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Overwash Controls on Barrier Island Morphodynamics during Storms

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Overwash Controls on Barrier Island Morphodynamics during Storms

A Thesis

Submitted to the Graduate Faculty of the
University of New Orleans
In partial fulfillment of the
Requirements for the degree of a

Master of Science
In
Earth and Environmental Science

By
Joshua Holland Alarcon
B.A. Tulane University, 2011
May 2017

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Abstract

Overwash, shoreface retreat, and barrier migration are common processes occurring in transgressive barrier island systems, the scale of which is exacerbated by sea level rise, subsidence and the frequency and magnitude of tropical and extratropical storms. Barrier morphology also clearly plays a key role in determining a morphological response to these processes. Using a hydrodynamic and sediment transport model (MIKE21) and selected barrier island and shoreface templates, informed by deltaic and coastal plain systems in the northern Gulf of Mexico, I performed simulations to determine barrier morphology in response to storms. A low dune with a gentle shoreface slope, characteristic of Louisiana deltaic barriers, demonstrates the greatest amount of shoreline erosion, dune overwash and barrier migration in response to a storm. Profile evolutions over time demonstrate the wider dune templates respond mostly via dune aggradation and barrier rollover whereas the narrow or low templates respond via dune overwash and barrier translation. Determining which barrier templates retain the most sediment over time becomes extremely important when planning coastal restoration projects here in Louisiana.

Keywords: Shoreface, Overwash

Introduction

Barrier island systems are important coastal landforms that harbor important marine life and act as a buffer to coastal ecosystems against storm surge and wave action (Barbier et al., 2013). The overall shape and volume of sand within barrier island systems fluctuate over time as a response to changes in relative sea level rise, sediment supply, the incidence of storms, and proximal substrate composition (Ritchie & Penland, 1988; List et al., 1997). The Louisiana coastline experiences some of the highest rates of wetland loss in the United States (16.57mi^2 per year from 1985 to 2010) due in part to high rates of subsidence, eustatic sea level rise, and a high frequency of tropical and extratropical storms (Miner et al., 2009; Couvillion et al., 2011; Georgiou et al. 2005). Currently, barrier islands in Louisiana, characteristic of low barriers with gentle shoreface slopes, are in a transgressive phase, undergoing fragmentation due to an ongoing rise in sea level and a lack of sediment supply. They are also subjected to frequent erosion events from storm-induced transport including overwash and/or lateral transport. (Stone et al., 2005; Georgiou et al., 2005; Miner et al., 2009). Barrier overwash, referred to as washover, promotes the cross-shore landward transfer of sediment across the barrier leading to migration of a barrier over time (Matias et al., 2009; Lorenzo-Trueba & Ashton, 2014). The variation in barrier response produced by a storm is highly dictated by the morphology of the shoreface slope and barrier template (Donnelly, 2007; Lorenzo-Trueba & Ashton, 2014). The goal of this research is to a) explore the relationship between shoreface morphology and overwash volume, leading to the landward migration of such landforms during the ongoing transgression b) examine various nourishing templates for barriers to determine which can help offset or reduce sediment loss from the system and help maintain subaerial extent for longer periods and c) better constrain morphological response of barriers to overwash events on short-term and decadal time-scales through the use of a morphodynamic model called MIKE 21. MIKE 21 by DHI is a 2D process based coastal hydrodynamic and morphology model with multiple applications and capabilities. Because Louisiana's barriers are eroding and disappearing at rapid rates, the importance of effective coastal protection grows exponentially every day. Increasing the accuracy of scientific predictions will allow for improved coastal planning and management practices.

Background and Significance

Barriers

The origin of barriers has been proposed and debated by a number of scientists including DeBeaumont (1845), Gilbert (1885), McGee (1890), Shepard (1960), Hoyt (1967) and Otvos (1970), but Short (1999) building on statements first promulgated by Swift (1975), states there is now common agreement that barriers form at sea level on suitable substrates by the action of waves and tides and that most modern barriers were established in the late Postglacial marine transgression in the mid-to late Holocene. In fact, Short (1999) states that the only essential prerequisites for barrier formation are a) accommodation space, b) ample sediment supply and c) waves to transport the sediment offshore into the accommodation space; and that subsequently tides, winds and sea level change will rework the sediment creating inlets and backbarrier deposits.

Barriers may exist in different marine settings including a) regressive sea level or progradational setting and b) transgressive sea level or retrogradational setting (Riggs, Cleary & Snyder, 1995). Short (1999) established that during a transgressive (rising) sea level setting, four barrier types may form depending on the rate of sea level rise, sediment supply and substrate slope including 1) prograded barriers and strandplains which prograde due to the landward transport of sediment from a local major sediment source, 2) retrogradational barriers which occur on coasts experiencing relative sea level rise, 3) retrogradational coastal plains and 4) retrogradational attached barriers. The evolution of the Mississippi River Delta Plain (MRDP) creates unique conditions and opportunities for the formation of deltaic barriers through shifting depocenters creating delta complexes facilitated by upriver avulsions during the Holocene. This is coupled with spatially variable and differential subsidence driven by various mechanisms including compaction of Holocene sediments (Penland & Boyd, 1981). Penland and Boyd (1981) suggested a cycle by which deltaic barrier islands can be formed and submerged over time. Initially, in the abandonment phase, a delta complex is abandoned and course grained sediments from distributary sand bodies are reworked creating an erosional headland with flaking barriers. Second, in the detachment phase, subsidence creates an open water lagoonal environment behind the barriers causing a separation from the mainland and creation of a transgressive barrier island arc. During the last phase of barrier formation, the submergence phase, continued subsidence and lack of fluvial sediments result in the transformation of barriers to inner shelf subaqueous shoals (Penland & Boyd, 1981). The authors emphasize that unless a reoccupation takes place where an active delta can introduce new fluvial sediments to the region, the subaqueous shoals will continue to degrade.

Shoreface

The shoreface extends from the upper limit of wave runup on the beach seaward to the point at which changes to the overall barrier profile are considered negligible, also termed the Depth of Closure (DoC) (Short, 1999). When considering morphological effects along a barrier island profile (from subaerial dunes to the toe of the shoreface) and the processes associated with that profile (e.g., overwash on barrier island systems) it becomes evident that success of the analysis will depend on carefully selecting the DoC which is a challenging endeavor due to its highly variable nature. The DoC is a function of the various physical processes occurring along the barrier island geometry over time (Nicholls, Birkemeier & Hallermeier, 1996). Due to the difficulty in calculating the DoC, an assumption is often made concerning the exact location of this point. Hallermeier (1981) was one of the firsts to define the DoC using the following expression:

$$d1 = 2.28He - 68.5 \left(\frac{He^2}{gTe^2}\right) \tag{1}$$

where d1 represents the calculated DoC, He and Te are the local significant wave height and wave period exceeding only 12 hours per year (0.137% of the time) and g is the acceleration due to gravity (Sabatier, Stive & Pons, 2004). Despite the presence of this equation, difficulty in defining the DoC leads to a difficulty in defining the gradient slope of the shoreface. The significance of the shoreface is in the sediment exchange between the continental shelf (seaward) and backshore beach and dunes (Short, 1999). The rate of sediment supply to the barrier from nearby sources on the shelf alters the overall shape and response of a barrier system to physical forces and the morphology of the dune restricts the deposition of the overwash volume (Donnelly, Kraus & Larson, 2006). The slope of the shoreface is important in dictating the dune crest morphological response during storm events (Short, 1999).

Niedoroda and Swift (1991) characterized the shoreface as a compound form consisting of two concave-up elements separated by an inflection point (upper and lower shoreface). The upper shoreface is defined as the region in which accretion and erosion result in significant (or measurable) changes in bed elevation in a given year (Short, 1999). More specifically, the upper shoreface ranges from the beach berm to an inflection point representative of a change in shoreface slope and substrate composition. As change in bed elevation is largest in the vicinity of the beach face and decreases progressively offshore, Stive and Vriend (1995) appropriately refer to the upper shoreface as the active zone. The lower shoreface represents a change in slope gradient and sediment grain size and extends from the lower limit of the upper shoreface to the outer DoC (Figure 1). The lower shoreface may require millennia to evolve toward equilibrium whereas the upper shoreface may adjust toward equilibrium within days to weeks in response to fluctuations in wave conditions (Short, 1999).

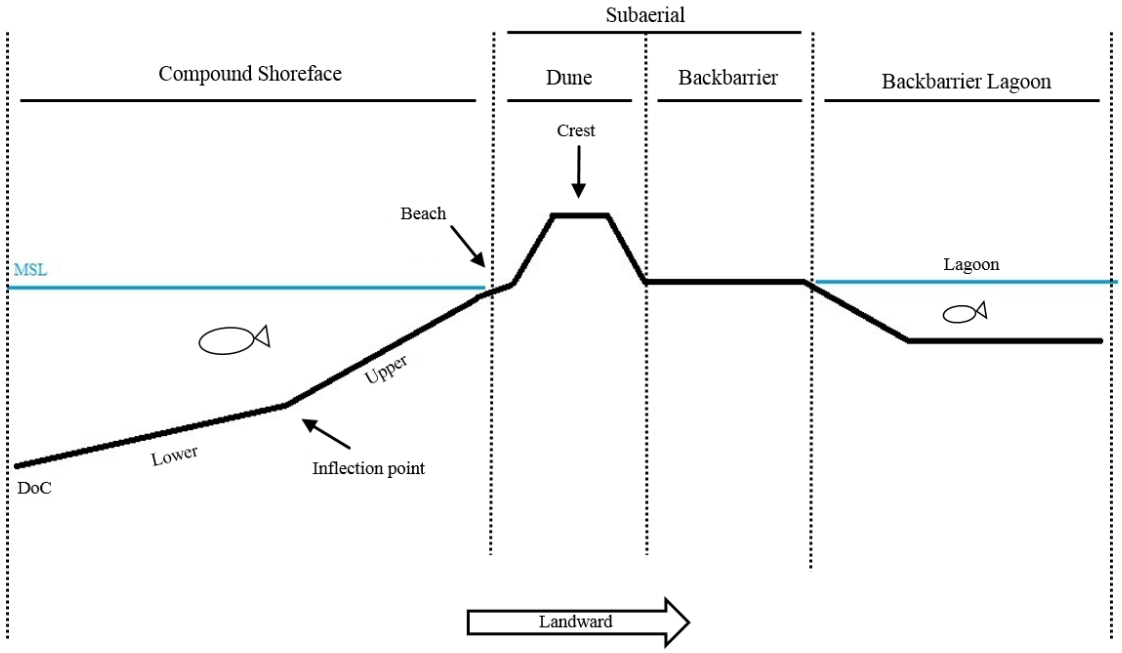


Figure 1: Barrier Profile modified from Dean and Dalrymple, 2004 and Niederoda and Swift, 1991

According to Short (1999), shoreface equilibrium may or may not exist at all considering the relative time scale. On a large enough time scale (>1000 years) shoreface equilibrium becomes evident, but on a shorter timescale (<1000 years) changes in equilibrium occur as a function of fluctuating sea level. The shoreface may exhibit a Null-point Equilibrium in which there is a balance in forces between waves pushing sediment onshore and gravity pulling sediment offshore. Regardless of the state of equilibrium, the most important pattern as identified by Short (1999) is the covariation of shoreface slope and near-bed wave orbital velocities as both decrease progressively offshore as the reduction in near-bed wave action is attributed to the effect of increasing water depth. The slope of the shoreface then, inherently, becomes important in not only breaking waves and dissipating energy, but defining the barrier profile and dictating morphological responses to cross-shore transport. In fact, beaches and barriers will only develop on slope gradients between 0.05 and 0.8 with a predicted optimum gradient of 0.1 (Short, 1999). On gentle sloping shelves (<0.05), frictional wave shoaling decreases wave energy progressively landward to the point where wave energy becomes incapable of reworking the sediment enough to create a beach or barrier profile whereas on a steep sloping shelf (>0.8), sediment may be transported offshore rather than onshore. Consequently, the slope of the shoreface exhibits a morphological control on the process of overwash and ultimately barrier migration.

Overwash

Overwash is an important physical process capable of significantly altering coastal morphology on beach and barrier systems. Overwash is a type of cross-shore sediment transport defined by Leatherman (1981) as "the flow of water and sediment over the crest of the beach that does not directly return to the water body where it originated". This occurs if either wave runup level or storm surge level exceeds the beach crest height (Donnelly et al., 2006). Overwash can actually result in increased elevation (height) or width of the subaerial exposure of a barrier island through deposition of sediment directly on top of the crest or on the backbarrier respectively; but can also result in the formation of washover fans or sheets and ultimately leading to landward translation (migration) of a barrier profile (Short, 1999).

There have been multiple attempts to quantify the effects of overwash in a coastal environment including the first estimation by Bruun (1956) termed the Bruun Rule, which measured overwash based on simple barrier geometric calculations and an assumption of barrier equilibrium via coastal profile translation (List et al., 1997). The Bruun Rule measures shoreline retreat rates based on sea level rise (SLR) and the distance and height of the DoC to the shoreface and mean water level respectively. The equation is presented as:

$$s = \frac{al}{h} \tag{2}$$

where ‘s’ is shoreline retreat, ‘a’ is SLR, and ‘l’ and ‘h’ are the length (distance) and height offshore to the DoC (List et al., 1997). Bruun also assumes an equilibrium profile over time that is translated vertically upwards and horizontally landwards meaning the volume of barrier sediment is maintained during translation (List et al., 1997). Finally, the biggest shortcoming for the Bruun Rule is in assigning a single value to the DoC primarily due to the highly variable nature of the DoC (Cooper & Pilkey, 2004).

Other long-term barrier retreat models have been proposed including Barrier Rollover by Swift (1975) and Barrier Overstepping by Dean and Maurmeyer (1983), but these models typically represent long-term (thousands of years to geologic scale) evolution of a barrier. A noteworthy attempt to quantify the relationship between barrier morphology and coastal processes via short-term evolution (high magnitude events) is Nguyen et al. (2006) who established an empirical formula for coastal overwash volume that incorporated three main data points 1. Maximum wave height 2. Wave period and 3. Water level during the storm. Nguyen’s equation is based on the assumption that excess runup transports sediment landward the entire duration of excess runup and is presented as:

$$Q = 0.0011\frac{H_c}{R}\frac{t_D}{T}(R - H_c)^2 \tag{3}$$

where ‘Hc’ is the average height of the dune crest, ‘R’ is the wave runup height, ‘T’ is the wave period, ‘tD’ is the dune overwash duration and ‘Q’ is the total overwash sediment discharge transported landward.

