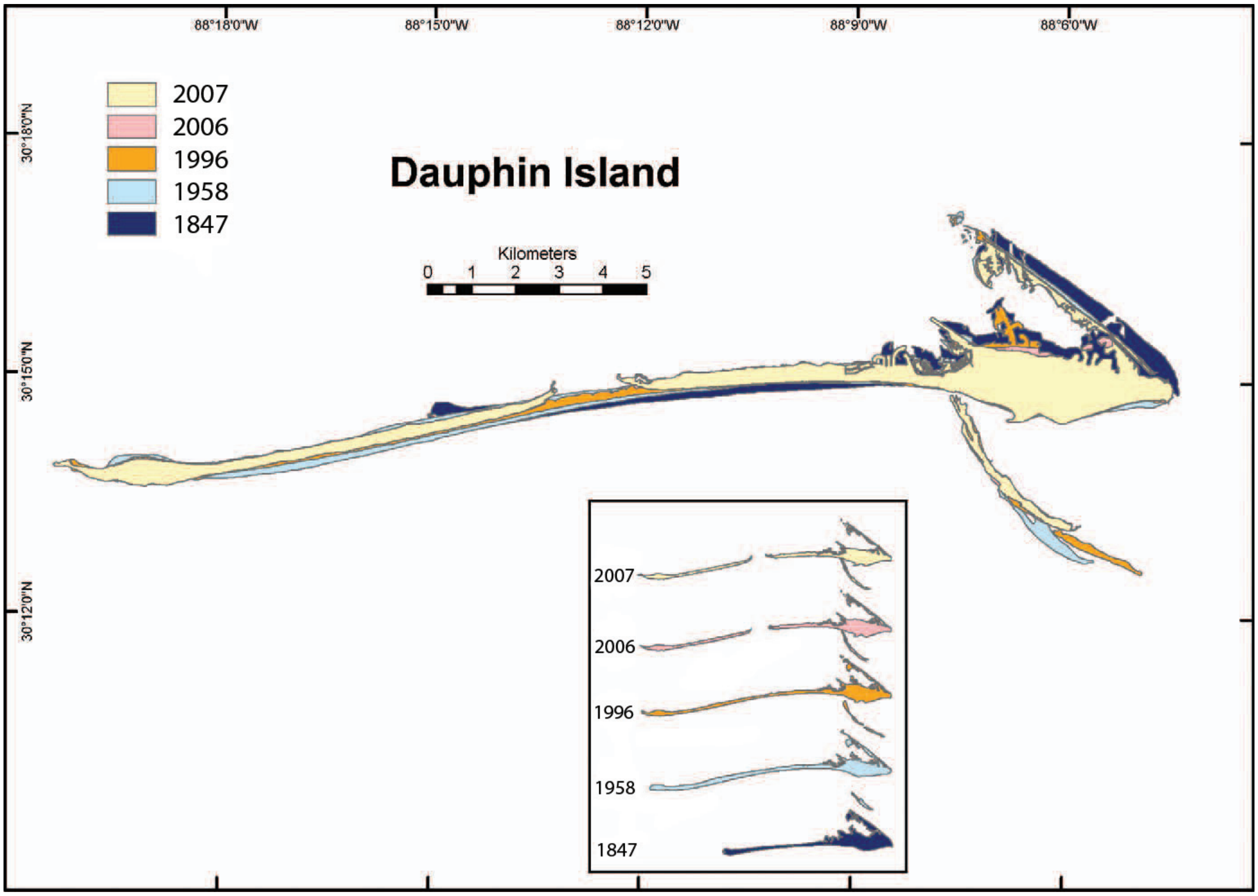

***Figure 3.** Morphologic and spatial changes in Dauphin Island between 1847 and 2007 (Morton 2008).*

***Figure 4.** Separation of the western portion of Dauphin Island shown on Oct. 3, 2007. The separation was initially caused by Hurricane Ivan in 2004. The separation was filled and then reopened by Hurricane Katrina in 2005. (http://blog.al.com/live/2009/08/large_Dauphin%20Island.JPG)*

3. Methodology

The Mobile DEMs were constructed to meet CSDL specifications, based on storm-surge inundation and sea-level-rise modeling requirements (Tables 1, 2). The best available digital data were obtained by NGDC and shifted to common horizontal and vertical datums: North America Datum 1983 (NAD 83) and North American Vertical Datum (NAVD 88). NGDC developed a conversion grid derived from *VDatum* project areas to transform the Mobile DEM in its entirety from NAVD 88 to MHW, for modeling of maximum flooding. Data were gathered in an area slightly larger (~5%) than the DEM extents. This data "buffer" ensures that gridding occurs across rather than along the DEM boundaries to prevent edge effects. Data processing and evaluation, and the DEM assembly and assessment are described in the following subsections.

Table 1. Specifications for the Mobile NAVD 88 DEM.

Grid Area	Mobile, Alabama
Coverage Area	87.65º to 88.3º W; 30.0º to 31.0º N
Coordinate System	Geographic decimal degrees
Horizontal Datum	North American Datum 1983 (NAD 83)
Vertical Datum	North American Vertical Datum 1988 (NAVD 88)
Vertical Units	Meters
Grid Spacing	1/3 arc-second
Grid Format	ESRI Arc ASCII grid

Table 2. Specifications for the Mobile MHW DEM.

Grid Area	Mobile, Alabama
Coverage Area	87.65º to 88.3º W; 30.0º to 31.0º N
Coordinate System	Geographic decimal degrees
Horizontal Datum	North American Datum 1983 (NAD 83)
Vertical Datum	Mean High Water (MHW)
Vertical Units	Meters
Grid Spacing	1/3 arc-second
Grid Format	ESRI Arc ASCII grid

3.1 Data Sources and Processing

Coastline, bathymetric, and topographic digital datasets (Fig. 5) were obtained from NOAA's Coastal Services Center (CSC), NGDC, OCS, and NGS, U.S. Army Corps of Engineers (USACE), National Aeronautic and Space Administration (NASA), Mobile County, AL, Baldwin County, AL, and the City of Gulf Shores, AL. Safe Software's *Feature Manipulation Engine*[3] (*FME)* data translation tool package was used to shift datasets to NAD 83 horizontal datum. The datasets were then displayed with ESRI's *ArcGIS,* ESRI's online *World 2D* imagery and Applied Imagery's *Quick Terrain Modeler* software (*QT Modeler*) to assess data quality and manually edit datasets. Vertical datum transformations to NAVD 88 were accomplished using NOAA's jointly developed *VDatum* software and *ArcGIS* based upon *VDatum* coverage (see section 3.2.3).

3. *FME* uses the North American Datum Conversion Utility (NADCON; http://www.ngs.noaa.gov/TOOLS/Nadcon/Nadcon.shtml) developed by NOAA's National Geodetic Survey (NGS) to convert data from NAD 27 to NAD 83. NADCON is the U.S Federal Standard for NAD 27 to NAD 83 datum transformations.

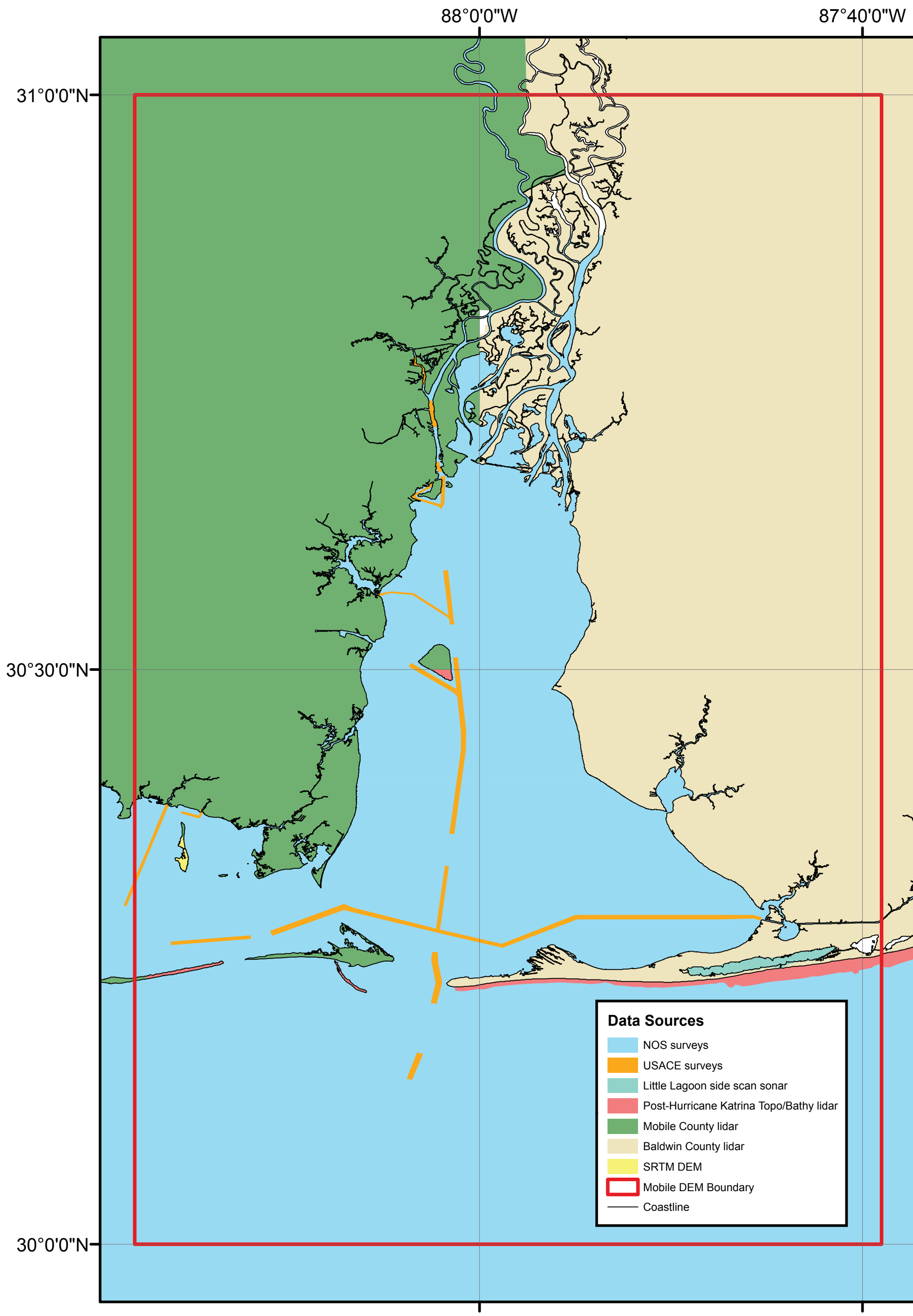

Figure 5. *Source and coverage of datasets used in building the Mobile NAVD 88 DEM.*

3.1.1 Coastline

Coastline datasets of the Mobile region were obtained from NGS and OCS (http://www.nauticalcharts.noaa.gov/). NGDC evaluated but did not use coastline data obtained from OCS ENCs (e.g. ENC US4AL11M; Fig. 6) as the NGS coastline was more detailed and closely matched bathymetric and high-resolution topographic datasets (Table 3).

Table 3. Coastline datasets used in building the Mobile NAVD 88 DEM.

Source	*Year*	*Data Type*	*Spatial Resolution*	*Original Horizontal Datum*	*Original Vertical Datum*	*URL*
NGS	1978 - 1986	Composite vectorized coastline from aerial photography	Not defined	NAD 83 geographic	MHW	http://www.ngs.noaa.gov/newsys_ims/shoreline/index.cfm

1) **NGS Alabama state composite coastline**

The Alabama state composite coastline was downloaded from NOAA's NGS web site (see Table 3). The coastline represents the NGS 2001 interpretation of aerial photographs taken between January 1, 1978 through March 1, 1986. NGDC edited the coastline to reflect the zero elevation line in lidar data referenced to NAVD 88 and to include recent morphologic change. The final coastline was draped over ESRI's online *World 2D* imagery in *ArcMap* and edited to include all tidal bays, channels, fingers, jetties, and breakwaters. Piers and bridges were excluded from the final coastline.

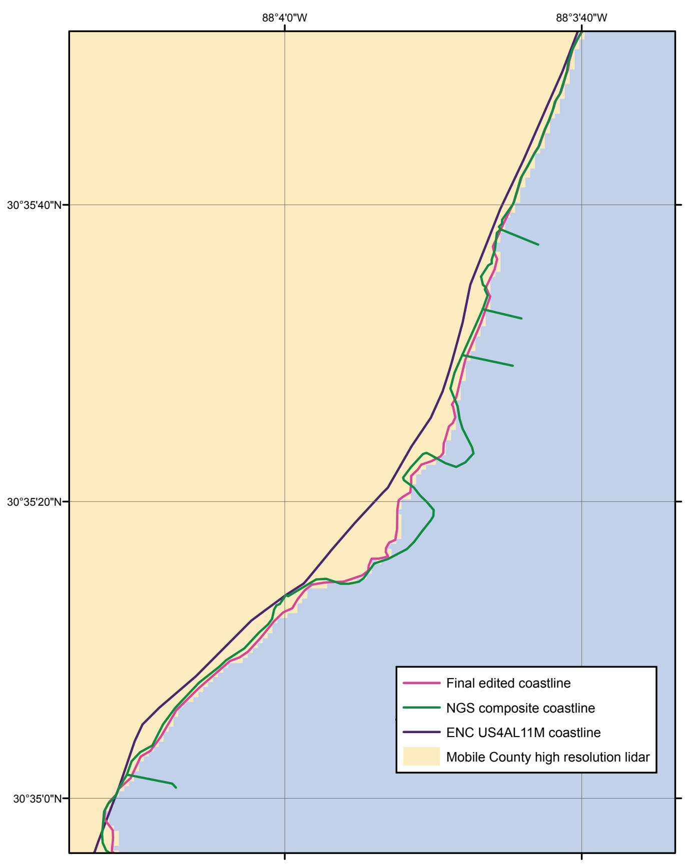

Figure 6. *Portion of available digital coastline datasets in the Mobile region.*

3.1.2 Bathymetry

Bathymetric datasets available in the Mobile region include 69 National Oceanographic Survey (NOS) hydrographic surveys, 14 USACE hydrographic surveys of dredged channels and bathymetric soundings from the City of Gulf Shores, AL (Table 4). The multibeam swath sonar survey EW0403 (http://www.ngdc.noaa.gov/mgg/bathymetry/multibeam.html) was evaluated but not used in building the DEM as the data coverage were noisy in the shallow waters of Mobile Bay.

Table 4. Bathymetric datasets used in building the Mobile NAVD 88 DEM.

Source	*Year*	*Data Type*	*Spatial Resolution*	*Original Horizontal Datum*	*Original Vertical Datum*	*URL*
NOS - CSDL	1888 to 2001	Hydrographic survey soundings	Ranges from 1:5,000 to 1:80,000 (varies with scale of survey, depth, traffic, and probability of obstructions)	NAD 83 geographic	MLLW or MLW	http://www.ngdc.noaa.gov/mgg/bathymetry/hydro.html
USACE Mobile District	2009	Hydrographic survey soundings	Line spacing ranging from 60 to 120 m apart and point spacing 5 to 10 m	NAD 83 Alabama State Plane West (feet)	MLLW (feet)	http://www.sam.usace.army.mil/
City of Gulf Shores	2002 to 2008	Side-scan sonar soundings	6.1 m	NAD 83 Alabama State Plane West (feet)	NAVD 88	http://www.gulf-shoresal.gov/
NGDC	2009	Digitized soundings		NAD 83 geographic	NAVD 88	

1) **NOS hydrographic surveys**

A total of 69 NOS hydrographic surveys conducted between 1888 and 2001 were available for use in developing the Mobile DEMs (Table 5; Fig. 7). CSDL provided NGDC with a non-superceded database of NOS hydrographic surveys. The database excluded NOS survey data if there were more recent NOS survey data at the same location. NGDC also manually edited older NOS hydrographic survey data that were inconsistent with USACE soundings in more recently dredged channels. The data are vertically referenced to Mean Lower Low Water (MLLW) or Mean Low Water (MLW) and horizontally referenced to NAD 83 geographic. Survey data were used in an area 0.05 degree (~5%) larger than the Mobile DEM extent to support data interpolation across grid edges. Data point spacing for the NOS surveys varies by collection date. In general, earlier surveys have greater point spacing than more recent surveys.

NOS survey data were transformed from MLLW or MLW to NAVD 88 using *VDatum*. NOS survey data in the bays and rivers that empty into Mobile Bay such as Weeks Bay and the Mobile River were located outside of the *VDatum* coverage area. Such data were vertically transformed to NAVD 88 by comparing the *VDatum* conversion of nearby soundings and using an equivalent constant offset (see Sec. 3.2.3). The data were displayed in ESRI *ArcMap* and reviewed for digitizing errors against scanned original survey smooth sheets and edited as necessary. The surveys were also compared to the various topographic and bathymetric data, the final coastline, and OCS Raster Navigational Charts (RNCs).

Table 5. Digital NOS hydrographic surveys available in the Mobile DEM region.

