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Bathymetric terrain model of the Atlantic margin for marine geological investigations.

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Conversion Factors and Datum

SI to Inch/Pound

Multiply	By	To obtain
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)
meter per second (m/s)	3.281	foot per second (ft/s)

Vertical coordinate information is referenced to the Instantaneous Sea Level.
Horizontal coordinate information is referenced to the World Geodetic System 1984 (WGS 84).

Abbreviations

BTM	bathymetric terrain model
CCOM	Center for Coastal and Ocean Mapping
CRM	coastal relief model
ECS	extended continental shelf
GCS	geographic coordinate system
GIS	geographic information system
HIPS	hydrographic information processing system
NOAA	National Oceanic and Atmospheric Administration
NRC	U.S. Nuclear Regulatory Commission
OE	NOAA Ocean Exploration Program

NGDC	National Geophysical Data Center
UNH	University of New Hampshire
USAM	U.S. Atlantic margin
USGS	U.S. Geological Survey
UNCLOS	United Nations Convention on the Law of the Sea
WMS	Web mapping service
WHOI	Woods Hole Oceanographic Institution

Bathymetric Terrain Model of the Atlantic Margin for Marine Geological Investigations

By Brian D. Andrews,[1] Jason D. Chaytor,[1] Uri S. ten Brink,[1] Daniel S. Brothers,[1] and James V. Gardner[2]

Abstract

Bathymetric terrain models of seafloor morphology are an important component of marine geological investigations. Advances in acquisition and processing technologies of bathymetric data have facilitated the creation of high-resolution bathymetric surfaces that approach the resolution of similar surfaces available for onshore investigations. These bathymetric terrain models provide a detailed representation of the Earth's subaqueous surface and, when combined with other geophysical and geological datasets, allow for interpretation of modern and ancient geological processes.

The purpose of the bathymetric terrain model presented in this report is to provide a high-quality bathymetric surface of the Atlantic margin of the United States that can be used to augment current and future marine geological investigations. The input data for this bathymetric terrain model, covering almost 305,000 square kilometers, were acquired by several sources, including the U.S. Geological Survey, the National Oceanic and Atmospheric Administration National Geophysical Data Center and the Ocean Exploration Program, the University of New Hampshire, and the Woods Hole Oceanographic Institution. These data have been edited using hydrographic data processing software to maximize the quality, usability, and cartographic presentation of the combined terrain model.

Introduction

The purpose of the bathymetric terrain model presented in this report is to provide a high-quality bathymetric surface of the Atlantic margin of the United States that can be used to augment current and future marine geological investigations. The input data for this bathymetric terrain model, covering almost 305,000 square kilometers, were acquired by several sources, including the U.S. Geological Survey, the National Oceanic and Atmospheric Administration National Geophysical Data Center and the Ocean Exploration Program, the University of New Hampshire, and the Woods Hole Oceanographic Institution. These data have been edited using hydrographic data processing software to maximize the quality, usability, and cartographic presentation of the combined terrain model.

The bathymetric data published in this report were compiled as part of a project funded by the Nuclear Regulatory Commission (NRC) to evaluate tsunami hazards along the East Coast of the United States. (ten Brink and others, 2010). This hazards analysis research required a high-quality bathymetric terrain model (BTM) to identify and characterize historical submarine landslides capable of generating

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tsunamis in order to assess potential tsunami impacts to nuclear power plants along the Atlantic coast (fig. 1). The BTM provided a consistent framework for hazard risk-assessment along the Atlantic margin of the United States, aiding in the interpretation of additional geophysical and geological datasets, allowing for the extraction of pertinent statistical risk parameters, and helping scientists to focus on critical areas for future data collection (Chaytor and others, 2009, 2011, 2012a,b; ten Brink and others, 2009, 2011, 2012; Flores and others, 2011;Geist and others, 2009, Brothers and others, 2013). The compilation benefited from bathymetric data collected by the University of New Hampshire (UNH) Center for Coastal and Ocean Mapping (CCOM) for the U.S. Extended Continental Shelf (ECS) program. The ECS program collected bathymetric data (from 2004 through 2005) on the slope and rise of the Atlantic Margin (Gardner, 2004; Cartwright and Gardner, 2005) as part of the evaluation of a potential claim by the United States within the framework of the United Nations Convention on the Law of the Sea (UNCLOS; Gardner and others, 2006).