Coastal overwash is a natural and frequent process but occurs most frequently following tropical and extratropical storm events (Donnelly, Kraus & Larson, 2006; Ritchie & Penland, 1988). Van Rijn (2013) demonstrated that during high-energy conditions with breaking waves, the mean water level rises due to the combined effects of the tide, wind and wave forces forming a wave setup and waves attack the beach (dunes) leading to erosional processes that transport sediment offshore. Whereas during low-energy conditions, onshore transport related to wave asymmetry and wave-induced streaming are dominant leading to accretional processes. Typically, overwash can occur via two mechanisms, runup and inundation. Runup overwash occurs when wave runup height exceeds the beach or dune crest height depositing sediment backshore known as washover (Donnelly, Kraus & Larson, 2006). Washover is a lower magnitude event capable of creating washover fans and terraces (Nguyen et al., 2006; Donnelly, Kraus & Larson, 2006; and Rosati et al., 2010). Runup overwash can be categorized by three conditions; (a) relative elevations of water level and the barrier beach, (b) the frequency of waves that exceed the barrier beach elevation, and (c) the excess wave runup (ΔR) which is the quantitative difference between wave runup height, R, added to the storm surge height, S, minus the elevation of the dune crest from the mean water level, dc: (Donnelly, Kraus & Larson, 2006)

$$\Delta R = R + S - dc \tag{4}$$

Runup overwash can lead to two alternative effects: 1. crest accumulation ($R + S \approx dc$) in which few waves overtop the dune, so sediment is deposited either on the dune crest or in the throat of an existing washover leading to a raising of the throat and possible halting of further overwash and 2. crest lowering ($R + S > dc$) where waves have enough runup to overtop the dunes and therefore sediment is eroded from the face of the dune and deposited backshore (Donnelly, Kraus & Larson, 2006). Runup overwash often leads to the development of washover fans, sediment transported through the throat deposited backshore, or even washover terraces or aprons (Donnelly et al., 2006; Nguyen et al., 2006; and Donnelly, 2007).

Inundation overwash occurs when the water level, as a result of storm surge and wave setup, exceeds the beach or dune crest submerging the barrier island (Donnelly, Kraus & Larson, 2006). The water and sediment transported landward, sluicing overwash or sheet wash, can lead to either minor inundation ($S \approx dc$) in which water flows constantly over the beach or dune crest causing sediment to erode from the beach face and/or back barrier or complete inundation ($S > dc$) in which the entire barrier becomes submerged causing erosion of the shoreline and deposition of large amounts of sediment inland (Donnelly, Kraus & Larson, 2006). Complete inundation can sometimes lead to channeling or temporary breaches or even full breaches in the shoreline.

Lorenzo-Trueba and Ashton (2014) used a reduced complexity model to demonstrate that barrier systems respond to SLR and overwash via four different mechanisms: height drowning, width drowning, constant landward retreat, and periodic retreat. They also reported that shoreline (landward) retreat may occur even in the absence of SLR or under constant (non-accelerating) SLR demonstrating the complexity of barrier morphology. According to Donnelly, (2007) overwash can cause fluctuations in volume of sediment transported alongshore but typically, overwash causes seven types of responses (Figure 2): crest accumulation, landward translation of dunes/berms, dune lowering, dune destruction, barrier accretion, barrier rollover, and barrier disintegration. Crest accumulation is thought to be caused by deposition of sediment from wave run-up as it decelerates up to and on the beach crest; however studies indicate that the variation in surge level is the controlling factor for crest accumulation and that crest accumulation occurs primarily at low surge levels, but can also occur at higher surge levels depending on the width of the crest or if the run-up height is exceeded (Donnelly, Kraus & Larson, 2006; and Donnelly, 2007*).*

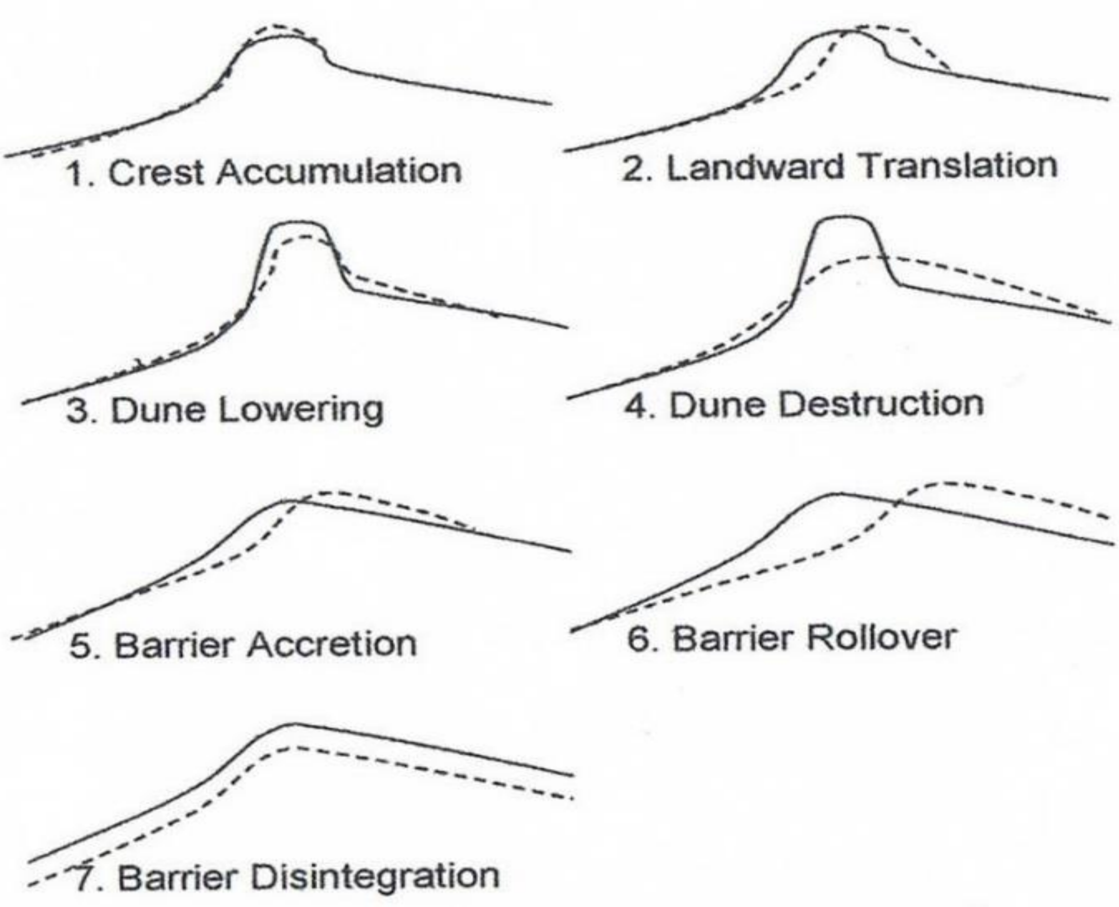


Figure 2: Seven barrier responses to overwash as proposed by Donnelly, 2007

Very little is known about the mechanisms driving landward translation of dunes or berms, however migration is often observed for dunes with higher crests or multiple dune systems and dunes that experience low run-up levels. One hypothesis is that an erosive overwash event for a wide range of surge levels causes dune lowering followed by dune accumulation landward restoring the dune to its original height *(*Donnelly, Kraus & Larson, 2006; and Donnelly, 2007*)*. Dune lowering and dune destruction generally occur under a threshold surge level for low relative dune widths and a wide range of run-up heights, however dune volume is a major factor as dunes with lower volumes are more readily destroyed

(Donnelly, Kraus & Larson, 2006). Still, it remains difficult to determine whether a dune will be lowered or destroyed during an overwash event.

The three barrier responses are characterized by higher surge levels, wider beach crest widths, low crest heights, and low foreshore slopes but may occur for a large range of relative run-up heights in the absence of a dune (Donnelly, 2007). Donnelly (2007) proposed that barrier rollover occurs for higher surge and run-up levels than barrier accretion because larger flow velocities are required to transport sediment into the back barrier bay and barrier disintegration occurs for even higher surge and run-up levels (Donnelly, 2007). In general, overwash and windblown sand that is lowered and re-accumulated landward can ultimately result in barrier migration (Donnelly, Kraus & Larson, 2006: and Donnelly, 2007). Donnelly (2007) not only demonstrated that morphological responses to overwash can vary as a function of surge height and barrier geometry, but also showed the importance of dune width and average slope in relation to defining the barrier profile in order to more accurately predict the overwash response to a specific event like a hurricane or tropical storm.

Objective

The objective of this study is to examine the relationship of both the shoreface and the dune morphologies on overwash and barrier landward migration as a result of a tropical storm period. More specifically, I hypothesized that (1) as the shoreface slope increases, the overwash and landward translation decrease and (2) as the dune crest width increases, the overwash and landward translation decrease. I intend to show the high degree of morphological responses produced by a dynamic environment like a barrier island and that a better understanding of these responses will enable coastal researchers to identify more resistant barrier templates that could be applicable to barrier restoration.

Methods

Model Setup

To test my hypotheses, we used a two-dimensional (2D) coastal and sea model called MIKE 21 provided by DHI to setup and run simulations of an actual storm period (with time-dependent water level variations, storm surge, wave height) for a schematized barrier island, formulated using various barrier island subaerial templates (eg, low-laying, narrow, wide etc). MIKE 21 is a versatile numerical modeling tool often used for coastal modelling worldwide, and is capable of simulating physical, chemical and biological processes in coastal or marine settings. With a number of benefits, MIKE 21 has a suite of submodels designed to study beach and barrier island morphodynamic responses to events as well as decadal scale evolution for deltaic barriers in coastal Louisiana, including the following modules specifically used herein: the Hydrodynamic (HD), Spectral Wave (SW) and Sand Transport (ST) modules. The HD module, providing the basic computational component of the entire modeling system, can be applied to the hydraulic processes occurring in lakes, estuaries, bays, coastal areas and seas. The SW module is not only applicable for predication and analysis of waves on local and regional scales, but also for the calculation of sediment transport in wave dominated environments. The ST module enables the user to evaluate the erosion, deposition and transport of non-cohesive sediment in coastal and offshore environments.

Boundary Conditions (The Storm)

To build our storm period, wind and wave data were obtained from the Wave Information Study (WIS), an online database containing hourly wind and wave data collected since January 1st, 1980. An actual winter storm period was found dating from January 13th to 26th 2010, a twelve-day storm period with maximum wave heights of about 2m from a WIS station approximately 38km offshore at latitude 28.7 longitude -90.8. Wind (speed and direction) and wave (speed, direction and spreading index) data were collected from this period to be used in our simulations (Figures 3b and 3c). Water level data were then collected from the closest available Tides and Currents station located near Port Fourchon, LA in order to complete our storm profile (Figure 3a).

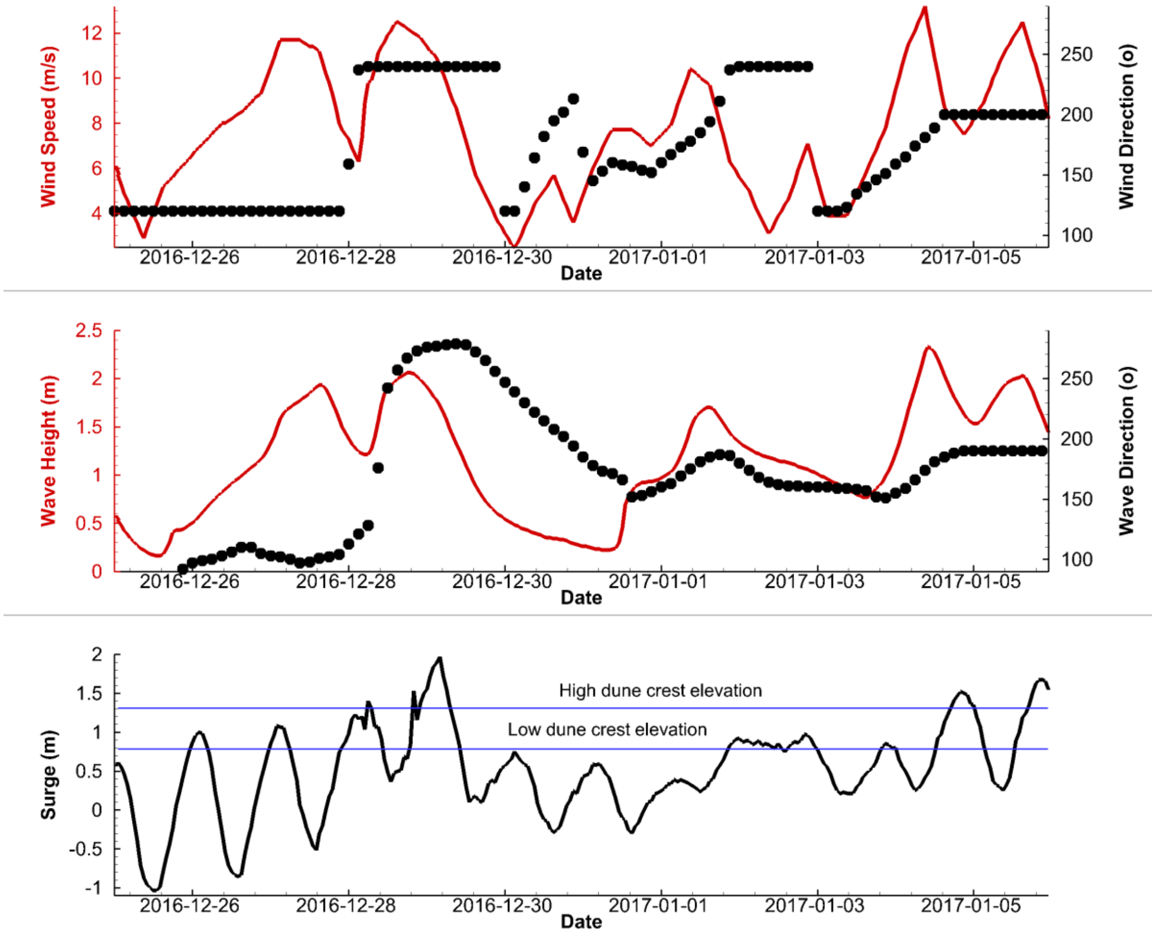


Figure 3: Time series input files. For the sake of standardizing all of our input files, we arbitrarily made December 25th, 2016 at 0:00 am the beginning of the simulation period. Therefore, all of the dates for the input files were synced to this date.

