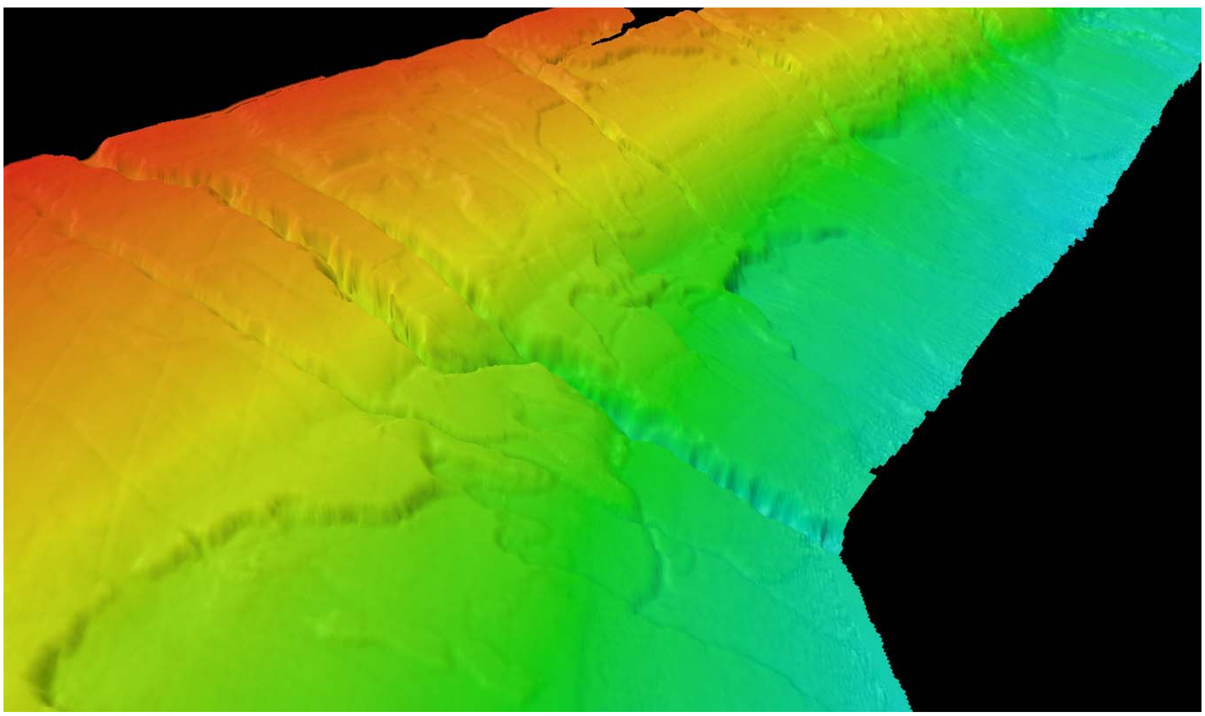
Seafloor Mapping of the Continental Slope of the U.S. Atlantic Margin to Study Submarine Landslides that Could Trigger Tsunamis

An additional Report to the Nuclear Regulatory Commission
Job Code Number: N6480

By Atlantic and Gulf of Mexico Tsunami Hazard Assessment Group



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Seafloor Mapping of the Continental Slope of the U.S. Atlantic Margin to Study Submarine Landslides that Could Trigger Tsunamis

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By Atlantic and Gulf of Mexico Tsunami Hazard Assessment Group:

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We would like to thank Captain Gerd Glang, and the officers and crew of the NOAA Vessel Ronald H. Brown, and especially the Chief Survey Technician, Jonathan Shannahoff for their professional help during the survey.

Cover: Oblique view from the west of the continental slope of southern New England, showing a convex profile and numerous landslide scarps. Most deeply incised canyon in this view is the meandering Block Canyon.

Executive Summary

Submarine landslides are considered to be the primary tsunami hazard to the U.S. Atlantic Coast. This report describes the operation and first results from a survey to map the bathymetry of the continental slope of the U.S. Atlantic margin. This 15-day survey aboard the NOAA vessel Ronald H. Brown took place in May 2009. The survey was highly successful with no time lost due to technical or weather problems. An area slightly larger than the area of the state of Maryland was mapped at a grid spacing of 25 m. The data show numerous landslides clustered in different areas along the margin. These data is presently being combined with other geological and geophysical data to determine the age of these landslides, their volumes, and their geotechnical properties.