Beyond the applied use of the bathymetric compilation in hazard characterization, the BTM provides a spatially consistent dataset for investigating modern and ancient geological processes along a passive margin that contains glacial, fluvial, and carbonate environments (for example, Twichell and others, 2009; Chaytor and others, 2012b; Brothers and others, 2013) and in support of habitat evaluations, physical oceanographic studies, and other evaluations of the seafloor off the coast of the eastern United States.

Common Processing Methods

The methods used to access, process, and compile the BTM published in this report are described in this section (fig. 2). The first step in the process inventories all existing bathymetric data using the Web mapping service (WMS) of the NGDC (National Geophysical Data Center, 2012). Individual surveys (fig. 3) covering areas seaward of the shelf break of the Atlantic margin of the United States were identified using the NGDC WMS. Initially, 38 individual surveys covering the area of interest were accessed; the number of surveys was later reduced to 22 for the final grid (fig. 1).

Data Access and Download

Bathymetric line files in compressed format (MB system format; Caress and Chayes, 2013) for each identified survey were downloaded from NGDC (see list of dataset download URLs in appendix 1). Three of these surveys (RB0904, NF–11–04–NC, and NF1208–USGS) were conducted by USGS scientists onboard National Oceanic and Atmospheric Administration (NOAA) vessels (appendix 1). The bathymetric line files for these three surveys were accessed in “raw. all” format by the USGS directly from the vessel during the survey and not downloaded from the NGDC. The USGS archived the line files from these three surveys after completion of the survey, and the NGDC converted the raw.all files to MB-System format for public access via the NGDC Web site.

Data Processing

The CARIS Hydrographic Information System (HIPS) was used to process the line files after they were downloaded from NGDC and uncompressed. A new HIPS Project was started for each of the individual surveys and the line files were imported for each day (Julian calendar). All bathymetric line files were collected, archived with NGDC, and imported to HIPS, using the Geographic Coordinate System (GCS). Bathymetric files were collected using instantaneous sea level, and no additional tidal corrections were applied during import into HIPS. Instantaneous sea level indicates that the data collected were not referenced to a tidal datum, rather that the depths represent a height that is dependent on the local sea level at that location and time. Instantaneous Sea Level does not correlate to Mean Sea Level, however for comparison, the total tidal levels (tides, plus no-tidal sea surface heights above the geoid) range between -2.3 meters and 2.0 meters above the geoid for the period 1992-2011 (Egbert and Erofeeva, 2013).

For each survey, an initial base (depth) surface was produced as a base to edit the data. The base surfaces were created using a Mercator projection which was more suitable for the spatial extent of this project than the GCS of the input line files. Several quality control steps were conducted to ensure the final base surfaces were free of depth spikes (erroneous data that would impact the quality of the final BTM) before combining the individual surfaces using CARIS Base Editor. For example, each survey line was reviewed and edited for bad soundings, and adjustments to the speed of sound corrections were applied if required. Depth and range filters were then applied using the Swath Editor feature within CARIS HIPS to eliminate erroneous soundings. After preliminary editing was completed, a final depth surface was produced and evaluated again for any remaining artifacts using both the three-dimensional (3D) editor and 3D viewer in HIPS. If additional edits were required, then the final surface was rebuilt and interpolated to fill in any remaining small data gaps (fig. 2).

Combining the individual surveys into one surface using Base Editor involved two basic steps: (1) surveys conducted by the same vessel were combined into a single surface, and (2) all surfaces were then combined into one final BTM of 100-meter (m) resolution, covering the extent of all surveys (fig. 2). Combining surveys from the same vessel is a logical first step; data acquisition techniques and equipment vary from vessel to vessel, thus different “vessel files” were used during the import of data into the CARIS HIPS software. Data collected with the same vessel but different surveys, for example, were combined into one base surface because they used the same sonar and acquisition methods.

