

Abstract

BERNSTEIN, DAVID JEROLD. Short-Term Evolution of Cape Morphology: Cape Lookout and Cape Fear, North Carolina (Under the direction of Tom Drake)

Cuspate forelands often occur as a series of seaward projecting capes and their cape-associated shoals. Capes are important physical and ecological discontinuities in a coastline, yet their dynamics are poorly understood. The barrier coastline of North Carolina, consisting of Capes Hatteras, Lookout and Fear, typifies a cuspate foreland coastline. The evolution and morphology of the subaerial cape points at Cape Lookout and Cape Fear, North Carolina were examined through a field-intensive study using Real-Time-Kinematic Global Positioning System (RTK-GPS) from September 2000 to August 2001.

Topographic surveys of the subaerial cape points were conducted to assess changes in volume and shoreline position. Direct observation of waves, currents and bathymetry on cape-associated shoals is extremely difficult and often hazardous. This field-intensive study at Cape Lookout and Cape Fear uses the changing geometry of the subaerial cape point as an easily observed proxy for complex nearshore sediment transport processes at capes. Geo-spatial analysis of topography and shoreline position was used to assess geomorphic trends in volume change and shoreline variability. These results indicate that: 1) Short-term and seasonal changes in shoreline position are a result of changes in nearshore wind and wave energy; 2) variability in shoreline position and morphology increases with distance from the landward end of the cape to the seaward tip; and 3) the seaward tip of the subaerial cape point responds uniquely to changes in the nearshore wind and wave energy, and indicates that this region of the

cape point plays a key role in sediment exchange between the subaerial cape and cape-associated shoal. Given the unique behavior of the seaward portion and transitional area of these capes, a previously un-described sequence of morphologic events I call “clipping” plays a dominant role in the transfer of sand from the tip of the subaerial cape point offshore to the adjacent shoals.

**Short-Term Evolution of Cape Morphology: Cape Lookout and
Cape Fear, North Carolina**

by

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Biography

David Jerold Bernstein was born on April 26, 1977 in Richmond, Virginia. He lived in Richmond, VA for eighteen years and spent a special part of his life at Sandbridge Beach, VA. He graduated from J.R. Tucker High School in 1995 and went to West Virginia University in Morgantown, WV. While working on his undergraduate degree in Environmental Geo-Sciences, he was stimulated to focus on his greatest interest and life's passion; beaches.

Days after his undergraduate career had culminated, he began his graduate work at North Carolina State University. Working with Dr. Tom Drake provided a unique opportunity to move to Morehead City, NC and collaborate research efforts with Jesse McNinch of University of North Carolina's Institute of Marine Science. This opportunity provided him with an ideal means of education and more opportunities. Throughout his graduate work, David has worked on many projects including the Queen Anne's Revenge mapping, Cliffs of the Neuse project, Cape Lookout Shoals project, Cape Fear River project, and Bald Head Island Re-nourishment project. His research focused on the evolution of the Cape Lookout and Cape Fear, North Carolina.

In the spring of 2001, David accepted a position with the Center for Marine and Wetland Studies of Coastal Carolina University in South Carolina. Shortly after moving to South Carolina, David met an incredibly special person. David married Mary Katherine Lee on September 14, 2002.

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I would like to thank Dr. Tom Drake and North Carolina State University for this incredible opportunity. It has sculpted me not only for the scientific career I have always dreamed of, but as a person. Tom supplied a tremendous amount of guidance, wisdom, and advice, and most importantly, made this a great experience. Dr. Jesse McNinch has played an integral role not only in my scientific development, but my personal development. Jesse has given me advice, criticism, and freedom to make key decisions when I needed. Tom and Jesse opened many new doors for me that led to the place I am now.

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Before I go, I would like to dedicate this to my grandfather, Jerry Bernstein.