Barrier Morphology Templates

The following step was to construct our barrier templates, which in order to standardize all templates, the same size domain: 1000m wide by 6500m long. For each shoreface profile, the seaward boundary is defined as the open boundary (or code 3) (Figure 4b) to receive the incoming waves and storm surge. The DoC at the lower shoreface, represented by the open boundary, is at a depth of 8m for each profile. Regardless of the elevation of the DoC, the focus of this research was to examine the trends of varying shoreface slopes and dune crest widths in response to storm events. Because our objective is to specifically measure the response of a barrier to a storm in terms of dune crest overwash and barrier landward migration, the model domain or computational mesh was designed with a higher resolution around the dune crest and subaerial portion of the barrier and an increasingly lower resolution moving offshore to the lower shoreface and landward to the backbarrier lagoon (Figure 4b). In order to test the response of various barrier templates to storm events, we varied two elements of the barrier template; the dune crest width and the shoreface slope. Both of these elements of the barrier profile are thought to be influencing the magnitude of the response among the various barrier templates to the same storm.

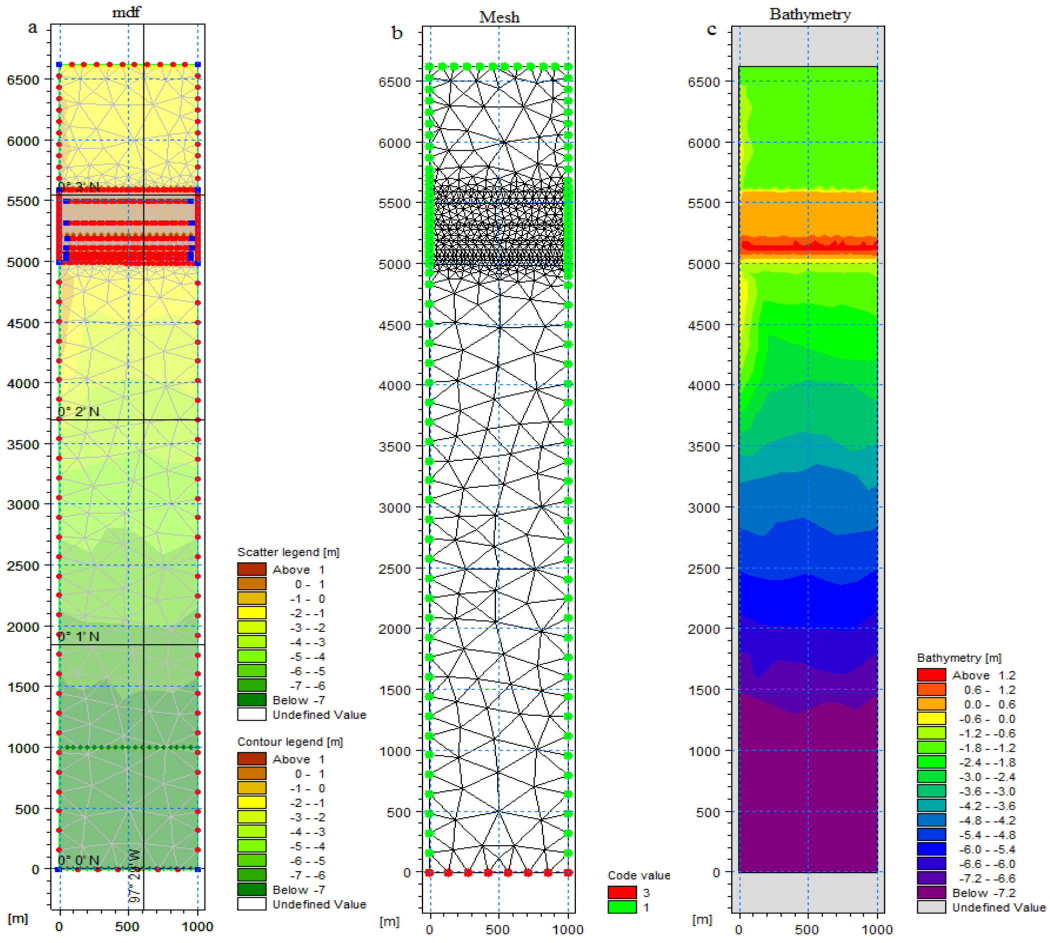


Figure 4: The process of building a bathymetry from the master definition profile (.mdf).

The four templates for the dune crest width profiles include the Narrow Width (NW), Intermediate Width (IW), Wide Width (WW) and Low Barrier (LB) in which there is essentially a lower dune. The initial elevation of the dune crest is 1.2m above MSL for NW, IW and WW and 0.83m above MSL for LB, a dune crest elevation that is common in deltaic barriers (Figure 5a). The templates for the shoreface slope profiles include the Gentle Slope (GS), Intermediate Slope (IS), Steep Slope (SS), New Slope (NS), and the Very steep Slope (VS) (Figure 5b). The NS was created after the original set of simulations in order to observe another level of sensitivity/variability.

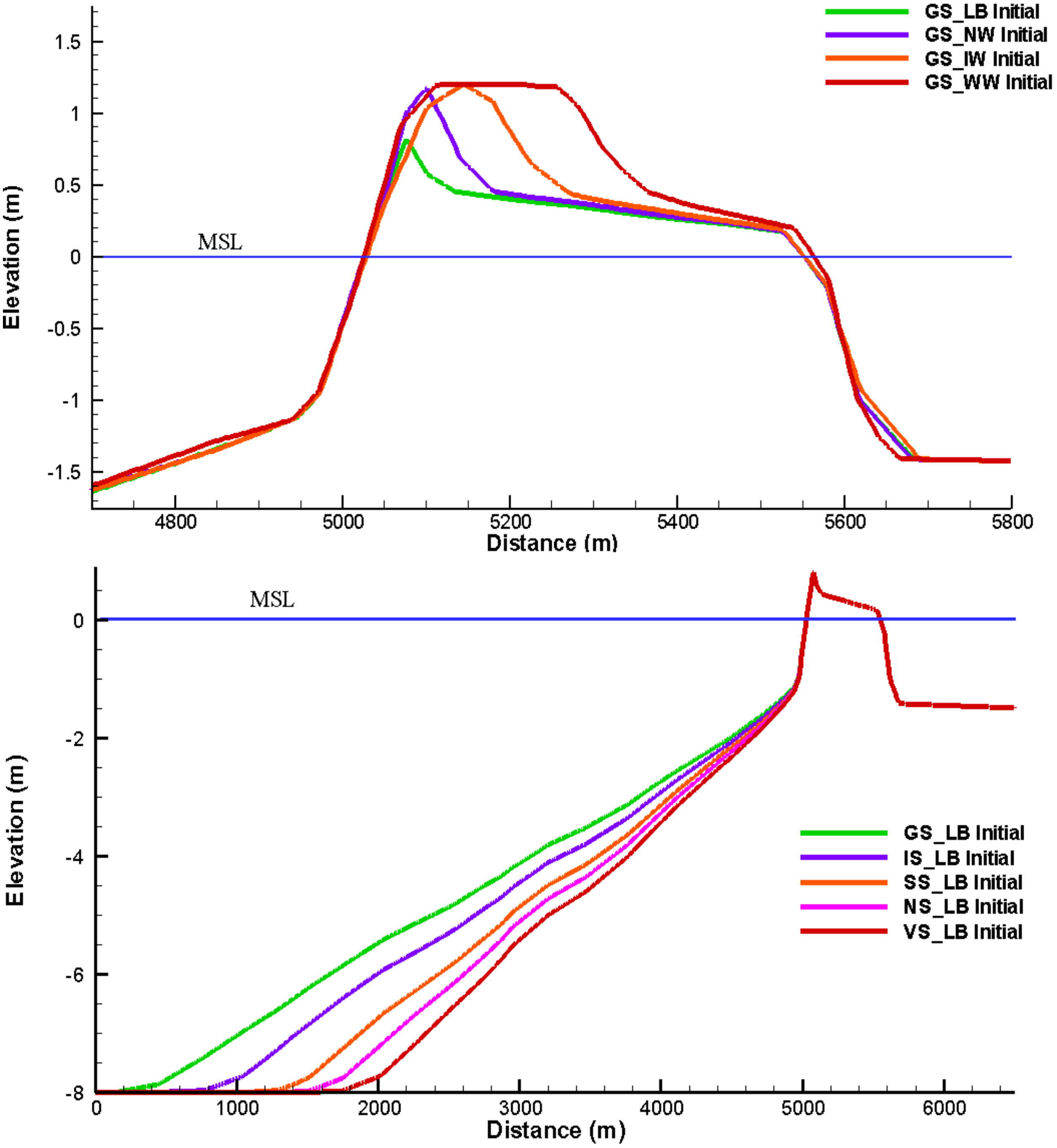
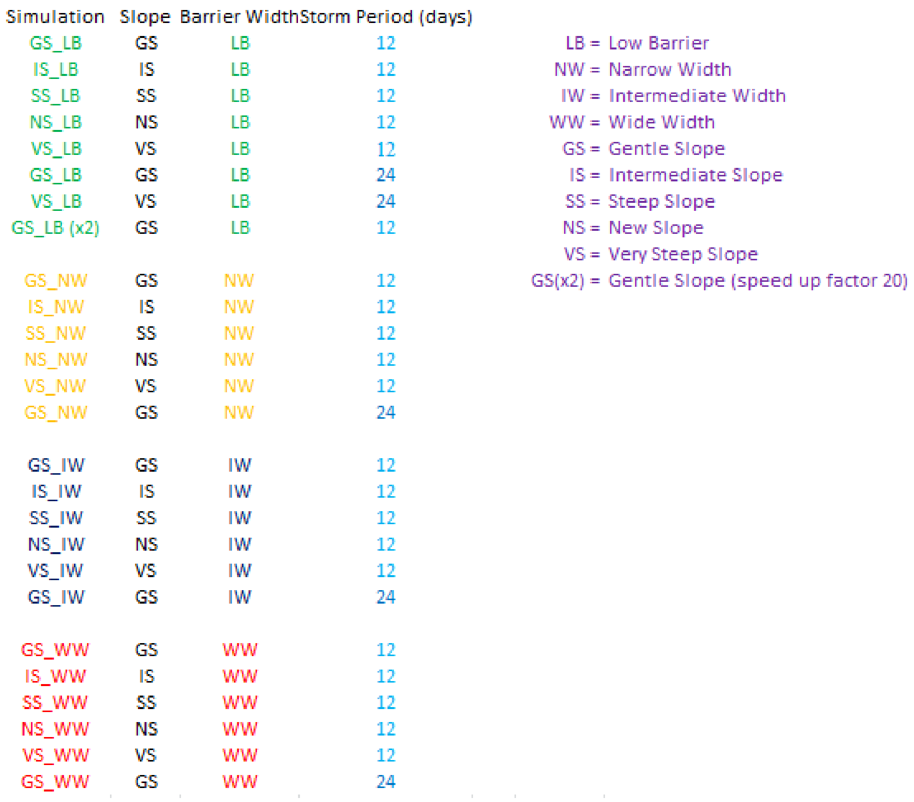


Figure 5: a. The dune crest widths are 50m for NW, 120m for IW, 220m for WW and 10m for LB. b. The shoreface slope gradients are 0.155 for GS, 0.175 for IS, 0.20 for SS, 0.215 for NS and 0.233 for VS.

Experimental Design

Out of necessity of organizing the number of templates and simulations, a simulation matrix is created categorizing a total of twenty six simulations based on barrier morphology, i.e., the dune crest widths and shoreface slopes (Table 1). Because each simulation was run with the same twelve day storm period, it was wise to run a sensitivity in order to see the different responses. Therefore, this sensitivity was examined by doubling the storm period from twelve to twenty four days simply by doubling the water level, wind and wave files. This was performed for GS for each dune crest width as well as VS for LB (Table 1). Finally, one additional sensitivity was examined by varying or doubling the morphological speed up factor. The morphological speed factor re-cycles hydrodynamic and sediment transport information to infer bed elevation and morphology changes; an upscaling of ten (10) for example would show barrier responses resulting from ten times the forcing period, making a 24 day simulation approximately equivalent to a 240 day simulation.

Table 1: Simulation Matrix arranged by increasing dune crest width and increasing shoreface slope.