During the “Combine” process, the order of the input surfaces was controlled using one of several queries provided in Base Editor. For example, in most cases, separate surveys from the same vessel were combined using the query “where creation date is greatest;” therefore, in the areas where input base surfaces overlapped, the output surface was produced using the surface with the most recent creation date and older data were omitted in the overlap area. This method ensured that the most recent version of the surface was used. The second step combined the individual “vessel” surfaces using the “creation date is greatest” query to determine the surface order and produce a single final surface with a cell resolution of 100 meters per pixel (fig. 1).

The “Combine” function in Base Editor also produces a “contributor” layer that records the extent of the input surface used as a source for each cell in the output surface. This is perhaps the greatest benefit of this method compared with previous bathymetric compilations in which the user cannot trace the source of the final compilation. This contributor layer is published in this report (in Esri shapefile format) as a record of the input surfaces used during the ”Combine” function and is ultimately the source of each pixel in the final BTM, using the “Source” attribute in the “AtlanticMarginBathSource” shapefile (see the Data Catalog section). The metadata that accompany the spatial data published in this report provide detailed descriptions of the methods and steps used to produce the final BTM and source polygon.

The ability to control the input order and the combination of large overlapping bathymetric surfaces within hydrographic software is a relatively new technique within the CARIS software suite. Similar operations could be performed using geographic information system (GIS) software; however, the ability to manipulate these data in their near-native form (as soundings) with in CARIS software makes the process of combining datasets of different age and quality on a margin-scale more efficient than working in GIS software. Furthermore, this method facilitates periodic updates to the BTM as new bathymetric data are acquired.

Data Catalog

If new bathymetric data become available from the NGDC and the USGS and the data published in this report need to be updated, the grid will be identified by the publication date and version number. For example the initial version of the data and publication will appear as “2013_1” (2013 for the year of publication, and 1 for the version number).

Projection

The data in this report are published using a Mercator projection with central longitude of 72 degrees west and latitude of true scale of 40 degrees north. All horizontal and vertical units are in meters. The projection parameters continued in the “prj.adf” file used by ArcGIS grid published in this report are listed below:

- Projection: MERCATOR
- Datum: WGS84
- Spheroid: WGS84
- Units: METERS
- Zunits: NO
- Xshift: 0.0
- Yshift: 0.0
- Parameters:
  - –72 0 0.0 /* longitude of central meridian
  - 40 0 0.0 /* latitude of true scale
  - 0.0 /* false easting (meters)
  - 0.0 /* false northing (meters)

Layer (metadata)	Description	View	Download
AtlanticMarginBathSource	Identifies the name of the source grid used in the combine operation		AM_SourcePgon.zip
ambath100m	100-m gridded bathymetry		ambath100.zip

Map Sheet

The data published in this report are also presented as a map sheet in portable document file (pdf) format. The data in this map are for cartographic display of the entire Atlantic margin of the United States and include data that were not collected for the purposes of the BTM published in this report. The areas covered by the BTM published in this report are outlined in gray in the inset map at the lower right of the map sheet. Other data are included for visual display only.

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Caress, D.W., and Chayes, D.N., 2013, Mapping the seafloor—Software for the processing and display of swath sonar data (version 5.3.2017): Columbia University MB-System, available at http://www.ldeo.columbia.edu/res/pi/MB-System/.

Cartwright, Doug, and Gardner, J.V., 2005, U.S. law of the sea cruise to map the foot of the slope and 2500-m isobath of the northeast U.S. Atlantic continental margin—Legs 4 and 5: University of New Hampshire cruise report, 30 p. (Also available at http://ccom.unh.edu/sites/default/files/publications/Cartwright_05_cruise_report_PF05-1.pdf.)

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Chaytor, J.D., Twichell, D.C., and ten Brink, U.S., 2012b, A reevaluation of the Munson-Nygren-retriever submarine landslide complex, Georges bank lower slope, western North Atlantic, *in* Yamada, Yasuhiro, Kawamura, Kichiro, Ikehara, Ken, Ogawa, Yujiro, Urgeles, Roger, Mosher, David, Chaytor, Jason, and Strasser, Michael, eds., Submarine mass movements and their consequences: Advances in Natural and Technological Hazards Research, p. 135–146.