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INTRODUCTION

Cuspate forelands are large-scale shoreline promontories formed by the juncture of two barrier island or mainland beach ridges at approximately right angles (McNinch, 1997). They are perhaps the largest form of rhythmic shoreline topography (Komar, 1976) and are often separated by tens to hundreds of kilometers. Cuspate forelands often occur as a series of seaward projecting capes and their cape-associated shoals. An integral part of a cuspate foreland is the transition zone between the subaerial cape, which is morphologically governed by wave-generated sediment transport processes in the surfzone, and the cape-associated shoals, governed by a different set of transport processes related to tidal currents (McNinch and Luettich, 2000). This study describes the highly variable morphology of the subaerial cape point and its relation to the wind and wave forcing that generates nearshore sediment transport. Morphologic description is a starting point for studies of the transport mechanisms and pathways responsible for sand transfer between the subaerial cape and cape-associated shoals. Such processes are directly relevant to understanding coastal erosion on both developed and non-developed shorelines and thus impact attempts to mitigate erosion problems by beach nourishment and other practices. States bordering the Atlantic Ocean and North Carolina, in particular, are faced with the threat of increased erosion due to rising sea level and predictions of increased hurricane activity after a period of relative quiescence that has extended over several decades. Cape-associated shoals contain enormous quantities of high-quality sand, and a more thorough understanding of their evolution may be of great value in determining the future of the shoreline in North Carolina and elsewhere along the Atlantic coast of North America.

Cuspate forelands are not isolated or rare features (McNinch, 1997), confined to the Atlantic coast of the U.S. They also occur along the U.S. Gulf coast, the United Kingdom coastline, the western coast of Australia, the Straits of Magellan, and the Alaskan Beaufort Sea, for example. The cuspate coastline of North Carolina is the archetypical example of a cuspate foreland shoreline (Shepard and Wanless, 1971; Komar, 1976). It consists of three cuspate capes and their associated shoals: Cape Hatteras, Cape Lookout, and Cape Fear (Figure 1). The origin and development of the North Carolina cuspate coastline has been debated since the mid 1800's, and many theories have been suggested. Very little field data pertaining to the capes and cape-associated shoals has been collected due to the fact that these features are dangerous to navigate due to shoaling and breaking waves, fast tidal currents, and rapidly changing bathymetry that prevents use of traditional navigational charts. New technologies, in particular, high-resolution topographic surveying techniques made possible by Global Positioning Systems (GPS) now allow rapid quantitative assessment of morphologic change.

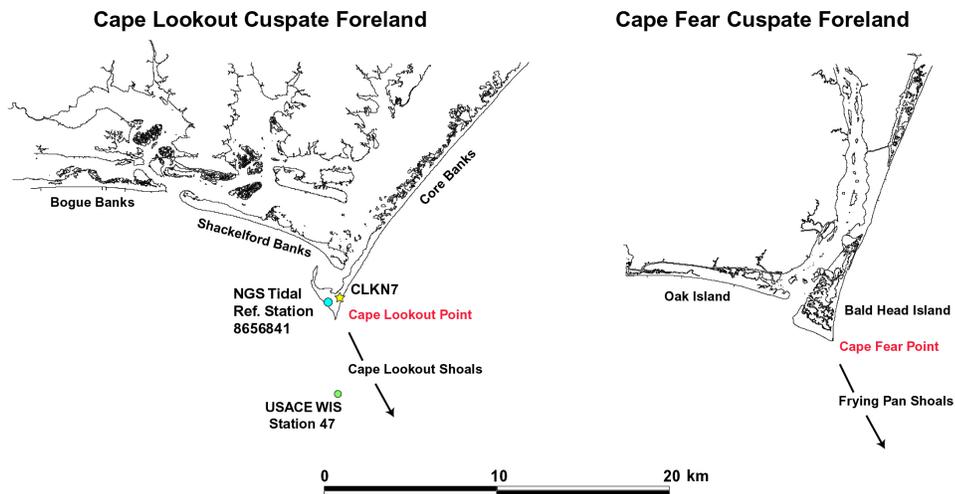
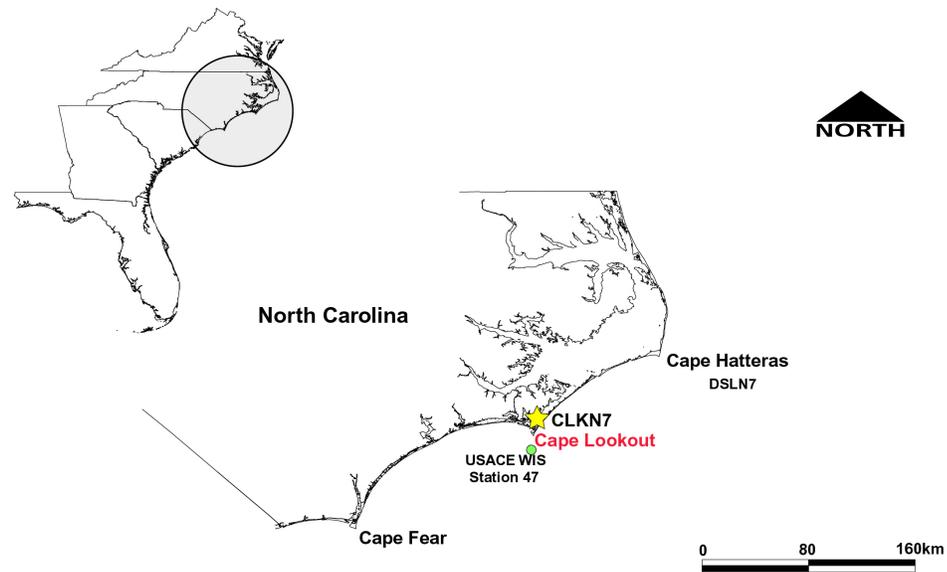