Simulation	Slope	Barrier Width	Storm Period (days)
GS_LB	GS	LB	12
IS_LB	IS	LB	12
SS_LB	SS	LB	12
NS_LB	NS	LB	12
VS_LB	VS	LB	12
GS_LB	GS	LB	24
VS_LB	VS	LB	24
GS_LB (x2)	GS	LB	12
GS_NW	GS	NW	12
IS_NW	IS	NW	12
SS_NW	SS	NW	12
NS_NW	NS	NW	12
VS_NW	VS	NW	12
GS_NW	GS	NW	24
GS_IW	GS	IW	12
IS_IW	IS	IW	12
SS_IW	SS	IW	12
NS_IW	NS	IW	12
VS_IW	VS	IW	12
GS_IW	GS	IW	24
GS_WW	GS	WW	12
IS_WW	IS	WW	12
SS_WW	SS	WW	12
NS_WW	NS	WW	12
VS_WW	VS	WW	12
GS_WW	GS	WW	24

LB = Low Barrier
NW = Narrow Width
IW = Intermediate Width
WW = Wide Width
GS = Gentle Slope
IS = Intermediate Slope
SS = Steep Slope
NS = New Slope
VS = Very Steep Slope
GS(x2) = Gentle Slope (speed up factor 20)

Metrics for evaluating barrier response

Comparisons of profile evolutions over time show when and how the barrier profiles respond to the storm. The shoreline erosion rate (SER) is obtained simply by dividing the total retreat of that profile during the simulation by the number of days in the storm period (either twelve or twenty four days).

$$SER\ (m/d) = total\ retreat/number\ of\ days$$

The dune crest migration rate (DCM) is obtained similarly by dividing the total migration by the total number of days in the storm period.

$$DCM\ (m/d) = total\ migration/number\ of\ days$$

In order to compute the cumulative change in bed level along a profile, the bed level change and integral bed level change along the profile were calculated first. The change in bed level is calculated simply by measuring the difference between the final and initial bed level positions at that point along the profile.

$$Change\ in\ bed\ level = Final\ bed\ level - Initial\ bed\ level$$

The integral change along a profile is then measured by multiplying the average of the changes in bed level between the first and second point by the distance between the first and second point

$$Integral = Average(change\ A\ and\ change\ B) * (distance\ from\ point\ A\ to\ B)$$

Finally, measuring the cumulative bed level change along a profile is simple. At the first point of the profile, the cumulative and integral are the same because that is the only change that has occurred thus far. At the second point along the profile, the cumulative will be the sum of the second integral point and the first cumulative point. The third cumulative will be the sum of the third integral and the second cumulative, and so on and so forth. For example,

$$Cumulative\ \#8 = Integral\ change\ \#8 + Cumulative\ \#7$$

There are three important limitations to this research worth mentioning. First and foremost, the composition of our sediment was 100% sand and therefore lacks the applicability to muddy environments. The Mud Transport (MT) module under MIKE 21 was not utilized for this particular research as we are mostly concerned with the barrier lithesome response to storms which would be comprised of mostly sand anyway (Twichell et al., 2009; Chandeleur Islands).

Second, the model only allows for the transport of sediment in the onshore direction neglecting the offshore transport of sediment to the lower shoreface. Although this limitation appears restricting, since the focus is on the subaerial barrier, this assumption can still offer good insights and usable results. Lastly, the results of these simulations are limited to short-term high magnitude events such as tropical and extratropical storms and up to the annual time scale and therefore lacks information on the morphological time scale of barriers from effects due to sea level rise, sediment supply and other climate driven processes.

Results

Upper Shoreface

Gentle shoreface slopes and narrow or low dunes are characteristic of barrier islands in Louisiana. With slopes ranging from 0.155 for the gentle slope to 0.233 for the very steep slope, the slopes used in our simulations were considered to be all fairly gentle (much less than 0.8 as identified by Short, 1999 as the steepest slope for barrier development), but are common for deltaic barriers on low gradient continental shelves (Penland et al., 1988; List et al., 1999). Results demonstrate upper shoreface erosion as waves from the storm break close to the shoreline reworking the sediment in an onshore direction leading to shoreline erosion. As a result of an incoming wave, the upper shoreface is the first domain of the barrier lithesome to respond.

Results for all shoreface slopes show a fairly uniform change throughout the profile with the exception of two specific areas; the upper shoreface and the dune crest (Figure 6 a, b). Sediment erosion in all cases occurs at the upper shoreface followed by a distinct deposition of sediment on the dune crest and in the back bay (Figure 6a). For the low barrier template, peak changes in erosive processes occur on the upper shoreface (~0.1m) and shoreline (~0.5m), whereas peak changes in depositional processes occur at the dune and lagoon, 0.3 m and 0.1 m respectively (Figure 6a). The backbarrier also reflects a depositional change, the volume of which, however, is very small. For the wider barrier template, peak changes in depositional processes occur at the front and back side of the dune resulting in dune aggradation and barrier rollover and therefore comparatively reduced change occurs in the lagoon (Figure 7a). In fact, the low dune scenario simulations show significant shoreline erosion (between 26m and 37m) (Figures 8 and 9; Table 2) and increased dune overwash and dune crest landward migration.

Barriers with a low dune and gentle slope (GS-LB) exhibit the greatest amount of shoreline erosion (~37m) as expected (Figure 6b), whereas barriers with wider dune crests for the same slope (GS-WW) show reduced shoreline erosion (~2m) (Table 2). This trend is also repeated for the steeper slopes where the barrier with a low dune (VS-LB) exhibits similarly large shoreline erosion (~26m) compared to the wide dune (VS-WW) scenario (-3.0m) (Table 2). The landward barrier migration trend is similar among the varying shoreface slopes (Figures 6 and 7), but variability in the response does exist with varying dune crest widths (Figures 8 and 9).

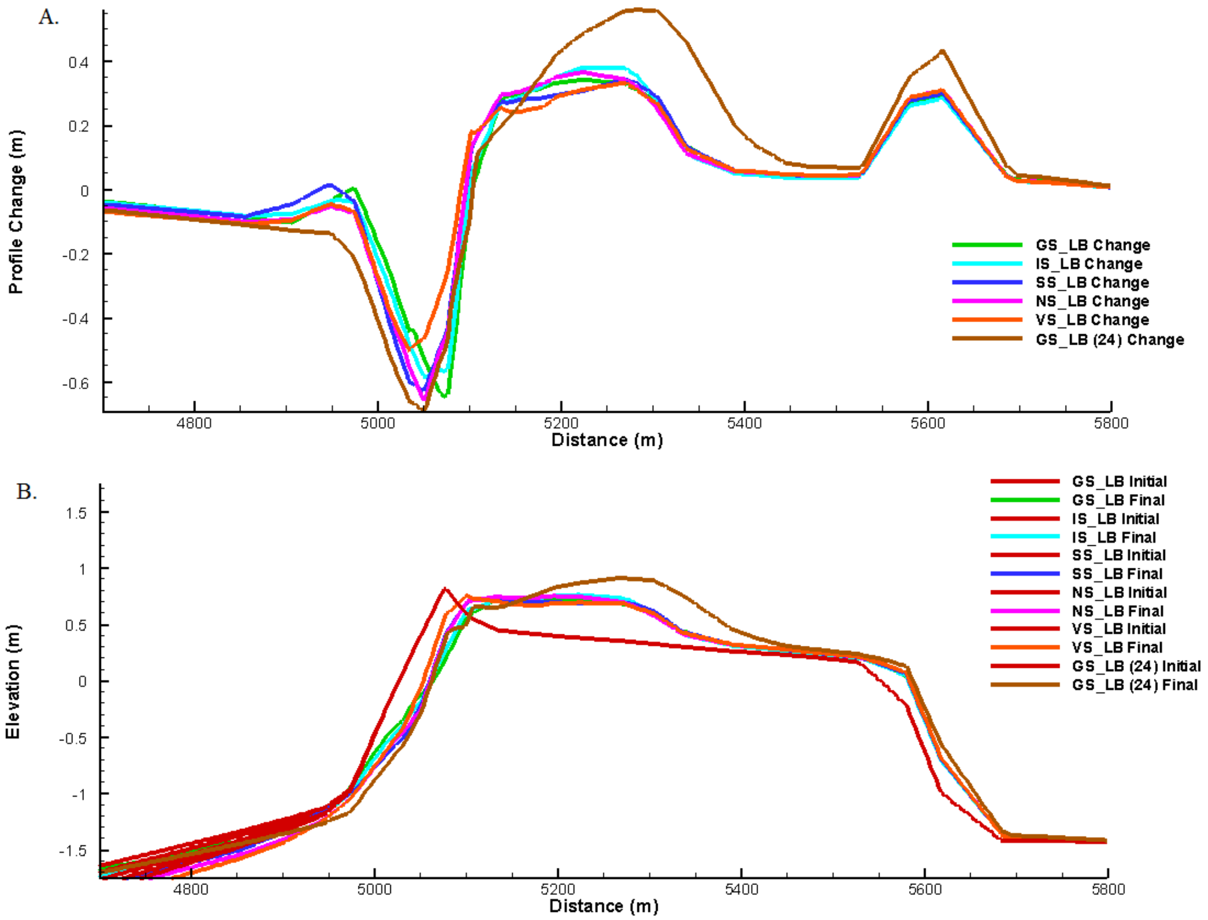
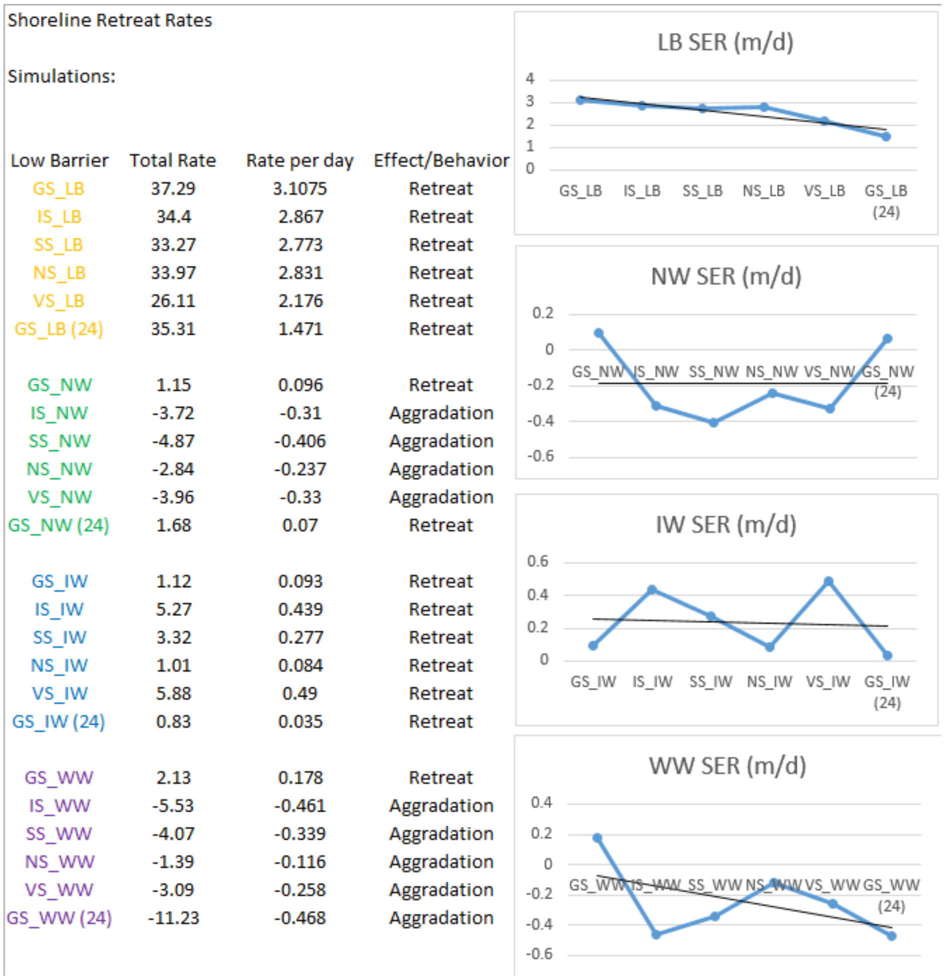


Figure 6: A. Profile change for each shoreface slope on the low barrier dune crest. Negative (-) means erosion and positive (+) deposition. B. Initial and final profile for each corresponding profile.

Table 2: Shoreline erosion rates at mean sea level (MSL) for each profile.



Shoreline Retreat Rates

Simulations:

Low Barrier	Total Rate	Rate per day	Effect/Behavior
GS_LB	37.29	3.1075	Retreat
IS_LB	34.4	2.867	Retreat
SS_LB	33.27	2.773	Retreat
NS_LB	33.97	2.831	Retreat
VS_LB	26.11	2.176	Retreat
GS_LB (24)	35.31	1.471	Retreat
GS_NW	1.15	0.096	Retreat
IS_NW	-3.72	-0.31	Aggradation
SS_NW	-4.87	-0.406	Aggradation
NS_NW	-2.84	-0.237	Aggradation
VS_NW	-3.96	-0.33	Aggradation
GS_NW (24)	1.68	0.07	Retreat
GS_IW	1.12	0.093	Retreat
IS_IW	5.27	0.439	Retreat
SS_IW	3.32	0.277	Retreat
NS_IW	1.01	0.084	Retreat
VS_IW	5.88	0.49	Retreat
GS_IW (24)	0.83	0.035	Retreat
GS_WW	2.13	0.178	Retreat
IS_WW	-5.53	-0.461	Aggradation
SS_WW	-4.07	-0.339	Aggradation
NS_WW	-1.39	-0.116	Aggradation
VS_WW	-3.09	-0.258	Aggradation
GS_WW (24)	-11.23	-0.468	Aggradation

Dune

The dune system is subjected to the majority of morphologic change throughout the simulation matrix, as it is highly affected by both the initial morphology of the dune crest (in terms of both elevation and width) and the shoreface slope. Dune widths used in our simulations vary from 10m for the low barrier dune to 220m for the wide dune crest. Because no sediment is lost offshore, all the sediment eroded from the upper shoreface during the storm is deposited onshore in the dune and backbarrier (Figure 6b). The dune morphology then exercises control on the amount of washover in the backbarrier and landward translation in the backbarrier lagoon. The low dunes experience significant landward translation (Figure 6b), whereas the wider dunes experiences less translation, more dune aggradation and thus contributing more to barrier rollover (Figure9b). Barriers with a low dune and gentle shoreface slope (GS-LB) exhibit the greatest amount of dune crest migration (~149m) as expected (Figure 6b) whereas barriers with wider dune crests for the same shoreface slope (GS-WW) show reduced dune crest migration (~96m) (Table 3). This trend is also repeated for the steeper slopes where the barrier with a low dune (VS-LB) exhibits similarly large dune crest migration (~500m) compared to the wider dune (VS-WW) scenario which no change was observed. Even though change in dune crest elevation is small (cm scale) and the result of one storm, twenty five of twenty six profiles exhibited dune crest aggradation behavior (Figures 9b, Table 3). According to these results, the intermediate slope with an intermediate dune crest width (IS-IW) experienced the largest change in dune crest elevation (0.45m). While there is a high degree of change occurring on the dune crest, there is much less change occurring in the backbarrier and lagoon (see section with cumulative sediment transport volumes in the backbarrier and lagoon; Figure 7).

