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Short communication: Multi-scale topographic anisotropy patterns on a Barrier Island

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ABSTRACT

Barrier islands exhibit a range of landforms that reflect the complex and varied combination of coastal and aeolian processes realized over the evolution of the island. A detailed analysis of the topography can be used to describe the evolution of a barrier island and provide insight on how it may be affected by a change in sea level, storm activity and wind exposure patterns. Topographic anisotropy, or the directional dependence of relief of landforms, can be used to determine the relative importance of different processes to island evolution at a range of scales. This short communication describes the use of scale-dependent topographic anisotropy to characterize the structure of Santa Rosa Island in northwest Florida. Scale-dependent topographic relief and asymmetry were assessed from a LiDAR-derived DEM from May 2004, a few months before the island experienced widespread erosion and overwash during Hurricane Ivan. This application demonstrates how anisotropy can be used to identify unique scale-dependent structures that can be used to interpret the evolution of this barrier island. Results of this preliminary study further highlight the potential of using topographic anisotropy to controls on barrier island response and recovery to storms as well as island resiliency with sea level rise and storm activity.

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1. Introduction

Transgressive barrier islands are complex landforms that developed through a combination of coastal and aeolian processes, as they migrated to their current position from further offshore on the continental shelf. Barrier island transgression through landward migration or shoreline retreat is accomplished during storms capable of overtopping or breaching the dunes washing sediment to the backbarrier shoreline in the form of washover fans and terraces (Houser et al., 2008). For an island to transgress and remain a subaerial landform requires that the island can move landward and remain above sea level, which is in turn dependent on the ability of the dunes to recover following storms and moderate washover and inundation (Houser et al., 2017). Islands tend to be high in elevation (i.e., large continuous dunes) when the biophysical processes driving dune recovery dominate, but when storm erosion is frequent and extensive, islands can enter a low-elevation state (characterized by small discontinuous dunes) that makes the island susceptible to erosion and washover during relatively mild storm conditions (Duran & Moore, 2013; Houser et al., 2015). Because the overwash threshold is reduced in lower elevation areas, gaps between larger dunes tend to be reinforced with each storm (Houser and Hamilton, 2009; Houser, 2012; Weymer et al., 2015) leading to a biogeomorphic feedback that further reinforces the variation in the dune line (Stallins and Parker, 2003; Duran & Moore, 2013). The sediment transferred to the backbarrier through washover plays an important role in determining the morphology of the backbarrier shoreline, and in maintaining island width. It is also possible to have a regular variation in washover and dune heights alongshore in response to edge wave set up or even infragravity resonance (Orford and Carter, 1984) that can be reinforced by subsequent washover or blowout development (Jewell et al., 2014, 2017).

The net result of the combined and in some cases inter-dependent coastal, aeolian, and ecological processes on a barrier islands is a complex mosaic of topographic variation and features across a range of scales. On many barrier islands, small-scale variations in morphology associated with shoreface (>1000 m) and surf/swash processes (<1000 m) are superimposed on a larger-scale variability associated with the framework geology that influences beach and dune morphology through variations in wave energy or sediment supply and texture (McNinch, 2004; Browder and McNinch, 2006; Houser and Mathew, 2011; Houser, 2012; Warner et al., 2014; Wernette et al., in review). It is therefore, possible to interpret the evolution of a barrier island based purely on an analysis of scale-dependent topographic variation and relief features, but the superposition of local-scale relief on mesoscale relief produces subtle relief

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features that are not readily visible upon examination of a digital elevation model using standard visualization or statistical techniques. Visualization of subtle and overlapping features has traditionally been accomplished through spectral or wavelet techniques (e.g. Houser et al., 2008) or higher-order exploratory statistics including principal component analysis (PCA; Barrineau et al., 2016).

As recently demonstrated by Roy et al. (2016), the anisotropy, or directional dependence, of topographic features can be used to assess the magnitude and orientation of past and present processes across multiple length scales. Specifically, they used topographic anisotropy of valleys and ridges in a mountainous environment to determine the magnitude and orientation of past and present tectonic strain fields. Surf, swash and aeolian landforms generate anisotropic features (bars, beaches and dunes) that are or near perpendicular to the primary transport direction, while extensive overwash (or barrier breakdown; Orford et al., 1991) can result in an isotropic topography in the form of washover fans and terraces. However, where there is sluicing discrete overwash it is possible to develop anisotropic features that are perpendicular to the barrier and distinct from the anisotropy of the beach and dune (Orford et al., 1991) This suggests that topographic anisotropy can be used to link barrier island morphology to formative process(es) on Santa Rosa Island in northwest Florida, but the technique has not been demonstrated in a coastal environment. The purpose of this short communication is to determine whether topographic anisotropy can be used to identify scale-dependent features in coastal LiDAR data.