Figure 1. The cuspate coastline of North Carolina. Cape Lookout is the middle of three cuspate forelands along the Outer Banks of North Carolina; Cape Hatteras lies 115 km northeast and Cape Fear lies 160 km southwest of Cape Lookout. Each subaerial cape point has a submerged cape-associated shoal. CLKN7 CMAN station maintained by the National Ocean Service and National Weather Service, and the United States Army Corp of Engineers Waterways Experiment (WIS) station 47.

Previous Work

Shepard and Wanless (1971) related the position and extent of the cape point to prevailing wind, gale force wind, and non-tidal currents, but did not address the sediment transport responsible for cape evolution. McNinch and Wells (1999) undertook a comprehensive field study of the Cape Lookout Shoals beginning in 1995, collecting near-bottom current measurements, detailed bathymetry, surface sediment grab samples, sub-surface seismic profiles, side-scan sonar, and vibracores, among other data. In conjunction with modeling studies (McNinch and Luettich, 2000) they found that 1) the sediment budget of the up-drift littoral cell is coupled directly to the Cape Lookout shoal, 2) the shoal serves as a long term sink for littoral-zone sediment and limits sediment exchange between adjacent littoral cells and shelf regions, 3) the sedimentary processes of the shoal remain active down its entire length, and 4) the landward-most portion of the shoals, adjacent to the apex of the subaerial cape point, is the most active sedimentary portion of the shoals.

Relatively less work has been devoted to the Cape Fear system and Frying Pan Shoals. Studies of shoreline position and beach morphology at Bald Head Island suggest the island is “rotating” along a pivot zone (Cleary, 1989) and that modern shoreline change involves varying erosion and accretion zones and a rapidly changing subaerial cape point (Cleary, 1989; Cleary et al, 2001; Denison, 1998; Mitasova, 2002).

In general, the short-term morphologic evolution of the subaerial cape points is less well known due in large part to lack of mapping technologies suitable to accurately survey large relatively featureless areas at high spatial and temporal resolution. Previous

studies (Shepard and Wanless, 1971; Cleary, 1989; Park, 2000; Borrelli, 2001) quantified subaerial change of the cape point using photogrammetry. While such studies indicate that the cape points have retreated, extended, and migrated extensively over the past half a century, they provide no measurements at time intervals less than several years, and furthermore, address only the planform morphology.