Although the overall change in dune crest elevation is insignificant, the majority of the dunes experience aggradation as a result of wave runup landward onto the dune crest. In terms of dune crest migration, about one third (7 of 24) of the simulations experience a progradation (seaward movement) of the dune crest while about two thirds (16 of 24) experience dune (landward) retreat (Table 3). The low barriers experience the greatest amounts of dune crest migration as a result of dune morphology. Rosati et al. (2010) showed that dunes with lower elevations tend to exhibit higher rates of barrier migration both for stable and compressible substrates. They also show that for barriers in Louisiana where composition of compressible substrates like mud vary, rates of barrier migration are substantially higher (Figures 10, 11). Low barriers with gentle shoreface slopes, like those here on the Louisiana coast, have a much lower sediment volume and therefore are undoubtedly more easily reworked and eroded.

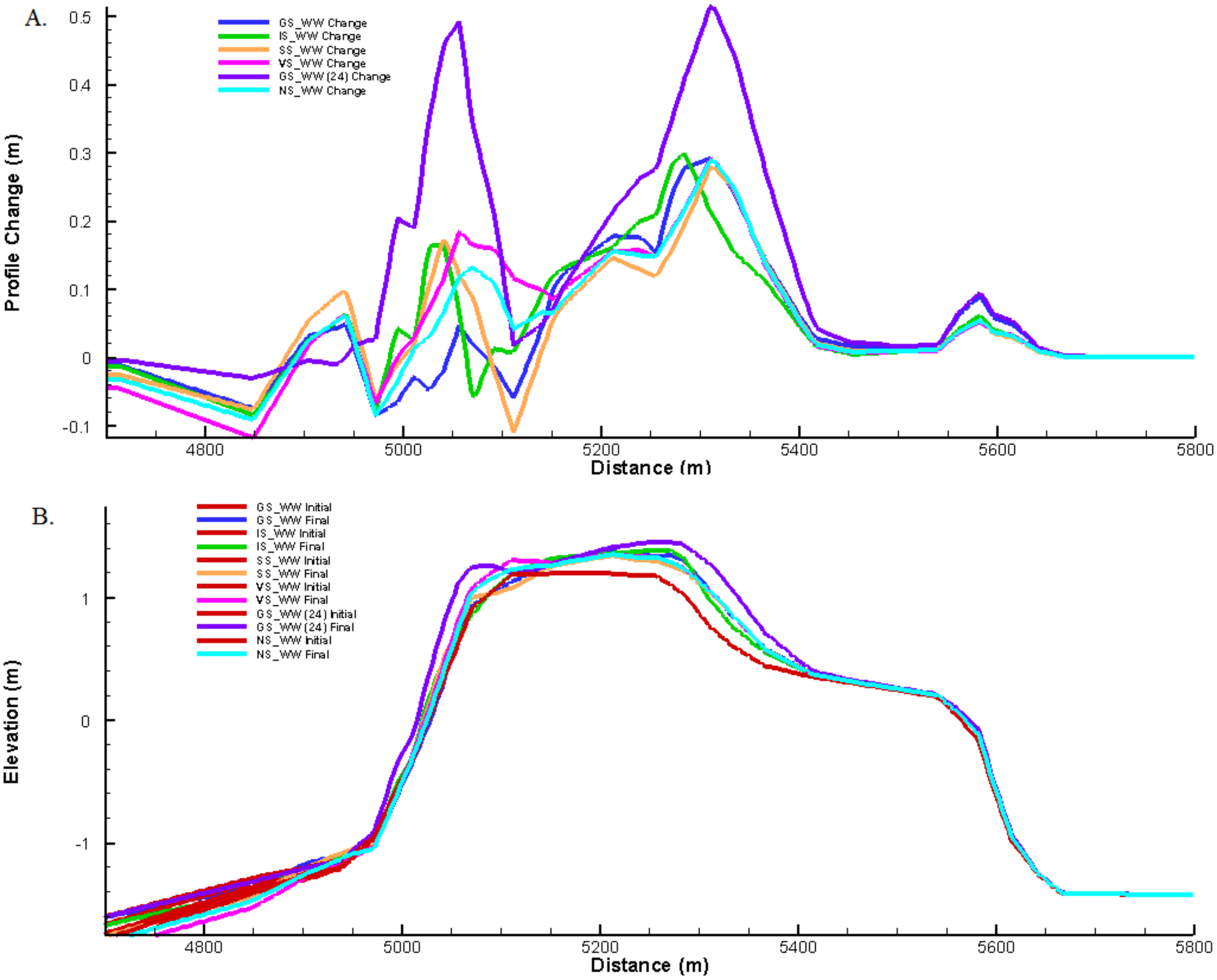
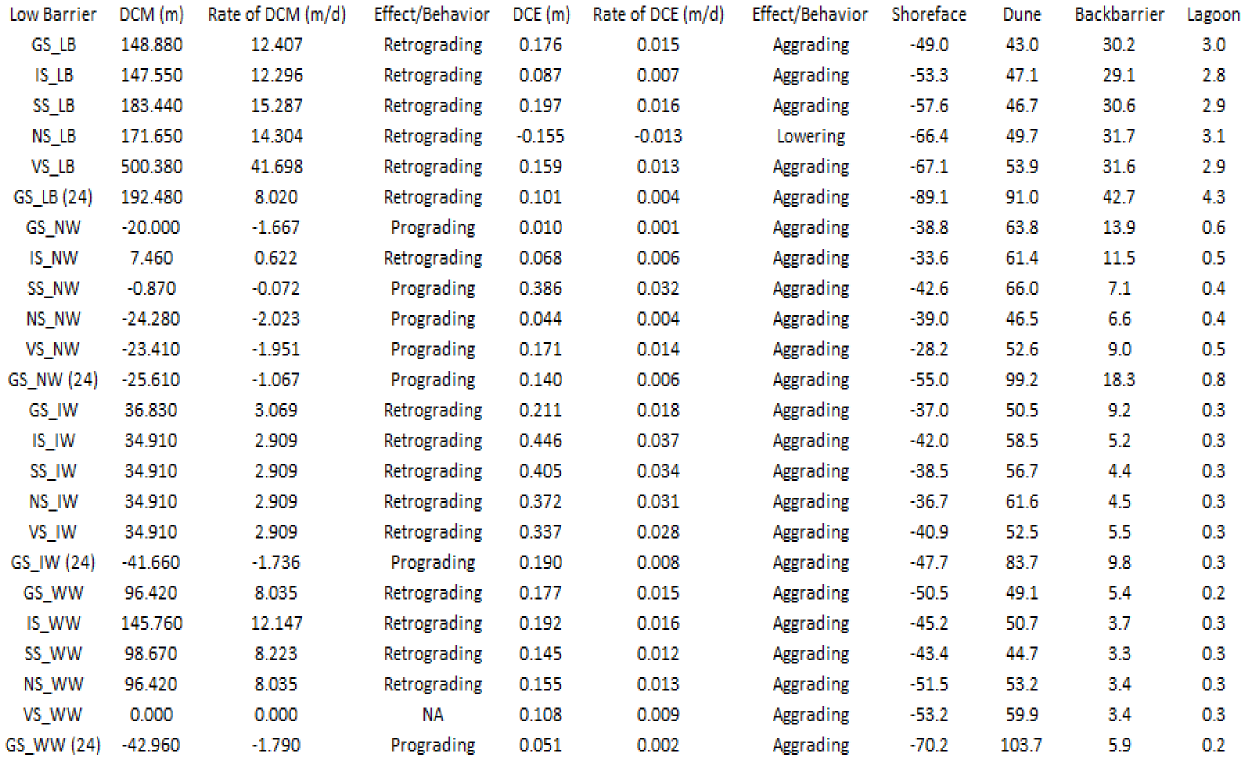


Figure 7: A. Profile change for each shoreface slope on the wide dune crest width. Negative (-) means erosion and positive (+) deposition. B. Initial and final profile for each corresponding profile.

Table 3: Dune crest migration, elevation and cumulative sediment transport volumes at the shoreface, dune, backbarrier and lagoon for each profile.



Low Barrier	DCM (m)	Rate of DCM (m/d)	Effect/Behavior	DCE (m)	Rate of DCE (m/d)	Effect/Behavior	Shoreface	Dune	Backbarrier	Lagoon
GS_LB	148.880	12.407	Retrograding	0.176	0.015	Aggrading	-49.0	43.0	30.2	3.0
IS_LB	147.550	12.296	Retrograding	0.087	0.007	Aggrading	-53.3	47.1	29.1	2.8
SS_LB	183.440	15.287	Retrograding	0.197	0.016	Aggrading	-57.6	46.7	30.6	2.9
NS_LB	171.650	14.304	Retrograding	-0.155	-0.013	Lowering	-66.4	49.7	31.7	3.1
VS_LB	500.380	41.698	Retrograding	0.159	0.013	Aggrading	-67.1	53.9	31.6	2.9
GS_LB (24)	192.480	8.020	Retrograding	0.101	0.004	Aggrading	-89.1	91.0	42.7	4.3
GS_NW	-20.000	-1.667	Prograding	0.010	0.001	Aggrading	-38.8	63.8	13.9	0.6
IS_NW	7.460	0.622	Retrograding	0.068	0.006	Aggrading	-33.6	61.4	11.5	0.5
SS_NW	-0.870	-0.072	Prograding	0.386	0.032	Aggrading	-42.6	66.0	7.1	0.4
NS_NW	-24.280	-2.023	Prograding	0.044	0.004	Aggrading	-39.0	46.5	6.6	0.4
VS_NW	-23.410	-1.951	Prograding	0.171	0.014	Aggrading	-28.2	52.6	9.0	0.5
GS_NW (24)	-25.610	-1.067	Prograding	0.140	0.006	Aggrading	-55.0	99.2	18.3	0.8
GS_IW	36.830	3.069	Retrograding	0.211	0.018	Aggrading	-37.0	50.5	9.2	0.3
IS_IW	34.910	2.909	Retrograding	0.446	0.037	Aggrading	-42.0	58.5	5.2	0.3
SS_IW	34.910	2.909	Retrograding	0.405	0.034	Aggrading	-38.5	56.7	4.4	0.3
NS_IW	34.910	2.909	Retrograding	0.372	0.031	Aggrading	-36.7	61.6	4.5	0.3
VS_IW	34.910	2.909	Retrograding	0.337	0.028	Aggrading	-40.9	52.5	5.5	0.3
GS_IW (24)	-41.660	-1.736	Prograding	0.190	0.008	Aggrading	-47.7	83.7	9.8	0.3
GS_WW	96.420	8.035	Retrograding	0.177	0.015	Aggrading	-50.5	49.1	5.4	0.2
IS_WW	145.760	12.147	Retrograding	0.192	0.016	Aggrading	-45.2	50.7	3.7	0.3
SS_WW	98.670	8.223	Retrograding	0.145	0.012	Aggrading	-43.4	44.7	3.3	0.3
NS_WW	96.420	8.035	Retrograding	0.155	0.013	Aggrading	-51.5	53.2	3.4	0.3
VS_WW	0.000	0.000	NA	0.108	0.009	Aggrading	-53.2	59.9	3.4	0.3
GS_WW (24)	-42.960	-1.790	Prograding	0.051	0.002	Aggrading	-70.2	103.7	5.9	0.2

The narrow dune widths interestingly respond with a seaward translation or accretion of the shoreline, likely due to lower wave runup overwash compared to the low dune/barrier scenarios. As the dune crest widens, the resulting effects brought on by a storm decrease (i.e. less overwash, migration and backbarrier deposition). The profile evolutions over time reveal a pertubation of the upper shoreface in which first we note a deposition and seaward migration of the shoreline followed immediately by erosion and shoreline retreat while at the same time the dune experiences crest accumulation contibuting to barrier rollover (Figure 11). With a total of about 26 simulations, about one third (1/3) of them experience a seaward translation of the shoreline and the rest retreat. While the GS profiles exhibit both barrier rollover and landward translation of the dune, they also show a variation in response during these processes (changing profile shape) that can often lead to temporary seaward movement of the shoreline (Figure 8b).

The VS profiles demonstrate a similar pattern where the change on the dune crest resulting in barrier rollover and landward translation is dependent upon the initial dune crest morphology (Figure 9b).

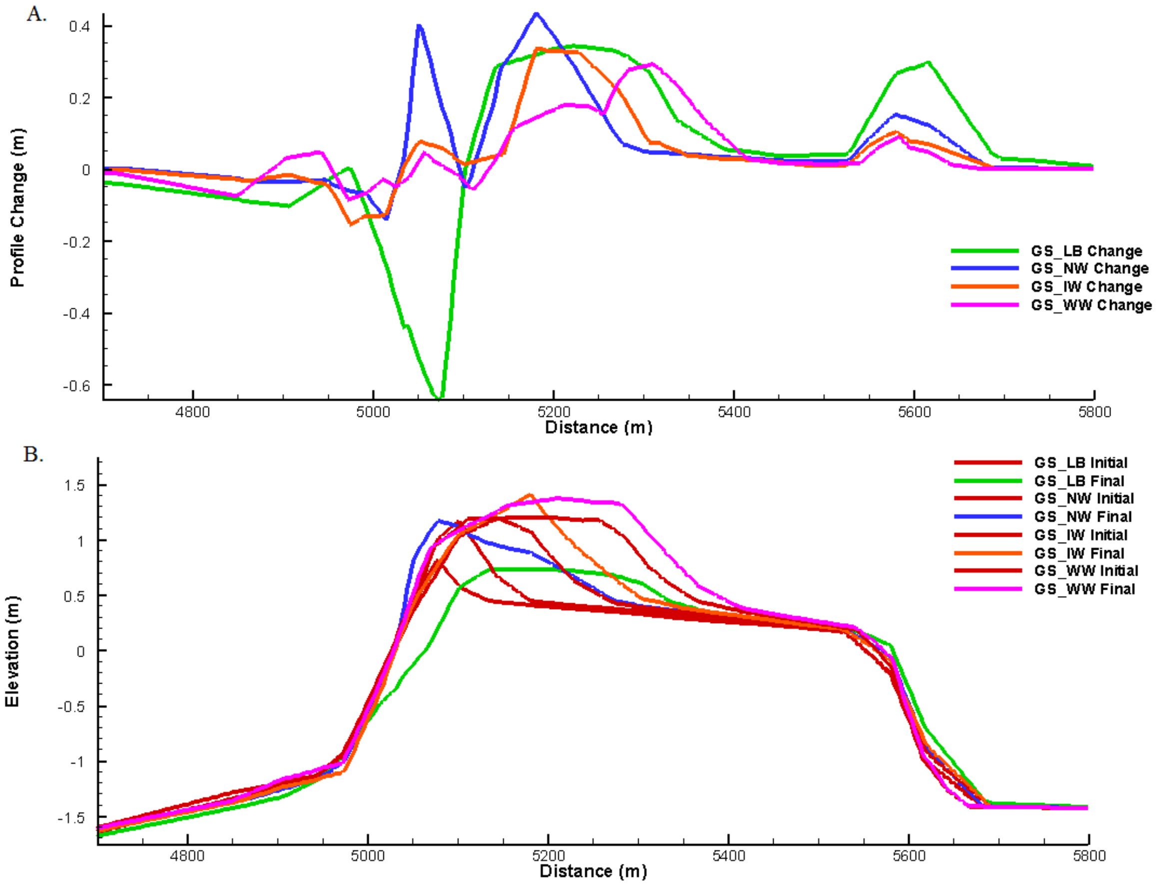


Figure 8: A. Profile change for each dune crest width on the gentle shoreface slope. Negative (-) means erosion and positive (+) deposition. B. Initial and final profile for each corresponding profile.