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Background

The recent assessment of tsunami hazards along the U.S. east coast, carried out by the U.S. Geological Survey (USGS) and funded by the U.S. Nuclear Regulatory Commission, has identified submarine landslides along the submerged continental margin as the primary potential source of dangerous tsunamis to this coast (ten Brink et al., 2008). This conclusion was underscored by the 1929 Grand Banks submarine landslide, which produced a 3 to 8 meter high tsunami that killed 28 people along the sparsely populated Newfoundland coast (Fine et al., 2005). Most submarine landslides on the continental margin occur on the continental slope and upper rise; a lack of detailed maps for parts of this region has hampered efforts to produce a quantitative assessment of tsunami hazards.

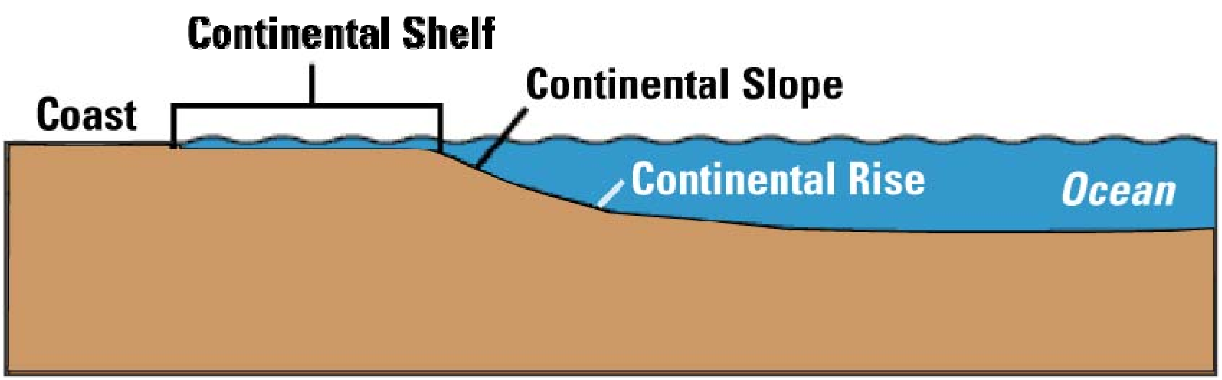

Figure 1: General shape of continental shelf, slope, and rise. Modified from U.S. Office of Naval Research (URL http://www.onr.navy.mil/Focus/ocean/regions/oceanfloor2.htm).

Operation

A 15-day survey aboard the National Oceanic and Atmospheric Administration (NOAA) ship Ronald H. Brown was conducted between May 11-25, 2009 to provide a complete sea-

floor topography map of the continental slope and upper rise from south of Cape Hatteras in the south to the eastern end of Georges Bank in the north, a distance of 1,200 km (750 mi). Data was collected along 5500 km of track lines at ship speed ranging from 6 to 12.5 knots (11-23 km/h). The total area mapped was 28,026 km^2, or 10% larger than the land area of the state of Maryland.