The formation and origin of the three North Carolina capes, Hatteras, Lookout, and Fear, has been debated from the mid 1800's to present. No single theory has yet explained the formation or evolution of these capes, but many attempts have been made (Toumay, 1848; Shaler, 1871; Abbe, 1895; Gulliver, 1896; White, 1966; Dolan and Ferm, 1968; Hoyt and Henry, 1971; Hopkins, 1971; Rosen, 1975; Mixon and Pilkey, 1976; Moslow and Heron, 1981, Blackwater et al, 1982). Recent theory explains that the cape-associated shoals formed as a prograding spit when sea level rise slowed approximately 4,000 years ago (McNinch, 1997).

Despite all the attention, questions regarding the origin as well as the sedimentary and physical processes responsible for shaping and maintaining the cape and cape-associated shoal persisted largely due to the limited amount of field data and the difficulty in data collection around these features (McNinch, 1997). Although many of these theories propose a mechanism(s) of cape formation, they do not focus specifically on the short term, modern processes of a cape and cape-associated shoal. Through recent field intensive studies (McNinch and Wells, 1999; McNinch and Luettich, 2000) of the physical properties of the Cape Lookout-associated shoal, and this study of the morphology of the subaerial cape points of Cape Lookout and Cape

Fear insight may be gained as to the mechanisms responsible for the initiation, formation, and evolution of a cusped foreland.

Long-term Changes of the Subaerial Cape Point

Cape Lookout

Aerial photos document the extension and retreat of the subaerial Cape Lookout point over a period of at least 50 years. Park (2000) analyzed long-term changes in the

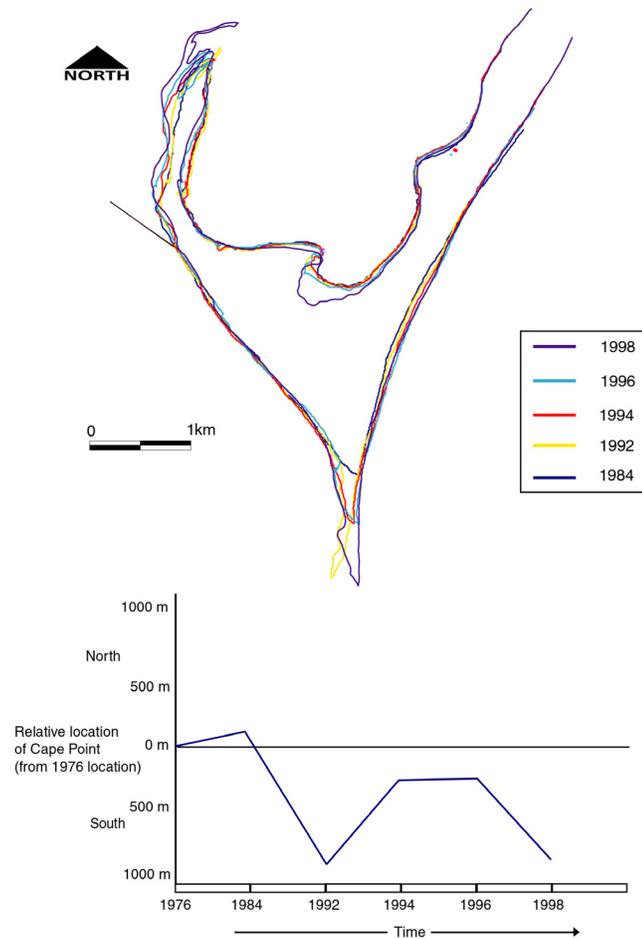


Figure 2. Long term shoreline change at Cape Lookout, North Carolina (Park, 2000). The subaerial cape point retreated about 100 m north from 1976 to 1984; from 1984 to 1992, it extended south about 1,000 m; from 1992 to 1994, the cape point retreated north approximately 800 m; from 1994 to 1996 the point location was relatively stable; finally from 1996 to 1998 the cape extended south about 700 m. The location of the point in 2000 at the initiation of this study was 500 m south of the 1998 location.

subaerial cape point from 1976 to 1998 by digitizing aerial photographs (Figure 2). The subaerial cape point retreated about 100 m (\pm 30m to 70m) north from 1976 to 1984; from 1984 to 1992, it extended south about 1,000 m; from 1992 to 1994, the cape point retreated north approximately 800 m; from 1994 to 1996 the point location was relatively stable; finally from 1996 to 1998 the cape extended south about 700 m. The location of the point in 2000, at the initiation of this study, was 500 m south of the 1998 location.

