Continental Shelf Research 104 (2015) 1–14

Contents lists available at ScienceDirect

Continental Shelf Research

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

Characteristics of storms driving wave-induced seafloor mobility on the U.S. East Coast continental shelf

P. Soupy Dalyander [a,*], Bradford Butman [b]

[a] U.S. Geological Survey, 600 4th Street S., St. Petersburg, FL 33701, USA
[b] U.S. Geological Survey, 384 Woods Hole Road, Woods Hole, MA 02543, USA

ARTICLE INFO

Article history:
Received 18 August 2014
Received in revised form
23 April 2015
Accepted 9 May 2015
Available online 13 May 2015

Keywords:
Bottom wave stress
Seafloor mobility
Extratropical storms
Tropical storms
U.S. East Coast continental shelf

ABSTRACT

This study investigates the relationship between spatial and temporal patterns of wave-driven sediment mobility events on the U.S. East Coast continental shelf and the characteristics of the storms responsible for them. Mobility events, defined as seafloor wave stress exceedance of the critical stress of 0.35 mm diameter sand (0.2160 Pa) for 12 or more hours, were identified from surface wave observations at National Data Buoy Center buoys in the Middle Atlantic Bight (MAB) and South Atlantic Bight (SAB) over the period of 1997–2007. In water depths ranging from 36–48 m, there were 4–9 mobility events/year of 1–2 days duration. Integrated wave stress during events (IWAVES) was used as a combined metric of wave-driven mobility intensity and duration. In the MAB, over 67% of IWAVES was caused by extratropical storms, while in the SAB, greater than 66% of IWAVES was caused by tropical storms. On average, mobility events were caused by waves generated by storms located 800+ km away. Far-field hurricanes generated swell 2–4 days before the waves caused mobility on the shelf. Throughout most of the SAB, mobility events were driven by storms to the south, east, and west. In the MAB and near Cape Hatteras, winds from more northerly storms and low-pressure extratropical systems in the mid-western U.S. also drove mobility events. Waves generated by storms off the SAB generated mobility events along the entire U.S. East Coast shelf north to Cape Cod, while Cape Hatteras shielded the SAB area from swell originating to the north offshore of the MAB.

Published by Elsevier Ltd.

1. Introduction

Near-bottom currents driven by tides, winds, and large-scale patterns in ocean circulation combine with wave orbital motion to induce a shear stress at the seafloor, with the largest stress events typically associated with storms (Dalyander et al., 2013; Grant and Madsen, 1979; Madsen, 1994; Nielsen, 1992; Oberle et al., 2014; Soulsby, 1997). When the bottom stress acting on the seafloor (i.e., the skin friction) exceeds a grain size and density specific critical threshold, sediment begins to move. Wave-driven bottom stress is larger for longer period waves; for example, in 50-m water depth, a JONSWAP (Hasselmann et al., 1973) spectrum of waves with significant wave height of 5-m and dominant wave period of 8, 10, and 14 s causes a stress on 0.35 mm diameter grains of 0.091, 0.293, and 0.747 Pa, respectively (Butman et al., 2008; Madsen, 1994; Wiberg and Sherwood, 2008). Through this interaction with the bottom (including the movement of sediment), long period waves dissipate energy during propagation over the shelf (e.g., Ardhuin et al., 2002, 2003; Herbers et al., 2012). As a result, more energetic shorter period swell or wind waves may dominate shear stress over portions of the inner- to mid-shelf. Although the physics of wave-driven bottom stress are generally well-known, the origins of the waves that cause the largest bottom stress and sediment mobility events have not been investigated. Understanding these relationships provides insight into processes currently shaping the shelf sedimentary environment and develops a framework for assessing the effects of the future wave-stress environment.

Investigations of the relationship between synoptic weather systems and seafloor mobility have primarily focused on km-scale geographic areas (e.g., Austin and Lentz, 1999; Kim et al., 1997; Warner et al., 2012). Warner et al. (2012) explored how storms impact waves and circulation at a 10 m site offshore of South Carolina (SC; Fig. 1) using the Austin and Lentz (1999) classification system for U.S. East Coast storms. This system divides wind events into those where the low pressure system passes to the east, but the site is still within the wind field of the system; those where the storm tracks north of the region from west to east and a cold front passes over the Cape Hatteras area; and those where the storm tracks west of the region from south to north and a warm

* Corresponding author. Fax +1 727 502 8001.
E-mail address: sdalyander@usgs.gov (P.S. Dalyander).

http://dx.doi.org/10.1016/j.csr.2015.05.003
0278-4343/Published by Elsevier Ltd.