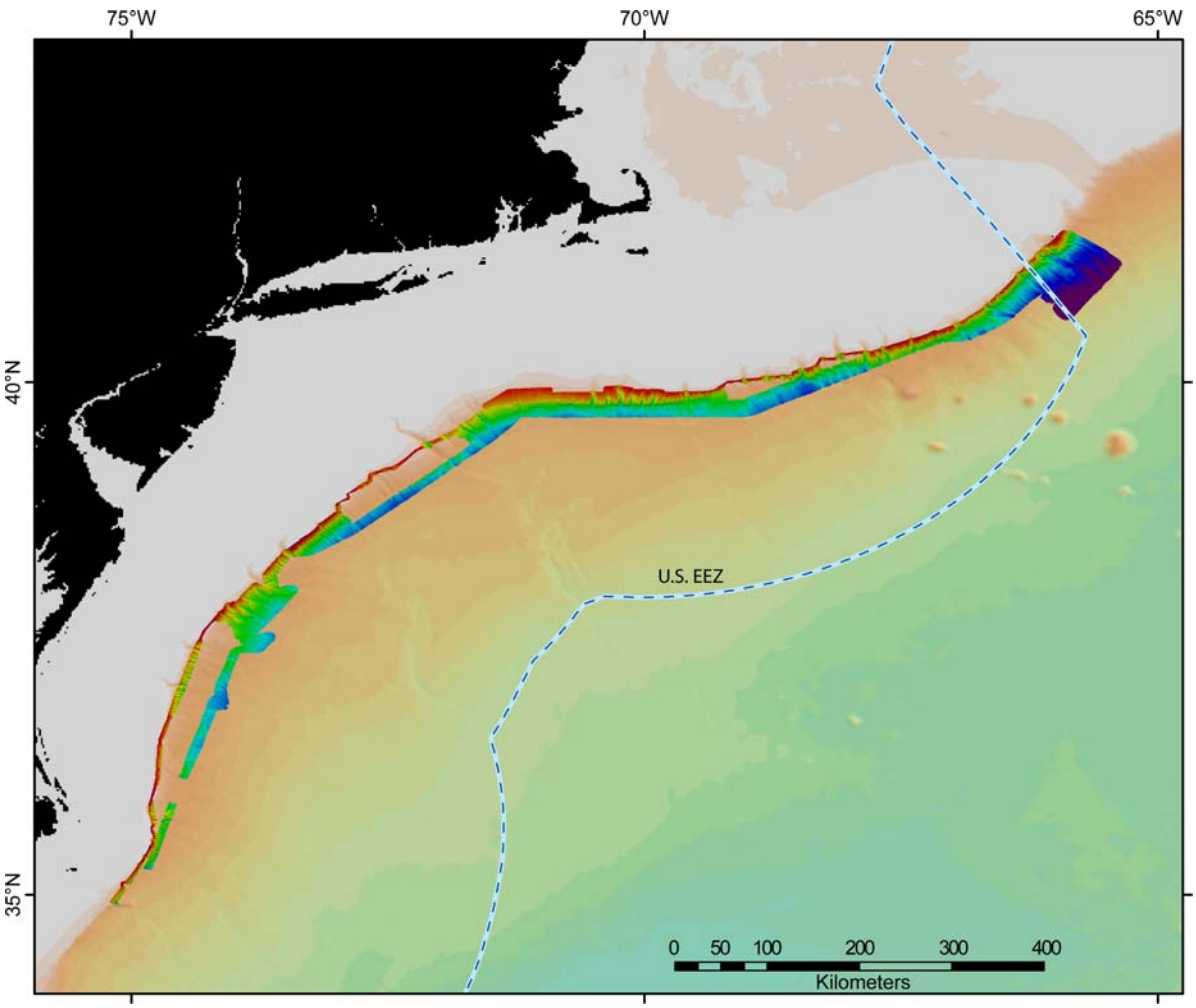

Figure 2: Relief map of the U.S. Atlantic margin (Pink - shallowest, green - deepest) gridded from single-beam bathymetric soundings, and new bathymetric data collected during the recent cruise (color-coded for depth) with a multibeam echosounder.

The ship left from and returned to Charleston, SC. The survey utilized the Ronald H. Brown's hull-mounted 12-kHz SeaBeam 2112 multibeam echosounder to carry out the

mapping. Accurate depth determinations require detailed knowledge of sound velocity variations in the water column. Acoustic velocity was mapped using 23 eXpendable BathyThermograph (XBT) which recorded temperature to a depth of 1600 m. The temperature was translated to sound velocity assuming constant salinity. For sound velocity deeper than 1600 m we used the Levitus tables for the world oceans (Levtius and boyer, 1994). Ship speed can affect data quality. Ship speed was adjusted during the cruise by examining the swath coverage in real time.

