Marine Geology 404 (2018) 1–14

Contents lists available at ScienceDirect

Marine Geology

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

Storm impacts on hydrodynamics and suspended-sediment fluxes in a microtidal back-barrier estuary

D.J. Nowacki*, N.K. Ganju

U.S. Geological Survey, Woods Hole, MA, USA

ABSTRACT

Recent major storms have piqued interest in understanding the responses of estuarine hydrodynamics and sediment transport to these events. To that end, flow velocity, wave characteristics, and suspended-sediment concentration (SSC) were measured for 11 months at eight locations in Chincoteague Bay, MD/VA, USA, a shallow back-barrier estuary. Daily breezes and episodic storms generated sediment-resuspending waves and modified the flow velocity at all sites, which occupied channel, shoal, and sheltered-bay environments with different bed-sediment characteristics. Despite comparable SSC during calm periods, SSC at the channel locations was considerably greater than at the shoal sites during windy periods because of relatively more erodible bed sediment in the channels. Sediment fluxes were strongly wind modulated: within the bay's main channel, depth-integrated unit-width sediment flux increased nonlinearly with increasing wind speed. When averaged over all sites, about 35% of the flux occurred during windy periods (wind speed greater than 6 m s^{-1}), which represented just 15% of the deployment time. At channel sites, the net water and sediment fluxes were opposite to the direction of the wind forcing, while at shoal sites, the fluxes generally were aligned with the wind, implying complex channel–shoal dynamics. Yearly sediment fluxes exceed previous estimates of sediment delivery to the entirety of Chincoteague Bay. These observations illustrate the dynamic sedimentary processes occurring within microtidal back-barrier lagoons and highlight the importance of storm events in the hydrodynamics and overall sediment budgets of these systems.

1. Introduction

Barrier islands make up about 10% of all continental shorelines, and occupy nearly 2300 km of the Atlantic coast of North America (Stutz and Pilkey, 2011). The lagoons that form landward of these barriers, extensive along the U.S. Atlantic and Gulf coasts, are important and dynamic sedimentary environments forming a key role in landward island transgression. Despite considerable attention paid to the sand dynamics of barrier islands, the sediment-transport regime of tidal inlets, and lagoon sedimentation, comparatively little research has been conducted on fine-sediment dynamics within back-barrier lagoons. Understanding these dynamics is crucial because every element of a barrier-island system influences or is influenced by the lagoon (Oertel, 1985).

Among other roles, back-barrier estuaries provide critical habitat for seagrass and salt marsh, and grounds for commercially important fisheries. These habitats are preferentially located in particular geomorphic settings, which can themselves modify the bathymetry and resultant water circulation (Ralston et al., 2010; Ralston et al., 2012; Defne and Ganju, 2015), sediment transport (Dronkers, 1986), and depositional regimes of the estuary (Nichols and Allen, 1981). Morphology of back-barrier estuaries also is closely linked to wave action, ecosystem functions, and water quality.

Because back-barrier estuaries tend to be low-pass filters, damping tides but allowing propagation of subtidal (i.e., longer than a tidal cycle) motions (Wong and Wilson, 1984; Aretxabaleta et al., 2014), forcing at periods other than tides becomes important in these environments. For example, wind forcing, in both its local and remote forms, is a major controlling influence on circulation (Chant, 2001), sediment resuspension (Wells and Kim, 1989; Nichols and Boon, 1994), and larval supply variability (Xie and Eggleston, 1999). Storms may also temporarily change lagoons from sediment sinks to sediment sources, and vice versa (Nichols and Boon, 1994).

Coastal lagoons tend to trap inorganic sediment and organic matter (Kjerfve, 1994) but are not necessarily passive features destined to infill with sediment (Nichols and Boon, 1994). Sediment delivered to back-barrier estuaries is generally a combination of riverine input, shoreline erosion, overwash or aeolian transport from barrier islands, and delivery from the coastal ocean (Nichols and Allen, 1981); reworking of sediment on the lagoon seabed can also be considerable (Nichols and Boon, 1994). Understanding how sediment fluxes can both modify and be controlled by local and regional morphology can lead to greater insight to how these systems evolve and how they may change in the face of changing sediment supply, connectivity with the ocean, and rising sea level. Sediment fluxes during fairweather and storm conditions are critical in determining the resilience of marsh systems that

* Corresponding author.
E-mail address: dnowacki@usgs.gov (D.J. Nowacki).

https://doi.org/10.1016/j.margeo.2018.06.016
Received 31 July 2017; Received in revised form 23 April 2018; Accepted 27 June 2018
Available online 01 July 2018
0025-3227/ Published by Elsevier B.V. This is an open access article under the CC BY license (http://creativecommons.org/licenses/BY/4.0/).