2. Study site

This demonstration of topographic anisotropy in a coastal environment was completed on a section of Santa Rosa Island in northwest Florida (Fig. 1). Santa Rosa Island is a narrow sandy Holocene barrier island extending 96 km from East Pass near Destin to Pensacola Pass in the west. The focus of this study is a 2.5 km stretch of the island that was impacted by hurricanes Ivan (2004), Dennis (2005) and Katrina (2005). This area has also been the focus of numerous previous studies of storm response and recovery within the Gulf Islands National Seashore (e.g., Houser et al., 2008, 2015; Houser and Hamilton, 2009; Claudino-Sales et al., 2010). The island is fronted by a ridge and swale bathymetry that creates a coincident variation in beach and dune morphology ranging from transverse bar and rip morphology and small discontinuous dunes landward of the swales to longshore-bar and trough with relatively large dunes landward of the offshore ridges that serve as an offshore source of sediment (see Short and Hesp, 1982; Hesp, 2002; Houser, 2009). A geological survey by Houser (2012) supported an earlier theory that the ridge and swale topography may be a transgressive surface, representing a multi-scale feedback of the response

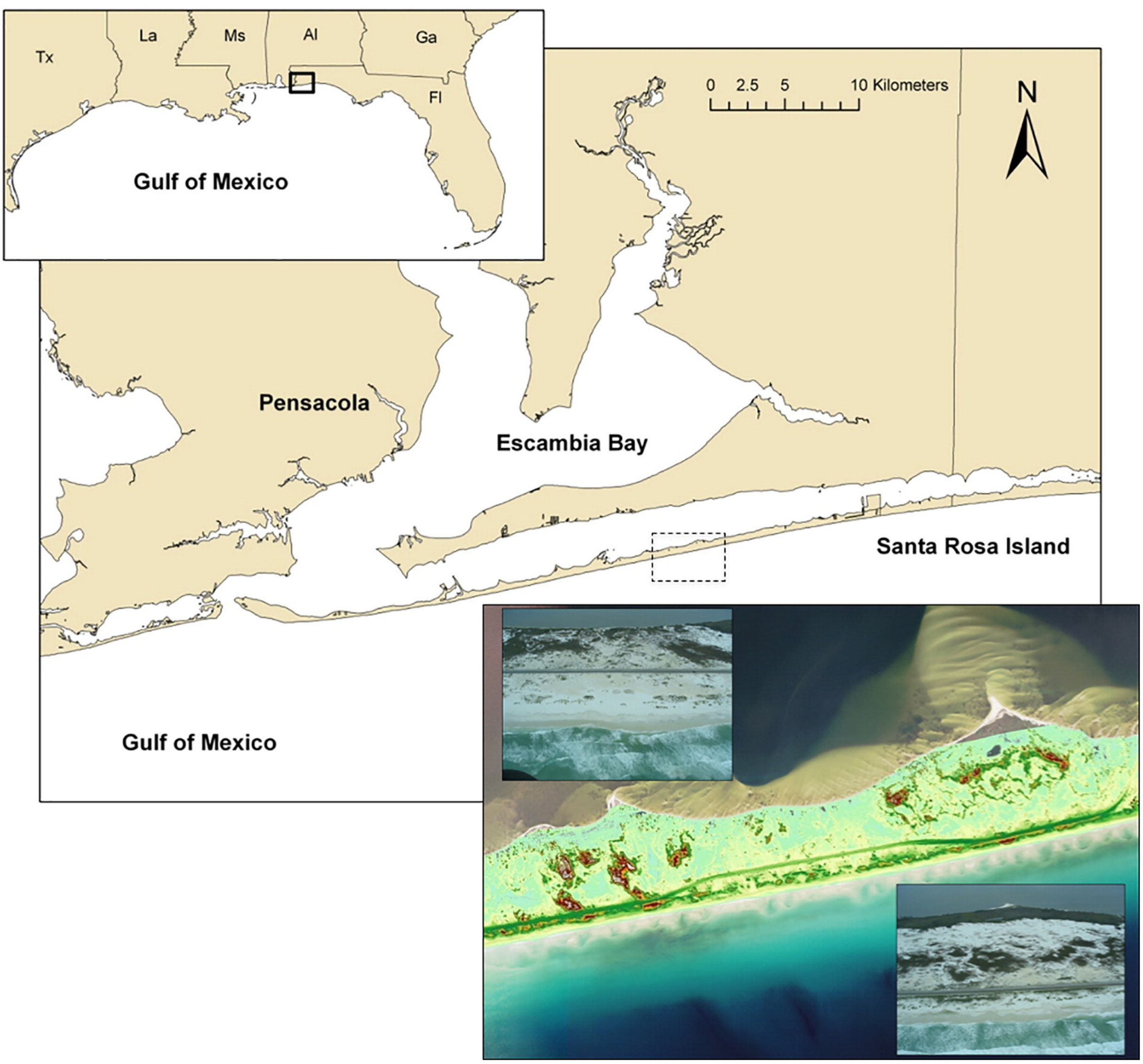

Fig. 1. Map of Santa Rosa Island in northwest Florida, showing LiDAR DEM of the study area, and oblique aerial photographs of the site before Hurricane Ivan in 2004.

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