Survey ID	*Year*	*Scale*	*Original Vertical Datum*	*Provided Horizontal Datum*
D00065	1987	80,000	MLLW	NAD 83 geographic
D00078	1987	40,000	MLLW	NAD 83 geographic
H01909	1888	5,000	MLW	NAD 83 geographic
H01910	1888	5,000	MLW	NAD 83 geographic
H01911	1888	5,000	MLW	NAD 83 geographic
H01912	1888	5,000	MLW	NAD 83 geographic
H01913	1888	5,000	MLW	NAD 83 geographic
H01914	1888	5,000	MLW	NAD 83 geographic
H01915	1888	5,000	MLW	NAD 83 geographic
H01916	1888	5,000	MLW	NAD 83 geographic
H04139	1920	80,000	MLW	NAD 83 geographic
H04171	1920	80,000	MLW	NAD 83 geographic
H05707	1935	10,000	MLW	NAD 83 geographic
H05723	1935	10,000	MLW	NAD 83 geographic
H05730	1935	20,000	MLW	NAD 83 geographic
H06552	1940	40,000	MLW	NAD 83 geographic
H06554	1940	40,000	MLW	NAD 83 geographic
H06634	1940	20,000	MLW	NAD 83 geographic
H06685	1941	20,000	MLW	NAD 83 geographic
H06686	1941	20,000	MLW	NAD 83 geographic
H06688	1941	40,000	MLW	NAD 83 geographic
H08524	1960	10,000	MLW	NAD 83 geographic
H08525	1960	10,000	MLW	NAD 83 geographic
H08526	1960	10,000	MLW	NAD 83 geographic
H08560	1961	10,000	MLW	NAD 83 geographic
H08561	1961	10,000	MLW	NAD 83 geographic
H08562	1960	10,000	MLW	NAD 83 geographic
H08563	1960	20,000	MLW	NAD 83 geographic
H08573	1961	10,000	MLW	NAD 83 geographic
H08574	1961	10,000	MLW	NAD 83 geographic
H08575	1961	10,000	MLW	NAD 83 geographic
H08584	1961	5,000	MLW	NAD 83 geographic
H08585	1961	5,000	MLW	NAD 83 geographic
H08586	1961	10,000	MLW	NAD 83 geographic
H08587	1961	10,000	MLW	NAD 83 geographic
H08588	1961	10,000	MLW	NAD 83 geographic
H08589	1961	10,000	MLW	NAD 83 geographic

Survey ID	*Year*	*Scale*	*Original Vertical Datum*	*Provided Horizontal Datum*
H08590	1962	10,000	MLW	NAD 83 geographic
H08591	1961	10,000	MLW	NAD 83 geographic
H08592	1961	10,000	MLW	NAD 83 geographic
H08633	1962	10,000	MLW	NAD 83 geographic
H08634	1961	10,000	MLW	NAD 83 geographic
H08635	1961	10,000	MLW	NAD 83 geographic
H08636	1961	10,000	MLW	NAD 83 geographic
H08642	1961	10,000	MLW	NAD 83 geographic
H08643	1962	10,000	MLW	NAD 83 geographic
H08644	1964	10,000	MLW	NAD 83 geographic
H08647	1962	20,000	MLW	NAD 83 geographic
H08948	1962	20,000	MLW	NAD 83 geographic
H09109	1970	20,000	MLW	NAD 83 geographic
H09118	1975	20,000	MLW	NAD 83 geographic
H10053	1985	40,000	MLLW	NAD 83 geographic
H10114	1986	20,000	MLLW	NAD 83 geographic
H10151A	1986	20,000	MLLW	NAD 83 geographic
H10151B	1986	20,000	MLLW	NAD 83 geographic
H10179	1987	20,000	MLLW	NAD 83 geographic
H10180	1986	40,000	MLLW	NAD 83 geographic
H10206	1985	40,000	MLLW	NAD 83 geographic
H10208	1985	20,000	MLLW	NAD 83 geographic
H10226	1988	20,000	MLLW	NAD 83 geographic
H10247	1987	20,000	MLLW	NAD 83 geographic
H10261	1987	20,000	MLLW	NAD 83 geographic
H10393	1991	20,000	MLLW	NAD 83 geographic
H10394	1992	10,000	MLLW	NAD 83 geographic
H10403	1991	10,000	MLLW	NAD 83 geographic
H10418	1992	10,000	MLLW	NAD 83 geographic
H10423	1992	10,000	MLLW	NAD 83 geographic
H10527	1994	10,000	MLLW	NAD 83 geographic
H11082	2001	10,000	MLLW	NAD 83 geographic

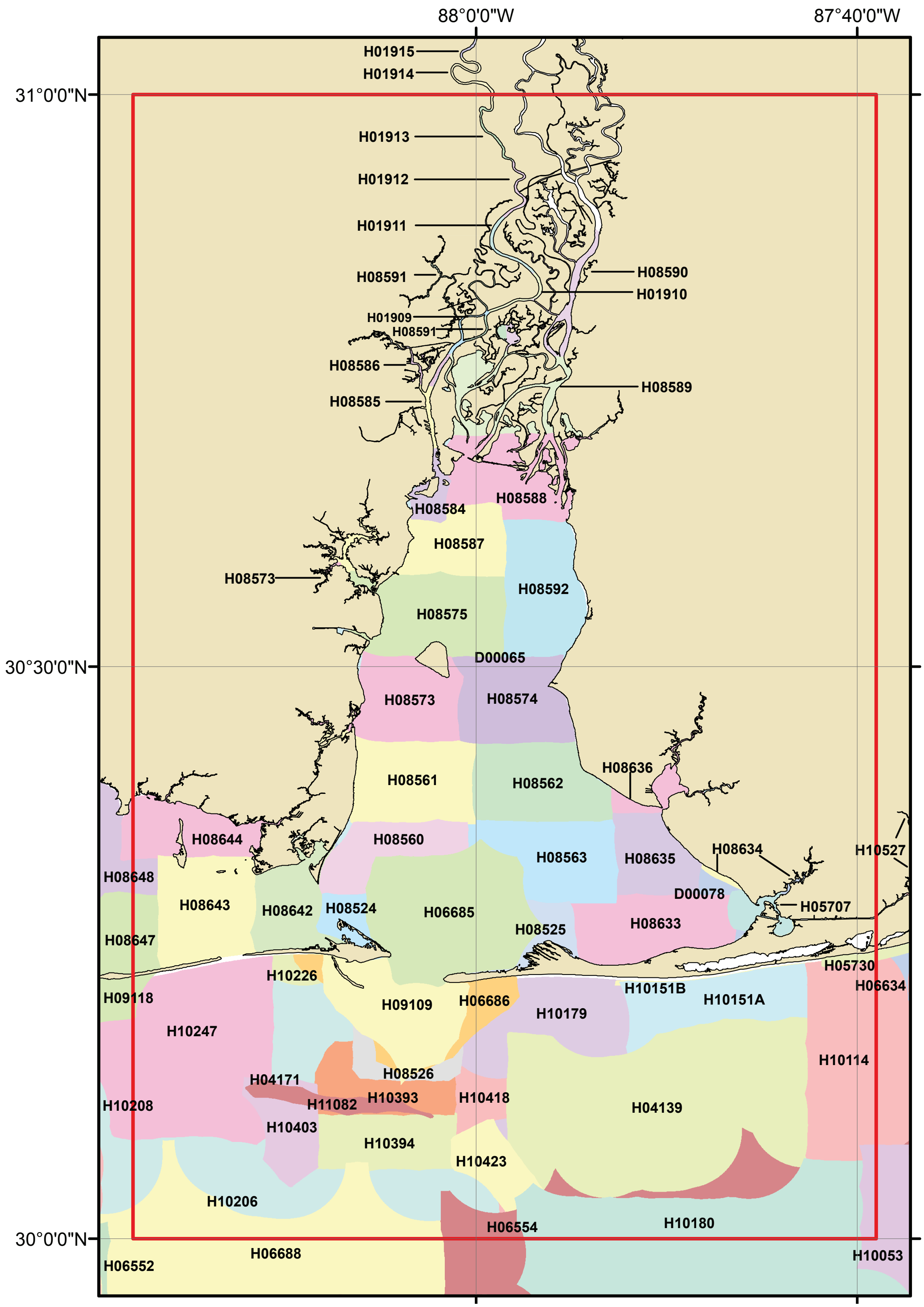

Figure 7. *Digital NOS hydrographic survey coverage in the Mobile region. Some soundings from earlier surveys were not used as they have been superseded by more recent surveys. DEM boundary in red.*

2) United States Army Corps of Engineers hydrographic surveys

Fourteen USACE bathymetric surveys of dredged shipping channels were downloaded from the USACE Mobile District web site in Design (DGN) format (Table 6; Fig. 8). NGDC used *FME* to extract xyz data from the DGN files. Several DGN files lacked corresponding xyz data. NGDC digitized the missing sections of the dredged channels to ensure their representation in the DEMs (Fig. 10). The surveys were collected in 2009, and referenced to NAD 83 Alabama State Plane (feet) and MLLW (feet) datums. The files were converted to NAD 83 geographic and NAVD 88 (meters) using *FME* and *VDatum.* Surveys consist of numerous, parallel, across-channel profiles, spaced 10 to 350 meters apart, with point soundings 1 to 10 meters apart.

Table 6. Digital USACE surveys available in the Mobile DEM region.

Region	*Year of Survey*	*Spatial Resolution*	*Original Vertical Datum*	*Original Horizontal Datum*
Alabama Gulf Intercoastal Waterway (GISS)	2009	~ 50 - 300 m profile spacing ~ 5 - 10 m point spacing	MLLW (feet)	NAD 83 Alabama State Plane (feet)
Arlington Ship Channel	2009	~ 15 - 75 m profile spacing ~ 5 m point spacing	MLLW (feet)	NAD 83 Alabama State Plane (feet)
Bayou Coden	2009	~ 30 m profile spacing ~ 1 - 4 m point spacing	MLLW (feet)	NAD 83 Alabama State Plane (feet)
Bayou La Batre	2009	~ 25 - 125 m profile spacing ~ 5 m point spacing	MLLW (feet)	NAD 83 Alabama State Plane (feet)
Bon Secour River	2009	~ 10 - 75 m profile spacing ~ 3 m point spacing	MLLW (feet)	NAD 83 Alabama State Plane (feet)
Chicksaw Creek	2009	~ 25 - 75 m profile spacing ~ 5 - 6 m point spacing	MLLW (feet)	NAD 83 Alabama State Plane (feet)
Dog River	2009	~ 10 - 75 m profile spacing ~ 3 m point spacing	MLLW (feet)	NAD 83 Alabama State Plane (feet)
Garrows Bend	2009	~ 20 - 40 m profile spacing ~ 5 -6 m point spacing	MLLW (feet)	NAD 83 Alabama State Plane (feet)
Mobile Bar Channel	2009	~ 15 - 350 m profile spacing ~ 10 m point spacing	MLLW (feet)	NAD 83 Alabama State Plane (feet)
Mobile Lower Bay Channel	2009	~ 30 - 175 m profile spacing ~ 10 m point spacing	MLLW (feet)	NAD 83 Alabama State Plane (feet)
Mobile River Channel	2009	~ 15 - 65 m profile spacing ~ 10 point spacing	MLLW (feet)	NAD 83 Alabama State Plane (feet)
Mobile Upper Bay Channel	2009	~ 25 - 125 m profile spacing ~ 10 m point spacing	MLLW (feet)	NAD 83 Alabama State Plane (feet)
Pass Drury	2009	~ 25 - 40 m profile spacing ~ 1 - 2 m point spacing	MLLW (feet)	NAD 83 Alabama State Plane (feet)
Theodore Ship Channel	2009	~ 40 - 125 m profile spacing ~ 7 - 8 m point spacing	MLLW (feet)	NAD 83 Alabama State Plane (feet)

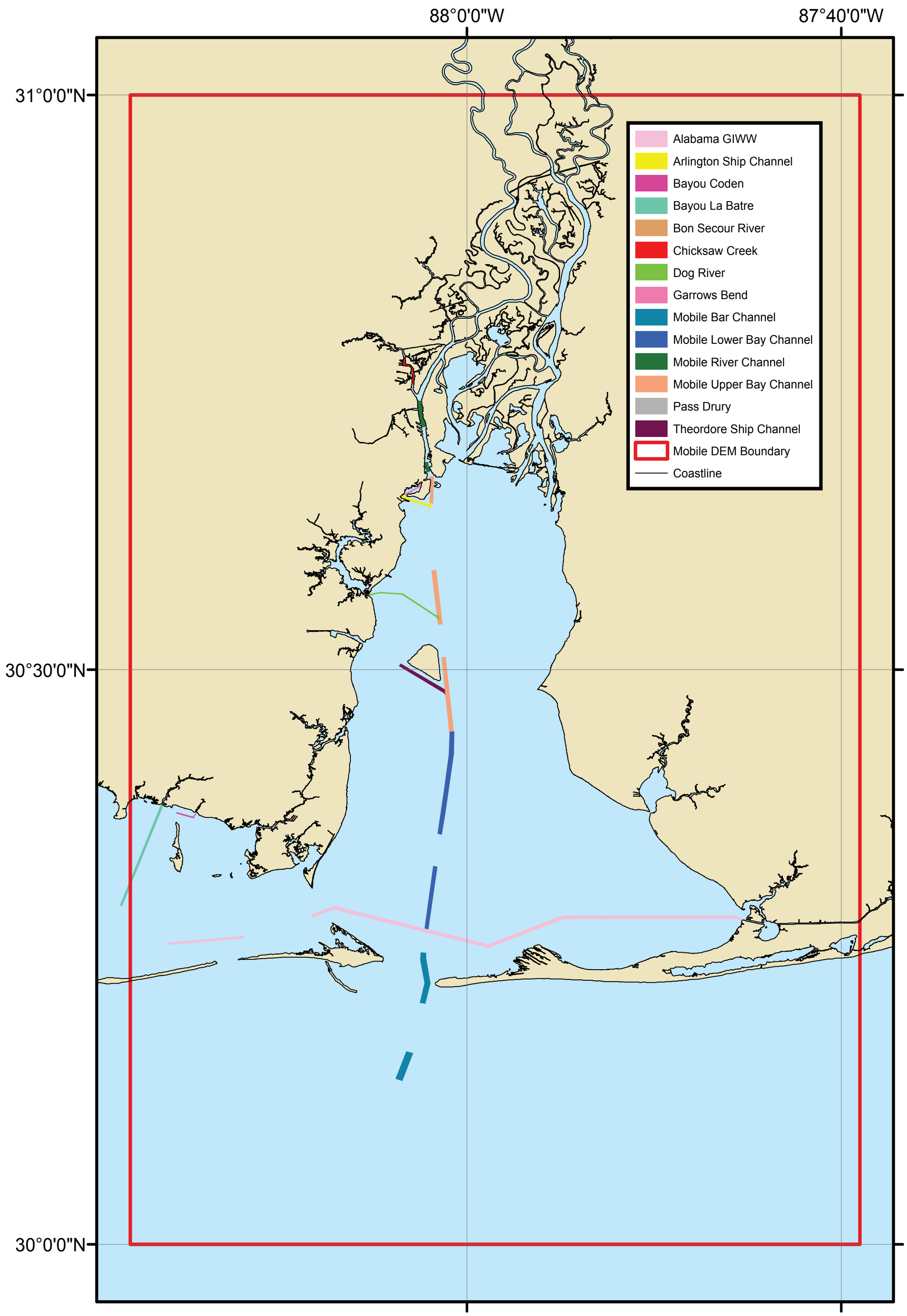

Figure 8. *Digital USACE hydrographic survey coverage in the Mobile region.*

3) City of Gulf Shores Little Lagoon side-scan sonar

Little Lagoon bathymetric soundings derived from side-scan sonar (Fig. 9) were provided to NGDC by Al Browder, Coastal Engineering Consultant to the City of Gulf Shores, AL. The Alabama Department of Conservation and Natural Resources (ADCNR) with assistance from the Federal Emergency Management Agency (FEMA) and NOAA, used side-scan sonar in Little Lagoon to identify marine debris resulting from Hurricanes Ivan and Katrina. The xyz data provided to NGDC were a mosaic of surveys conducted between 2002 and 2008.

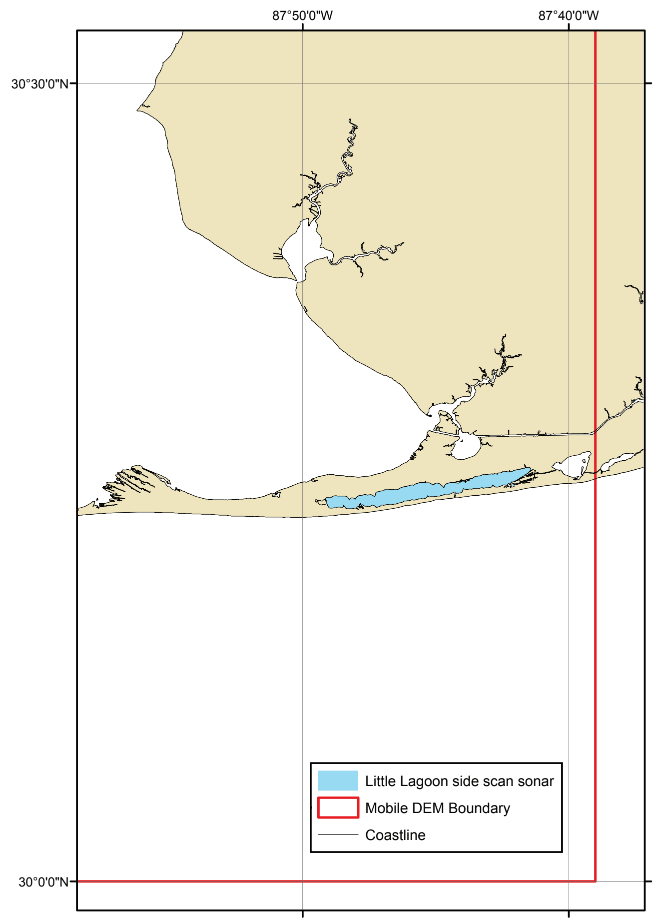

Figure 9. *Little Lagoon side-scan sonar coverage in the Mobile region.*

4) NGDC digitized soundings

NGDC used *GEODAS Hydro-Plot*[4] to digitize bathymetric soundings in estuary rivers and dredged channels. NGDC interpolated bathymetric soundings at 5 meter spacing based on available NOS hydrographic soundings and OCS RNCs. Interpolated soundings were created in estuary rivers and dredged channels to more accurately model the channels' morphology where there were no NOS hydrographic survey soundings or the NOS soundings were significantly greater than 10 meters apart (Figs. 10, 11).

4. *Hydro-Plot* is a MS Windows and Linux-x86 GEODAS application developed by NGDC to display geographical plots of data from the *GEODAS* DVD sets, including NOS Hydrographic Surveys, Marine Trackline Geophysics and *GEODAS* Gridded Databases, as well as XYZ-type data files, Arc-type grids and ESRI shapefiles for data, contours and coastlines. Hydro-Plot displays maps of data directly on the screen, coloring the data according to their value. *Hydro-Plot* can also be used for viewing histograms and profiles of the data, and for editing data, including deleting records, changing record fields, and creating new records, as well as for automated Quality control of data files [Extracted from *GEODAS Hydro-Plot* help section].