Chaytor, J.D., ten Brink, U.S., Twichell, D.C., Baxter, C.D., Hallam, T.D., and Brothers, D.S., 2011, Submarine landslides along the U.S. Atlantic margin—Their distribution, failure processes, and age: American Geophysical Union, fall meeting, San Francisco, Calif., December 5–9, 2011, abstract T21A–2302.

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Egbert, G.D., and Erofeeva, Svetlana, [2013]: The OSU TOPEX/Poseidon global inverse solution TPXO: Oregon State University TPXO version [8.0], accessed July 18, 2013, at http://volkov.oce.orst.edu/tides/global.html.

Flores, C.H, Brothers, D.S., ten Brink, U.S., and Chaytor, J.D., 2011, New geophysical constraints on the stratigraphy and structure of the southern New England continental margin: American Geophysical Union, fall meeting, San Francisco, Calif., December 5–9, 2011, abstract T21A–2286, accessed July 10, 2013, at http://adsabs.harvard.edu/abs/2011AGUFM.T21A2286F.

Gardner, J.V., 2004, U.S. law of the sea cruise to map the foot of the slope and 2500-m isobath of the northeast U.S. Atlantic continental margin—Legs 1, 2, and 3: University of New Hampshire cruise report, 61 p. (Also available at http://ccom.unh.edu/sites/default/files/publications/Gardner_04_cruise_report_HEN04-1.pdf.)

Gardner, J.V., Mayer, L.A., and Armstrong, Andrew, 2006, Mapping supports potential submission to U.N. law of the sea: Eos, Transactions, American Geophysical Union, v. 87, no. 16, p. 157–160.

Geist, E.L., Lynett, P.J., and Chaytor, J.D., 2009, Hydrodynamic modeling of tsunamis from the Currituck landslide: Marine Geology, v. 264, nos. 1–2, p. 41–52.

National Geophysical Data Center, 2012, Web_mercator/trackline_bathymetry (mapserver): National Oceanic and Atmospheric Administration, National Geophysical Data Center Web mapping service, accessed December 21, 2012, at http://maps.ngdc.noaa.gov/arcgis/rest/services/web_mercator/trackline_bathymetry/MapServer.

ten Brink, U.S., Chaytor; J.D., Andrews, B.D., Brothers, D.S., and Geist, E.L., 2012, Updated size distribution of submarine landslides along the U.S. Atlantic margin: American Geophysical Union, fall meeting, San Francisco, Calif., December 3–7, 2012, abstract OS43C–1827.

ten Brink, U.S., Chaytor, J.D., Brothers, D.S., Twichell, D.C., Ross, S.W., and Brooke, Sandra, 2011, New high-resolution mapping of submarine canyons in the mid-Atlantic continental margin: American Geophysical Union, fall meeting, San Francisco, Calif., December 5–9, 2011, abstract T21A–2299.

ten Brink, U.S., Barkan, R., Andrews, B.D., and Chaytor, J.D., 2009, Size distributions and failure initiation of submarine and subaerial landslides: Earth and Planetary Science Letters, v. 287, nos. 1–2, p. 31–42.

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Twichell, D.C., Chaytor, J.D., ten Brink, U.S., and Buczkowski, Brian, 2009, Morphology of late Quaternary submarine landslides along the U.S. Atlantic continental margin: Marine Geology, v. 264, nos. 1–2, p. 4–15.