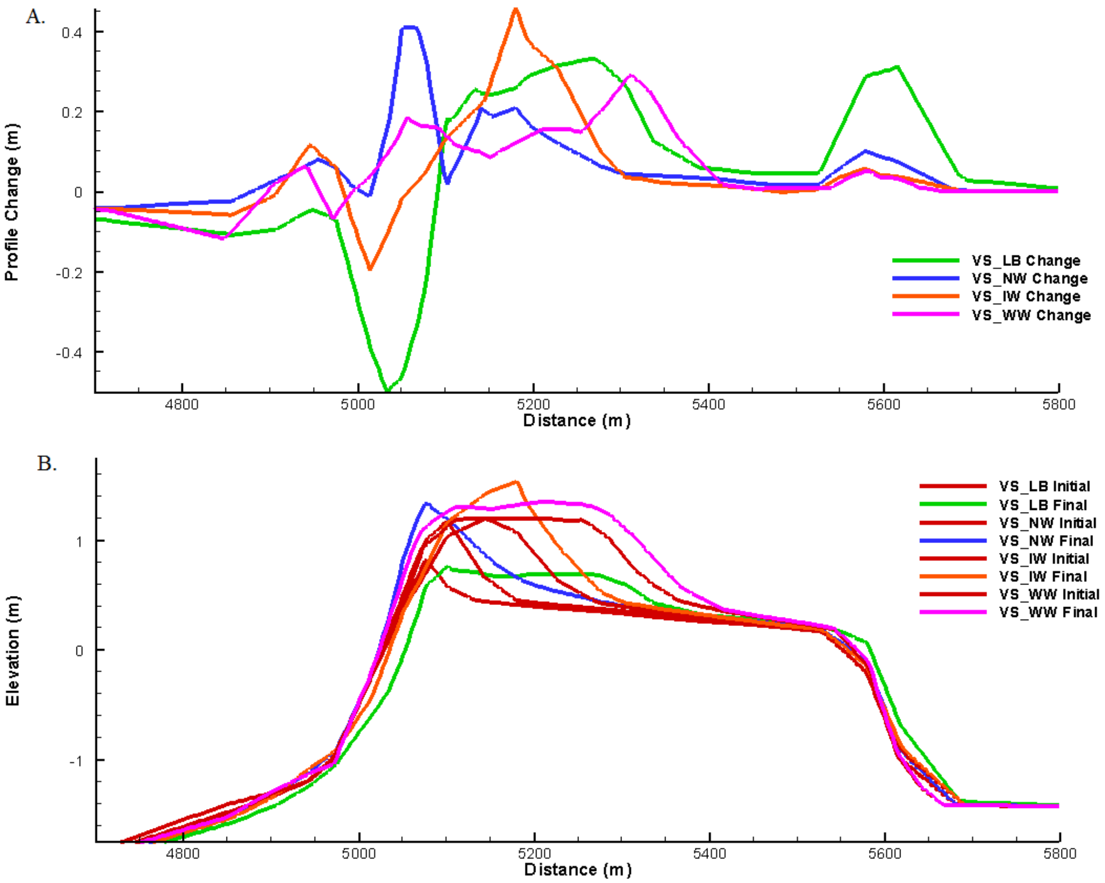


Figure 9: A. Profile change for each dune crest width on the very steep shoreface slope. Negative (-) means erosion and positive (+) deposition. B. Initial and final profile for each corresponding profile.

By examining the specific profile evolutions over time, we observe variance in rates of change. The majority of profile change as a result of the 280 hour storm occurs in the beginning of the period before 180 hours as indicated by the blue and green colors (Figures 10 and 11). For the low dune barrier scenario, the first profile response to the storm occuring in the first 24 to 48 hours is an erosion of the dune (~0.4 m) followed by a washover (~0.25 m thick; 200 m penetration) and a small landward translation (~25m) of the backbarrier (Figure 10a). For the wider dune crest scenario, the first profile response to the storm occuring in the first 24 to 48 hours is an erosion of the front of the dune (~0.1 m) followed by a washover (~0.1 m thick; ~20 m penetration) and a small landward translation (~1-2m) of the backbarrier (Figure 10b). By hour 130, which is the peak of storm, both scenarios experienced landward dune migration ranging from (~148m) for the low dune (GS-LB) to (~96m) for the wide dune (GS-WW). (Figures 10b).

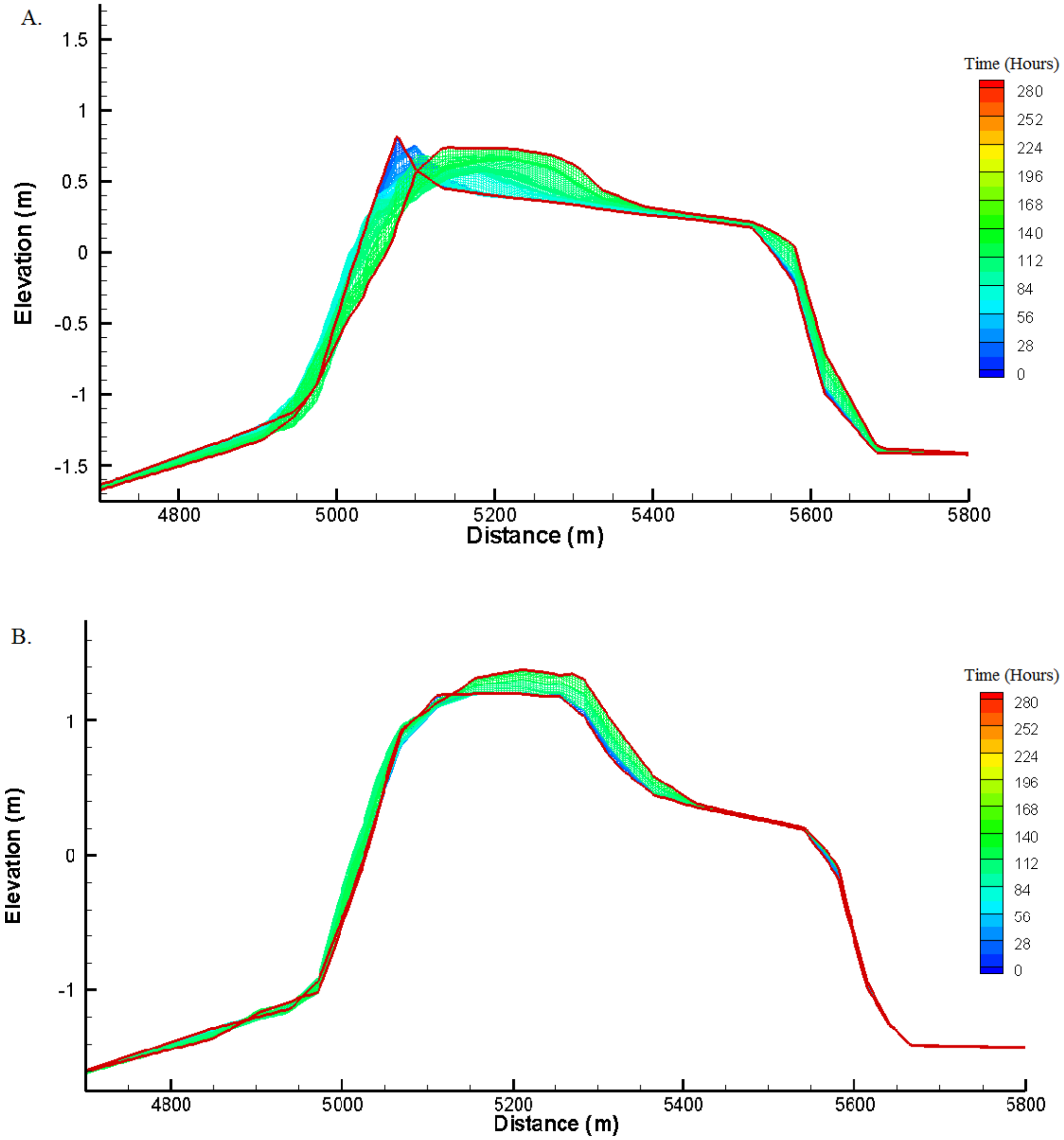


Figure 10: A. Profile Evolution of GS_LB. B. Profile Evolution of GS_WW.

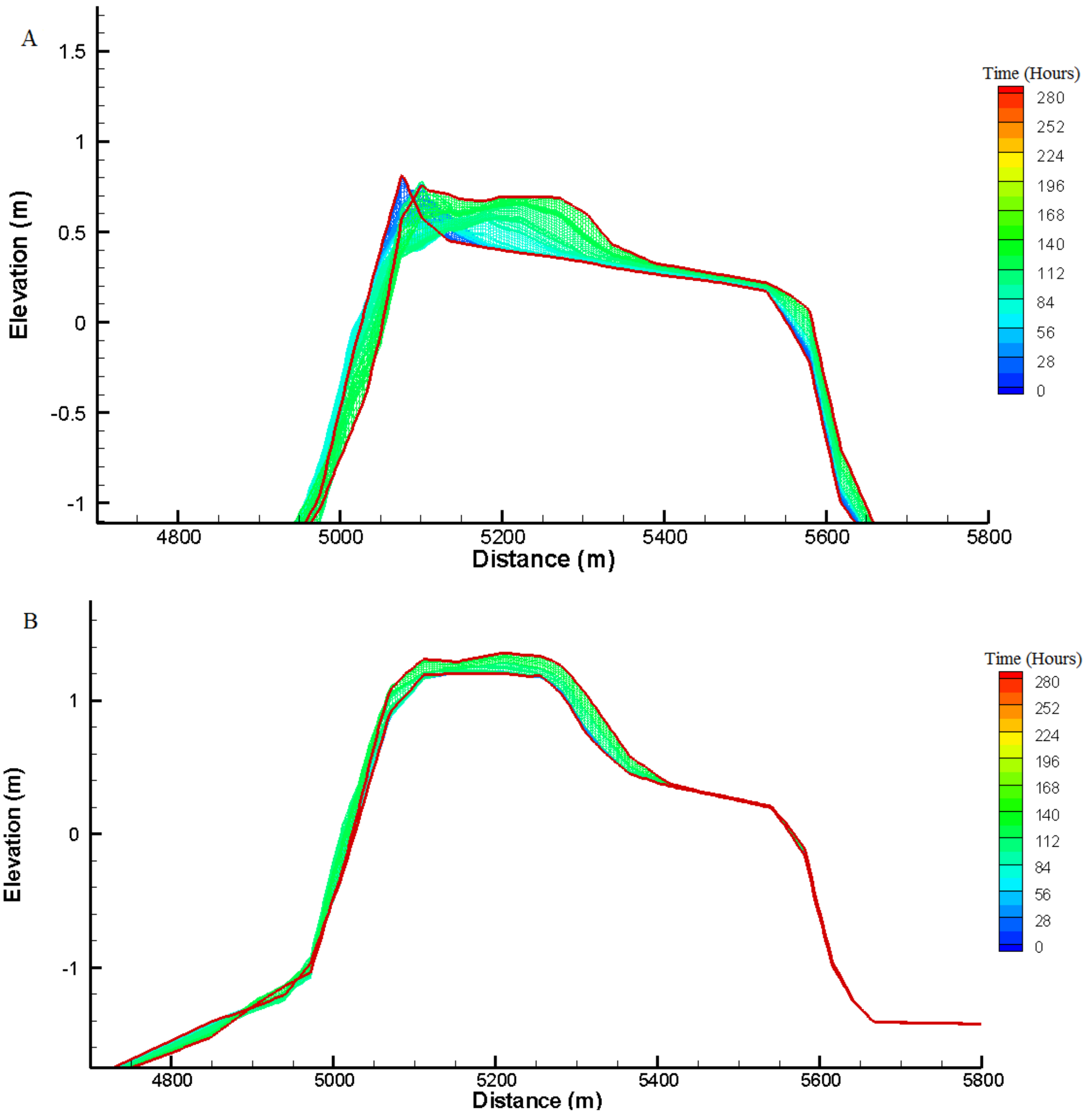


Figure 11: A. Profile Evolution for VS_LB. B. Profile Evolution for VS_WW.