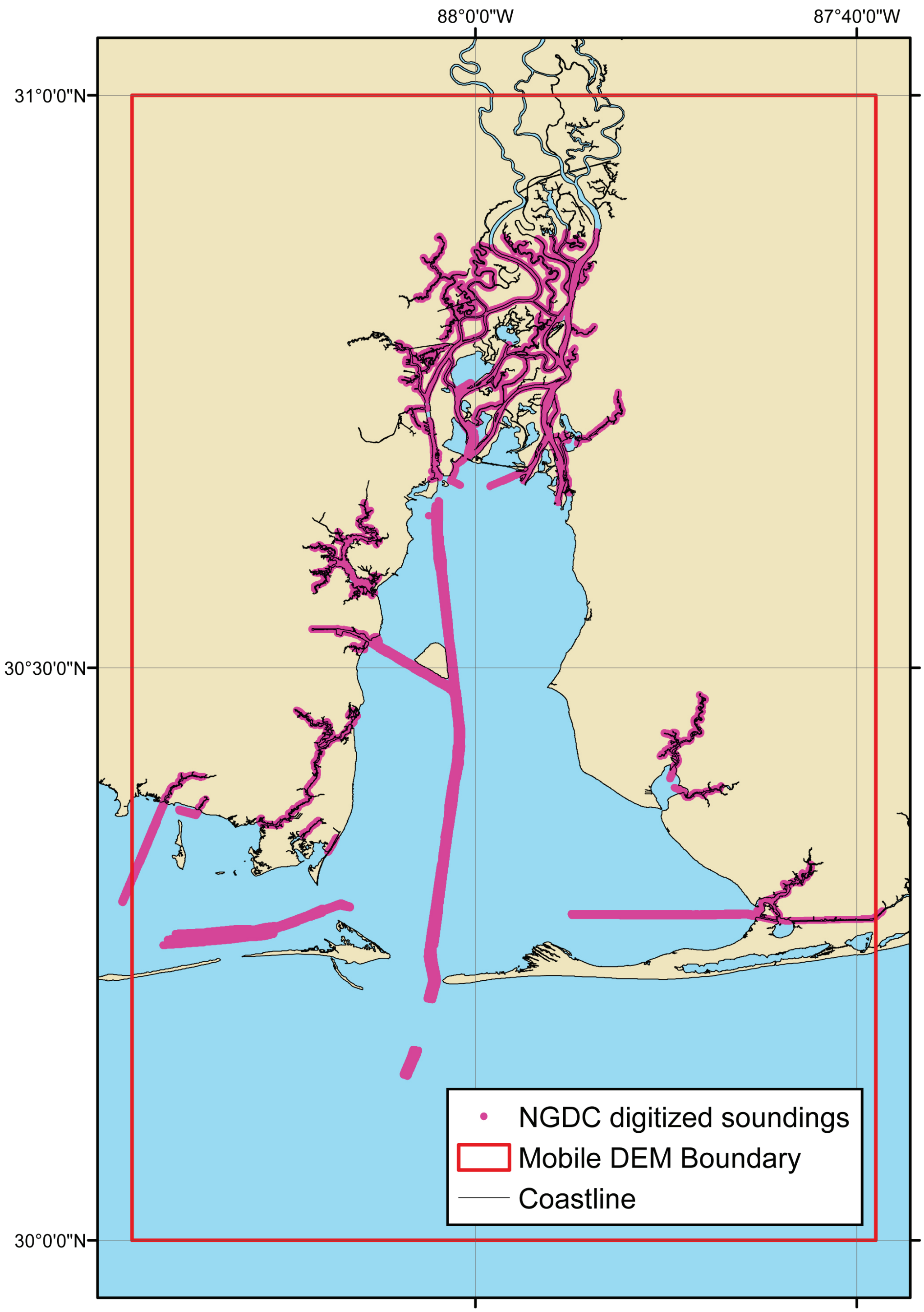

Figure 10. *NGDC Hydro-Plot digitization coverage in the Mobile region.*

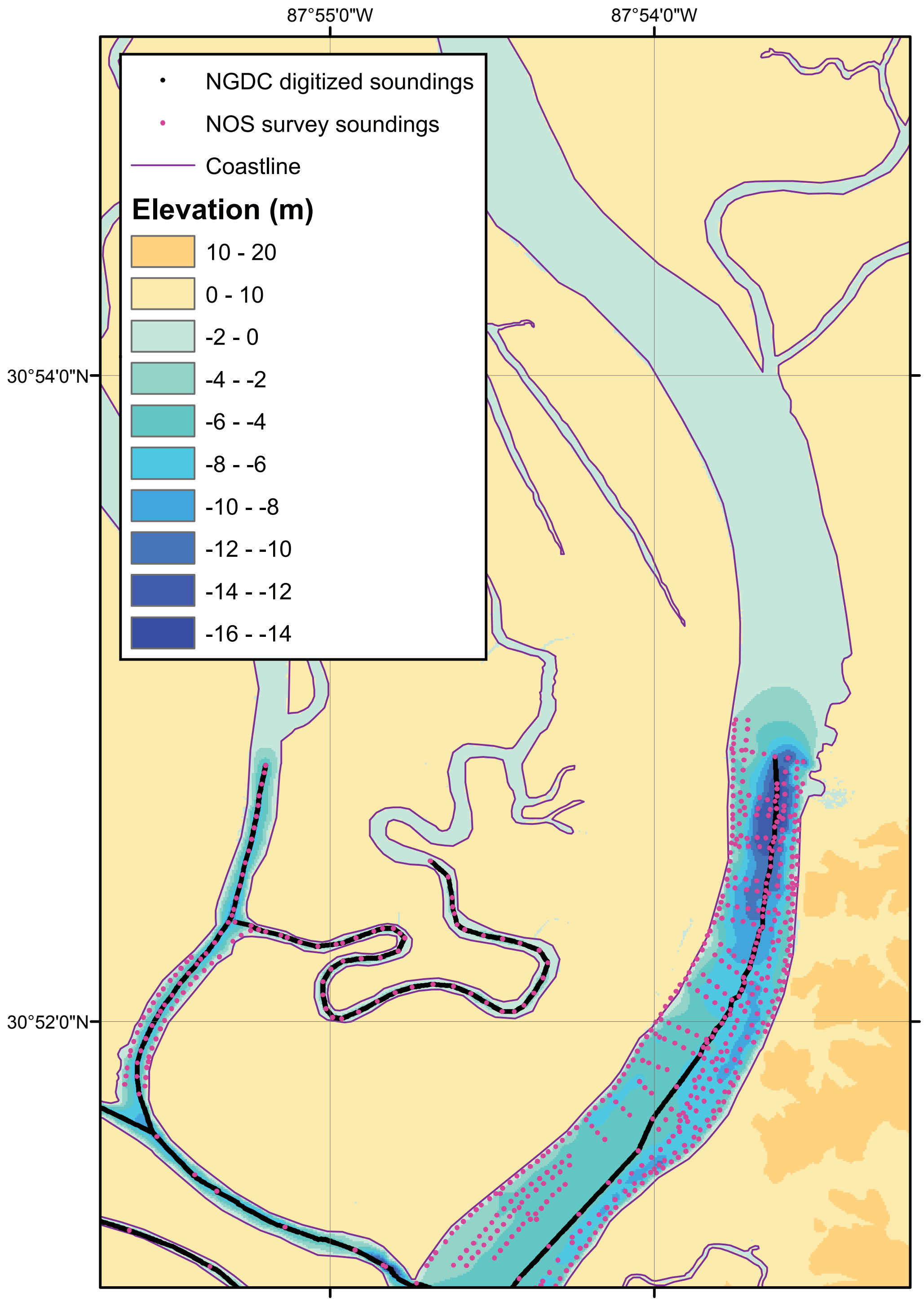

Figure 11. *Example of Hydro-Plot digitization in the Tensaw River at the end of NOS coverage.*

3.1.3 Topography

The topographic datasets used to build the Mobile NAVD 88 DEM include: Mobile County, AL lidar, Baldwin County, AL lidar, and SRTM (Table 7; Fig. 12). NGDC evaluated but did not use the USGS NED 1/3 or NED 1/9 arc-second DEM. NGDC also evaluated but did not use the USACE 2005 Post-Hurricane Katrina Topographic Mapping lidar as it was not processed to bare-earth.

Table 7. Topographic datasets used in building the Mobile NAVD 88 DEM.

Source	*Year*	*Data Type*	*Spatial Resolution*	*Original Horizontal Datum/Coordinate System*	*Original Vertical Datum*	*URL*
Mobile County Government	2002	Bare-earth lidar	1 - 5 meters	NAD 83 Alabama State Plane West (feet)	NAVD 88	http://www.mobilecountypublicworks.net/
Baldwin County Government	2001	Bare-earth lidar	3.3 meters	NAD 83 Alabama State Plane West (feet)	NAVD 88	http://www.co.baldwin.al.us/
NASA SRTM	2000	Topographic DEM	1 arc-second grid	WGS 84 geographic	NAVD 88	http://srtm.usgs.gov/

1) Mobile County Government lidar

The Mobile County Government collected topographic lidar processed to bare-earth for Mobile County in 2002. The data were provided to NGDC as ESRI point shapefiles from Scott Kearney, GIS Manager of the City of Mobile. Data from the water surface were removed by clipping to the coastline using *ArcGIS*. Data were referenced vertically to NAVD 88 and horizontally to NAD 83 Alabama State Plane West (feet). Vertical accuracy was 13.9 cm root mean squared error (rmse) while horizontal accuracy was not assessed.

2) Baldwin County Government lidar

The Baldwin County Government collected topographic lidar processed to bare-earth for Baldwin County in 2001. The data were provided to NGDC as raw xyz points from Keil Schmid of NOAA CSC. Data from the water surface were removed by clipping to the coastline using *ArcGIS*. Data were referenced vertically to NAVD 88 and horizontally to NAD 83 Alabama State Plane West (feet). The data meet the FEMA standard of vertical accuracy of 15 cm rmse for lidar data used to create DEMs for hydraulic modeling of floodplains, digital terrain maps, and other National Flood Insurance Program (NFIP) products. The horizontal accuracy was not assessed. There is an artificial step of less than a meter between lidar flight lines (e.g. Fig. 13). Baldwin County lidar is also sparse and inconsistent where it overlaps with the Mobile County lidar. NGDC clipped each dataset to the river boundaries to minimize artificial steps where the two datasets overlap (Figs. 14, 15).

3) NASA Shuttle Radar Topography Mission

The NASA SRTM obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth[5]. The SRTM consisted of a specially modified radar system that flew onboard the Space Shuttle Endeavour during an 11-day mission in February of 2000. Data from this mission have been processed into 1 degree × 1 degree tiles that have been edited to define the coastline, and are available from the USGS Seamless web site (http://seamless.usgs.gov/) as raster DEMs. The data have not been processed to bare earth, but meet absolute horizontal and vertical accuracies of 20 and 16 meters, respectively. The SRTM data were used for the barrier island, Isle Aux Herbes (also known as Coffee Island), in the Mississippi Sound. Mobile County lidar was only partially available for this island.

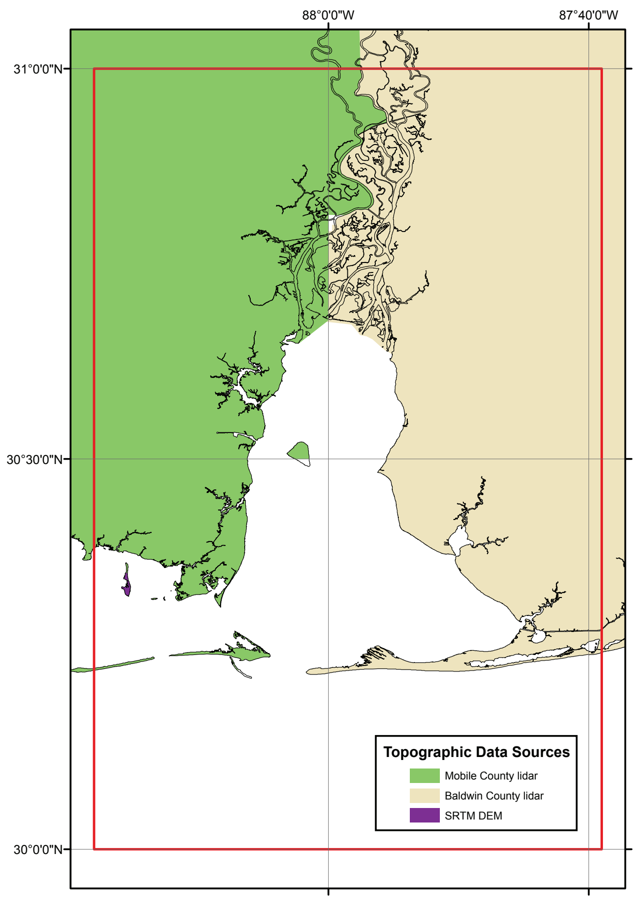

Figure 12. *Spatial coverage of topographic datasets used in the building the Mobile NAVD 88 DEM.*

5. The SRTM data sets result from a collaborative effort by the National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA – previously known as the National Imagery and Mapping Agency, or NIMA), as well as the participation of the German and Italian space agencies, to generate a near-global digital elevation model (DEM) of the Earth using radar interferometry. The SRTM instrument consisted of the Spaceborne Imaging Radar-C (SIR-C) hardware set modified with a Space Station-derived mast and additional antennae to form an interferometer with a 60 meter long baseline. A description of the SRTM mission can be found in Farr and Kobrick (2000). Synthetic aperture radars are side-looking instruments and acquire data along continuous swaths. The SRTM swaths extended from about 30 degrees off-nadir to about 58 degrees off-nadir from an altitude of 233 km, and thus were about 225 km wide. During the data flight the instrument was operated at all times the orbiter was over land and about 1000 individual swaths were acquired over the ten days of mapping operations. Length of the acquired swaths range from a few hundred to several thousand km. Each individual data acquisition is referred to as a "data take." SRTM was the primary (and pretty much only) payload on the STS-99 mission of the Space Shuttle Endeavour, which launched February 11, 2000 and flew for 11 days. Following several hours for instrument deployment, activation and checkout, systematic interferometric data were collected for 222.4 consecutive hours. The instrument operated almost flawlessly and imaged 99.96% of the targeted landmass at least one time, 94.59% at least twice and about 50% at least three or more times. The goal was to image each terrain segment at least twice from different angles (on ascending, or north-going, and descending orbit passes) to fill in areas shadowed from the radar beam by terrain. This 'targeted landmass' consisted of all land between 56 degrees south and 60 degrees north latitude, which comprises almost exactly 80% of Earth's total landmass. [Extracted from SRTM online documentation]

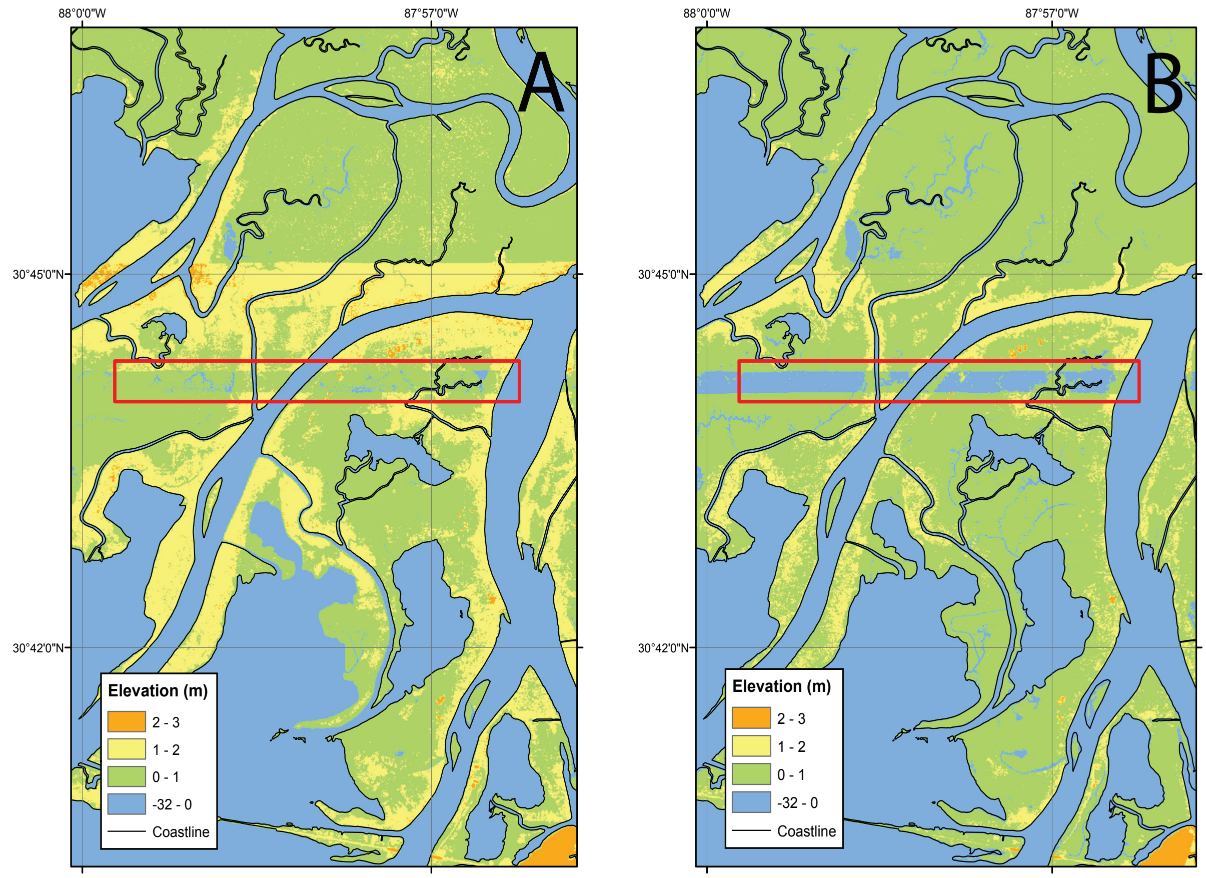

Figure 13. *Artificial steps between flightlines in Baldwin County lidar.*
A) Lidar data referenced to NAVD 88. Note step in red box and near 30°45'0."
B) Lidar data referenced to MHW. Note inappropriate coastal flooding in red box.

.