Cape Fear

Digital shoreline maps document the extension, retreat, and planform migration of the Cape Fear point over a period of 140 years. Harris and Dufrene (per comm, 2002), georeferenced Anders (1990) shoreline maps for GIS. With average RMS errors of up to 10 m, the long-term evolution of the Cape Fear shoreline can easily be described (Figure 3). The subaerial cape point retreated to the northwest approximately 1500 m from its vastly extended position in 1878. The cape point migrated to the northeast about 160 m from 1914 to 1923; from 1923 to 1933, the cape point extended to the southeast about 400 m; from 1933 to 1972, the cape point shifted to north approximately 300 m; from 1972 to 1983 the cape point extended to the east about 200 m and then retreated back to the southwest about 300 m by 1998. Clearly these points migrate substantially. The following sections describe changes in the point location and morphology over time scales from days to months from fall 2000 to summer 2001.

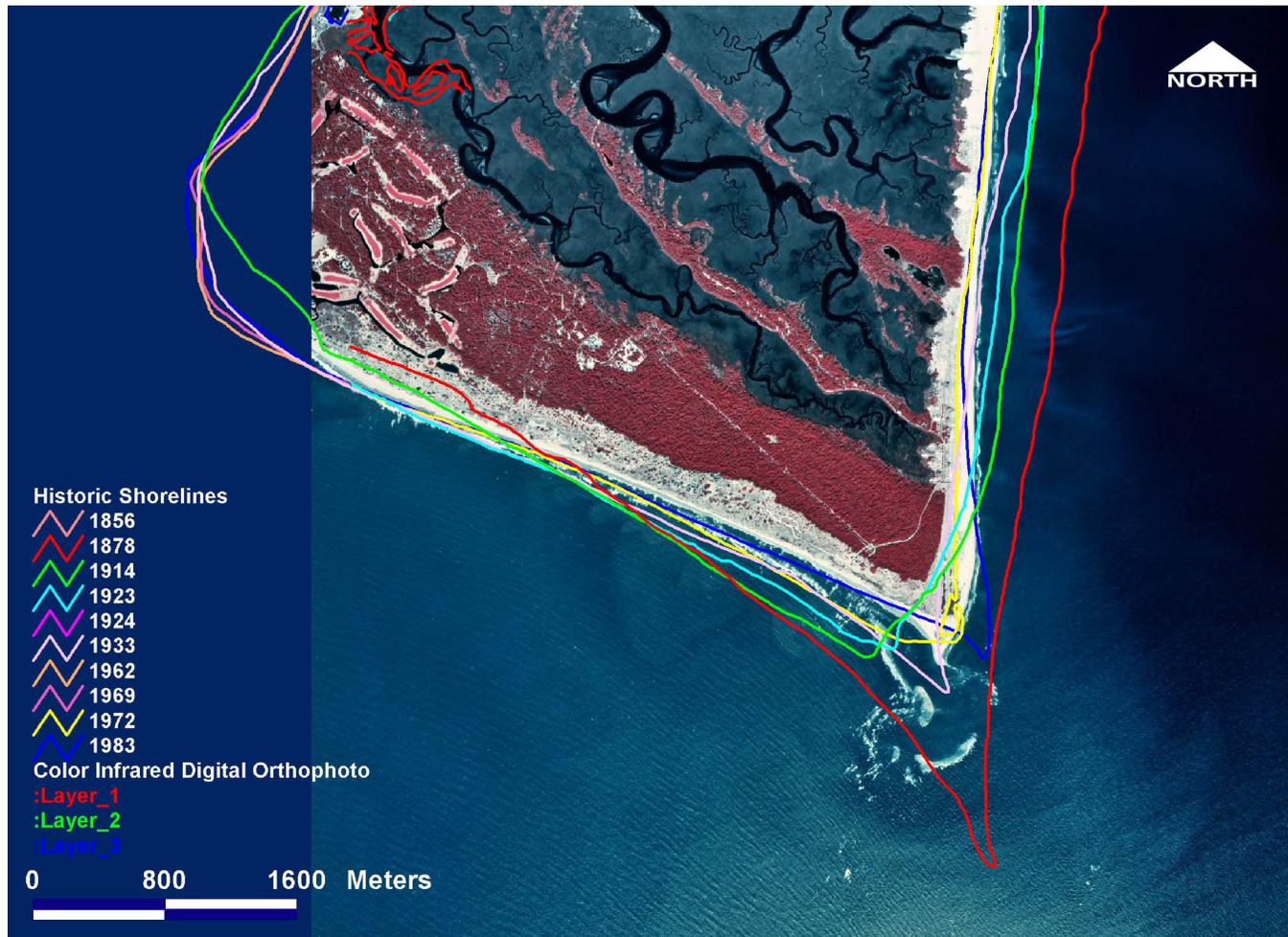


Figure 3. Long term shoreline change at Cape Fear, North Carolina. The subaerial cape point retreated to the northwest approximately 1500 m from its vastly extended position in 1878. The cape point migrated to the northeast about 160 m from 1914 to 1923; from 1923 to 1933, the cape point extended to the southeast about 400 m; from 1933 to 1972, the cape point shifted to north approximately 300 m; from 1972 to 1983 the cape point extended to the east about 200 m and then retreated back to the southwest about 300 m by 1998.

FIELD SETTING

Cape Lookout

