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Storm Tide Monitoring During the Blizzard of January 26–28, 2015, in Eastern Massachusetts

Open-File Report 2015–1081

U.S. Department of the Interior
U.S. Geological Survey

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SALLY JEWELL, Secretary

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Suzette M. Kimball, Acting Director

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Conversion Factors

Inch/Pound to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
	Flow rate	
mile per hour (mi/h)	1.609	kilometer per hour (km/h)

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

Abbreviations

GNSS	Global Navigation Satellite System
NOAA	National Oceanic and Atmospheric Administration
NWIS	National Water Information System
NWS	National Weather Service
SWaTH	Surge, Wave, and Tide Hydrodynamic [Network]
USGS	U.S. Geological Survey

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Introduction

The U.S. Geological Survey (USGS) deployed a temporary monitoring network of six storm surge sensors and four barometric pressure sensors along the Atlantic coast in eastern Massachusetts, from Plymouth to Newburyport, before the blizzard of January 26–28, 2015 (Blizzard of January 2015), to record the timing and magnitude of storm tide at select locations where forecasters had predicted the potential for coastal flooding. Additionally, water-level data were recorded and transmitted in near real-time from four permanent USGS tidal stations—three on Cape Cod and one near the mouth of the Merrimack River in Newburyport. The storm surge sensors were deployed at previously established fixed sites outfitted with presurveyed mounting brackets. The mounting brackets were installed in 2014 as part of the USGS Surge, Wave, and Tide Hydrodynamic (SWaTH) Network (https://water.usgs.gov/floods/STN/), which was funded through congressional supplemental appropriations for the U.S. Department of the Interior after the devastating landfall of Hurricane Sandy on October 29, 2012 (Simmons and others, 2014). The USGS received this funding to enable better understanding of coastal flooding hazards in the region, to improve preparedness for future coastal storms, and to increase the resilience of coastal cities, infrastructure, and natural systems in the region (Buxton and others, 2013). The USGS established 163 monitoring locations along the New England coast for the SWaTH Network, including 70 sites in Massachusetts.

The Blizzard of January 2015 was a powerful and destructive storm that threatened public safety and led to wide-spread cancellations and delays at transportation hubs, schools, and businesses in Massachusetts, including, for example, the closure of General Edward Lawrence Logan (Boston-Logan) International Airport and cancellation of all flights on January 27 and a statewide travel ban issued for January 28. A total of 24.6 inches of snowfall and winds up to 45 miles per hour (mi/hr) were recorded at the airport. Several coastal communi-ties were affected and experienced flooding, overwash, and damage to seawalls, dwellings, and other infrastructure. In Scituate, the National Guard was sent to rescue people from flooding, and power was cut to some areas of the town to prevent electrical fires.