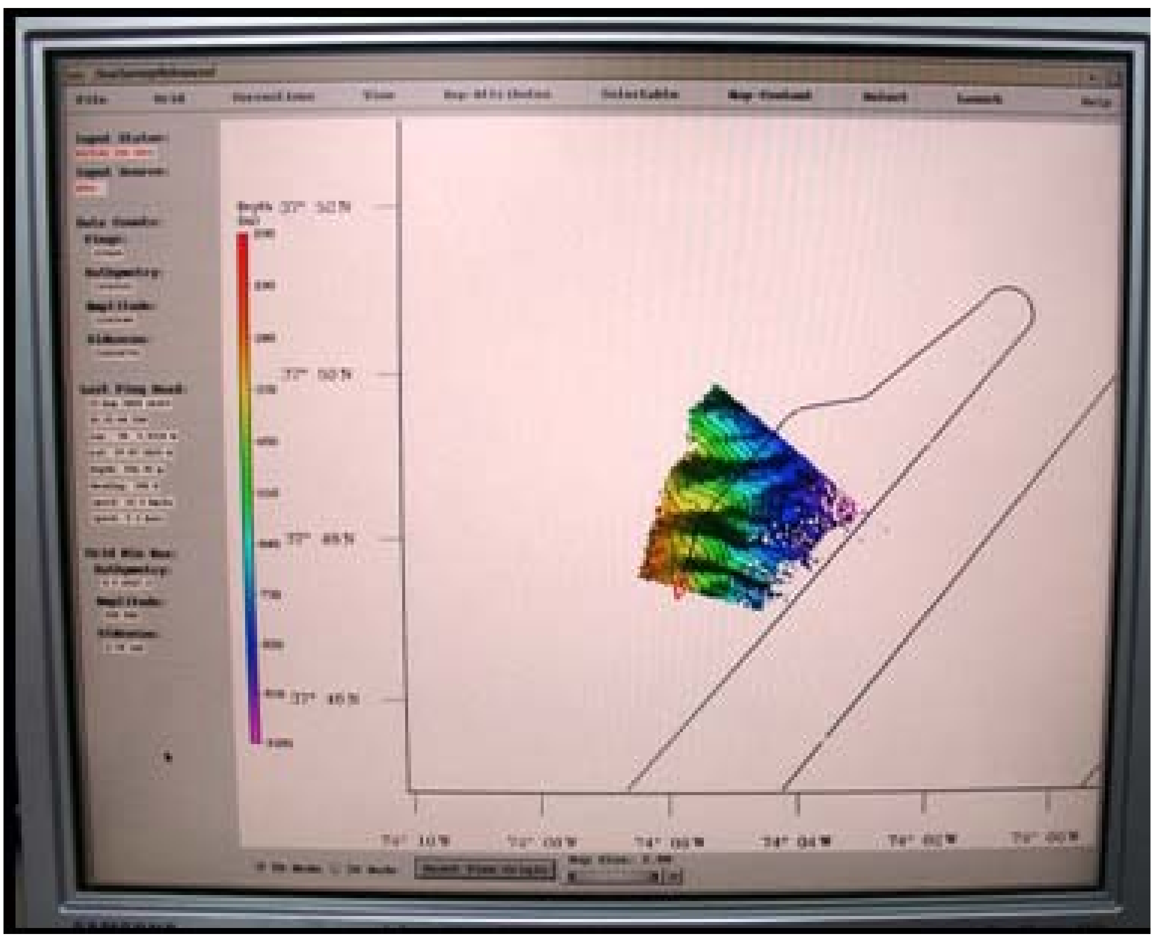

Figure 3: A screen capture of the SeaBeam monitor showing the collected data in real time. The display helps in quality control. Note for example the gaps in coverage on the right side of the swath, which indicate poor reflection from the sea bottom. Such problems can be avoided with enough overlap between swaths and with slowing down the ship speed.

Before the survey, we compiled available multibeam bathymetric data to help focus new data collection on areas that were lacking coverage, particularly along the southern New England and Georges Bank margins. Onboard preliminary processing and incorporation into a GIS system guided the adjustment of ship track to assure complete coverage and served as near real-time quality control.