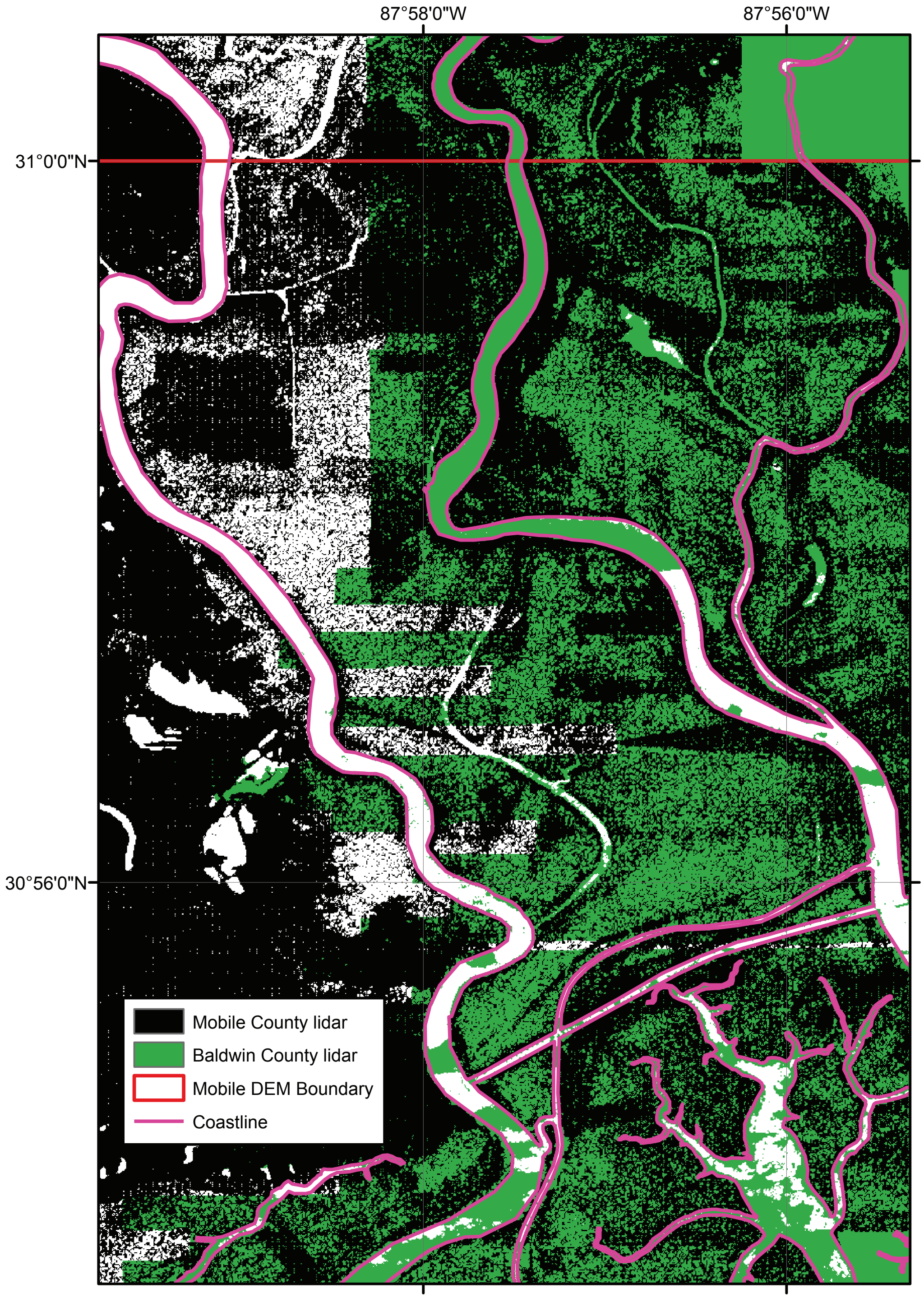

Figure 14. *Raster image of available Mobile County and Baldwin County lidar. The two datasets have sparse coverage in the low-lying marshland north of Mobile Bay and inconsistent elevations that differ up to 1 meter.*

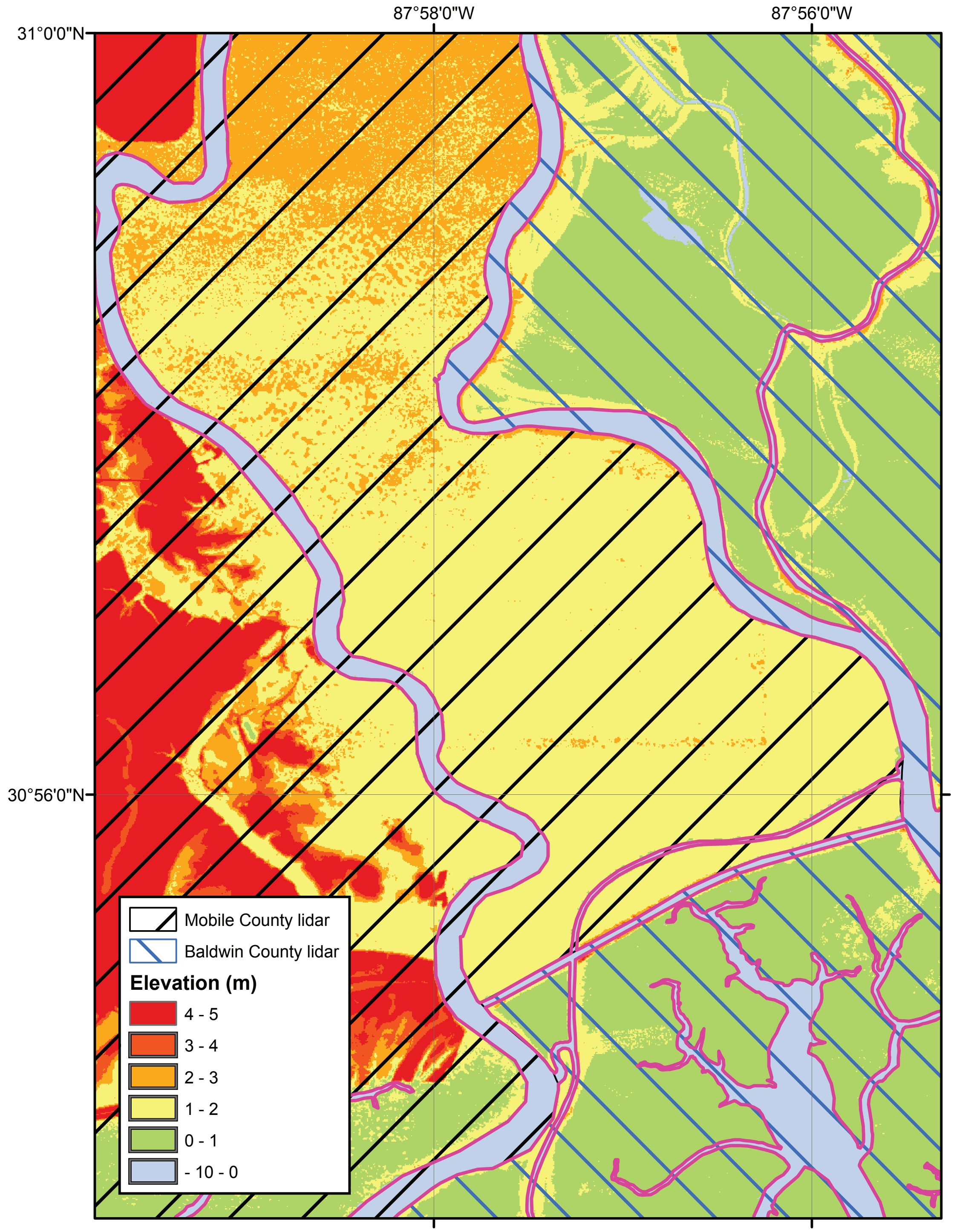

Figure 15. *Spatial coverage of Mobile County and Baldwin County lidar datasets used in building the Mobile NAVD 88 DEM. Inconsistent elevations values between Mobile County and Baldwin County lidar results in an artificial step of less than 1 meter at the river boundaries.*

3.1.4 Bathymetry/Topography

One combined bathymetric-topographic dataset was downloaded from the NOAA CSC Coastal Lidar web site (Table 8).

Table 8: Bathymetric-topographic datasets used in building the Mobile NAVD 88 DEM.

Source	*Year*	*Data Type*	*Spatial Resolution*	*Downloaded Horizontal Datum/ Coordinate System*	*Downloaded Vertical Datum*	*URL*
CSC	2005	USACE non bare-earth lidar	2.0 m	NAD 83 geographic	NAVD 88	http://www.csc.noaa.gov/digitalcoast/data/coastallidar/index.html

1) **CSC Post-Hurricane Katrina Topographic/Bathymetric Mapping**

The bathymetric-topographic lidar-derived data were collected by the Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX) using the Compact Hydrographic Airborne Rapid Total Survey (CHARTS) system. The data were collected to depict the elevations above and below water along the immediate coastal zone. The survey generally extends 750 meters inland and up to 1500 meters over the water (depending on water depth and clarity). The vertical accuracy is 0.20 meters at 1 sigma and the horizontal accuracy is 0.75 meters at 1 sigma[6]. NGDC used topographic data from the dataset only for Gaillard Island and the western portion of Dauphin Island because it was not processed to bare-earth. Bathymetric data was used at the Fort Morgan Peninsula and Gulf of Mexico interface (Fig. 16).

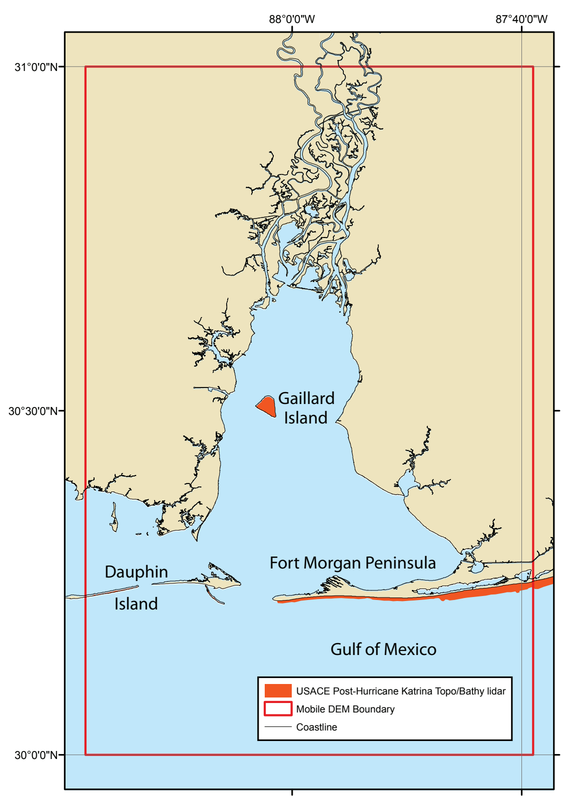

Figure 16. *Spatial coverage of the USACE Topographic/Bathymetric Mapping used in building the Mobile NAVD 88 DEM*

6. The goal of the project is to collect data covering the shoreline of the conterminous United States where feasible. The project is led by USACE. [Extracted from CSC Coastal Lidar web site].

3.2 Establishing Common Datums

3.2.1 Vertical datum transformations

Datasets used in the compilation and evaluation of the Mobile NAVD 88 DEM were originally referenced to several vertical datums including MLLW, MLW, and NAVD 88. All datasets were transformed to NAVD 88 using *VDatum*. The Mobile DEMs contained three separate *VDatum* project areas: Alabama - Florida - Gulf of Mexico to East of Choctawhatchee Bay V. 01, Alabama - Mobile Bay V. 01, and Eastern Louisiana and Mississippi V. 01 (Fig. 17). Units were converted from feet to meters as appropriate.

1) **Bathymetric data**

   The NOS and USACE hydrographic surveys were transformed from MLLW and MLW to NAVD 88, using *VDatum*. Several hydrographic surveys extended farther upriver than the *VDatum* coverage, in which case NGDC manually transformed the vertical datum to NAVD 88 by comparing the conversion of nearby soundings and using an equivalent constant offset.

2) **Topographic data**

   The Mobile County lidar, Baldwin County lidar, USACE bathymetric-topographic lidar, and SRTM DEM were all received or downloaded referenced to NAVD 88. No further vertical transformation was required.

3.2.2 Horizontal datum transformations

Datasets used to build the Mobile NAVD 88 DEM were downloaded or received referenced to WGS 84 geographic, NAD 83 geographic, and NAD 83 Alabama State Plane West (feet) horizontal datums. The relationships and transformational equations between these horizontal datums are well established. Data were converted to a horizontal datum of NAD 83 geographic using *FME* software or *ArcGIS*.

3.2.3 VDatum Assessment

VDatum is a free software tool developed jointly by NOAA's OCS, NGS and CO-OPS. *VDatum* is designed to vertically transform geospatial data among a variety of tidal, orthometric and ellipsoidal vertical datums - allowing users to convert their data from different horizontal/vertical references into a common system and enabling the fusion of diverse geospatial data in desired reference levels (http://vdatum.noaa.gov/).

NGS first noticed discontinuity between these three *VDatum* project areas in its generation of the Topography of the Sea Surface (TSS) Transformation Grids (http://vdatum.noaa.gov/docs/sop_v02_tss.html). Maximum differences of 0.04 meters have been noticed between the Eastern LA and MS and AL - Mobile Bay project areas. Maximum differences of 0.19 meters have been noticed between the Eastern LA and MS and the AL - FL - Gulf of Mexico to East of Choctawhatchee Bay project areas. NGDC used *Gnuplot*[7] to create histograms of the differences between the *VDatum* project areas where they overlapped (Figs. 18 - 20).

These continuity issues can be attributed to recent updates of elevation information in Louisiana, Mississippi, and Alabama that were not originally incorporated into the *VDatum* project areas. Also, there are several new data that have been made available since the AL - FL - Gulf of Mexico to East of Choctawhatchee Bay and AL - Mobile Bay project areas were constructed. These discrepancies have been noticed, and NOAA is currently looking to resolve these discontinuity issues with updated Topography of the Sea Surface grids [Extracted from http://vdatum.noaa.gov/misc/LAMS_eastern121908.html]. A detailed report on the estimation of vertical uncertainties of *VDatum* can be found at http://vdatum.noaa.gov/docs/est_uncertainties.html.

7. *Gnuplot* is a portable command-line driven graphing utility for linux, OS/2, MS Windows, OSX, VMS, and many other platforms. The source code is copyrighted but freely distributed. It was originally created to allow scientists and students to visualize mathematical functions and data interactively, but has grown to support many non-interactive uses such as web scripting. It is also used as a plotting engine by third-party applications like Octave. *Gnuplot* has been supported and under active development since 1986. *Gnuplot* supports many types of plots in either 2D and 3D. It can draw using lines, points, boxes, contours, vector fields, surfaces, and various associated text. It also supports various specialized plot types [Extracted from *Gnuplot* web site].

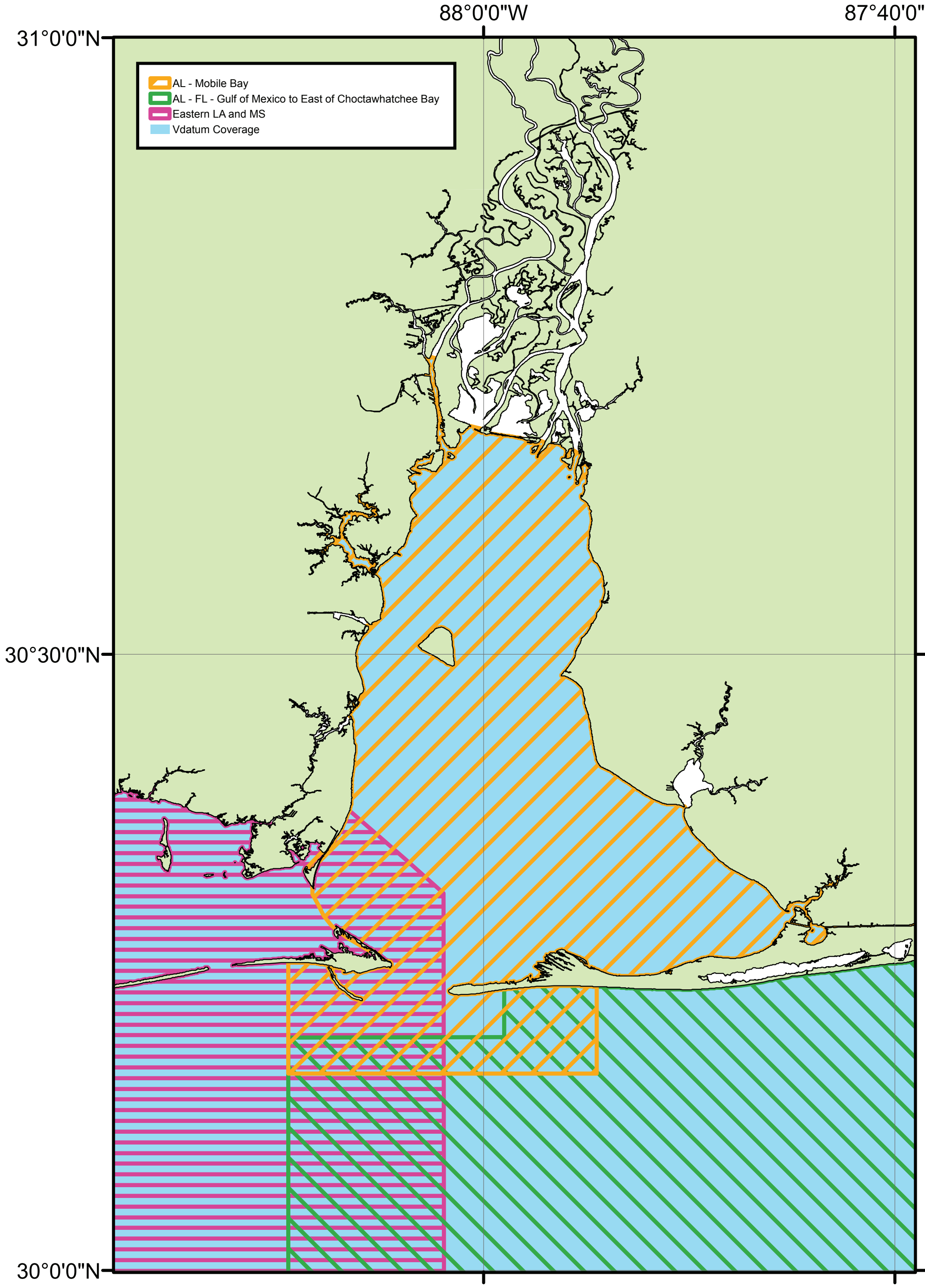

Figure 17. *Spatial coverage of the VDatum projects in the Mobile area.*

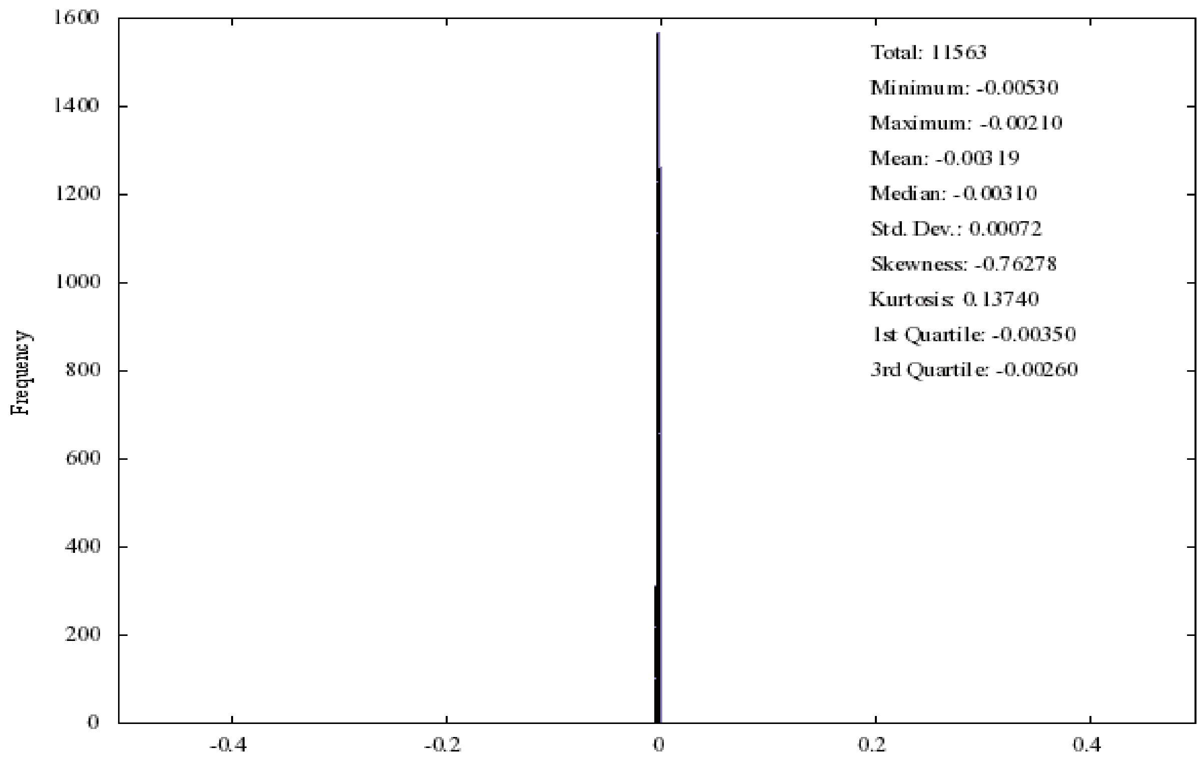

Figure 18. *Histogram of the differences between the AL - FL - Gulf of Mexico to East of Choctawhatchee Bay and the AL - Mobile Bay VDatum project areas*

