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Storm-induced semidiurnal perturbations to surges on the US Eastern Seaboard

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ABSTRACT

Analysis of 19-year-long tidal gauge records along the US East Coast has revealed the appearance of semidiurnal perturbations to storm surges in the South Atlantic Bight. A total of 85 events with semidiurnal-surge amplitudes higher than 20% of the astronomic tidal amplitude and durations longer than two days were identified. These semidiurnal surge events were triggered by the passage of tropical storms and cold fronts. As a consequence of the storm-induced forcing, observed tides were delayed and partially damped with respect to the predictions. Such delay and damping resulted in a semidiurnal signal on the surge. Parallel-to-shore winds in the shelf region between Cape Hatteras and the South Atlantic Bight were highly correlated with the generation of the semidiurnal perturbations. Increased bottom friction combined with Coriolis acceleration, resulting from enhanced wind-driven alongshore currents, are proposed to be the primary factors delaying and attenuating astronomic tides.

1. Introduction

The US eastern coast has been recently affected by extreme storm events. Hurricanes *Isabel* (2003), *Katrina* (2005), *Ike* (2008), *Irene* (2011), and *Sandy* (2012) all left their names in the US coastal flooding history, which caused severe socioeconomic loss to the coastal communities. Consequently, there is a pressing need to increase understanding and predicting capabilities for storm surges on coastal waters. During extreme storms, water levels can exceed sea defenses and cause flooding (i.e. Jones and Davies, 2007). Storm surges and astronomic tides both contribute to the high water levels during extreme events. For simplicity, many coastal flooding studies consider a linear superposition of astronomic (or predicted) tides and storm surges in the assessment of high water levels. These studies typically disregard the possible nonlinear interactions between astronomic tides and surges, i.e. tide–surge interactions (e.g. the Nivmar system, Álvarez Fanjul et al., 2001; NOAA system, Glahn et al., 2009). The pioneering studies of Proudman (1955a,b; 1957) indicated that tide–surge interactions can be relevant, especially in shallow waters. Tide–surge interactions can affect the arrival time and the peak value of the water levels, and consequently the flooding threat.

Tide–surge interactions have been analyzed extensively around the world. Most of these studies have focused on the British Coasts (e.g. Proudman, 1957; Prandle and Wolf, 1978; Horsburgh and Wilson, 2007; Jones and Davies, 2007). Relevant surge–tide interactions have also been identified in many other coastal regions, including the Orissa coastline in the Bay of Bengal (e.g. Sinha et al., 1996, 2008; Nayak et al., 2012), the Fujian coast in China (Zhang et al., 2010), the Gulf of Suez at the north end of the Red Sea (Rady et al., 1994; 1998), the Gulf of Mexico during Hurricane Rita 2005 (Rego and Li, 2010), and northeast coasts of North America (Bernier and Thompson, 2007). Tide–surge interactions were observed on the US East Seaboard of the South Atlantic Bight during Hurricane *Irene* 2011 and *Sandy* 2012 (Valle-Levinson et al., 2013). However, the dynamic factors, regarding meteorological and hydrodynamic conditions, for triggering the semidiurnal surges in the South Atlantic Bight remain unclear. Elucidating these factors is the primary goal of the present study.

2. Background

One of the consequences of tide–surge interactions is the appearance of periodic oscillations (with the same period as the main astronomic tidal component) in the storm surge, often known as “semidiurnal residuals” or “semidiurnal surges” (Horsburgh and Wilson, 2007; Valle-Levinson et al., 2013). Atmospheric pressure and wind stress usually play an important role in tide–surge interactions. Mercer et al., (2002) showed that the atmospheric pressure contributes the most in triggering barotropic waves in the Grand Bank of Canada. Other studies (e.g. Morey et al., 2006; Rego and Li, 2010) demonstrated the dominant role of wind forcing in promoting periodic oscillations on the storm

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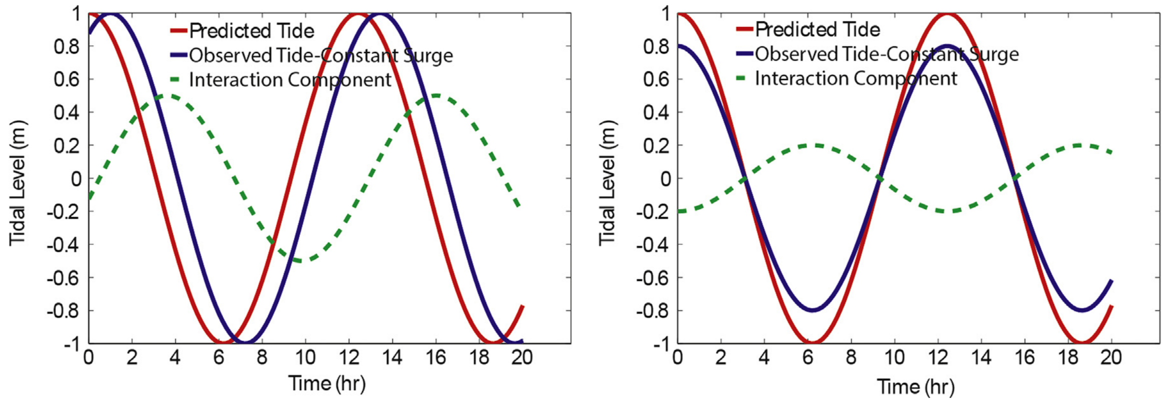