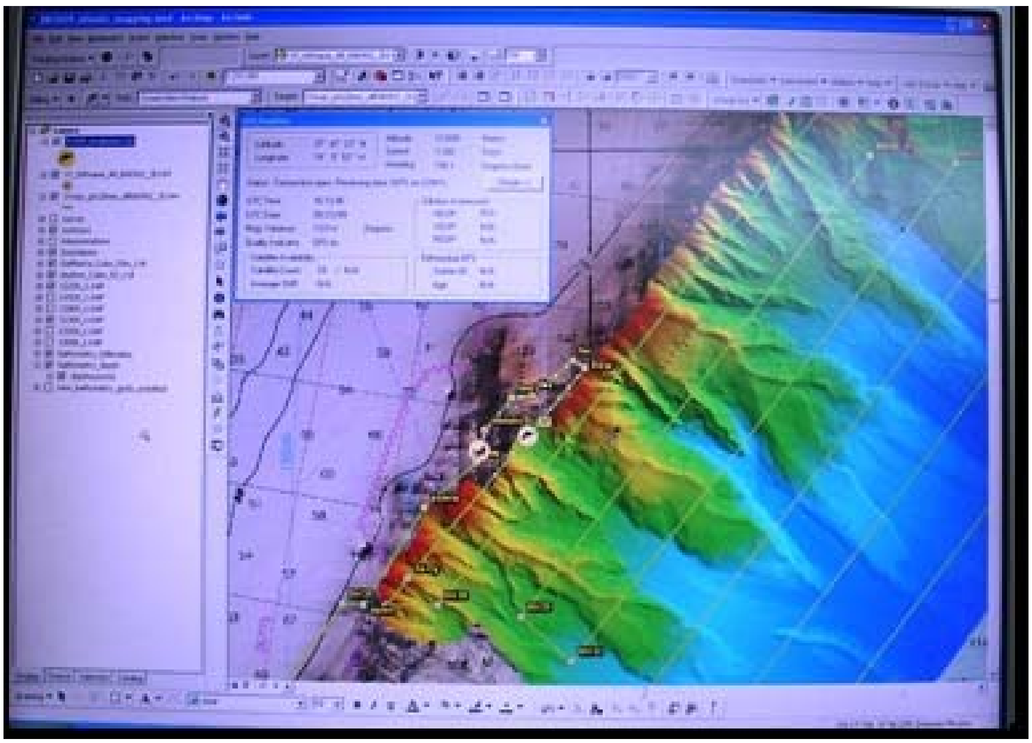

Figure 4: Screen shot of a GIS of the area. The GIS includes navigation charts, older survey data, the Ron Brown ship track and the new survey data being updated in near real-time.

The Ron Brown was equipped with Bathy2100 hull-mounted chirp sub-bottom profiler which can image the subsurface to a depth of ~50m below the sea floor. The data was displayed in real-time, however, the data could not be recorded in a usable form for replay and further processing. Therefore, the chirp seismic data are not used in the analysis, despite their value to the analysis of landslides.

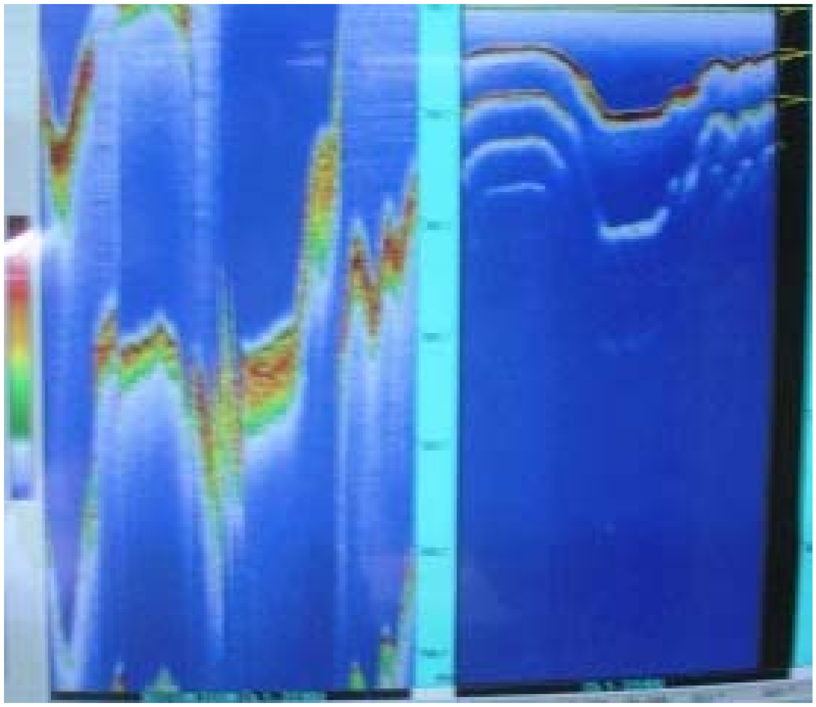

Figure 5: Screen display of the Bathy2100 chirp sub-bottom profiler.