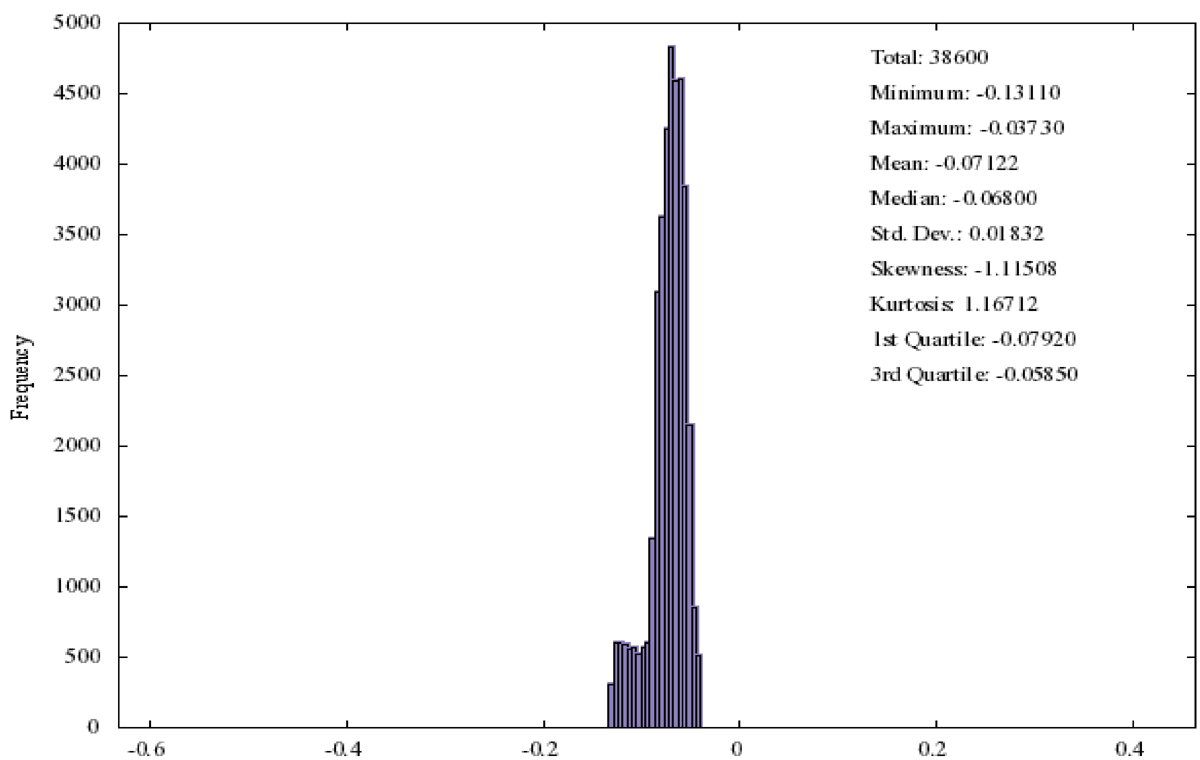

Figure 19. *Histogram of the differences between the AL - FL - Gulf of Mexico to East of Choctawhatchee Bay and the Eastern LA and MS VDatum project areas*

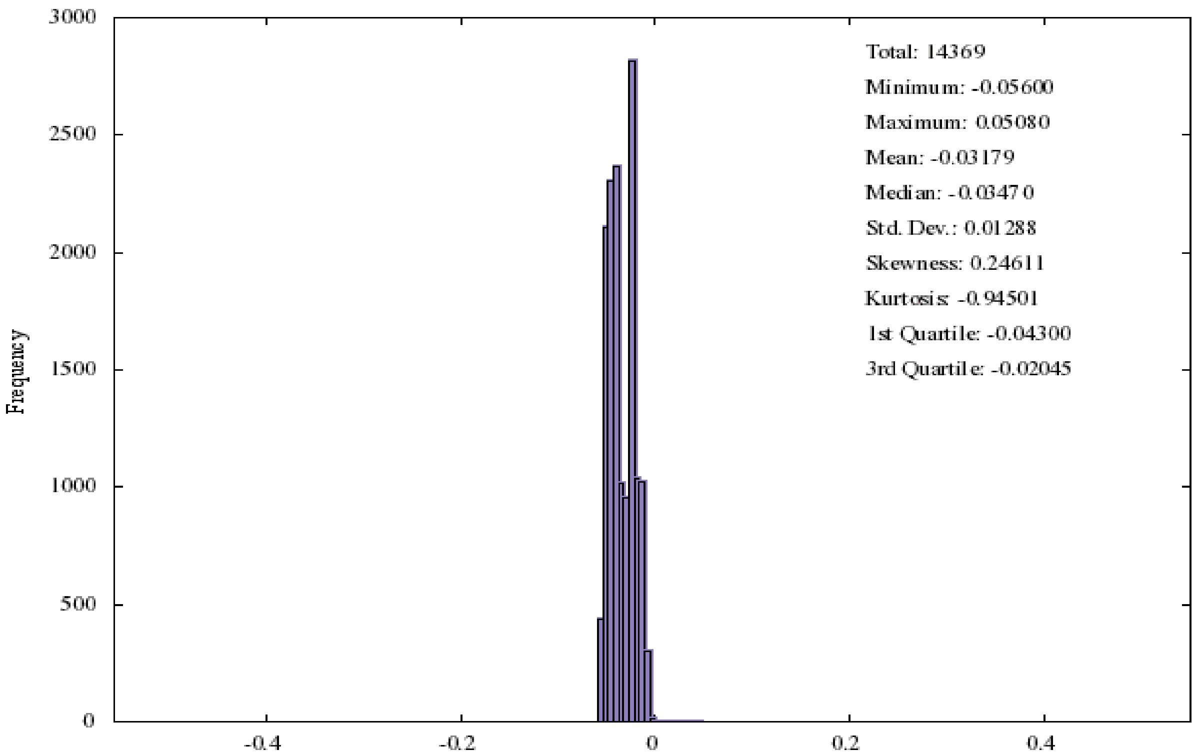

Figure 20. *Histogram of the differences between the AL - Mobile Bay and the Eastern LA and MS VDatum project areas.*

3.3 Digital Elevation Model Development

3.3.1 Verifying consistency between datasets

After horizontal and vertical transformations were applied, the resulting ESRI shapefiles were checked in *ArcMap* for consistency between datasets. Problems and errors were identified and resolved before proceeding with subsequent gridding steps. The evaluated and edited ESRI shapefiles were then converted to xyz files using *FME* in preparation for gridding. Problems included:

- Artificial steps between flightlines in Baldwin County lidar
- Inconsistent elevation values between the Mobile County lidar and Baldwin County lidar
- Elevation values located over the open-ocean in the Mobile County lidar and Baldwin County lidar
- Bathymetric values in older NOS surveys dating back over 100 years are inconsistent with USACE surveys
- Lack of bathymetric data in estuary bays and rivers
- Sparse NOS soundings in Mobile Bay

3.3.2 Smoothing of bathymetric data

The NOS hydrographic survey data are generally sparse relative to the resolution of the 1/3 arc-second Mobile NAVD 88 DEM. This is especially true for deeper-water surveys in the Gulf of Mexico and shallow water surveys in Mobile Bay where data have point spacing up to 350 meters apart. In order to reduce the effect of artifacts created in the DEM by the low-resolution NOS datasets, and to provide effective interpolation in the deep water and into the coastal zone, a 1 arc-second-spacing 'pre-surface' bathymetric grid was generated using Generic Mapping Tools[8] (*GMT)*. The coastline elevation value was set at -1 meters to ensure a bathymetric surface below zero in areas where data are sparse or non-existent.

The point data were median-averaged using the *GMT* tool 'blockmedian' to create a 1 arc-second grid 0.05 degrees (~5%) larger than the Mobile NAVD 88 DEM gridding region. The *GMT* tool 'surface' was then used to apply a tight spline tension to interpolate elevations for cells without data values. The netcdf grid created by 'surface' was converted into an ESRI Arc ASCII grid file, and clipped to the final coastline (to eliminate data interpolation into land areas). The resulting surface was compared with original NOS soundings to ensure grid accuracy (Fig. 21), and then exported as an xyz file for use in the final gridding process (see Table 9).

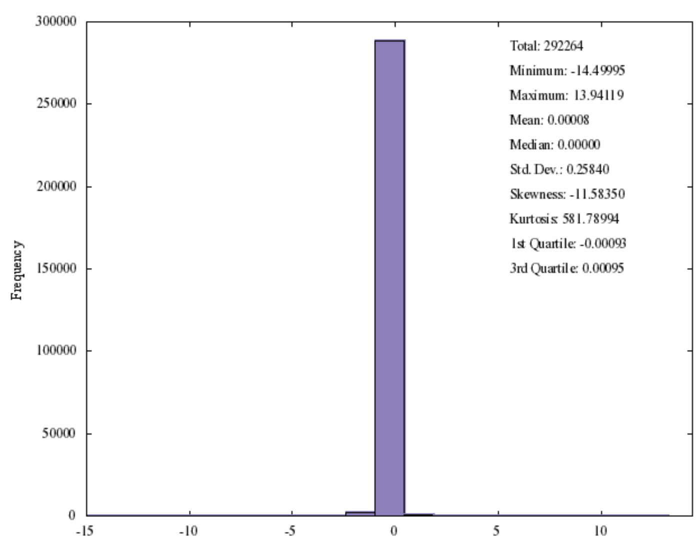

Figure 21. *Histogram of the differences between the NOS hydrographic survey data and the bathymetric surface.*

8. *GMT* is an open source collection of ~60 tools for manipulating geographic and Cartesian data sets (including filtering, trend fitting, gridding, projecting, etc.) and producing Encapsulated PostScript File (EPS) illustrations ranging from simple x-y plots via contour maps to artificially illuminated surfaces and 3-D perspective views. *GMT* supports ~30 map projections and transformations and comes with support data such as GSHHS coastlines, rivers, and political boundaries. *GMT* is developed and maintained by Paul Wessel and Walter H. F. Smith with help from a global set of volunteers, and is supported by the National Science Foundation. It is released under the GNU General Public License. URL: http://gmt.soest.hawaii.edu/ [Extracted from *GMT* web site.]

3.3.3 Building the NAVD 88 DEM

MB-System was used to create the 1/3 arc-second Mobile NAVD 88 DEM. *MB-System*[9] is an NSF-funded shareware software application specifically designed to manipulate submarine multibeam sonar data, though it can utilize a wide variety of data types, including generic xyz data. The *MB-System* tool 'mbgrid' was used to apply a tight spline tension to the xyz data, and interpolate values for cells without data. The data hierarchy used in the 'mbgrid' gridding algorithm, as relative gridding weights, is listed in Table 9. Equal weight was given to all datasets except the SRTM DEM and the 'pre-surface' bathymetric grid. Gridding was performed in quadrants with the resulting binary grid seamlessly merged using the GMT tool 'grdpaste' and converted to an Arc ASCII grid using the MB-System tool 'mbm grd2arc' to create the final 1/3 arc-second Mobile NAVD 88 DEM. Figure 22 illustrates cells in the DEM that have interpolated values (shown as white) versus data contributing to the cell value (shown as black).

Table 9. Data hierarchy used to assign gridding weight in MB-System.

Dataset	*Relative Gridding Weight*
NOS hydrographic surveys	10
USACE hydrographic surveys	10
Little Lagoon side scan sonar	10
Digitized features	10
CSC bathymetric-topographic lidar	10
Mobile County lidar	10
Baldwin County lidar	10
Coastline	10
SRTM DEM	1
Pre-surfaced bathymetric grid	1

9. *MB-System* is an open source software package for the processing and display of bathymetry and backscatter imagery data derived from multibeam, interferometry, and sidescan sonars. The source code for *MB-System* is freely available (for free) by anonymous ftp (including "point and click" access through these web pages). A complete description is provided in web pages accessed through the web site. *MB-System* was originally developed at the Lamont-Doherty Earth Observatory of Columbia University (L-DEO) and is now a collaborative effort between the Monterey Bay Aquarium Research Institute (MBARI) and L-DEO. The National Science Foundation has provided the primary support for *MB-System* development since 1993. The Packard Foundation has provided significant support through MBARI since 1998. Additional support has derived from SeaBeam Instruments (1994-1997), NOAA (2002-2004), and others. URL: http://www.ldeo.columbia.edu/res/pi/MB-System/ [Extracted from *MB-System* web site.]

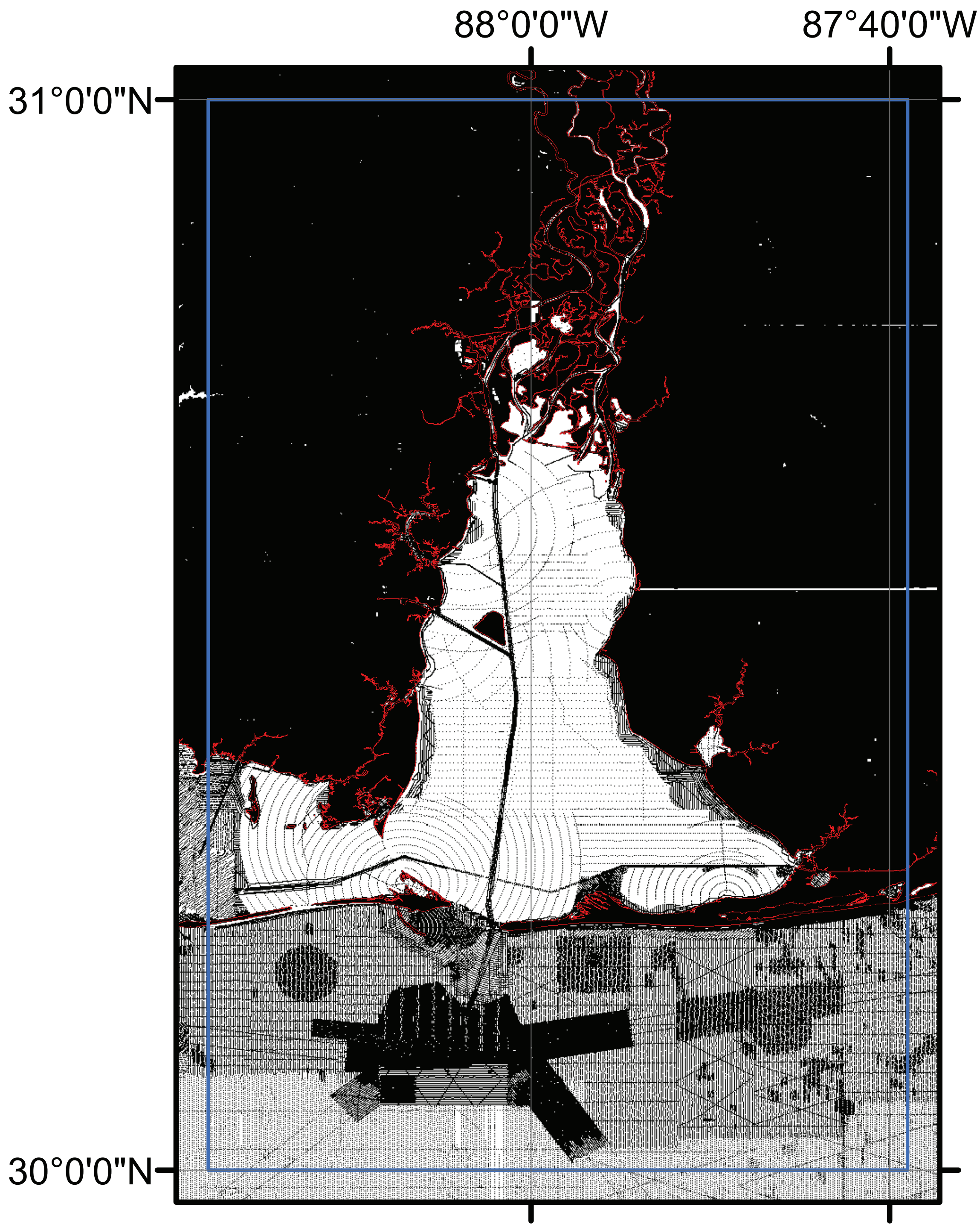

Figure 22. Data distribution plot of the Mobile DEMs. Areas where source data were available are depicted in black; areas where grid interpolation was necessary are depicted in white. Mobile DEM boundary in blue; coastline in red.

3.3.4 *Developing the MHW DEM*

The MHW DEM was created by adding a NAVD 88 to MHW conversion grid to the NAVD 88 DEM.

1) Developing the conversion grid

Using extents slightly larger (~5%) than the NAVD 88 DEM, an initial xyz file was created that contained the coordinates of the four bounding vertices and midpoint of the larger extents. The elevation value at each of the points was set to zero. The *GMT* tool 'surface' applied a tension spline to interpolate cell values making a zero-value 3 arc-second grid. This zero-grid was then converted to an intermediate xyz file using the *GMT* tool 'grd2xyz.' Conversion values from NAVD 88 to MHW at each xyz point were generated using *VDatum* and the null values were removed. NGDC used the *GMT* tool 'block median' to median-average multiple elevation values where *VDatum* project areas overlapped.

The median-averaged xyz file was then interpolated with the GMT tool 'surface' to create the 1/3 arc-second 'NAVD 88 to MHW' conversion grid with the extents of the NAVD 88 DEM. NGDC then used the *GMT* tool 'surface' to interpolate values that represented the differences between the two datums onshore to the DEM extents (Fig. 23).

2) Assessing accuracy of conversion grid

The NAVD 88 to MHW conversion grid was assessed using the NOS survey data. For testing of this methodology, the NOS hydrographic survey data were transformed from MLW and MLLW to NAVD 88 using *VDatum*. Shapefiles of the resultant xyz files were created and null values removed using *FME*. The shapefiles were then merged to create a single shapefile of all NOS surveys with a vertical datum of NAVD 88. A second shapefile of NOS data was created with a vertical datum of MHW using the same method. Elevation differences between the MHW and NAVD 88 shapefiles were computed after performing a spatial join in *ArcGIS*.

To verify the conversion grid methodology, the difference shapefile created using *ArcGIS* was converted to xyz format using *FME*. A histogram was created using *Gnuplot* to evaluate the performance of the 1/3 arc-second conversion grid by comparing the 'NAVD 88 to MHW' grid to the combined difference xyz files from the three VDatum project areas (Fig. 24). Histograms were also made to compare the individual *VDatum* project areas to the conversion grid (Figs. 25 - 27). Errors in the vertical datum conversion method will reside for the most part in the NAVD 88 to MHW conversion grid, as the topographic data are already referenced to NAVD 88. Errors in the source datasets will require rebuilding just the NAVD 88 DEM.

3) Creating the MHW DEM

Once the NAVD 88 DEM was complete and assessed for errors, the conversion grid was added using *ArcCatalog*. The resulting MHW DEM was reviewed and assessed using RNCs, USGS topographic maps, and ESRI *World 2D* imagery. Problems encountered were determined to reside in source datasets, which were corrected before building a new NAVD 88 DEM.