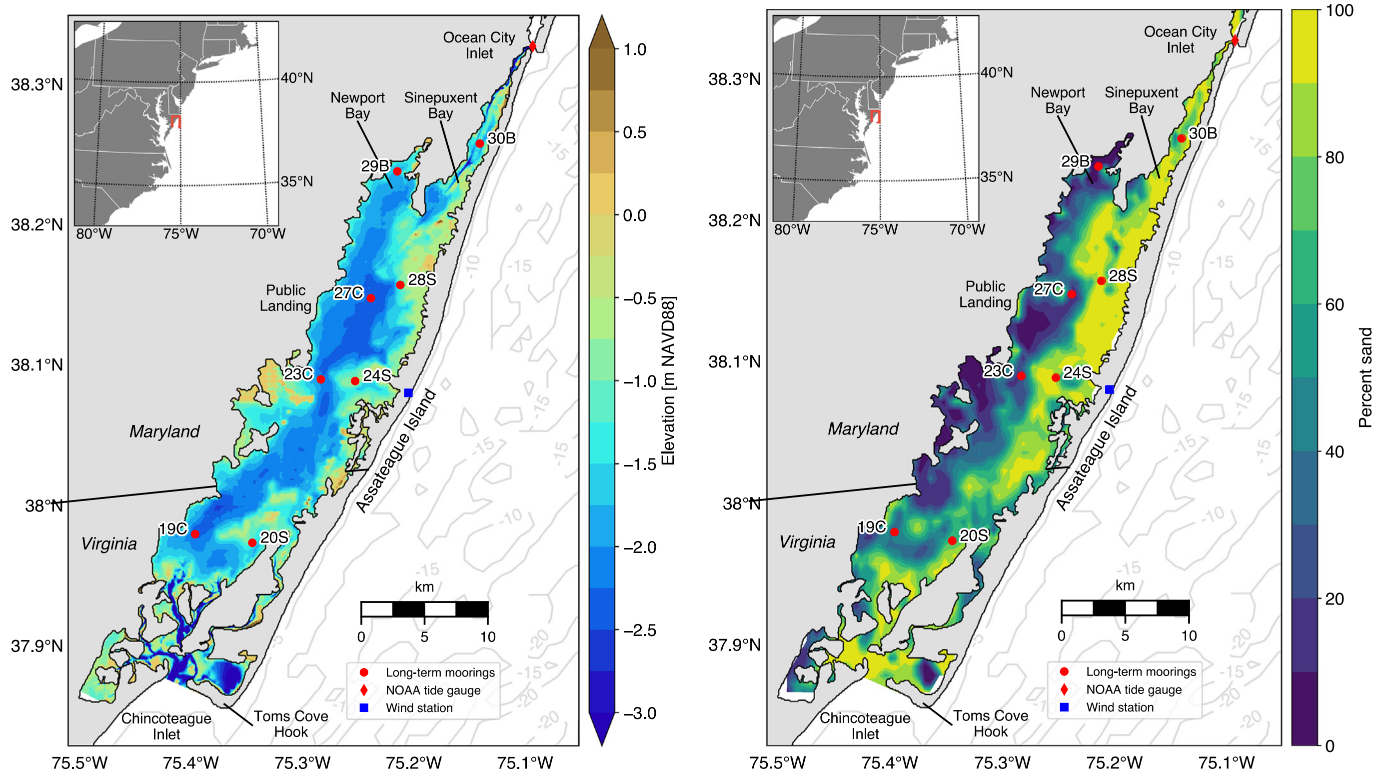

Fig. 1. (Left) Bathymetric map of Chincoteague Bay showing locations of moorings, the NOAA tide gauge at Ocean City, MD, and the wind station on Assateague Island. (Right) Map showing bed-sediment sand fraction in Chincoteague Bay (National Park Service, 2017). Darker colors indicate regions of finer sediment. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

protect habitat, shorelines, and communities, and a better understanding helps inform restoration and preservation of these systems.

