Continental Shelf Research 98 (2015) 13–25

Contents lists available at ScienceDirect

Continental Shelf Research

journal homepage: www.elsevier.com/locate/csr

Research papers

The impact of Hurricane Sandy on the shoreface and inner shelf of Fire Island, New York: Large bedform migration but limited erosion

John A. Goff[a,*], Roger D. Flood[b], James A. Austin, Jr.[a], William C. Schwab[c], Beth Christensen[d], Cassandra M. Browne[a], Jane F. Denny[c], Wayne E. Baldwin[c]

[a] Institute for Geophysics, Jackson School of Geosciences, University of Texas at Austin, Austin, TX 78758, USA
[b] School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY 11794, USA
[c] US Geological Survey, Woods Hole, MA 02543, USA
[d] Environmental Studies Program, Adelphi University, Garden City, NY 11530, USA

ARTICLE INFO

Article history:
Received 24 September 2014
Received in revised form
16 February 2015
Accepted 2 March 2015
Available online 4 March 2015

Keywords:
Superstorm Sandy
Sand ridges
Sorted bedforms
Shoreface
Inner shelf
Ravinement

ABSTRACT

We investigate the impact of superstorm Sandy on the lower shoreface and inner shelf offshore the barrier island system of Fire Island, NY using before-and-after surveys involving swath bathymetry, backscatter and CHIRP acoustic reflection data. As sea level rises over the long term, the shoreface and inner shelf are eroded as barrier islands migrate landward; large storms like Sandy are thought to be a primary driver of this largely evolutionary process. The "before" data were collected in 2011 by the U.S. Geological Survey as part of a long-term investigation of the Fire Island barrier system. The "after" data were collected in January, 2013, ~two months after the storm. Surprisingly, no widespread erosional event was observed. Rather, the primary impact of Sandy on the shoreface and inner shelf was to force migration of major bedforms (sand ridges and sorted bedforms) 10's of meters WSW alongshore, decreasing in migration distance with increasing water depth. Although greater in rate, this migratory behavior is no different than observations made over the 15-year span prior to the 2011 survey. Stratigraphic observations of buried, offshore-thinning fluvial channels indicate that long-term erosion of older sediments is focused in water depths ranging from the base of the shoreface (~13–16 m) to ~21 m on the inner shelf, which is coincident with the range of depth over which sand ridges and sorted bedforms migrated in response to Sandy. We hypothesize that bedform migration regulates erosion over these water depths and controls the formation of a widely observed transgressive ravinement; focusing erosion of older material occurs at the base of the stoss (upcurrent) flank of the bedforms. Secondary storm impacts include the formation of ephemeral hummocky bedforms and the deposition of a mud event layer.

1. Introduction

"Superstorm" Sandy made landfall as a post-tropical cyclone, with 70-knot maximum sustained winds, near Brigantine, NJ, on October 29, 2012 (Figures 1, 2). Its sustained winds were ~25% higher, and significant wave heights ~50% higher than most other large storms over the previous 17 years (Fig. 2). Its unusual shoreward trajectory and massive size created record storm surges for longer periods along the heavily populated New Jersey and New York coastlines (Fig. 1; http://www.nhc.noaa.gov/data/tcr/AL182012Sandy.pdf). Infrastructure in the New York City metropolitan area was heavily damaged, and the Long Island barrier island system was both breached in places and seriously eroded (Hapke et al., 2013).

The impacts of this storm on the shoreface and inner shelf, which are permanently submerged and therefore primarily accessible only through acoustic mapping, are harder to observe. However, although the shoreface and inner shelf are neither populated nor veneered with human infrastructure, they are nevertheless critical to both people and their structures, because they are the first line of defense of barrier island systems against a naturally retreating, or "transgressing," coastline. Under rising sea level conditions, the natural condition today along most of the U.S. east coast, barrier islands will back-step (retreat landward) by erosion on the seaward side and deposition on the landward side (Bruun, 1962; Swift and Thorne, 1991; Thorne and Swift, 1991). Large storms, with consequent high waves, strong currents and above-normal tidal ranges/surges, are thought to be primary drivers of such shoreface erosion (Swift, 1968; Swift and Thorne,