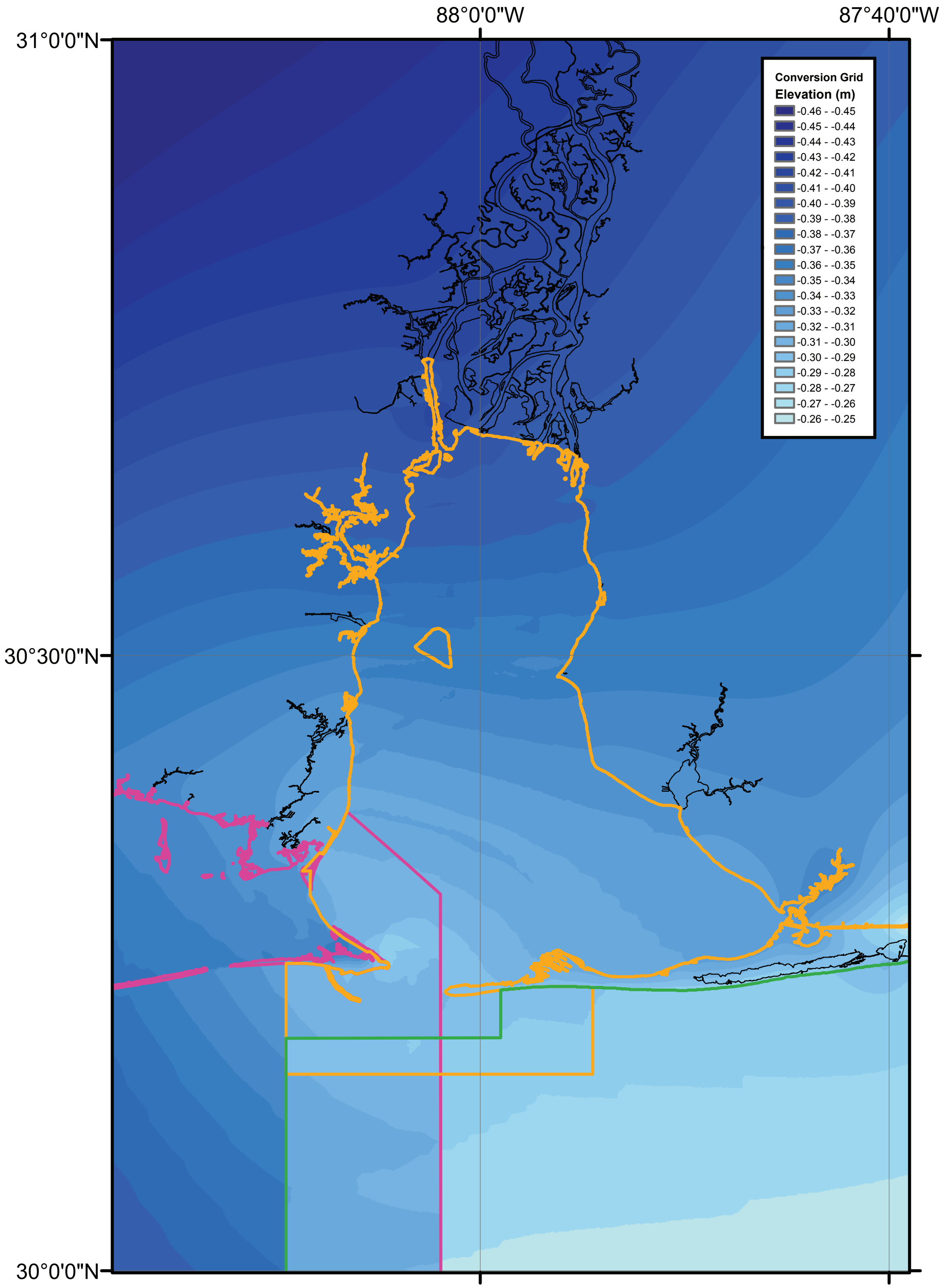

Figure 23. *Elevation values of the conversion grid derived from VDatum project areas (outlined in pink, orange, green). Values equal difference between NAVD 88 and MHW.*

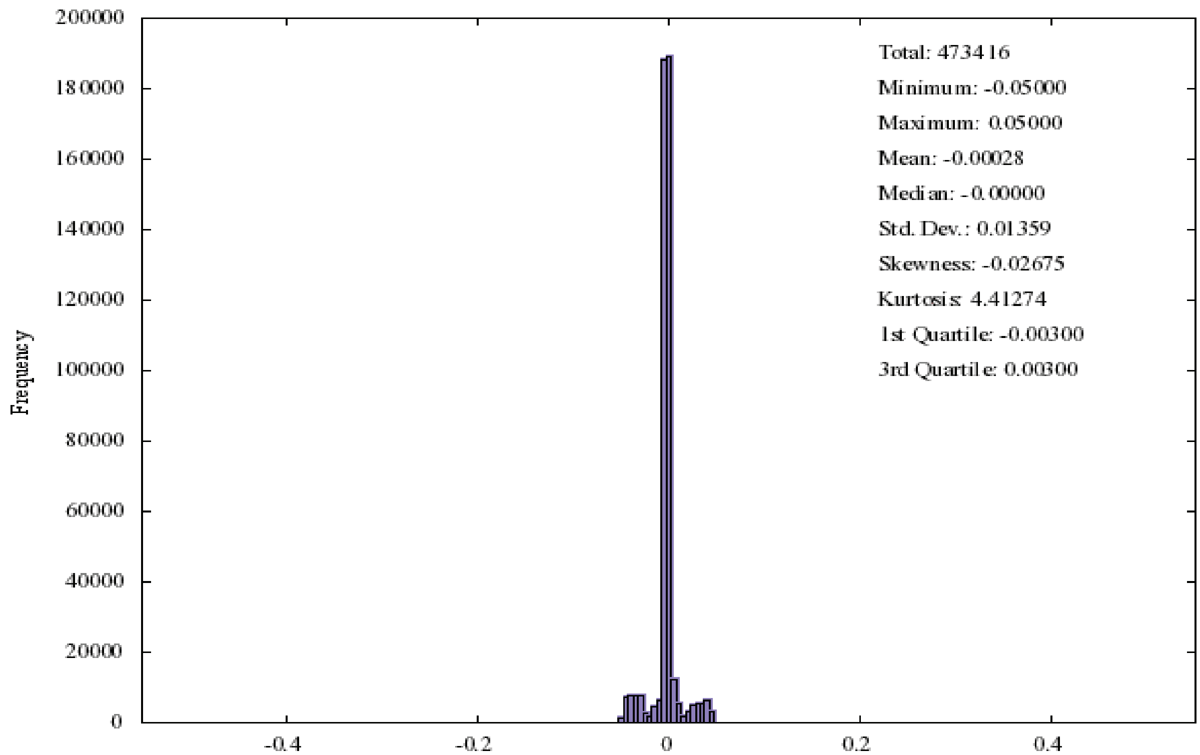

Figure 24. *Histogram of the differences between the conversion grid and xyz difference files using NOS hydrographic survey data in all three VDatum project areas.*

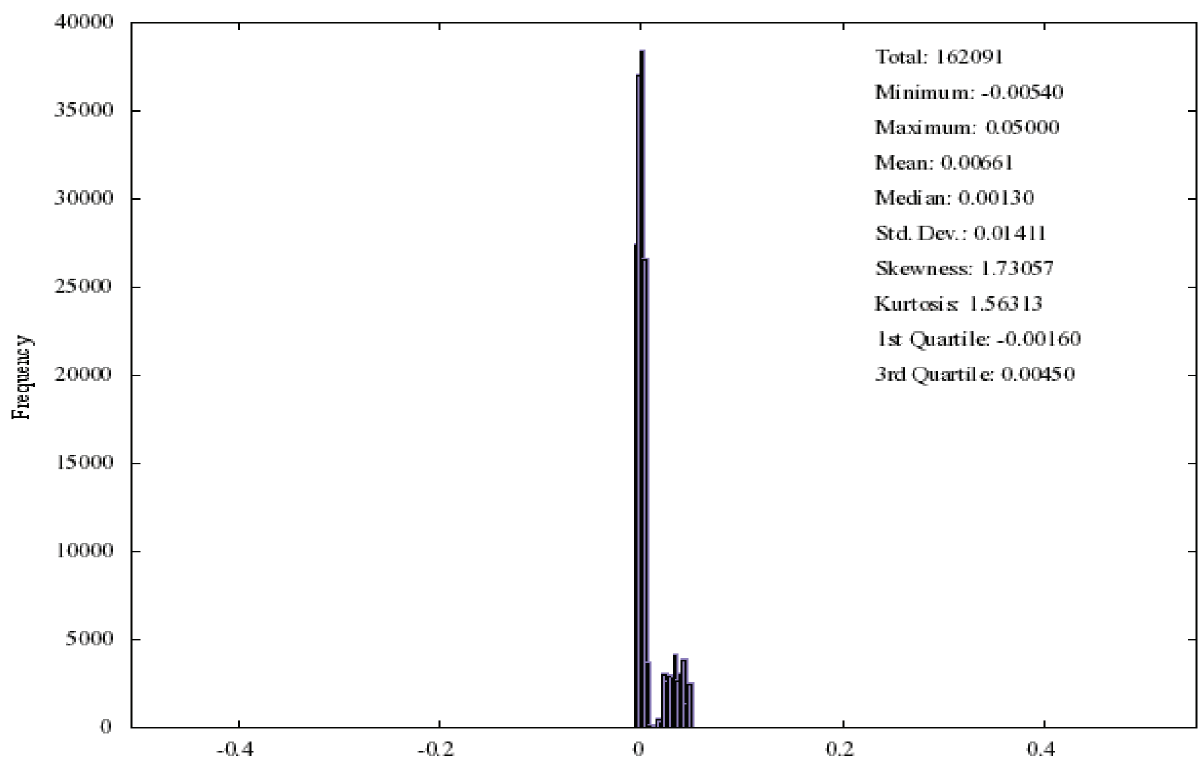

Figure 25. *Histogram of the differences between the conversion grid and xyz difference files using NOS hydrographic survey data in the AL -FL Gulf of Mexico to East of Choctawhatchee Bay VDatum project area.*

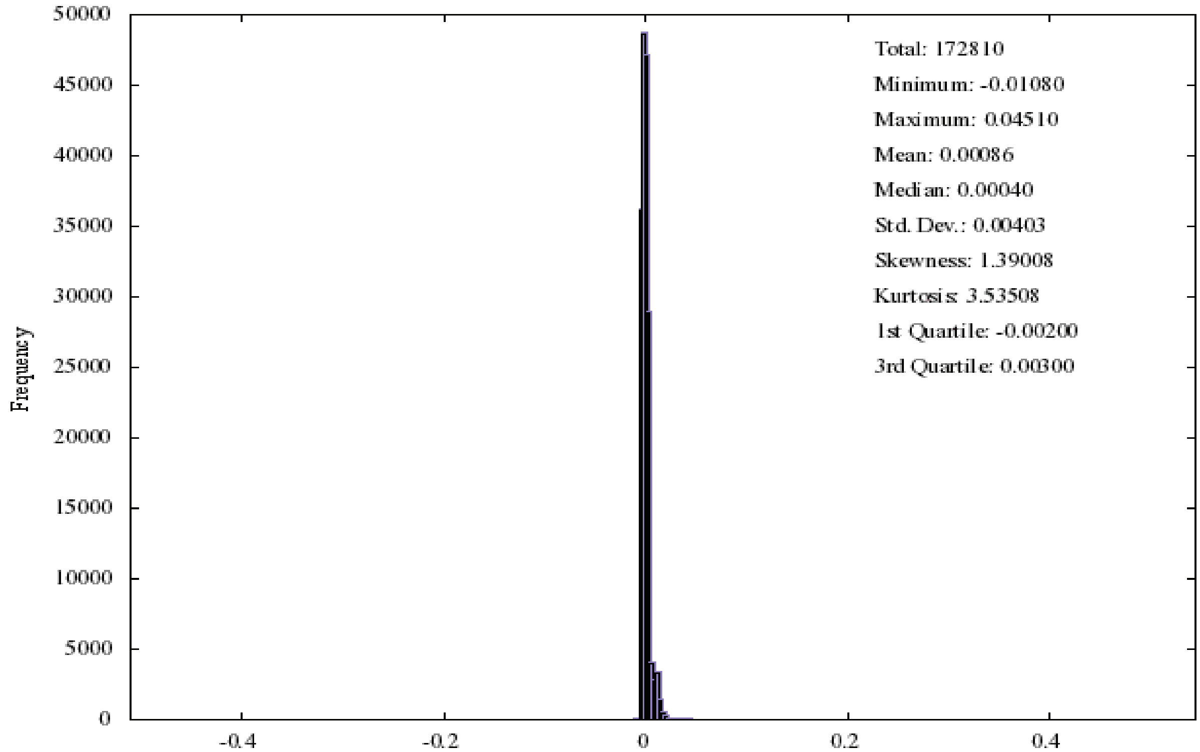

Figure 26. *Histogram of the differences between the conversion grid and xyz difference files of NOS hydrographic survey data in the AL - Mobile Bay VDatum project area.*

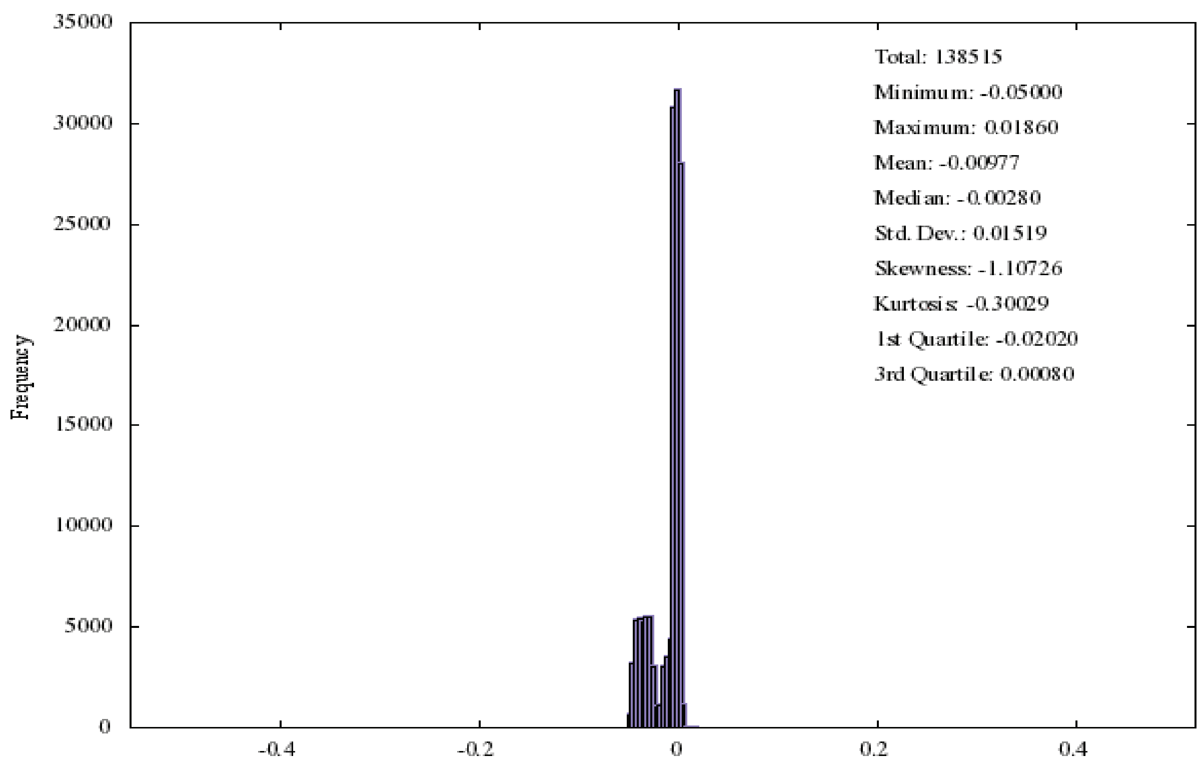

Figure 27. *Histogram of the differences between the conversion grid and xyz difference files of NOS hydrographic survey data in the Eastern LA and MS VDatum project area.*

3.4 Quality Assessment of the DEM

3.4.1. Horizontal accuracy

The horizontal accuracy of topographic and bathymetric features in the Mobile DEMs is dependent upon the datasets used to determine corresponding DEM cell values and the cell size of the DEM. The horizontal accuracy is 10 meters where topographic lidar datasets contribute to the DEM cell value. The horizontal accuracy is 0.75 meters at 1 sigma where only bathymetric-topographic lidar-derived data contributes to the DEM cell value and 20 meters in the small area with contributing SRTM data. Bathymetric features are resolved only to within a few tens of meters in deep-water areas. Shallow, near-coastal regions, rivers, and harbor surveys have an accuracy approaching that of sub aerial topographic features. Positional accuracy is limited by: the sparseness of deep-water soundings; potentially large positional uncertainty of pre-satellite navigated (e.g., GPS) NOS hydrographic surveys; and by the morphologic change that occurs in this dynamic region.

3.4.2 Vertical accuracy

Vertical accuracy of the Mobile DEMs is also highly dependent upon the source datasets contributing to DEM cell values. Topographic lidar has an estimated rmse of 13.9 to 20 cm. SRTM topography has a vertical accuracy of 16 meters and bathymetric-topographic lidar-derived data has a vertical accuracy of 0.20 meters at 1 sigma. Bathymetric areas have an estimated accuracy of between 0.1 meters and 5% of water depth. Those values were derived from the wide range of input data sounding measurements from the early 20th century to recent, GPS-navigated sonar surveys. Gridding interpolation to determine values between sparse, poorly-located NOS soundings degrades the vertical accuracy of elevations.

3.4.3 Slope maps and 3-D perspectives

ESRI *ArcCatalog* was used to generate a slope grid from the Mobile NAVD 88 DEM to allow for visual inspection and identification of artificial slopes along boundaries between datasets (Fig. 28). The DEM was transformed to UTM Zone 16 North coordinates (horizontal units in meters) in *ArcCatalog* for derivation of the slope grid; equivalent horizontal and vertical units are required for effective slope analysis. Three-dimensional viewing of the UTM-transformed DEM was accomplished using ESRI *ArcScene*. Analysis of preliminary grids revealed suspect data points, which were corrected before recompiling the DEM. Figure 29 shows a perspective view image of the 1/3 arc-second Mobile NAVD 88 DEM in its final version.