In this work, we present results from an 11 month study of hydrodynamics and sediment transport within Chincoteague Bay, MD/VA, a back-barrier estuary on the mid-Atlantic coast of the United States. We describe the characteristics of fine-sediment transport under both calm and stormy conditions and emphasize the importance of storms in this microtidal environment. We decompose the processes driving the sediment flux and characterize the long-term sediment fluxes at diverse locations within the bay. The observed subtidal velocity patterns are shown to be reproducible with a relatively simple analytical model and describable with empirical orthogonal functions. We compare our observed fluxes to previous estimates of sediment delivery to the bay and consider the importance of morphology in this system.

1.1. Study site

Chincoteague Bay is a coastal-plain back-barrier lagoon separated from the Atlantic Ocean by Assateague Island, the northernmost undeveloped barrier island on the U.S. East coast (Fig. 1). The bay is about 55 km in length and 10 km in width, has a surface area of 417 km^2, and is oriented NNE–SSW. Ocean City Inlet and Chincoteague Inlet are the only present connections to the Atlantic Ocean. There are two subembayments at the north end of the bay. Newport Bay is a small, sheltered bay at the extreme northwest of Chincoteague Bay. It is a flooded extension of Trappe Creek and receives about one quarter of the freshwater that enters Chincoteague Bay despite occupying only about four percent of the surface area. The estimated mean freshwater input to Newport Bay is 1.5 m^3 s^{-1}. Sinepuxent Bay, immediately to the east of Newport Bay, is a long, narrow basin that connects Chincoteague Bay and Ocean City Inlet.

Chincoteague Bay has an average depth of 1.4 m, and is characterized by a deep (~3 m) basin (the "channel") in the central-to-western section of the bay, which shallows toward the eastern side (the "shoal"). Chincoteague Bay is microtidal, with tidal ranges greatest near the inlets (~1 m) that rapidly diminish from friction, resulting in a mean tidal range of 0.16 m at Public Landing.

As described by Bartberger (1976), approximately equal quantities of sand and mud are supplied to Chincoteague Bay from two principal sources. The sand comes primarily from Assateague Island, both from storm overwash and from aeolian transport, and this material makes up much of the shoal areas (Fig. 1). Mud comes from the mainland, mostly from marsh erosion; winds have been shown to undercut tidal-marsh root mat and lead to marsh erosion in Chincoteague Bay (Krantz et al., 2009) and wind-wave power is linearly correlated with marsh erosion (Leonardi et al., 2016). Local streams provide a small (< 10%) additional fine-sediment source. This finer material is prevalent throughout the channel (Fig. 1). The total annual sediment delivery to Chincoteague Bay is about 0.1 Mt y^{-1}, although more recent studies using radiochemical methods suggest an annual sediment delivery of 1 Mt y^{-1} or more (Wells et al., 1997, 1998, Wegner et al., 2011).

Chincoteague Bay experiences two main categories of storms: cold-core extra-tropical storms (nor'easters) during the fall and winter, and hurricanes during summer and fall. Fall and winter storms generally feature winds with a northern component, while summer winds are mostly from the SSW (Carruthers et al., 2011). These storm wind patterns are approximately aligned with the longitudinal axis of the bay; winds are particularly important in Chincoteague Bay because they have a greater effect on water levels and currents than do tides (Casey and Wesche, 1981).

The importance of wind in Chincoteague Bay has also been confirmed via numerical modeling: wind dominates water and salt flux at higher wind speeds, while tides are most important at lower wind speeds (Kang et al., 2017). These findings are consistent with previous studies which have emphasized the importance of wind on estuarine hydrodynamics, salinity structure, and sediment transport (Goodrich,

Download English Version:

https://daneshyari.com/en/article/8911898

Download Persian Version:

https://daneshyari.com/article/8911898

Daneshyari.com