Storm Characteristics

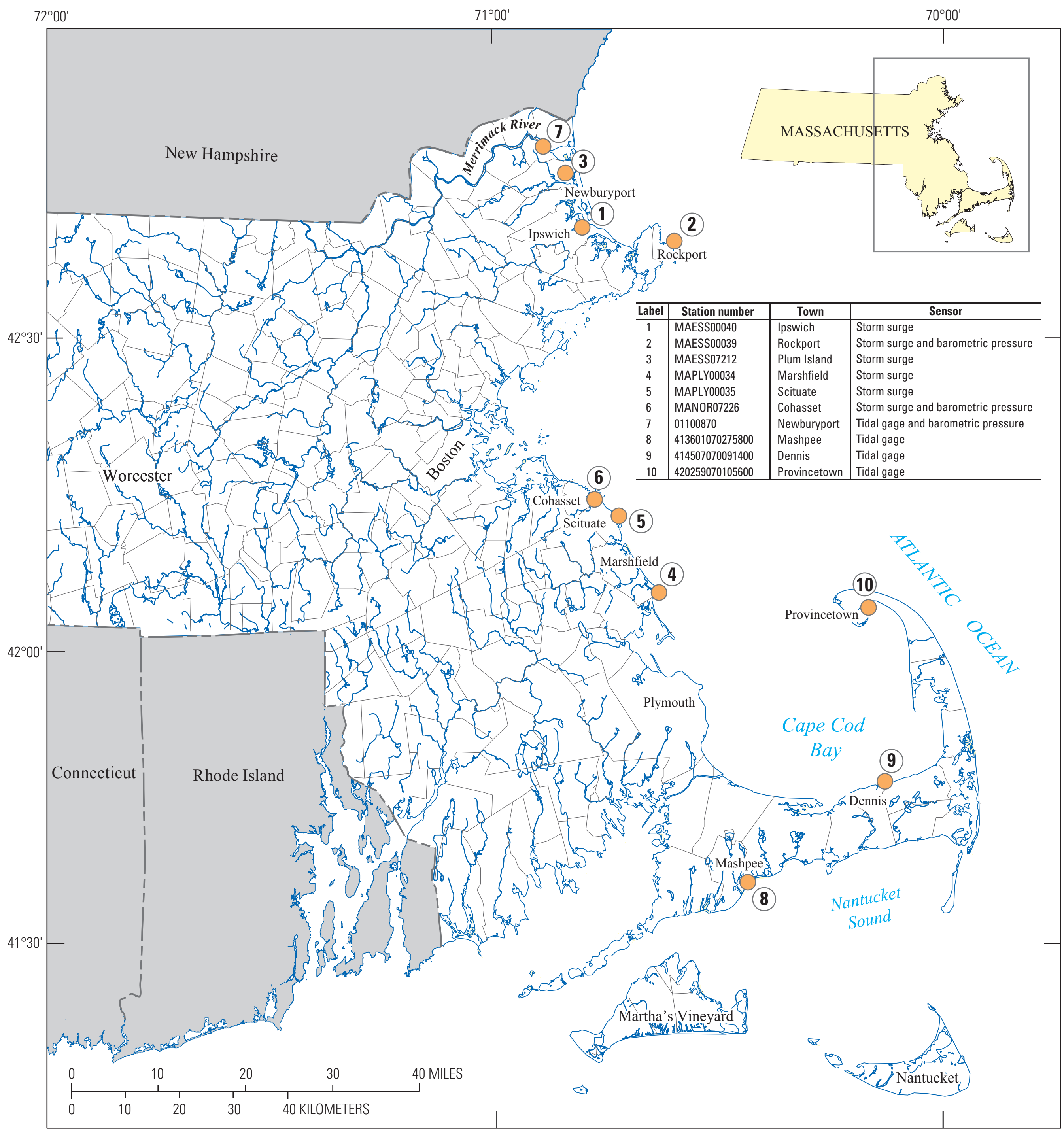
The weather system that evolved into the Blizzard of January 2015 originated when an upper-level low-pressure system moving from the Midwest toward the east coast combined with energy from the Gulf of Mexico to form a low-pressure system that developed off the mid-Atlantic coast. The storm system followed a classic nor’easter track, traveling north along the east coast. The storm gathered moisture and energy from the Gulf Stream and intensified as it moved into New England, producing blizzard-strength winds, coastal flooding, and heavy snow. It was not until late in the forecast period when meteorologists were able to predict what areas of the region would be hardest hit by the storm.

The Blizzard of January 2015 contributed to the snowiest 30-day period on record in Boston and surrounding areas (Robert Thompson, Glenn Field, and Joseph DelliCarpini, National Oceanic and Atmospheric Administration, National Weather Service, written commun., 2015). Boston, for example, received more than 2 feet (ft) from this storm, and recorded the greatest January snowfall for the period of record there (123 years). Wind gusts along the coast, including island coasts such as Martha’s Vineyard and Nantucket, exceeded 70 mi/hr in some locations. For example, maximum wind gusts at Nantucket and Plymouth were 78 mi/hr and 72 mi/hr, respectively. At Marshfield, maximum wind gusts were 54 mi/hr (Robert Thompson, Glenn Field, and Joseph DelliCarpini, National Oceanic and Atmospheric Administration, National Weather Service, written commun., 2015), and at Rockport, the maximum wind gust was 64 mi/hr (National Oceanic and Atmospheric Administration, National Weather Service, 2015).

Deployment of Storm Surge Sensors

Storm surge sensors were deployed on January 26, 2015, before the onset of the storm, in an effort to measure storm tide, defined by the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) as the water-level rise associated with the combination of storm surge and astronomical tide during a coastal storm

(National Oceanic and Atmospheric Administration, National Weather Service, 2008, 2014). The USGS deployed 10 sensors along the Massachusetts coast for this storm; 6 of which were deployed to measure and record tidal water level at selected monitoring sites from Newburyport in the north to Plymouth in the south and 4 of which were colocated at selected monitoring sites to measure and record barometric pressure for use in correcting the water levels for changes in barometric pressure (fig. 1). Locations were selected on the basis of predictions of the storm path and at locations historically most susceptible to the northeasterly winds and storm tides generated by nor'easter type storms in the region.