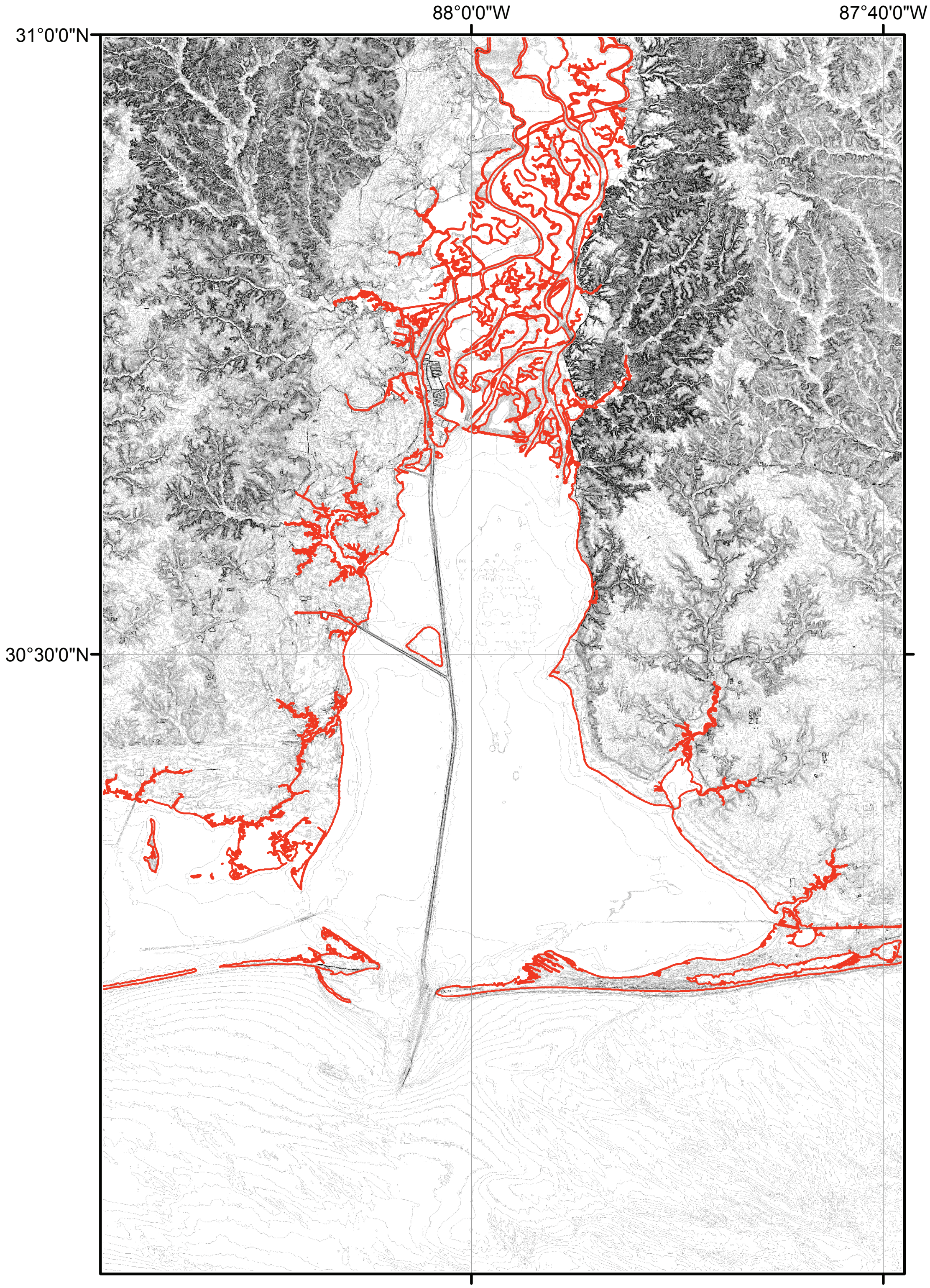

Figure 28. *Slope map of the Mobile NAVD 88 DEM. Flat-lying slope are white; dark shading denotes steep slopes; Mobile coastline in red*

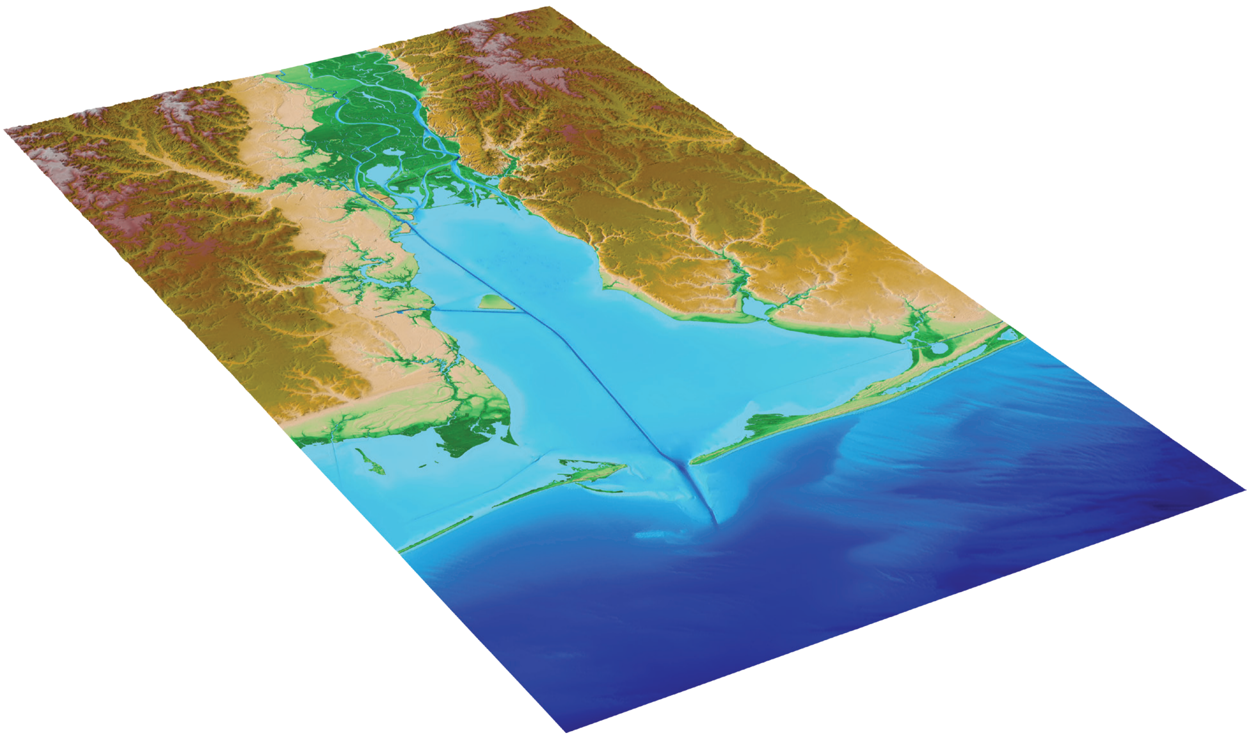

Figure 29. *Perspective view from the southwest of the Mobile NAVD 88 DEM. Five times vertical exaggeration.*

3.4.4 Comparison with source data files

To ensure grid accuracy, the Mobile NAVD 88 DEM was compared to source data files. All bathymetric and topographic source data was compared to the Mobile NAVD 88 DEM using *Gnuplot, Fledermaus, FME* and *ArcMap.* Histograms of the differences between individual datasets and the Mobile NAVD 88 DEM are shown in Figures 30 - 35. Largest differences between source datasets and the DEM resulted from the averaging of multiple topographic source datasets where data coverage overlapped, particularly in regions of steep slopes. Bathymetric data sources had the smallest differences from the DEM, which can be attributed to the shallow nature of Mobile Bay.

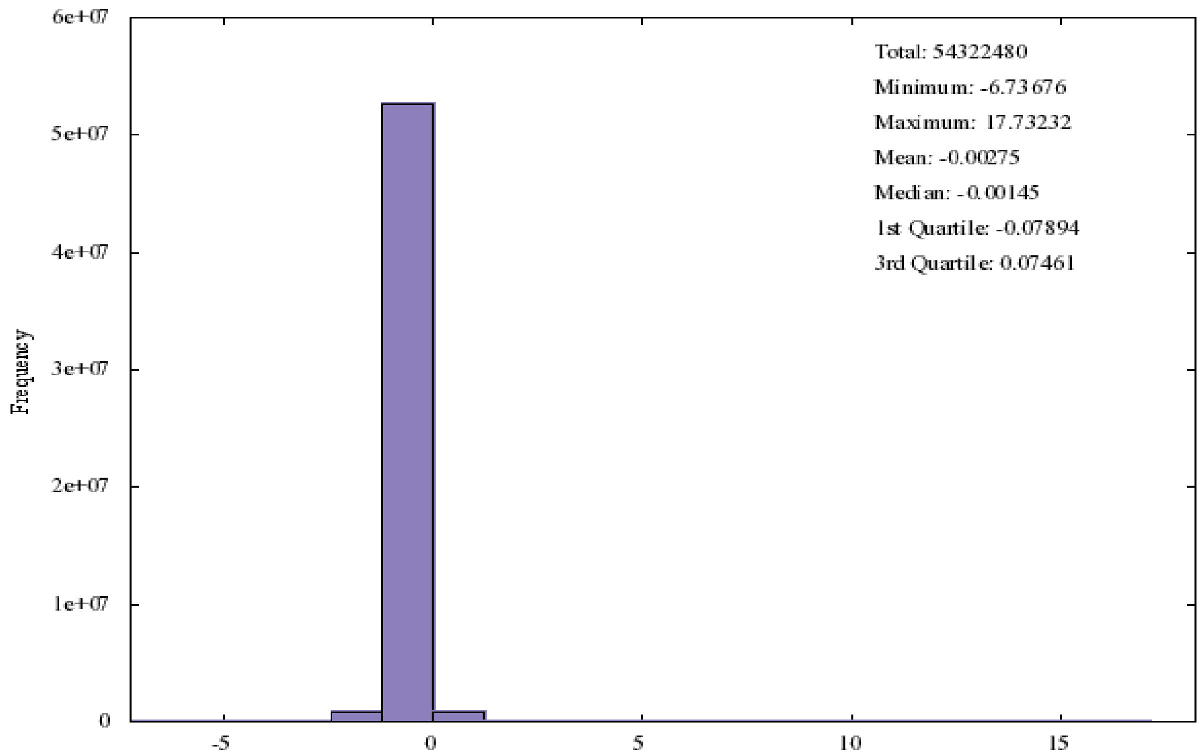

Figure 30. *Histogram of the differences between the Mobile County lidar data and the Mobile DEM.*

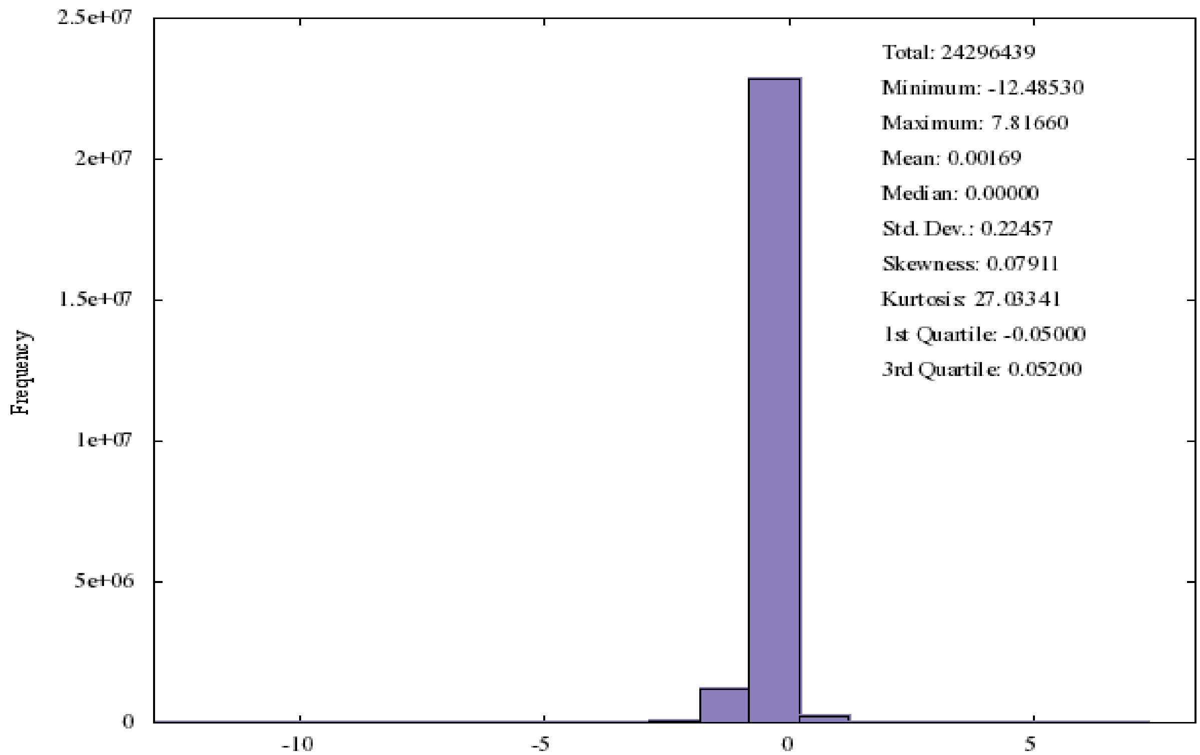

Figure 31. *Histogram of the differences between the Baldwin County lidar data and the Mobile DEM*

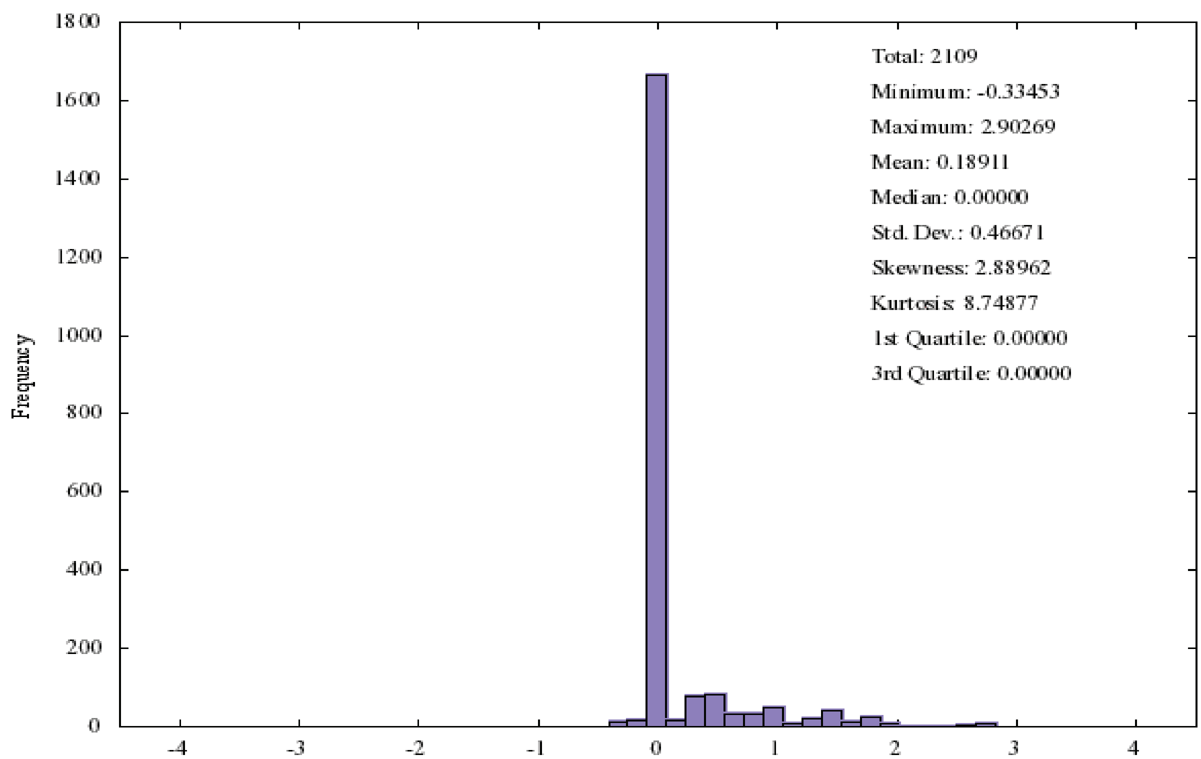

Figure 32. *Histogram of the differences between the SRTM data and the Mobile DEM.*

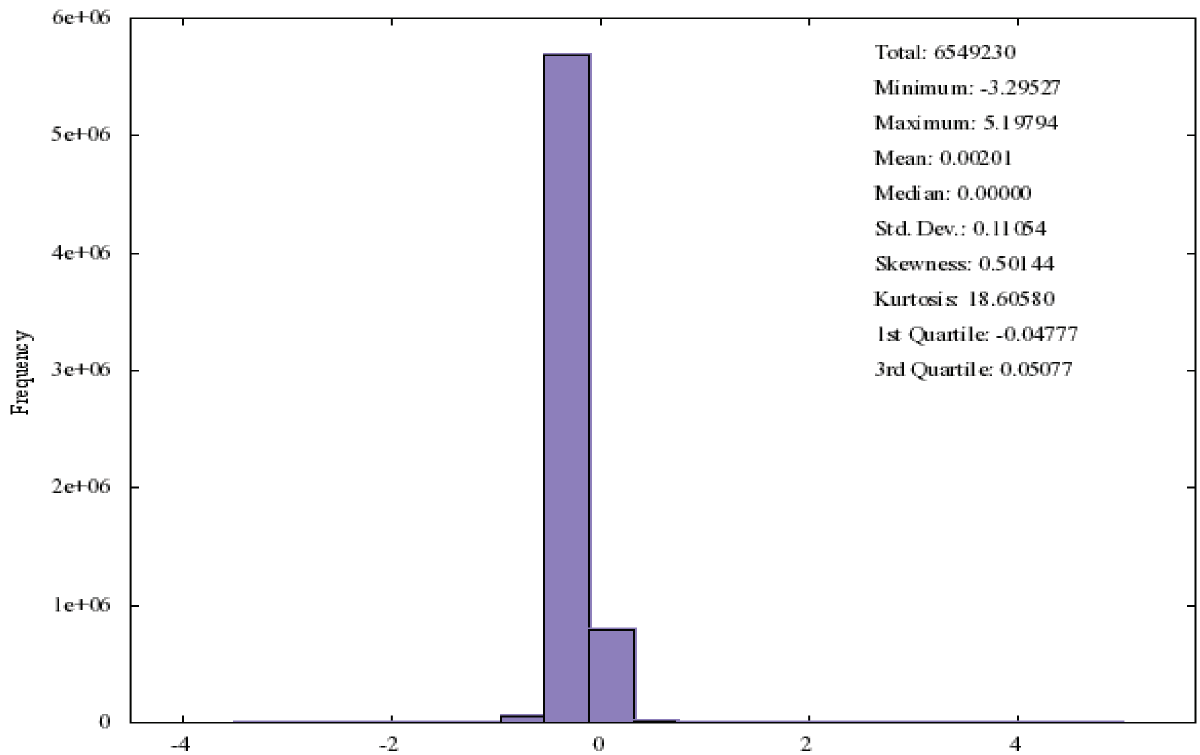

Figure 33. *Histogram of the differences between the USACE bathymetric-topographic lidar data and the Mobile DEM.*