Cape Lookout is a large classic cape and cape-associated shoal in close proximity to the marine sciences laboratories at UNC-IMS and NCSU-CMAST. Furthermore, it is part of the Cape Lookout National Seashore and has had little anthropogenic modification, and thus forms an ideal study site to examine morphologic changes of a cusped foreland. Cape Lookout forms the apex of one of the extensive cusped forelands that dominate the coastal and inner shelf morphology of the southeastern United States (Moslow and Heron 1981). Cape Hatteras lies 115 km to the northeast and Cape Fear, the supplementary field area, lies 160 km to the southwest (Figure 1). The shorelines connecting the capes are smooth arcs with midpoints 25 to 40 km landward of the straight lines connecting the successive capes.

The subaerial cape at Cape Lookout lies at the 90 degree junction of Core Banks on the north and east and Shackleford Banks on the west (Figure 4). Prior to the opening of Barden Inlet in 1933, the east-west trending barrier island limb of Shackleford and Bogue Banks adjoined the northeast-southwest trending barrier island limb of Core Banks. Core Banks extends 32 km northeastward from Cape Lookout toward Cape Hatteras. It is unbroken by tidal inlets except for Drum Inlet, and has a wide berm and low dune line ranging from 1.8 to 2.5 m in elevation above sea level. Shackleford Banks extends west from Cape Lookout to Beaufort Inlet. The western half of Shackleford Banks has large dunes and a maritime forest, whereas the eastern half has a lower topography and is covered in grass and shrubs (Park, 2000). The contrasting shoreline

orientation of these two barrier islands exposes them to different wind and wave energy regimes. Wind energy is fetch-limited during the spring and summer in which southerly wind energy affects Onslow Bay, while more powerful winter northeasterly storms generate more energetic waves in Raleigh Bay. Consequently, the longshore transport