Label	Station number	Town	Sensor
1	MAESS00040	Ipswich	Storm surge
2	MAESS00039	Rockport	Storm surge and barometric pressure
3	MAESS07212	Plum Island	Storm surge
4	MAPLY00034	Marshfield	Storm surge
5	MAPLY00035	Scituate	Storm surge
6	MANOR07226	Cohasset	Storm surge and barometric pressure
7	01100870	Newburyport	Tidal gage and barometric pressure
8	413601070275800	Mashpee	Tidal gage
9	414507070091400	Dennis	Tidal gage
10	420259070105600	Provincetown	Tidal gage

Figure 1. The eastern shore of Massachusetts where storm surge sensors, barometric pressure sensors, and tidal stations were operating during the blizzard of January 26–28, 2015.

Sensors were deployed at selected monitoring locations established and surveyed in 2014 as part of the SWaTH Network. These monitoring locations had been outfitted with presurveyed mounting brackets specifically designed for rapid storm surge sensor deployments (fig. 2). The brackets were surveyed to the North American Vertical Datum of 1988 (NAVD 88) using survey-grade Global Navigation Satellite System (GNSS) equipment following USGS protocols (Rydlund and Densmore, 2012). Prior to deployment for this storm, each sensor was installed in a protective aluminum housing, then the housings were affixed to the brackets to hold the storm surge sensors securely in place. The housing pipes range in length from 4 to 12 ft to hold the storm surge sensors about 1 ft above land surface and below sea level. The housings are perforated to allow water movement. The storm surge sensors and accompanying barometric pressure sensors were set to record at 30-second intervals. Manual water-level measurements were recorded at the time of deployment to calibrate the water level data to the NAVD 88.

Figure 2. U.S. Geological Survey scientist Andrew Massey deploying a storm surge sensor in a presurveyed mounting bracket before the onset of the blizzard of January 26–28, 2015. Photograph by David S. Armstrong, U.S. Geological Survey.

Storm Tide Measurements

The storm surge and barometric pressure sensors and the protective aluminum housings were retrieved on January 29, 2015, after the storm moved away from New England to a location off the coast of the Canadian Maritime provinces. Manual water level measurements were recorded at the time of retrieval for comparison with recorded data, where possible. Photographs were also taken to document high water marks and conditions in the aftermath of the storm. Data were collected and processed following protocols established by McGee and others (2006) and modified by McCallum and others (2012) and included correcting water levels for changes in barometric pressure and salinity. Quality-control checks were made by comparing water levels computed from the temporary storm surge sensors to water levels recorded at nearby NOAA and USGS tidal stations. The water-level elevation data from three sites north of Boston and three sites south of Boston are shown in figures 3 and 4, respectively. For comparison, the hydrograph recorded in Cape Cod Bay at the USGS Sesuit Harbor tide gage, Dennis, MA (414507070091400) tidal gage shows data for a longer period (from January 23 to 31, 2015) and includes several tidal cycles before and after the storm (fig. 5; U.S. Geological Survey, 2015).

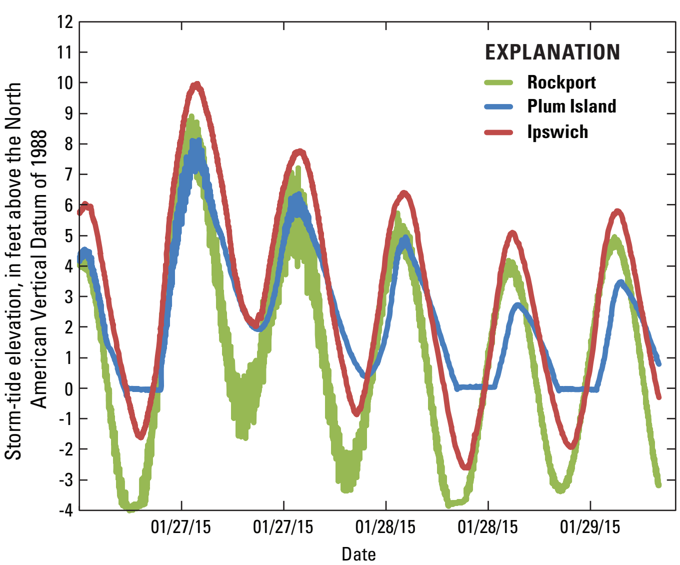


Figure 3. Storm tide elevation recorded at Rockport, Plum Island, and Ipswich on the northern shore of eastern Massachusetts during the blizzard of January 26–28, 2015.