Fig. 1. Schematic diagram of the generation of semidiurnal surges during positive surge events: (a) due to a phase delay of the observed tide; (b) due to the effect of the local surge modification. The red line represents the predicted tide, the blue line represents the observed tide with adjustment to the mean sea level, and the dashed green line represents the interaction component (I). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

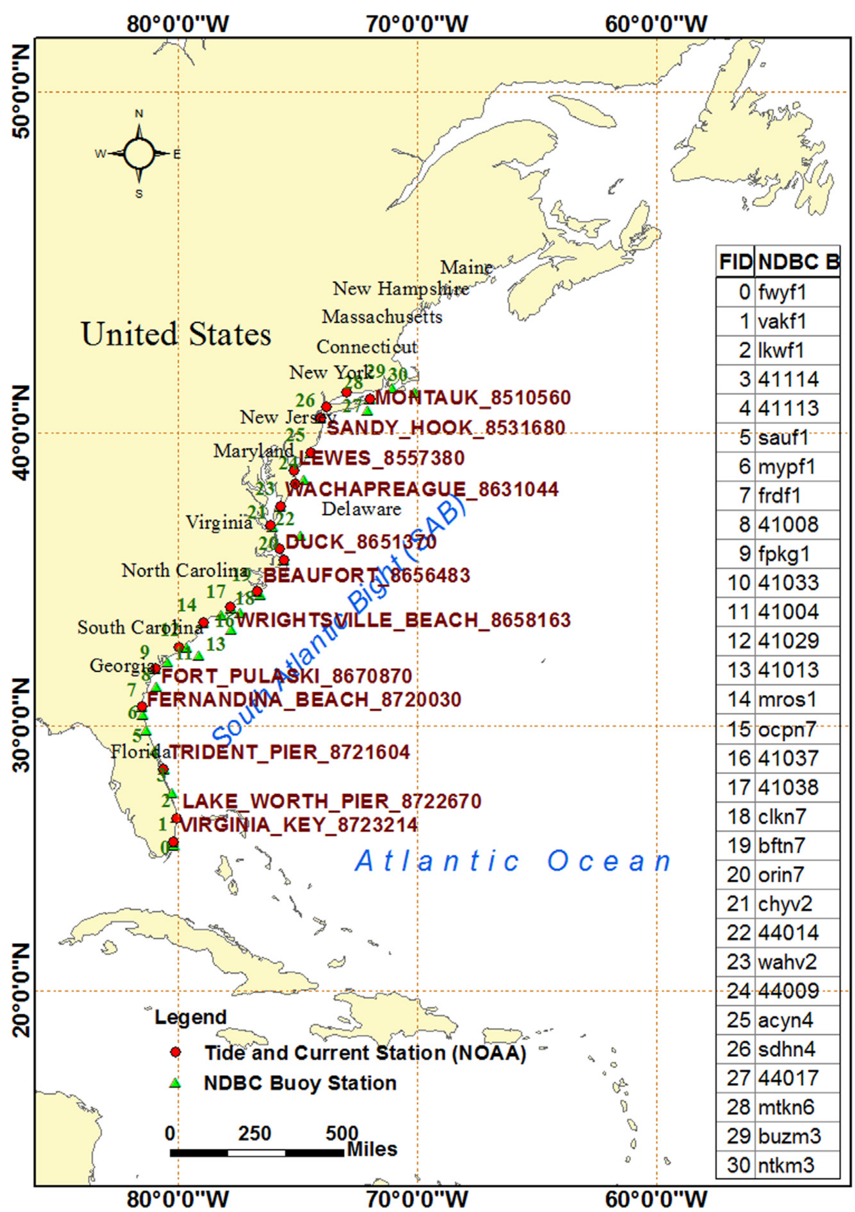

Fig. 2. Location of tidal gauges (red dots) and buoy stations (green triangles) used for data collection and analysis. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)