* Corresponding author.
E-mail address: goff@ig.utexas.edu (J.A. Goff).

http://dx.doi.org/10.1016/j.csr.2015.03.001
0278-4343/

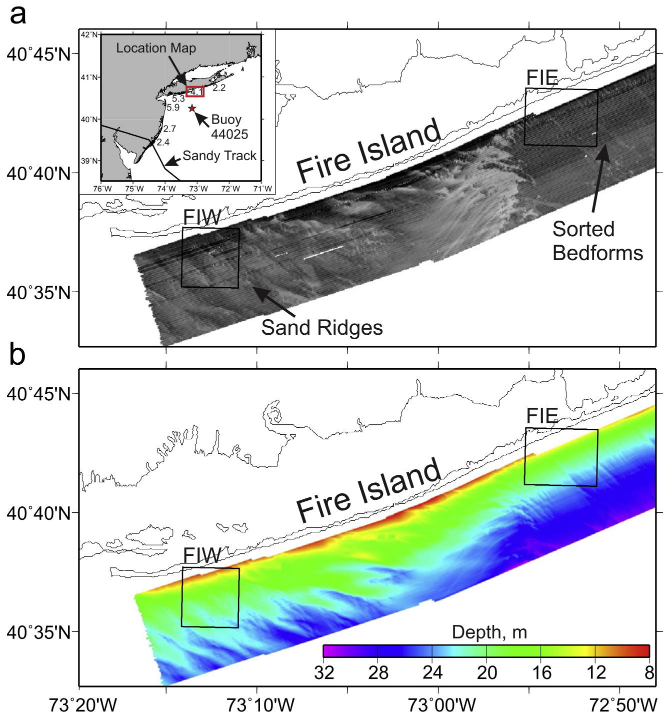

Fig. 1. (a) Backscatter and (b) swath bathymetry data collected by the USGS in 2011 (Schwab et al., 2013), providing a basis for pre- and post-Sandy comparisons. Boxes indicate locations of post-Sandy Fire Island West (FIW) and Fire Island East (FIE) surveys. The FIW survey sampled sand ridges, whereas the FIE survey sampled a sorted bedform morphology. Inset shows location on south shore of Long Island, the track of Sandy, location of buoy 44025 used for data plotted in Fig. 2, and sampled storm tide elevations above normal along the coast in meters (USGS Portal for Hurricane Response, http://54.243.149.253/; McCallum et al., 2013).