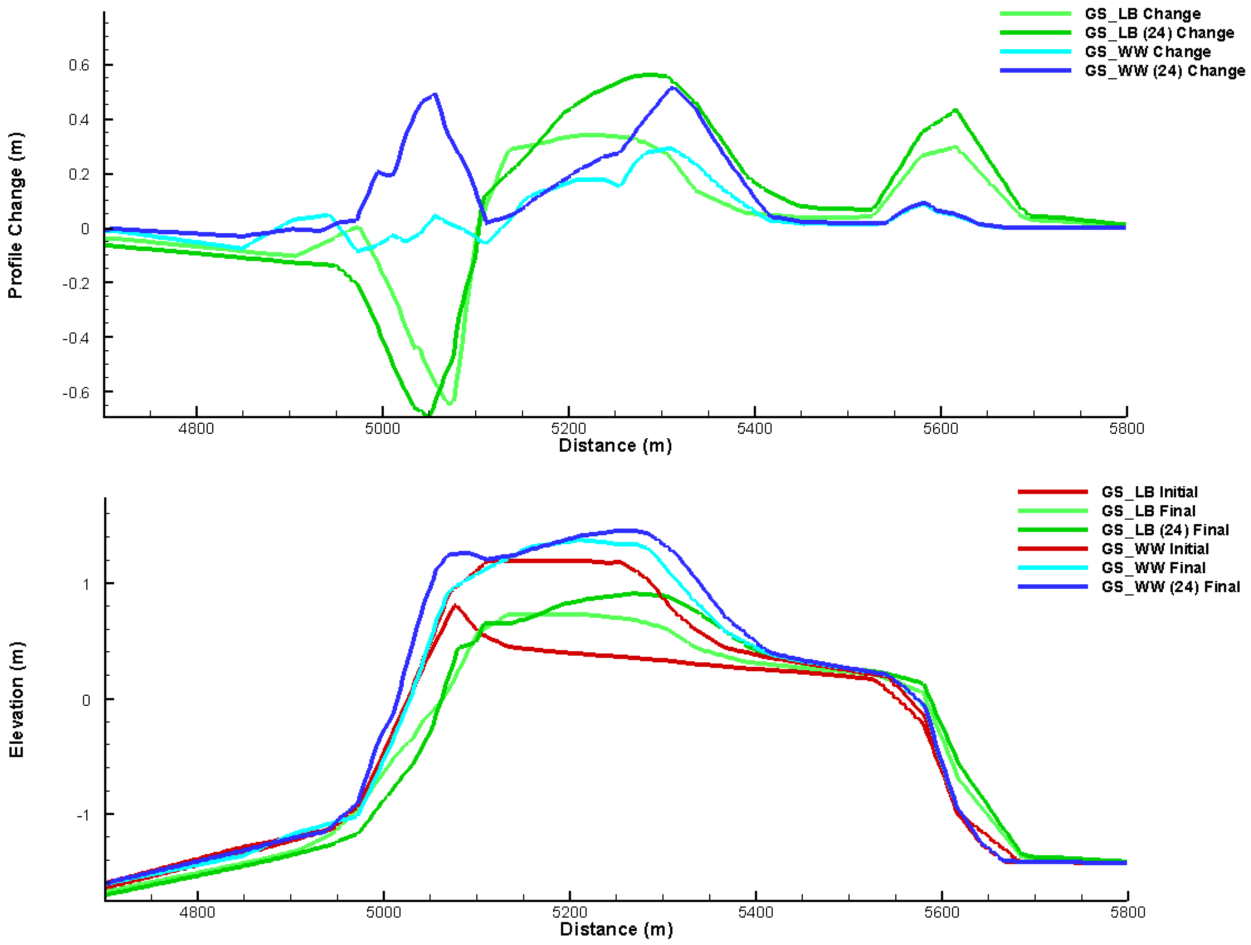


Figure 12: A. Profile change for the low barrier and wide dune crest width on the gentle shoreface slope for the twelve and twenty-four day periods. Negative (-) means erosion and positive (+) deposition. B. Initial and final profile for each corresponding profile.

We observe an interesting behavior in the change that occurs in the barrier lithesome between the twelve and twenty-four day periods. Due to a morphodynamic upscaling of 10, the 12 and 24 day storm periods are adjusted to 120 and 240 day periods. The 240 day period exposes the barrier to storm conditions for a longer duration therefore resulting in greater amounts of shoreface erosion in turn leading to greater amounts of dune and barrier translation landward (Figure12; Table 3). For instance, the low dune barrier with a gentle slope experiences dune crest migration ranging from 148 m to 192 m respectively (12 to 24 days), while the gentle shoreface slope wide dune scenario experience lower dune crest migration, ranging from 96 m to 43m seaward migration (for 12 to 24 days) respectively.

Backbarrier

The backbarrier is where overwash is deposited as a result of wave runup onto the dune crest depositing sediment landward often in the form on a washover fan or where inundation overwash when the dune crest is submerged may occur. The barriers with a low dune and gentle slope (GS-LB) exhibit the greatest volume of dune washover (~30.2 m^3/m), as expected (Figures 8b, 12b), whereas barriers with wide dune fields for the same slope (GS-WW) show reduced overwash (~5.4 m^3/m) (Figures 8b, 12b). This trend was repeated for steeper slopes (Figure 9b) where the barrier with a low dune (VS-LB) experiences similarly larger overwash volumes (~31.6 m^3/m) compared to the wide dune (VS-WW) scenario (~3.4 m^3/m; Figure 9b).

Backbarrier Lagoon

The backbarrier lagoon experiences the least amount of change as a result of the storm. Deposition rates in the lagoon varied little with respect to shoreface slope, but exhibited significant divergence with respect to dune morphology. The deposition for the barrier with a low dune varied from 3.0 m^3/m for the gentle shoreface slope to 2.9 m^3/m for the steeper shoreface slope. Contrastingly, the barriers with wide dunes experienced deposition rates of approximately 0.2-0.3 m^3/m regardless of shoreface slope field (Figures 6, 7, 10, 11, Table 3).

Discussion

Upper Shoreface

Results show that shoreface slope drives morphodynamic change at the shoreline and dune of barrier islands during storms. As hypothesized, steeper shoreface slopes produce less overwash compared to gentle shoreface slope systems during storms, with upper shoreface erosion being proportional to shoreface slope (Figure 6). The complexity of the experimental design, as expected, shows that erosion and migration rates can be quite variable for the several slopes and barrier templates examined (Table 2 and 3) ranging from -11.2m to 37.3m of shoreline erosion and -43m to 500m of dune crest migration. Regardless of this variability, an obvious trend emerges where the steeper shoreface produces less shoreline erosion, indicating an inverse relationship between shoreface slope and shoreline erosion (Table 2). At first, this response appears counterintuitive, but can be explained by the lack of transfer of material offshore as the storm peaks; although this response would be common to all simulations, hence a meaningful comparison can still be made between model simulations. With continued erosion of the upper shoreface, coupled with lack of wave runup overwash, sediment deposits and helps maintain or limit erosion at the shoreline and contributes more to dune aggradation.

The storm influence of the upper shoreface and dune crest is directly proportional to changes in shoreface slope (Figure 6), while in the backbarrier marsh and lagoon, change is independent of shoreface slope. For example, the change in shoreface slope does in fact generate a variable response in the backbarrier deposition (leading to dune overwash), but is not significant enough to suggest that a dependency exists (Figure 7).

A steeper shoreface suggests a larger barrier volume to be eroded to facilitate a change on the backbarrier and lagoon. Aagaard et al. (2004) suggest that for gently sloping shorefaces, behavior oriented models predict net onshore sediment translation in the long term and that process-based models predict net offshore sediment translation in the long run. On the contrary, MIKE 21 by DHI is a numerical model where we predict a net onshore sediment translation, but on an inter-annual time scale. Our results with respect to shoreline erosion coincide with Short (1999) in that an increasing shoreface slope tends to enhance the effect of gravity thereby reducing the amount of onshore sand transport. This implies that while overwash still may occur, the rates of overwash and barrier migration are low and independent of shoreface slope. The amounts of shoreline erosion, overwash and landward migration are also related to the morphology of the backbarrier and the frequency and magnitude of hurricanes and tropical storm events.

There is considerable variation in shoreline erosion rates for each barrier profile; however it becomes evident that the low barriers with low dunes experience significantly greater shoreline erosion than the wider dune crests (Table 2), regardless of shoreface slope. This response is expected, as low barriers are subjected to higher runup overwash, facilitating the transfer of sediment to the back-dune and subsequently, sediment eroded from the shoreline continuously supplies the dune with sediment during the storm. Inundation overwash at the peak of the storm enhances this response. In the scenario where the dune system is higher, and wider (WW), the continued erosion on the upper shoreface, coupled with reduced overwash volumes, supplies the berm and dune toe with sediment, which reduces (initially) the shoreline erosion. This behavior, however, is restricted to differences in the initial dune morphology, and appears to be independent of shoreface slopes examined in this study. This result is corroborated further by assessing cumulative sediment transport trends across the barrier for the duration of the storm (discussed in more detail below), showing clearly that the higher shoreline erosion and dune crest migration for the low barriers are attributed to the dune crest morphology.

Dune

Barrier island change during storms is also coupled to the dune crest morphology controlling the overwash volume in the backbarrier. Considering dunes are highly dynamic environments dependent on the shoreface slope and dune morphology, results demonstrate significant changes occurring on the dune as a result of the storm. Barriers with wide dune fields contain more subaerial sediment volume compared to barriers with narrow or low dunes and therefore require larger amounts of washover to occur during an event to facilitate a comparable translation of the dune and barrier profile. A low or narrow barrier experiences erosion of the upper shoreface and deposition in the backbarrier in the form of an overwash fan or sheet and as a result experiences higher rates of landward migration for the same events (Figure 6b). Instead of deposition in the backbarrier, a wider barrier experiences deposition on top of the dune crest causing crest accumulation (Figure 7b). Donnelly (2007) demonstrated that a larger crest width restricts more erosive overwash types (Figure 8). Over time, and after several events, sediment begins to deposit in the backbarrier leading to a translation of the barrier (Figures 10, 11). Thus, a wider barrier is more resistant to net sediment loss than a narrow barrier during the same high-magnitude event.

Although there appears to be no immediate pattern for the cumulative sediment transport volumes occurring at the dune, we do, in fact, note that the values are much higher for the twenty-four day periods (83.7m^3/m to 103.7m^3/m) than the twelve day periods (43.0m^3/m to 66.0m^3/m) at the dune (Figure 10, Table 3). The backbarrier shows a similar pattern where the values for the twenty-four day simulations are much higher than the twelve day simulations. For instance, volume at the dune for the twenty-four day storm for a low barrier with a gentle shoreface is 42.7m³/m whereas volume for the twelve day storm for the same template is 30.2m³/m. This implies that while there is a high degree of variability in response, a longer duration of storm conditions undoubtedly results in higher volumes of dune overwash and backbarrier translation. These variability in results at the dune crest are due, as Short, 1999 describes, to the greatest profile change occurring in amplitude and frequency at the upper shoreface having a morphological control on the response of the dune.

Backbarrier

The cumulative sediment transport occurring in the backbarrier is directly proportional to the initial morphology of the dune crest and the change, as a result of the storm, is reflective in the washover volume deposited in the backbarrier. Because the dune is both lower in height and narrower in width, the low barriers experience the greatest amount of overwash (29.1m³/m to 31.7m³/m of cumulative sediment transport) whereas wider dune crests experience progressively reduced amounts of overwash (3.3m³/m to 5.4m³/m for the wide width dune crest) (Table 3). This process is the result of higher dune crest migration rates for the low barriers (Tables 2 and 3). The higher dune crest migration rates are a response to higher shoreline erosion rates and landward transfer of sediment from the shoreface onto the dune crest after which it becomes overwashed. Wider dune fields experience lower shoreline erosion rates and lower dune crest migration rates as a result of shoreface sediment deposited on top of the dune crest leading to aggradation instead of rollover or overwash. As a result, we observe an inverse relationship between dune crest width and cumulative sediment transport volumes in the backbarrier leading to dune overwash.

Backbarrier Lagoon

The cumulative sediment transport volumes in the lagoon, reflective in the landward translation of the backbarrier, display a similar inverse relationship with dune crest width. Once again, the low barriers experience the greatest amounts of lagoon deposition ($2.8m^3/m$ to $3.1m^3/m$) (Table 3). Wider crests undergo a similar lagoon transformation to the narrow crest and low barrier but at much slower rates ($0.2m^3/m$ to $0.3m^3/m$) (Figures 8, 9; Table 3). Because a higher, wider dune reduces lagoon deposition whereas a low dune narrow barrier maximizes it, lagoon deposition is perhaps again directly proportional to the overwash volume, which is directly proportional to the dune crest width.

Profile Evolution

The profile evolutions over time serve as a useful tool to assess barrier dynamics, as they allow for close examination and observation of exactly when, where and how the barrier profile responds to the storm. Profile evolutions, as a result of the twelve day storm, show the majority of change occurring within the first 130 hours (a little over 5 days) coinciding with the peak of the storm, whereas little change is evident in the remaining period. For barriers with a low dune and gentle shoreface slope, the storm initially generates a destructive phase causing dune lowering and landward rollover within the first twenty four hours (Figure 15). By the second day (48 hours), the dune begins to experience a loss in elevation or dune lowering as sediment begins to move into the backshore. By hour seventy-two (Figure 15), the dune experiences a total loss in elevation and the shoreline and upper shoreface experience a temporary seaward movement, driven likely by combined runup overwash and inundation overwash, and is characteristic of dune destruction as identified by Donnelly (2007). Up to this point in the storm, the overall change to the barrier profile has been destructive. However, at hour 110, a constructive phase of the barrier begins. The sediment from the upper shoreface is eroded generating landward transport initiating construction of a new dune development as a result of barrier rollover. Deposition on the dune begins to occur leading to dune crest aggradation and overwash processes. At this time, the majority of deposition into the lagoon occurs causing landward translation of the barrier. Continued dune aggradation and landward translation occurs until about 130 hours at which point very little changes occur for the remainder of the simulation period (Figure 15).