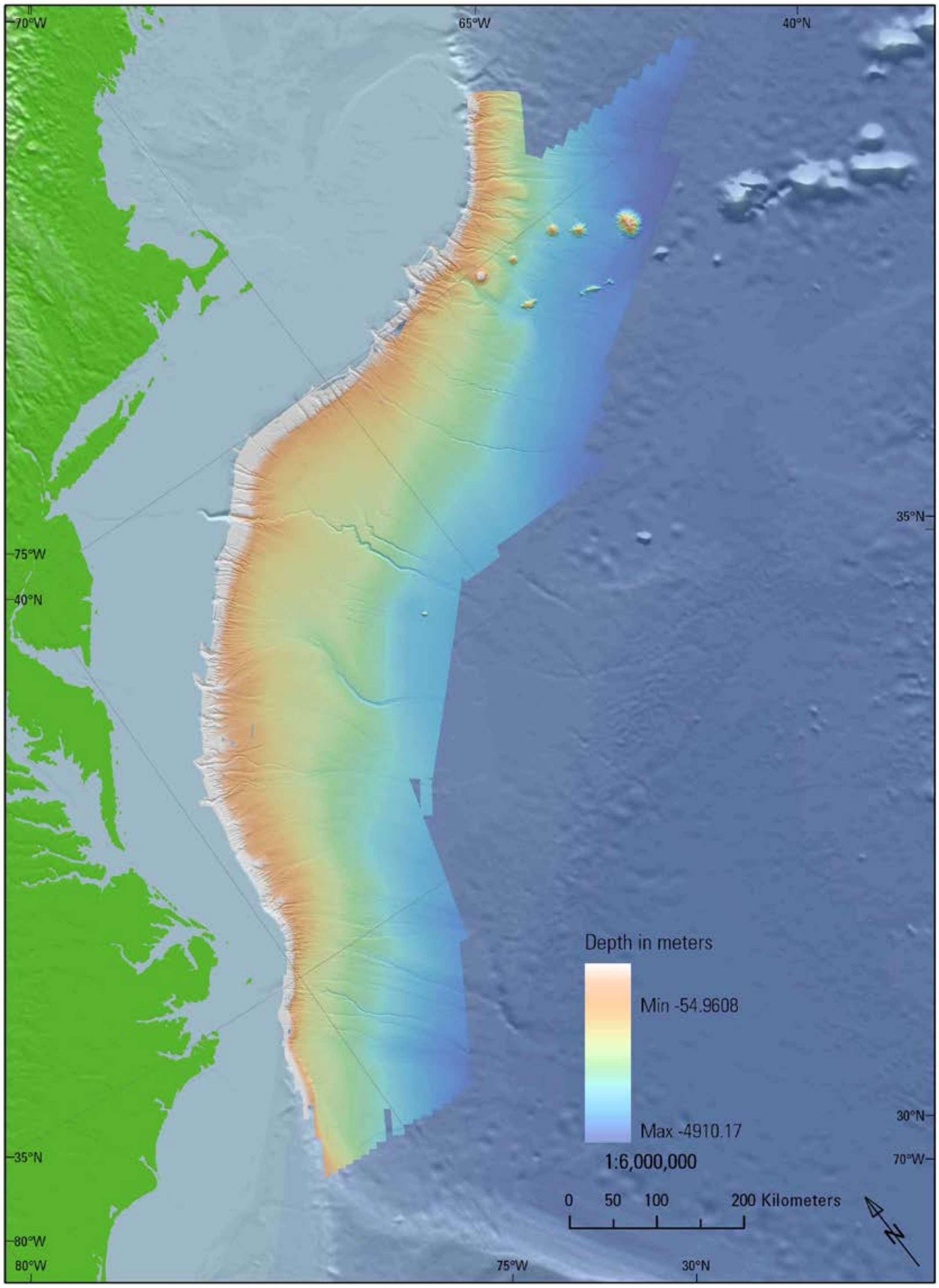

Figure 1. Map showing the location of the Atlantic margin seaward of the U.S. Atlantic coast showing the extent of the bathymetric terrain model published in this report. Land elevations in green and additional regional bathymetry in light blue are for basemap purposes only and are not published in this report. Data are from the U.S. Geological Survey and the National Oceanic and Atmospheric Administration National Geophysical Data Center. Max, maximum; Min, minimum.