The survey had an educational component as well. Prof. Leslie Sautter, and four of her students from the College of Charleston participated in all aspects of the survey and learned about the survey goals and the science behind the work. LTjg. Lindsey Waller from NOAA's Pacific Marine Environmental Laboratory, a NOAA Corp officer with no experience in this type of work, was also trained. The U.S. Geological Survey team aboard the ship included Uri ten Brink (chief scientist), David Twichell, Bill Danforth, and Elizabeth Pendleton.

Analysis

With the newly collected bathymetric data, more than 99 percent of the sea floor deeper than 400 m (and some areas to depths as shallow as 150 m) has now been mapped with a multibeam echosounder, allowing us to draw accurate maps of submarine canyons and the

remains of past landslides along the entire U.S. east coast continental margin. These data are also useful as input in tsunami propagation models.

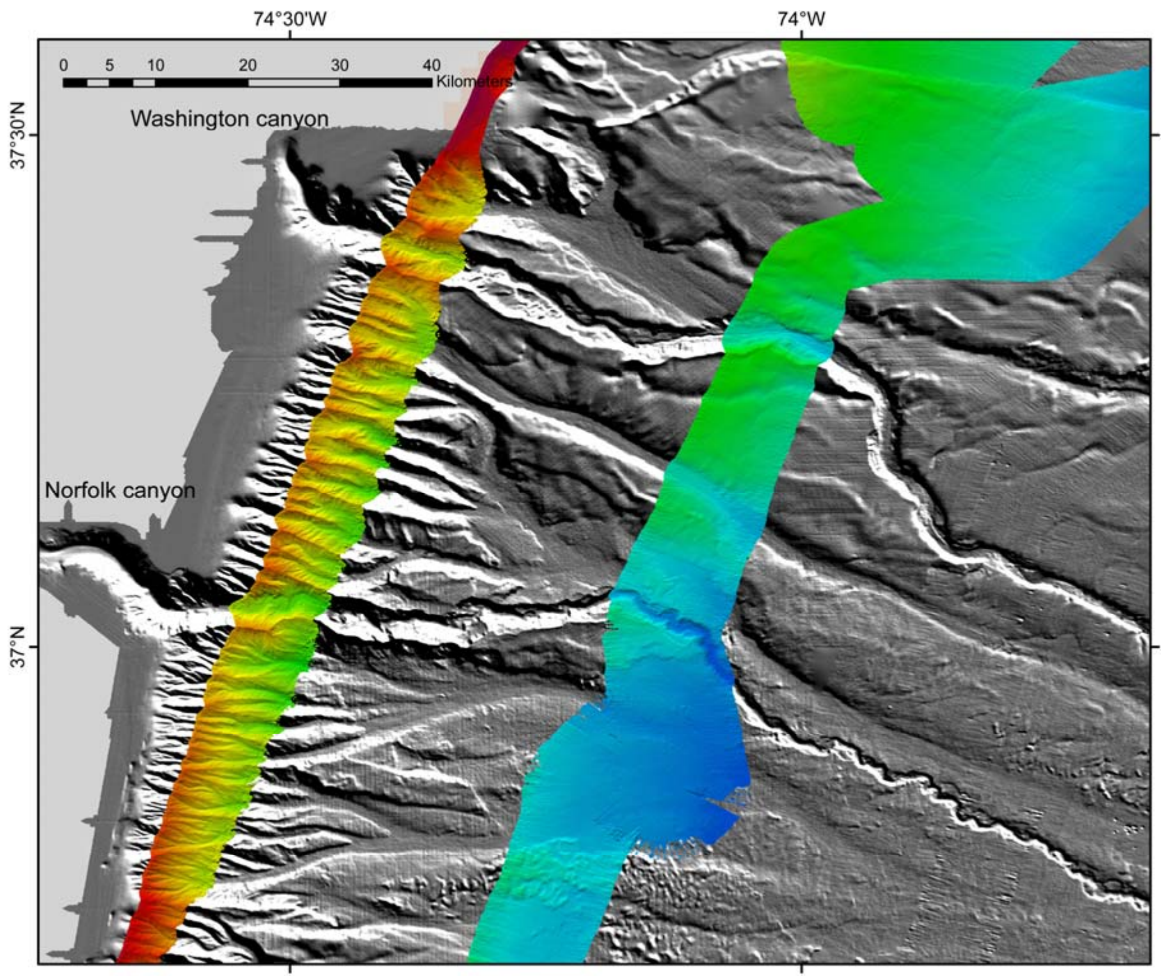

Figure 6: Bathymetry collected during our survey off the mouth of Chesapeake Bay (in color) overlain on shaded relief of the topography (in grey) from previous surveys. Grid interval for our survey was 50 m and for previous surveys it was 100 m.