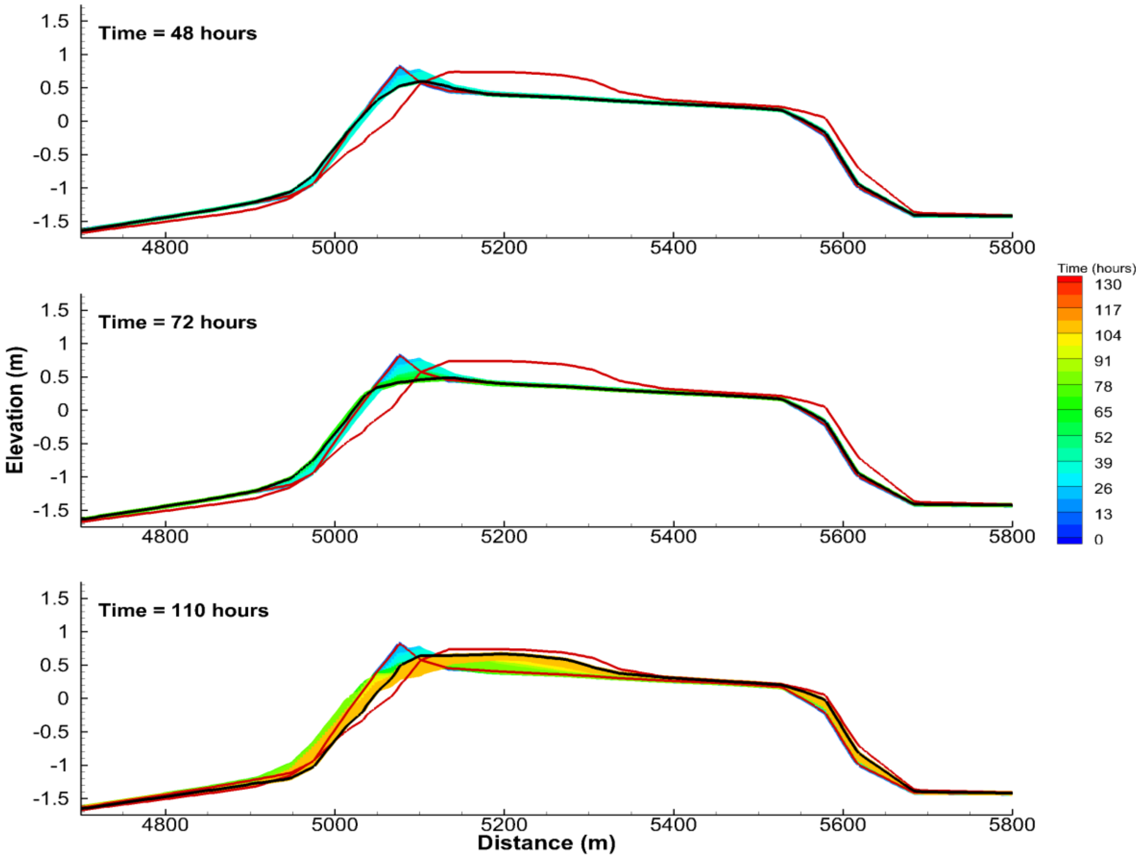


Figure 13: Profile evolution for a low barrier with a gentle shoreface slope. Red lines indicate Initial and Final profiles. Black line indicates profile at specified time. Color shows change at specific hours.

Profile evolution of a barrier with low dunes with a very steep shoreface slope demonstrates a similar response at which a destructive phase initiates dune lowering and eventually dune destruction. Second, the storm produces shoreline pertubations resulting in a constructive phase where deposition of sediment from the shoreline initiates a new dune development landward of the old dune while continually depositing sediment landward into the backbarrier and lagoon resulting in migration of the barrier (Figure 16). In this case however, the steeper shoreface slope prevents greater amounts of shoreline erosion, but the morphology of the low barrier still allows for considerable dune overwash to occur resulting in barrier migration (Figure 16).

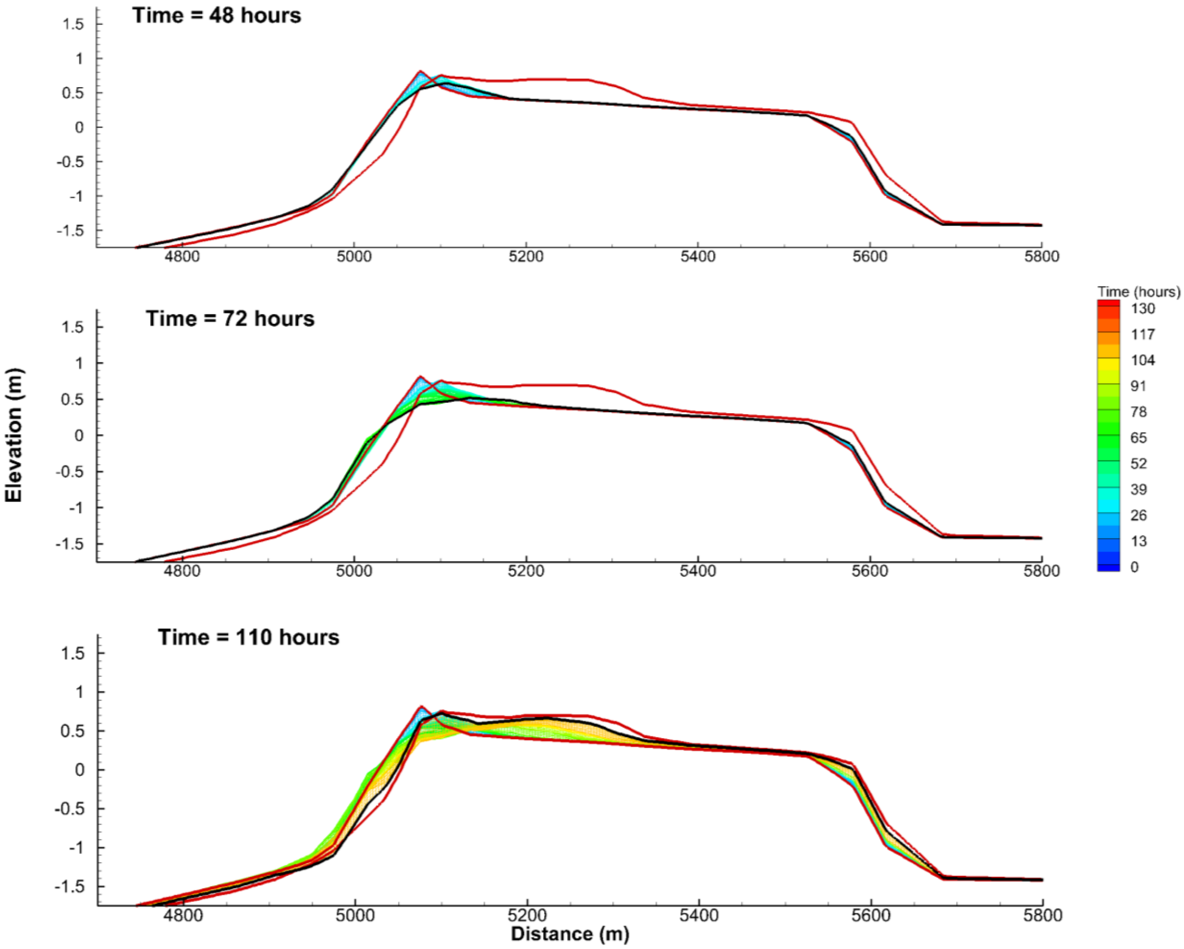


Figure 14: Profile evolution for a low barrier with a very steep shoreface slope. Red lines indicate Initial and Final profiles. Black line indicates profile at specified time. Color shows change at specific hours.

The profile evolution of the wider dune crest with a gentle slope demonstrates the resistance of a wider barrier to a storm through a different response. Initially, runup of waves onto the dune crest causes small amounts of dune scouring leading to a deposition of sediment on top of the dune. Between hours 48 and 72 however, very little change occurs on the shoreface, dune, backbarrier or lagoon (Figure 17). At 110 hours, fluctuation of the shoreline initiates a constructive phase causing deposition landward onto the dune crest leading to crest aggradation and dune landward translation leading to barrier rollover (Figure 17). Overall, little to no change occurs in the backbarrier and lagoon as a result of reduced washover volume resulting in lower rates of barrier migration, suggesting an inverse relationship between dune crest width and backbarrier and lagoon deposition.

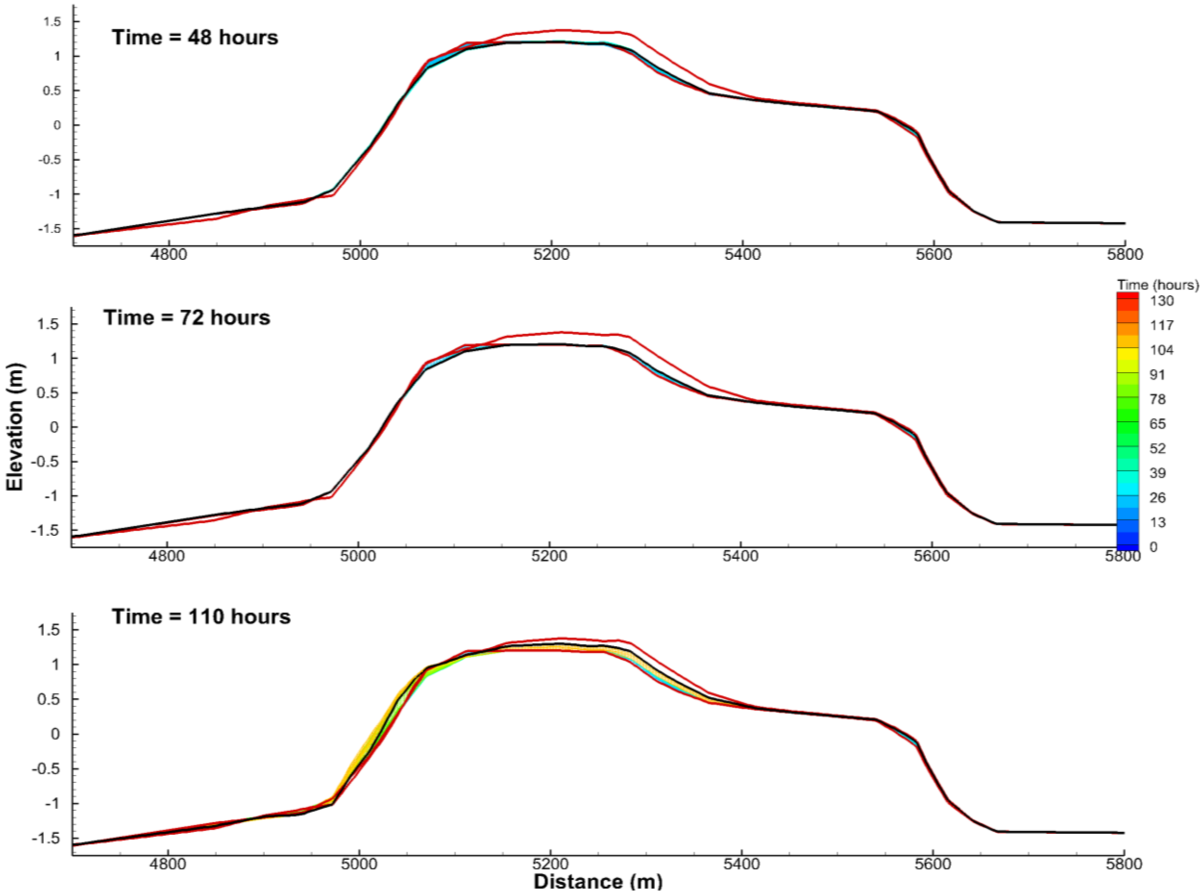


Figure 15: Profile evolution for a wide dune crest with a gentle shoreface slope. Red lines indicate Initial and Final profiles. Black line indicates profile at specified time. Color shows change at specific hours.

Summary and Conclusions

With a goal to accurately represent deltaic barriers in Louisiana and coastal plain barriers in the rest of the northern Gulf of Mexico, a schematized barrier island system was utilized including all sub-environments (e.g., shoreface – various slopes - dunes - various crest widths), informed from field data (e.g., Miner et al., 2009) and literature (e.g., Short, 1999). The simulation matrix ranged from environments that included gentle to very steep slopes representative of deltaic system, and dune morphology that ranged from low and narrow dune fields to high and wide, informed by robust barriers in Louisiana or those produced by barrier island restoration projects. Furthermore, additional templates representing additional restoration templates were incorporated and tested (e.g. Campbell 2005). Using observed water levels, wind and wave data from an actual storm along the Louisiana coast, MIKE 21 by DHI was used to gain a better understanding on the dynamic response of barrier islands during storms.

The hypothesis, that barrier systems with gentle shoreface slopes and low and narrow dune crests are less resistant to storms, and hence experience greater amounts of upper shoreface erosion and dune transgression compared to their steeper slopes and wider dune counterparts, is accepted. The hydrodynamic, spectral wave and sand transport modules offered by MIKE 21 have provided exceptional data for comparing the response of various barrier templates to low-frequency high-magnitude events such as tropical and extratropical storms. Generally, dune aggradation in wider dune systems is a constructive process that while initially limits overwash, eventually promotes overwash in a high dune setting, whereas in low dune systems, this function is lost due to shoreline erosion and significant landward translation. Results show that the angle or morphology of the shoreface slope proportionately determines the amount of shoreline erosion; as the shoreface slope increases the shoreline erosion decreases. Results also show the dune crest morphology (height and width) exerts a first order control on the washover volumes during storms, and thus determines the amount of dune overwash, backbarrier deposition and lagoon deposition leading to backbarrier migration; as the dune crest width increases, dune washover, backbarrier deposition and lagoon deposition decrease.

Implications for barrier island restoration

Our results corroborate results from previous studies (Campbell, 2005; Donnelly, 2007; Donnelly et al., 2006; and Lorenzo-Trueba and Ashton, 2014), that barriers with steeper shoreface slopes and wider dune crests are more resistant to overwash processes and hence backbarrier landward migration, and therefore serve as exemplary nourishing templates for barrier island restoration projects. Having a more detailed understanding of the dynamics of barrier systems will provide more appropriate methods for restoring or nourishing barrier islands. Our study shows that numerical models can be effectively used to assess and test restoration templates further for the specific setting, taking into account other environmental factors at play including physical forcing, geomorphology etc. This becomes extremely important when planning coastal restoration projects here in Louisiana as managing our coast during the ongoing transgression is becoming increasingly important every day.

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Vita

The author grew up in New Orleans, LA having graduated from Metairie Park Country Day School in May 2005. After high school, he began college life at Millsaps College in Jackson, MS where he participated in collegiate soccer. During the first semester of college, unfortunately Hurricane Katrina struck the Gulf Coast at which point the author moved back home and began studying at Tulane University while helping to rebuild his home. After graduating from Tulane in 2011, the author decided to gain some work experience before re-entering the world of academia. Jobs included life support management (pumps, filtration and water quality) at the Gulf World Marine Park in Panama City Beach, FL and animal husbandry, quarantine and animal rescue at the Institute for Marine Mammal Studies in Gulfport, MS. In 2014, the author once again moved back to New Orleans to take necessary undergraduate courses until requirements were fulfilled to be accepted into the Earth and Environmental Studies Masters' Program under the guidance of Dr. Ioannis Georgiou.