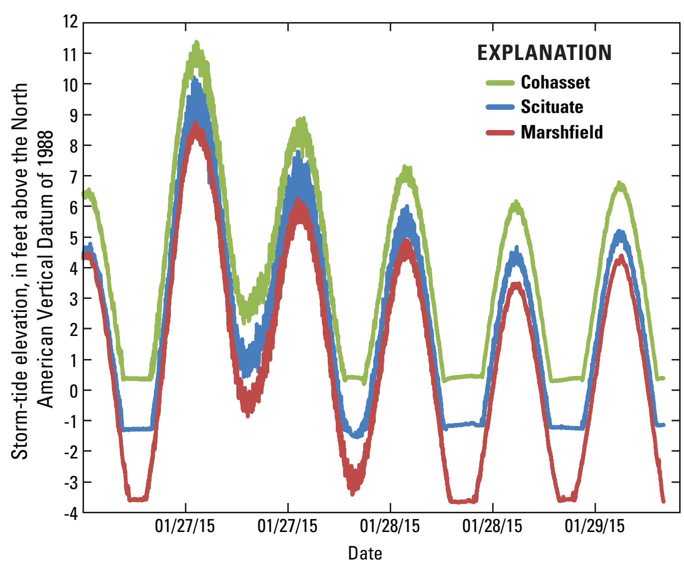


Figure 4. Storm tide elevation recorded at Cohasset, Scituate, and Marshfield on the southern shore of eastern Massachusetts during the blizzard of January 26–28, 2015.

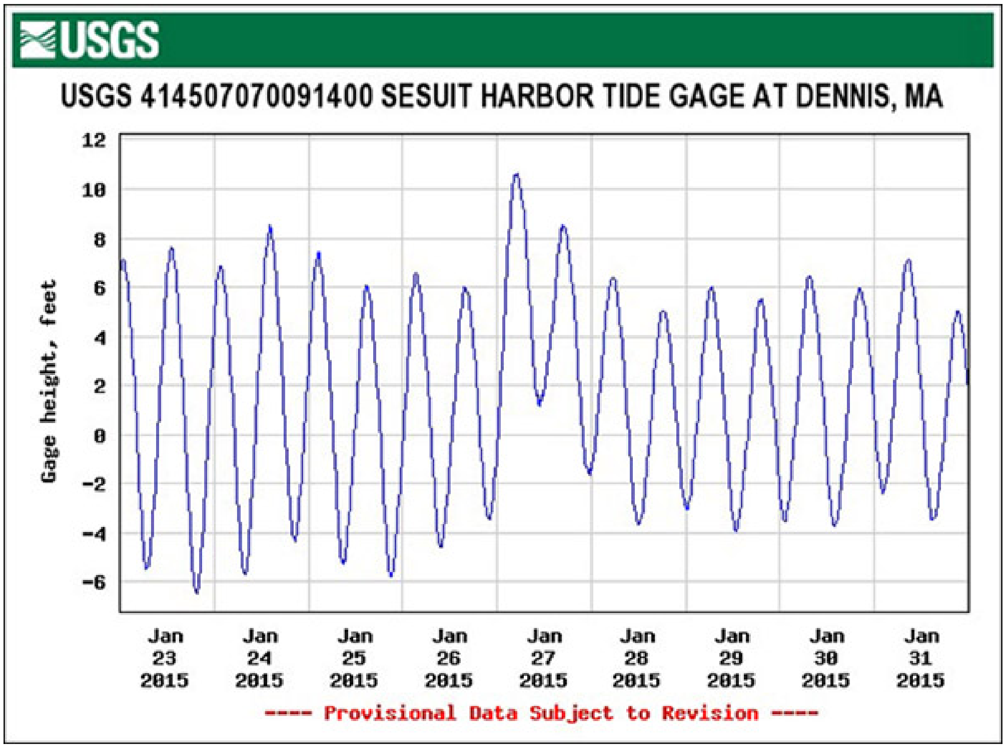


Figure 5. Tidal elevations at the U.S. Geological Survey (USGS) Sesuit Harbor tide gage at Dennis, MA (414507070091400) from January 23 to 31, 2015. Gage height is in feet above the North American Vertical Datum of 1988.