The new bathymetry data provide the first detailed understanding of the morphology of the source areas for many of the largest landslides. These data show that the largest landslides have occurred along the southern New England continental slope and upper rise between Hudson Canyon and Atlantis Canyon.

This section of the continental slope is characterized by numerous steep cliffs, some of them exceeding 100 m in relief. The cliffs are the headwall scarps of landslides—the surfaces that remain after the landslide material has fallen away. Some of the headwall scarps can be traced along the slope for 15-22 km, indicating that huge volumes of sediment were removed during single events.

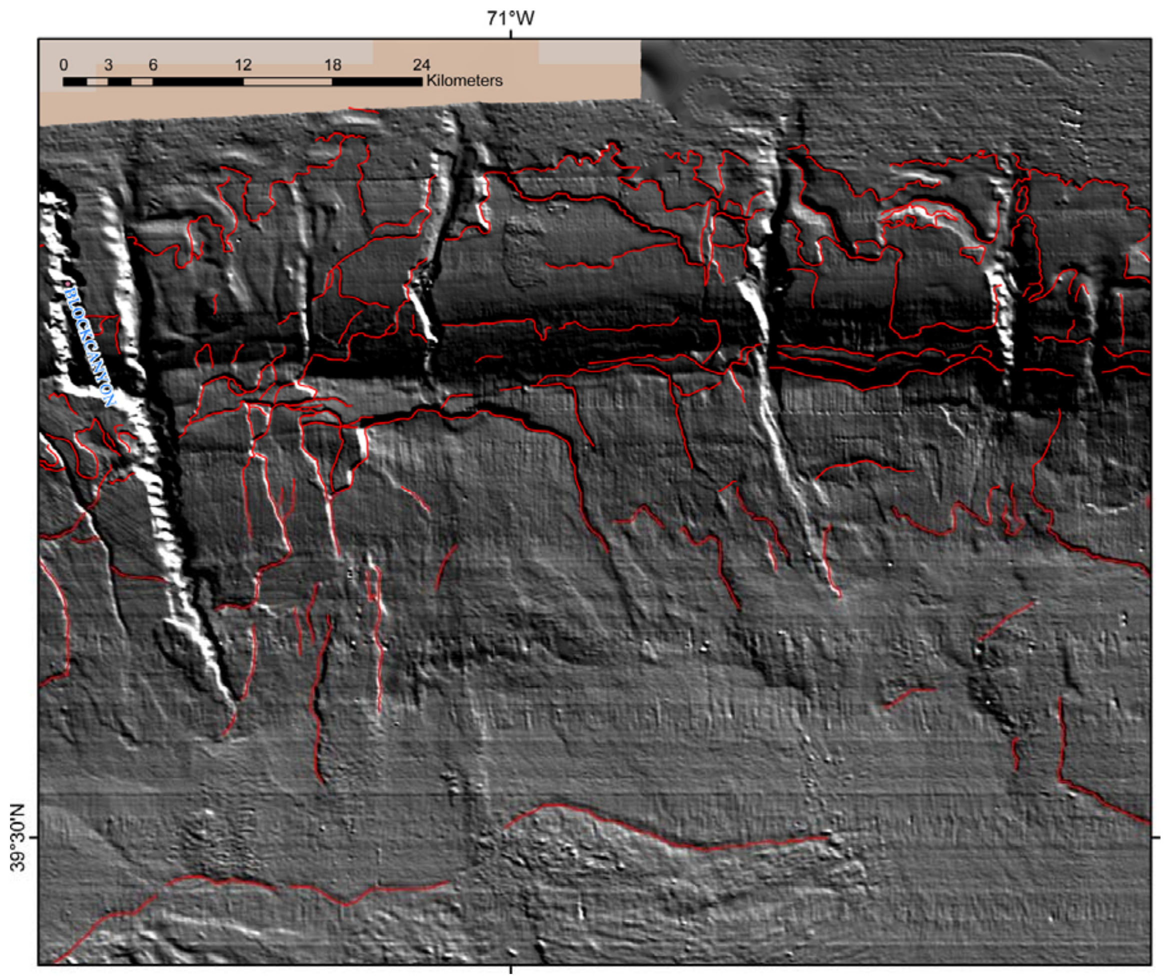

Figure 7: Preliminary analysis of submarine landslides on the continental slope of southern New England, numerous landslide scarps (red lines). Most deeply incised canyon in this view is the meandering Block Canyon. Note earth flow at the bottom of the image. Water depth is between 400 m at the top of the image and 2500 m at the bottom of the image.