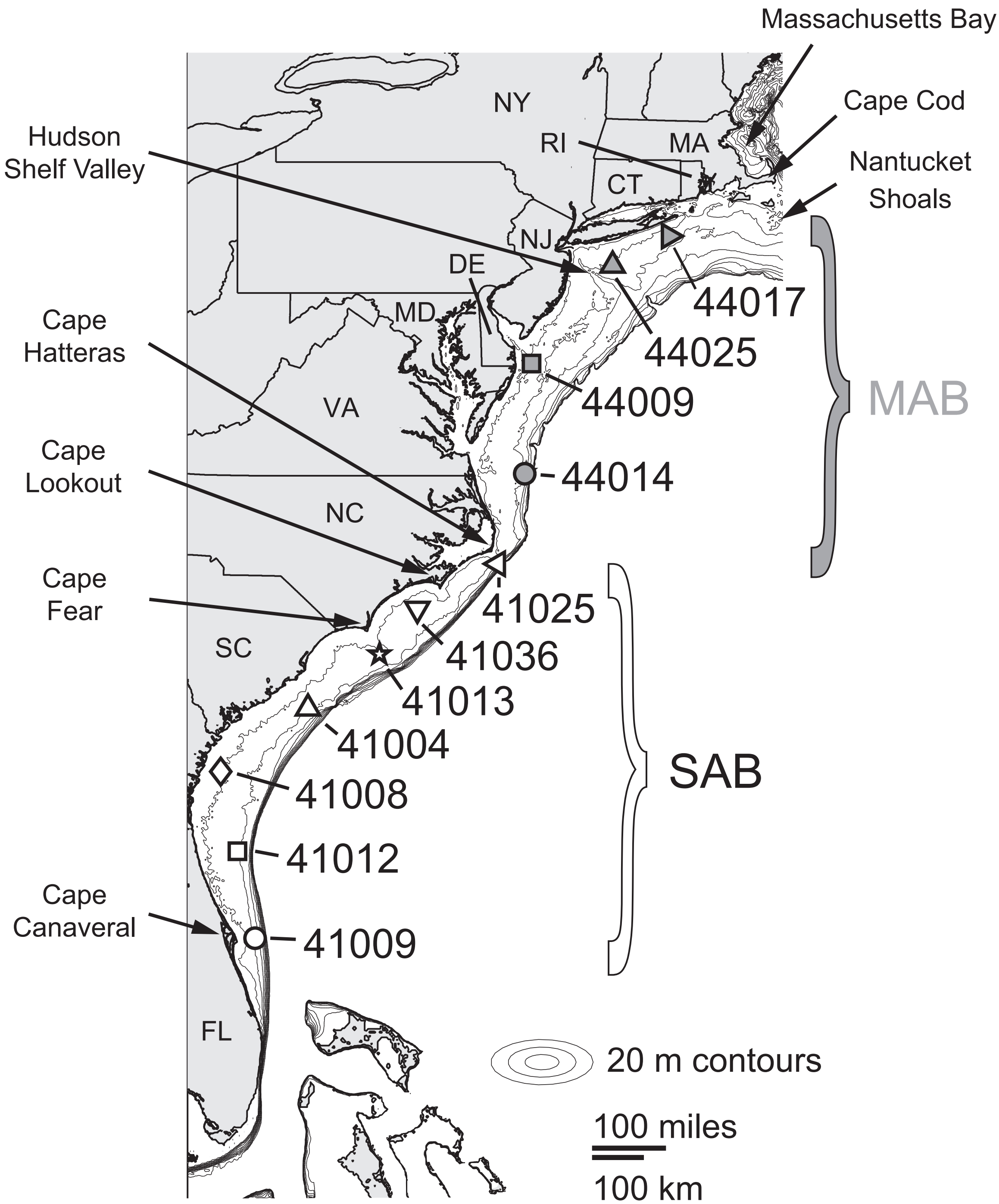

Fig. 1. Map showing the location of buoys from which surface wave data were obtained in the Middle Atlantic Bight (MAB; gray symbols) and the South Atlantic Bight (SAB; white symbols). Symbol shapes delineating individual buoys are the same as used in Figs. 7 and 9. State abbreviations are Florida (FL), North Carolina (NC), South Carolina (SC), Virginia (VA), Maryland (MD), Delaware (DE), New Jersey (NJ), New York (NY), Connecticut (CT), Rhode Island (RI), and Massachusetts (MA).

front passes the area. Warner et al. (2012) found that inshore low-pressure centers could drive significant events at their ~10 m site. Kim et al. (1997) characterized phases of inner shelf sediment response to a passing near-field extratropical storm. Studies along the Pacific Coast of the United States (Drake and Cacchione, 1985; Sherwood et al., 1994), the Gulf of Mexico (Snedden et al., 1988), the Mediterranean Sea (Dufois et al., 2008), and Australia (Gagan et al., 1990) have similarly identified sediment suspension at selected locations on the inner shelf in response to near- and far-field storms. Swell from the Pacific Ocean was identified through a numerical modeling study as driving sediment suspension along a broad region of the shelf along the coast of Australia (Porter-Smith et al., 2004), but the relationship between storm characteristics and shelf response was not explored.

Studies characterizing storms have focused on the atmosphere, sea surface, or onshore, classifying events based on origin and track and benchmarking them by wind speed, central pressure, wave height, or coastal damage (e.g., Davis et al., 1993; Dolan and Davis, 1992; Hart and Grumm, 2001; Keim et al., 2004; Mather et al., 1964; Simpson, 1974; Zielinski, 2002). For example, Davis et al. (1993) considered storms impacting Cape Hatteras and found that “Bahamas lows” and “Florida lows”, two types of storms