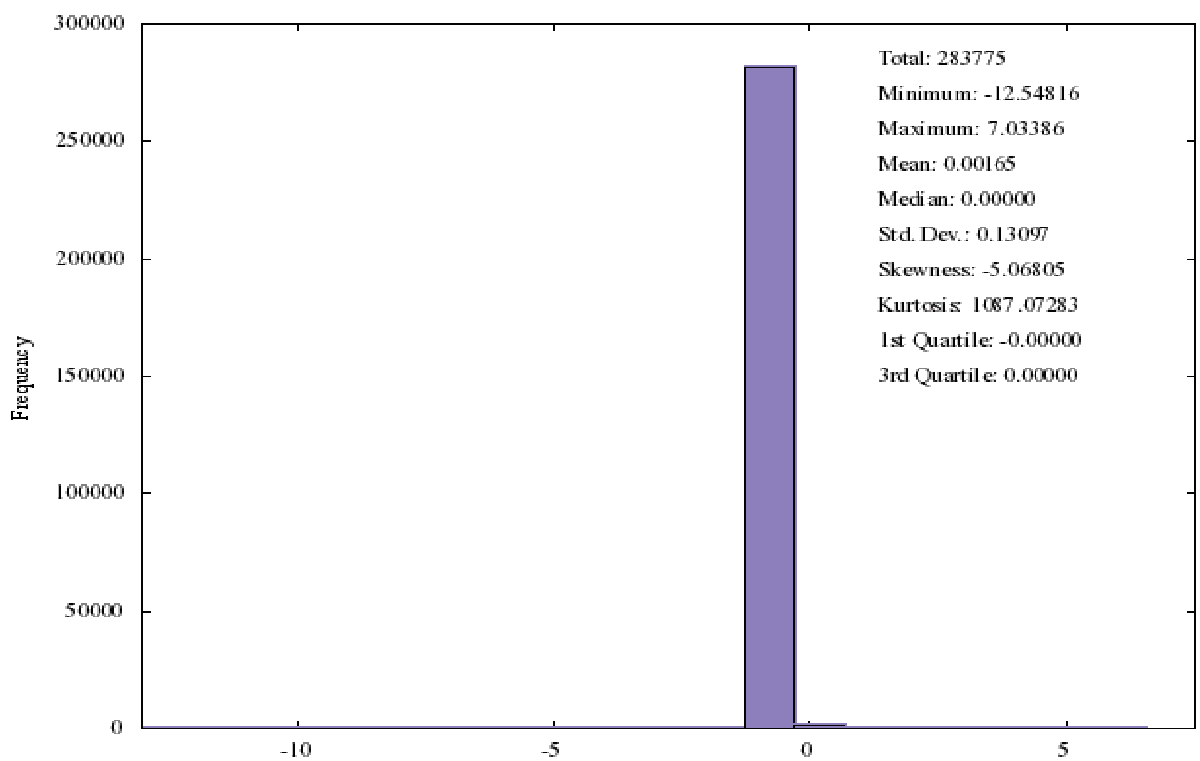

Figure 34. *Histogram of the differences between the NOS hydrographic survey data and the Mobile DEM.*

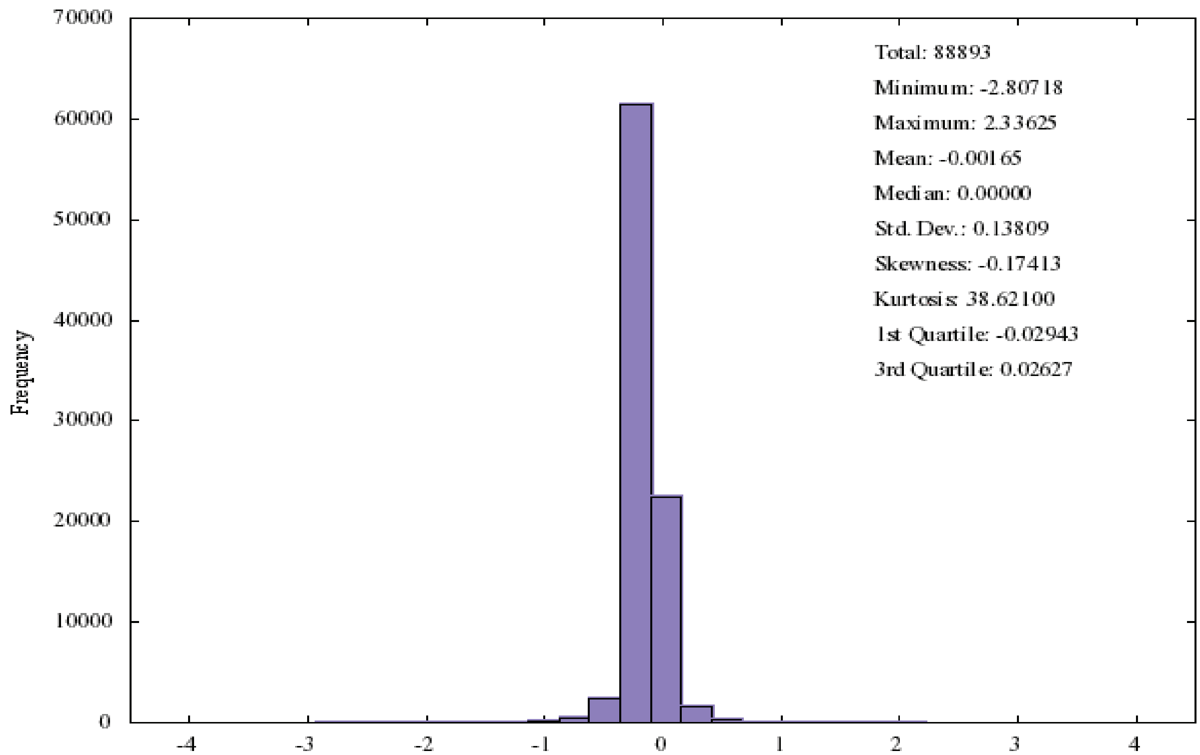

Figure 35. *Histogram of the differences between the USACE hydrographic survey data and the Mobile DEM.*

3.4.5 Comparison with National Geodetic Survey geodetic monuments

The elevations of 647 NOAA NGS geodetic monuments (Fig. 36) were extracted from online shapefiles of monument datasheets (http://www.ngs.noaa.gov/cgi-bin/datasheet.prl), which give monument positions in NAD 83 (typically sub-mm accuracy) and elevations in NAVD 88 (in meters). Monument elevations were compared with elevations of the Mobile NAVD 88 DEM. Differences between the Mobile NAVD 88 DEM and the NGS geodetic monument elevations range from -7.41 to 58.30 meters, with the majority of them being within +/-1 meter (Fig. 37). Negative values indicate that the monument elevation is less than the DEM elevation. Only 4 monuments out of 647 total monuments showed deviations less than -5 meters. 19 monuments out of the 647 monuments showed deviations greater than +5 meters from the DEM. After examination, it was determined that those monuments with the largest deviations do not represent ground surface as they are located on top of an observation tower, light house or at the apex of other structures.

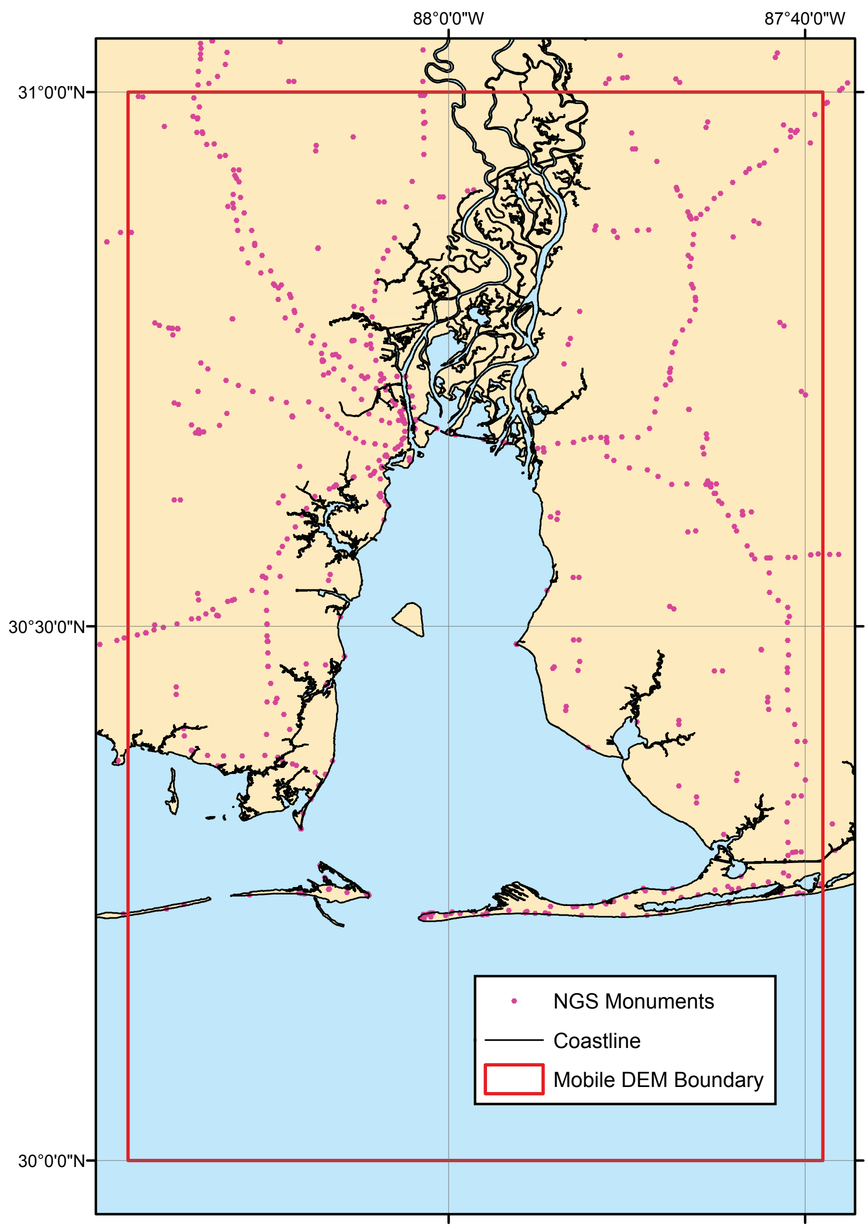

Figure 36. *NGS geodetic monument locations in the Mobile area.*

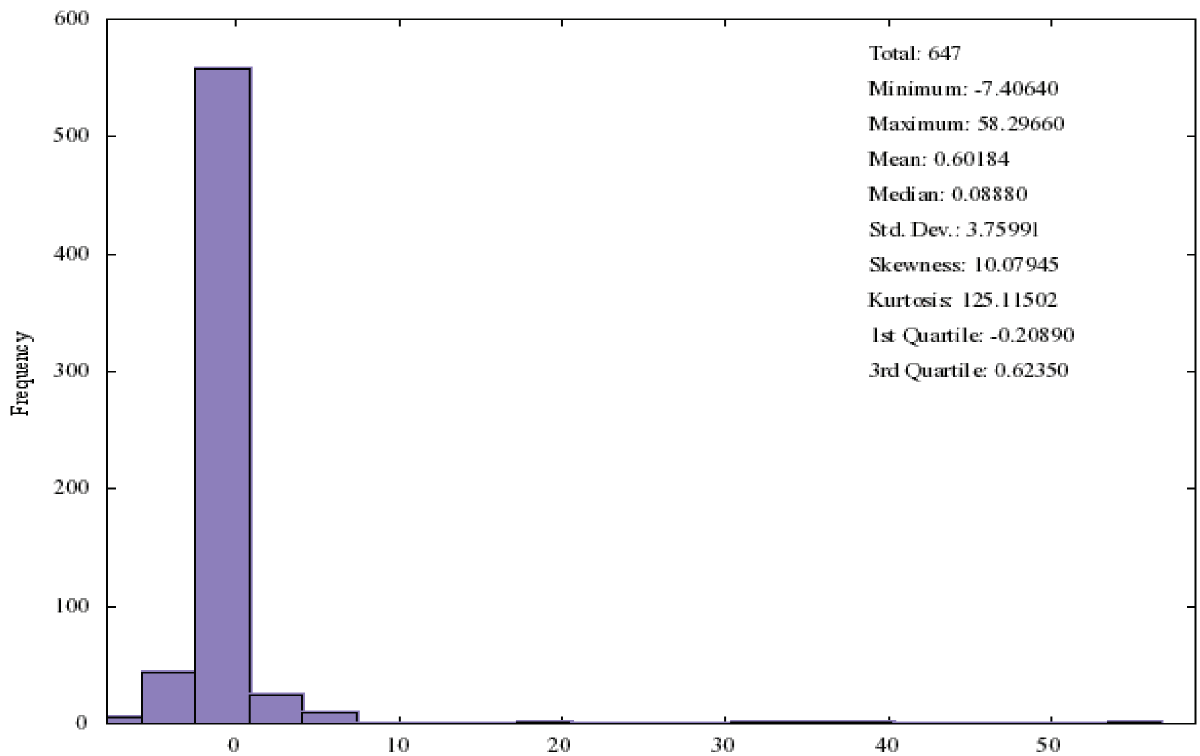

Figure 37. *Histogram of the differences between NGS geodetic monument elevations and the Mobile NAVD 88 DEM.*

4. Summary and Conclusions

Two bathymetric–topographic digital elevation models of the Mobile, Alabama region, with cell spacing of 1/3 arc-second, and vertical datums of NAVD 88 and MHW were developed for CSDL through the American Recovery and Reinvestment Act (ARRA) of 2009. The DEMs were developed to validate the utility of NOAA's OCS, NGS, and CO-OPS jointly developed *VDatum* tool and will be used for storm-surge inundation and sea-level-rise modeling. The best available digital data from U.S. federal, state and local agencies were obtained by NGDC, shifted to common horizontal and vertical datums, and evaluated and edited before DEM generation. The data were quality checked, processed and gridded using ESRI *ArcGIS*, *FME*, *GMT*, *MB-System*, *Quick Terrain Modeler*, *Gnuplot* and *Fledermaus* software. *VDatum* was utilized throughout the development of the Mobile DEMs to transform data to common vertical datums. Furthermore, NGDC developed a conversion grid derived from the *VDatum* project areas that transformed the Mobile NAVD 88 DEM to MHW.

Recommendations to improve the Mobile DEMs, based on NGDC's research and analysis, are listed below:

- Process USACE 2005 Post-Hurricane Katrina Topographic Mapping lidar to bare-earth.
- Conduct up-to-date topographic lidar surveys for all near-shore regions.
- Conduct up-to-date topographic lidar surveys in Mobile and Baldwin Counties.
- Conduct NOS hydrographic surveys in hydrographic data gaps and in estuary bays and rivers.
- Obtain missing xyz data sections of USACE hydrographic surveys

Recommendations to improve *VDatum*, based on NGDC's research and analysis, are listed below:

- Extend *VDatum* coverage to include estuary bays, such as Weeks Bay, Grand Bay, and Chacaloochee Bay
- Extend *VDatum* coverage to include estuary rivers, such as the Mobile River and Tensaw River.
- Resolve discontinuity issues with *VDatum* coverage in the Mobile region.

5. Acknowledgments

The creation of the Mobile DEMs was funded by the American Recovery and Reinvestment Act (ARRA) of 2009. The authors thank Scott Kearney (City of Mobile, AL) and Keil Schmid (NOAA CSC) for providing NGDC with topographic lidar for Mobile and Baldwin Counties, respectively. The authors also thank Cuong Hoang and Maureen Kenny (NOAA CSDL) for providing NGDC with the NOS survey non-superceded database and Al Browder (City of Gulf Shores, AL) for providing NGDC with bathymetric data of Little Lagoon, AL.

6. References

Kindinger, J. 2004. Evolution and History of Incised Valleys: The Mobile Bay Model. U.S. Geological Survey Fact Sheet. http://pubs.usgs.gov/fs/incised-valleys/index.html

Morton, R.A., 2008. Historical changes in the Mississippi-Alabama barrier-island chain and the roles of extreme storms, sea level, and human activities. Journal of Coastal Research, 24(6), 1587–1600. West Palm Beach (Florida), ISSN 0749-0208

Nautical Chart #11374 (RNC) 34th Edition, 2007. Dauphin Island to Dog Key Pass. Scale 1:40,000. U.S. Department of Commerce, NOAA, National Ocean Service, Coast Survey.

Nautical Chart #11376 (ENC and RNC) 53rd Edition, 2008. Mobile Bay. Scale 1:80,000. U.S. Department of Commerce, NOAA, National Ocean Service, Coast Survey.

Nautical Chart #11377 (ENC and RNC) 8th Edition, 2008. Mobile Bay Approaches and Lower Half. Scale 1:40,000. U.S. Department of Commerce, NOAA, National Ocean Service, Coast Survey.

Nautical Chart #11378 (ENC and RNC) 36th Edition, 2009. Santa Rosa Sound to Wolf Bay. Scale 1:40,000. U.S. Department of Commerce, NOAA, National Ocean Service, Coast Survey.

Nautical Chart #11377 (ENC and RNC) 1st Edition, 2005. Mobile Bay East Fowl River to Deer River Point. Scale 1:20,000. U.S. Department of Commerce, NOAA, National Ocean Service, Coast Survey.

7. Data Processing Software

ArcGIS v. 9.3.1, developed and licensed by ESRI, Redlands, California, http://www.esri.com/

ESRI Imagery World 2D Online World Imagery 2D – ESRI ArcGIS Resource Centers, http://resources.arcgis.com/content/arcgis-content/about

Fledermaus v. 7.0 – developed and licensed by Interactive Visualization Systems (IVS 3D), Fredericton, New Brunswick, Canada, http://www.ivs3d.com/

FME 2009 GB – Feature Manipulation Engine, developed and licensed by Safe Software, Vancouver, BC, Canada, http://www.safe.com/

GEODAS v. 5 – Geophysical Data System, free software developed and maintained by Dan Metzger, NOAA National Geophysical Data Center, http://www.ngdc.noaa.gov/mgg/geodas/

GMT v. 4.2.1 – Generic Mapping Tools, free software developed and maintained by Paul Wessel and Walter Smith, funded by the National Science Foundation, http://gmt.soest.hawaii.edu/

Gnuplot v. 4.2, free software developed and maintained by Thomas Williams, Colin Kelley, Russell Lang, Dave Kotz, John Campbell, Gershon Elber, Alexander Woo http://www.gnuplot.info/

MB-System v. 5.1.1, free software developed and maintained by David W. Caress and Dale N. Chayes, funded by the National Science Foundation, http://www.ldeo.columbia.edu/res/pi/MB-System/

Quick Terrain Modeler v. 6.0.6, Lidar processing software developed by John Hopkins University's Applied Physics Laboratory (APL) and maintained and licensed by Applied Imagery, http://www.appliedimagery.com/

VDatum Transformation Tool, Alabama, Florida, Louisiana, Mississippi, Alabama - Florida - Gulf of Mexico to East of Choctawhatchee Bay V. 01, Alabama - Mobile Bay V. 01, and Eastern Louisiana and Mississippi V. 01 – developed and maintained by NOAA's National Geodetic Survey (NGS), Office of Coast Survey (OCS), and Center for Operational Oceanographic Products and Services (CO-OPS), http://vdatum.noaa.gov/