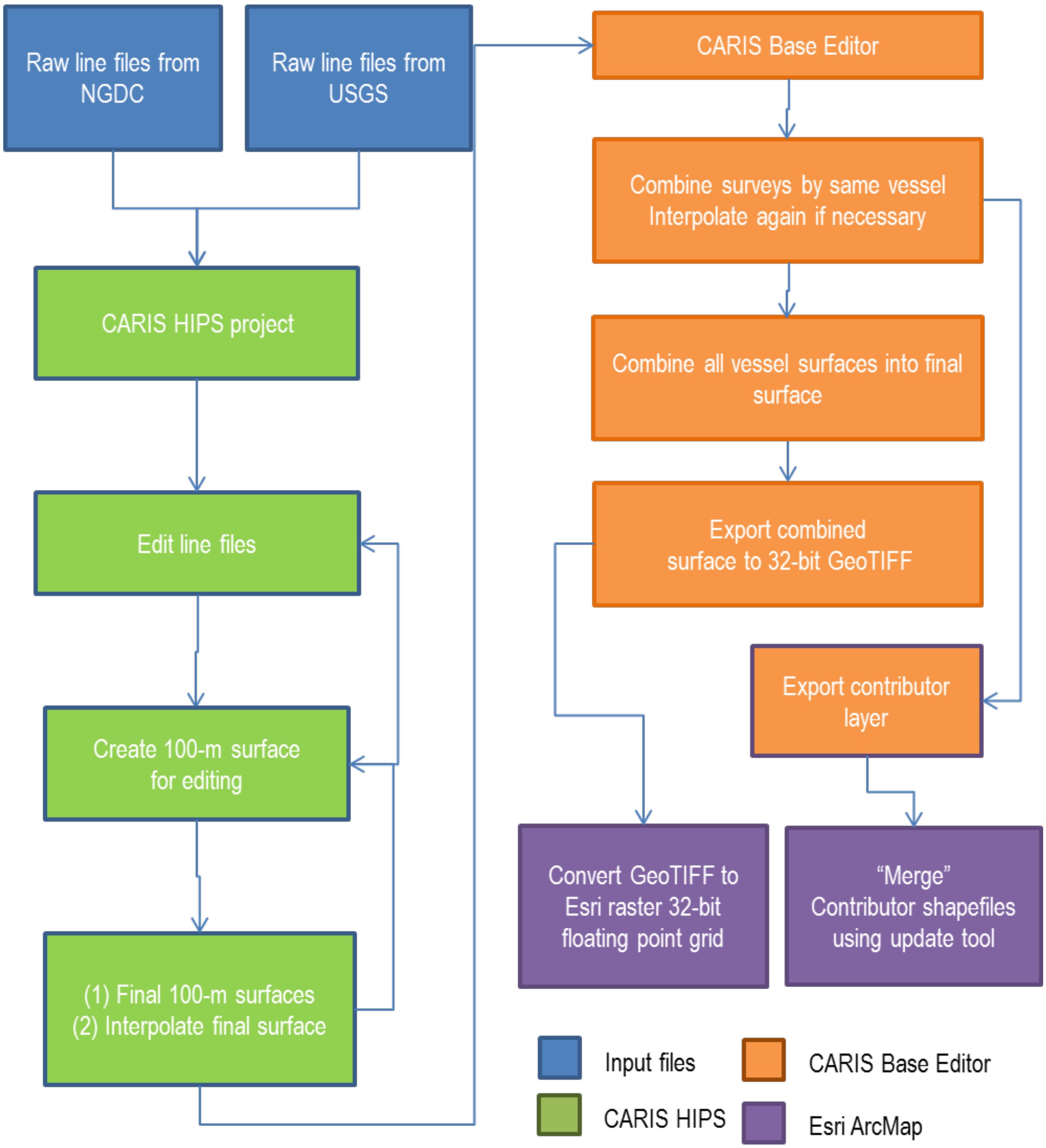

Figure 2. Generalized flow diagram showing the process used to process raw multibeam files into final data products published in this report. CARIS HIPS, CARIS Hydrographic Information Processing System; GeoTIFF, georeferenced tagged image file format; m, meters; NGDC, National Oceanic and Atmospheric Administration National Geophysical Data Center; USGS, U.S. Geological Survey.