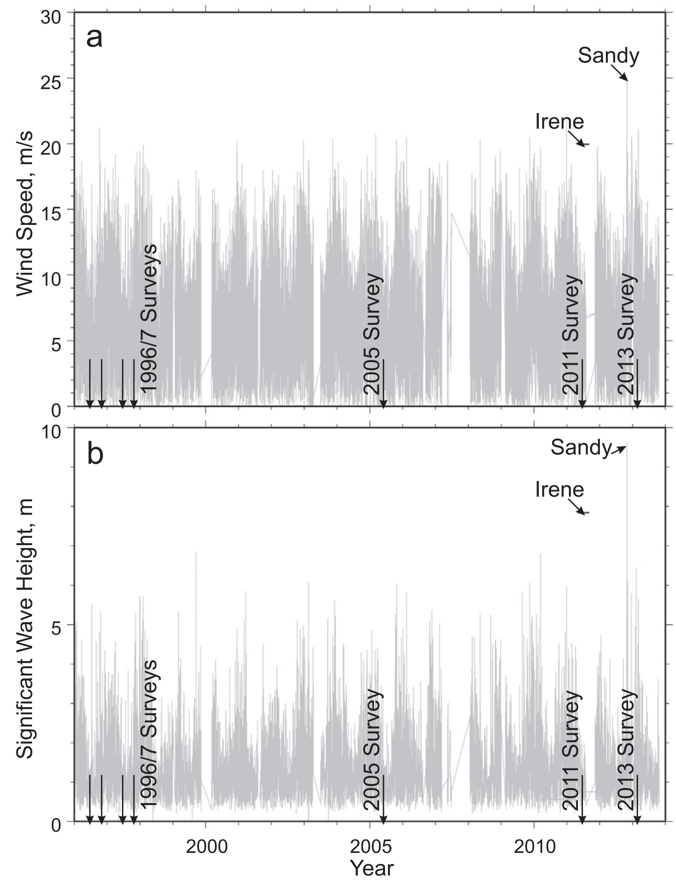

Fig. 2. Sustained wind speeds (a) and significant wave heights (b) from 1996 through 2013 at NOAA buoy 44025 (http://www.ndbc.noaa.gov/station_page.php?station=44025) anchored offshore of Fire Island at ~40 m water depth (location shown in Fig. 1 inset). The timing of the surveys discussed in this paper are identified. Sandy attained sustained wind speeds of 25.1 m/s and significant wave heights of 9.65 m. These values are ~25% and ~50% higher, respectively, than most other strong storms during this time period. Wave heights (b) for Tropical Storm Irene represent the lone exception. Irene impacted the Mid Atlantic Bight in late August of 2011, after the 2011 survey and therefore within the same time window between surveys as Sandy. Buoy 44025 was not operational during the passage of Irene. Peak wind and wave values for Irene are indicate from nearby buoy 44065.

1991). Such storms are also considered important contributors to landward aggradation through overwash deposition (Lentz et al., 2013), although island breaching and inlet formation/closure are also major drivers over the short term (Leatherman, 1985).

There are few observational studies of large-storm impacts on the shoreface that can help constrain the storm-driven sediment budget for any barrier system. Logistically, such studies are difficult to organize because they require rapid mobilization of survey assets as soon after the storm as possible. Some luck is also required in order to have available any recent pre-storm surveys of like kind against which post-storm data can be compared. Furthermore, comparative studies done to date have resulted in different conclusions about hurricane impacts. After Hurricane Ike in 2008, for example, Goff et al. (2015) documented a widespread “storm” event involving up to 1 m of erosion on the Bolivar Peninsula, TX, shoreface. In contrast, after Hurricane Ivan in 2004, Kraft and de Moustier (2010) found up to 1 m of deposition along the shoreface of Santa Rosa Island, FL. These examples suggest that how a storm impacts the shoreface is likely to be dependent in part on local factors, such as wave/current history, abundance of mobile sand, and shoreface/barrier morphology. Multiple before-and-after storm maps of the seafloor and shallow subsurface, as well as access to key observational data (waves, currents, sediment transport processes), are required before we can constrain physics-based models of processes driving sediment flux on the shoreface and inner shelf during storms.

A comprehensive survey of the Fire Island, NY, lower shoreface and inner shelf was conducted by the U.S. Geological Survey (USGS) in June, 2011 (Figs. 1 and 2; Schwab et al., 2013, 2014), approximately a year and a half prior to Sandy. This pre-storm survey provides an important baseline for quantifying seabed changes during this time period. The same area was also surveyed by the USGS in 1996 and 1997 (Fig. 2; Schwab et al., 2000), providing a longer-term rates-of-change baseline to compare against short-term (i.e., baseline+storm-induced) changes. To complement these pre-storm data sets, we mounted a collaborative post-Sandy survey in early January, 2013, aboard the R/V *Seawolf* to collect multibeam bathymetry and backscatter, CHIRP (compressed high-intensity sonar [previously radar] pulse) acoustic reflection data, and sediment grab samples offshore of part of southern Long Island. Two survey patches, “Fire Island West” (FIW) and “Fire Island East” (FIE), overlap the 2011 USGS survey (Fig. 1), and are the focus of the results presented in this paper. The intervening time between 2011 and 2013 surveys also included the passage of Irene, which impacted the Mid Atlantic Bight as a tropical storm in late August, 2011 (http://www.noaa.gov/extreme2011/irene.html). Irene was a lesser storm in terms of winds and waves than Sandy (Fig. 2). Its peak sustained winds were on par with more typical large storms in the region, but its significant wave heights were larger (Fig. 2). Although our primary focus is on the larger storm, Irene could also have contributed to any observed “storm-induced” component of change.

The seabed offshore of Fire Island undergoes a significant change in morphology between the eastern and western ends of Fire Island (Fig. 1; Schwab et al., 2000, 2013, 2014). To the west, the seabed morphology is dominated by shoreface-attached sand