Storm surge was measured at all gaged locations and ranged from about 4 to 4.5 ft above normal tide before and after the storm. The hydrographs also provide additional information, indicating conditions at the sensors. For example, the water-level elevations recorded at areas directly exposed to the prevailing winds, such as T-Wharf in Rockport Harbor, recorded up to 3 ft of chop (small wind-generated waves) during the height of the storm. Water-level elevations recorded at wind-protected locations away from the coast, such as Ipswich town wharf in Ipswich, recorded less variation from wave-action. The storm surge sensors at a few of the sites became exposed to the air during low tide before and after the storm; their hydrographs display a “flat line” at the bottom of the tidal cycle during these time periods (figs. 3 and 4).The Plum Island storm surge sensor was buried by sand deposited by the storm, indicated in the hydrograph by lower magnitude high tides and delayed high and low tides after the storm (fig. 3).

In recent years, movement of sand has changed the beach front significantly at the northern end of Plum Island. The Plum Island storm surge sensor, which is at the mouth of the Merrimack River at the northern end of Plum Island near the Massachusetts Division of Marine Fisheries pier in Newburyport, was buried by approximately 3 ft of sand deposited during the Blizzard of January 2015. A large hole was dug in the sand to access the bracket and unlock the storm surge sensor housing during retrieval of the equipment (fig. 6). Evidence of sand deposition over time is shown in figure 7. The photograph in figure 7*A*, captured in October 2012 before the landfall of Hurricane Sandy, shows the end of the pier to be exposed by

Figure 6. U.S. Geological Survey scientist Christopher Bruet excavating a storm surge sensor after sand was deposited by the blizzard of January 26–28, 2015, on Plum Island at Newburyport, Massachusetts. Photograph by Josh Combs, U.S. Geological Survey.

12 ft or more. The photograph in figure 7*B*, taken in June 2014 when the USGS installed a mounting bracket on the same wooden piling, shows several feet of sand deposition. The photograph in figure 7*C* shows that the piles were nearly buried as a result of the Blizzard of January 2015. Overall, more than 10 ft of sand has accreted at this site since October 2012.

Figure 7. Evidence of sand deposition on Plum Island at Newburyport, Massachusetts, from 2012 to 2015. Photographs were taken *A*, on October 26, 2012, before Hurricane Sandy, *B*, during bracket installation on June 19, 2014, and *C*, during sensor retrieval on January 29, 2015, after the blizzard of January 26–28, 2015. Photographs by the U.S. Geological Survey.

Effects on Coastal Communities

The eastern shore of Plum Island and other barrier beach locations that are regularly susceptible to damage from tidal surge and waves during nor'easters were battered by the Blizzard of January 2015. Some of the greatest effects occurred south of Boston along the southern shore and on Nantucket Island. Homes were damaged by flooding, strong winds, splashover, and icing. Sections of seawall in Scituate and Marshfield were damaged and breached by the storm, exacerbating local flooding of roads, homes, and businesses. Ocean sediment and beach material were also deposited overland by the storm surge (fig. 8). About 30,000 households were without power during and immediately after the storm. On Nantucket Island, about 12,800 households were without power for up to 3 days after the onset of the storm.

Figure 8. Examples of damage to infrastructure and property on the southern shore of Massachusetts as a result of flooding, strong wind, overwash, and icing during the blizzard of January 26–28, 2015. Examples shown are in the towns of *A*, Marshfield and *B*, Scituate, where frozen splashover and high water marks of the storm tide height remained on structures for days after the storm. Photographs by the U.S. Geological Survey.

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For more information concerning this report, contact:
Director, New England Water Science Center
U.S. Geological Survey
10 Bearfoot Road
Northborough, MA 01532
dc_nweng@usgs.gov
or visit our Web site at:
http://ma.water.usgs.gov
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