The height of a tsunami generated from a submarine landslide is strongly dependent on the landslide's volume, so the evidence for high-volume offshore landslides suggests that the southern New England coast may be prone to landslide-generated tsunamis. Farther east, offshore of Georges Bank, the continental slope is incised by numerous submarine canyons, and the headwall scarps of past landslides are smaller and more widely spaced.

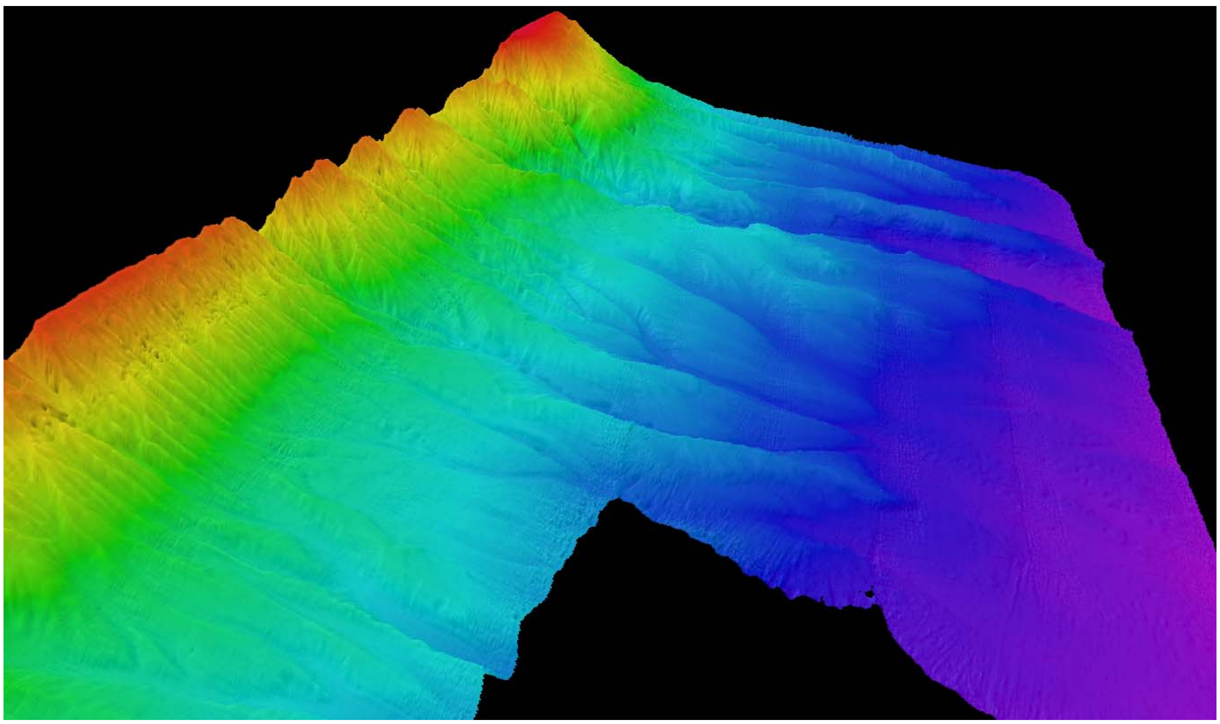

Figure 8: Oblique view from the west of the continental slope of Georges Bank, showing numerous canyons incising the slope and relatively few landslide scarps.

The newly collected multibeam echosounder data, coupled with available seismic-reflection data, fill a key gap in our information on submarine-landslide source areas. This new information is central to refining our assessment of tsunami hazards along the densely populated U.S. Atlantic coast.

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