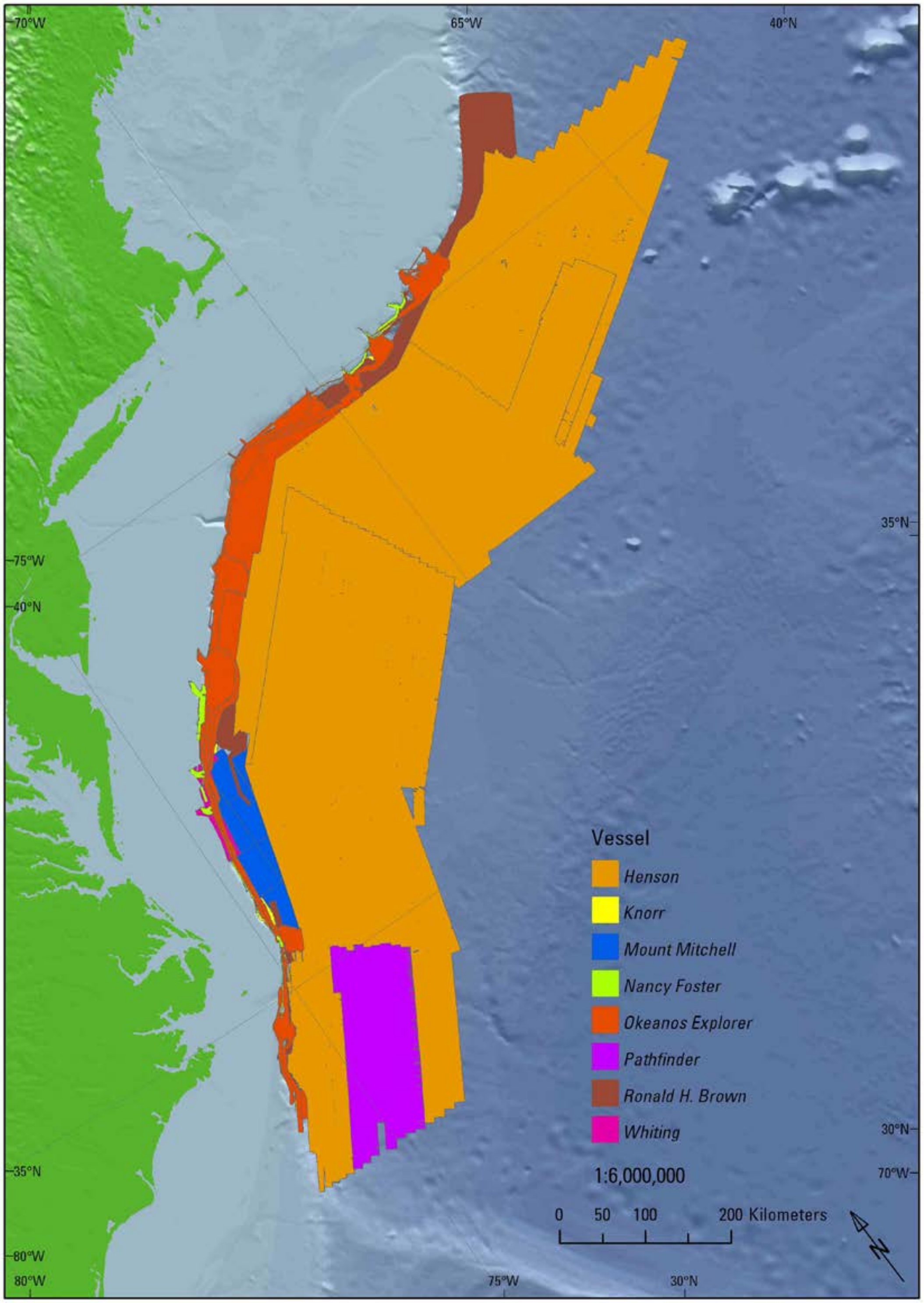

Figure 3. Map showing the source surveys (color coded by survey vessel) used to compile the final bathymetric terrain model and published as an Esri shapefile in this report. Surveys are listed in appendix 1. Land elevations in green and regional bathymetry in light blue are for basemap purposes only and are not published in this report. Data are from the U.S. Geological Survey and the National Oceanic and Atmospheric Administration National Geophysical Data Center.

Appendix 1. Individual Surveys Used as Sources for the Bathymetric Terrain Model for the Atlantic Margin of the United States

Table 1–1. Surveys used as sources for the bathymetric terrain model for the Atlantic Margin of the United States

[kHz, kilohertz; NGDC, National Geophysical Data Center; USNS, U.S. Navy ship]

Survey	Vessel	Start date	End date	Frequency, in kHz	Format	Link to NGDC data
EX1106	*Okeanos Explorer*	9/15/2011	9/28/2011	30	mb58	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/okeanos_explorer/EX1106/multibeam/data/version1/MB/
EX1201	*Okeanos Explorer*	2/14/2012	2/23/2012	30	mb58	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/okeanos_explorer/EX1201/multibeam/data/version1/MB/
EX2104	*Okeanos Explorer*	5/30/2012	6/13/2012	30	mb58	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/okeanos_explorer/EX1204/multibeam/data/version1/MB/
NF1208_USGS	*Nancy Foster*	6/29/2012	7/3/2012	95	.all	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/nancy_foster/NF1208_USGS/multibeam/data/version1/MB/
NF–11–04_NC	*Nancy Foster*	6/4/2011	6/17/2011	95	.all	Data are not publicly available because of possbile sensitive marine archeological sites within the survey area
RB0904	*Ronald H. Brown*	5/11/2009	5/25/2009	12	.all	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/ronald_h.brown/RB0904/multibeam/data/version1/MB/
PF05–1	USNS *Pathfinder*	5/1/2005	5/9/2005	12	mb57	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/pathfinder/PF0501/multibeam/data/version1/MB/
HEN04–1	USNS *Henson*	8/30/2004	9/18/2004	12	mb51	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/henson/HEN04-1/multibeam/data/version1/MB/
HEN04–2	USNS *Henson*	9/25/2004	10/20/2004	12	mb51	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/henson/HEN04-2/multibeam/data/version1/MB/
HEN04–3	USNS *Henson*	10/29/2004	11/29/2004	12	mb51	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/henson/HEN04-3/multibeam/data/version1/MB/
B00213	*Whiting*	3/10/1990	4/7/1990	12	mb15	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/whiting/B00213/multibeam/data/version1/MB/
B00214	*Whiting*	3/10/1999	7/15/1999	12	mb15	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/whiting/B00214/multibeam/data/version1/MB/
B00215	*Whiting*	6/28/1990	7/14/1990	36	mb15	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/whiting/B00215/multibeam/data/version1/MB/
B00217	*Mount Mitchell*	4/28/1990	5/22/1990	12	mb15	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/mt._mitchell/B00217/multibeam/data/version1/MB/
B00218	*Mount Mitchell*	5/17/1990	5/22/1990	12	mb15	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/mt._mitchell/B00218/multibeam/data/version1/MB/
B00219	*Mount Mitchell*	4/20/1990	4/25/1990	12	mb15	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/mt._mitchell/B00219/multibeam/data/version1/MB/
B00220	*Mount Mitchell*	4/25/1990	4/28/1990	12	mb15	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/mt._mitchell/B00220/multibeam/data/version1/MB/
B00221	*Mount Mitchell*	5/22/1990	5/25/1990	12	mb15	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/mt._mitchell/B00221/multibeam/data/version1/MB/
B00308	*Mount Mitchell*	9/10/1992	10/12/1992	12	mb15	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/mt._mitchell/B00308/multibeam/data/version1/MB/

Survey	Vessel	Start date	End date	Frequency, in kHz	Format	Link to NGDC data
B00309	*Mount Mitchell*	9/15/1992	10/1/1992	12	mb15	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/mt._mitchell/B00309/multibeam/data/version1/MB/
B00310	*Mount Mitchell*	10/21/1992	11/17/1992	12	mb15	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/mt._mitchell/B00310/multibeam/data/version1/MB/
KN178	*Knorr*	6/18/2004	7/11/2004	12	mb41	http://surveys.ngdc.noaa.gov/mgg/MB/ocean/knorr/KN178/multibeam/data/version1/MB/