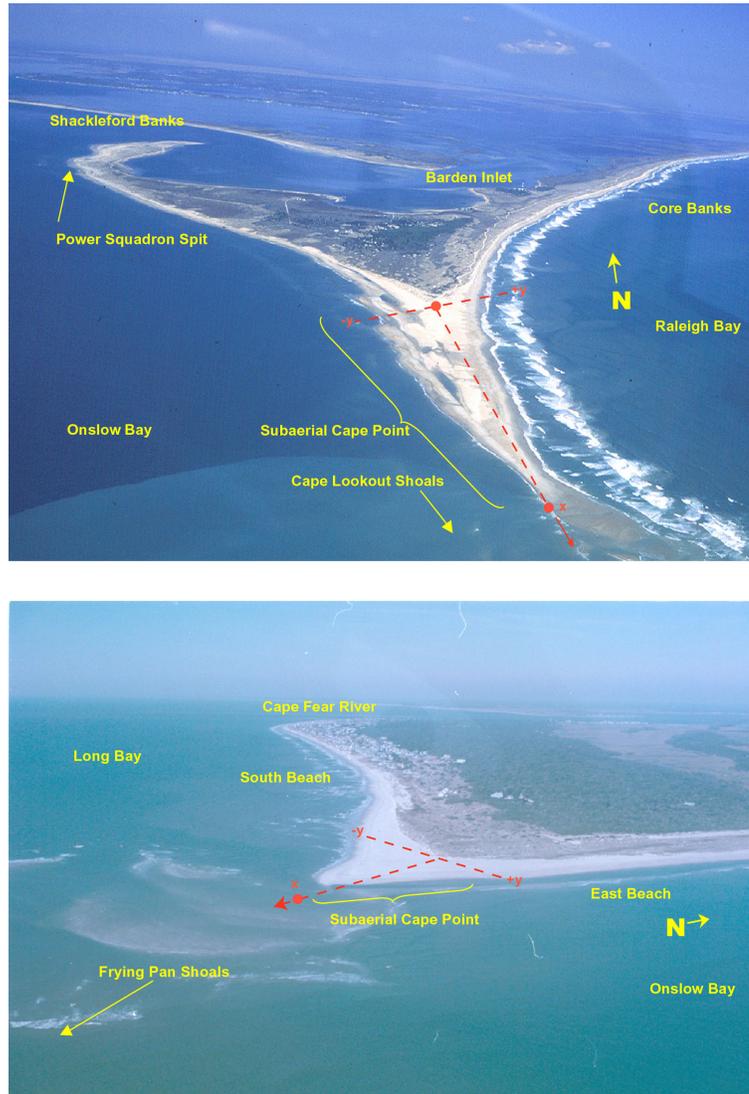


Figure 4. Cape Lookout National Seashore and Bald Head Island, study areas. (Top) Cape Lookout lies at the 90 degree junction of Core Banks on the north and east and Shackleford Banks on the west. (Bottom) The subaerial cape at Cape Fear lies at the southeast corner of Bald Head Island. Bald Head Island is bounded by the Atlantic Ocean on the east and south-facing beaches, and the Cape Fear River inlet on the west. The local coordinate system (dashed lines) for each cape, originates at the seaward-most vegetated point of the cape and extends seaward through the mean tip location determined from surveys conducted during the study period and historical shoreline locations.

direction and magnitude along the two adjacent barrier island limbs is thought to differ significantly. McNinch and Wells (1999) estimate net southerly longshore transport along Core Banks to be approximately 400,000 to 500,000 m³ y⁻¹.

Cape Lookout is classified as a microtidal environment (Nummedal *et al.*, 1977) with different tidal ranges on each flank of the cape. The Core Banks flank has a mean tidal range of 0.47 m, while Shackleford Banks has a mean tidal range of 0.89 m. This difference in tidal range is thought to have a distinct impact on the morphology of the seaward-most tip of the cape point, and has also been suggested by Heron *et al.* (1984) to partially explain the variation in morphology and sedimentation patterns for the two barrier island limbs. McNinch and Luetlich (2000) suggest that a seaward directed, tidal-driven headland flow plays a significant role in the directing of sediment transport seaward along the axis of the shoal. This residual tidal flow is directed from the margins of the shoal toward the crest of the shoal at speeds of 2.1-3.7 cm/s, while residual flow from the crest is directed seaward along the axis of the shoal at speeds of 3.7-5.9 cm/s (McNinch and Luetlich 2000).

The two opposing barrier island limbs that form Cape Lookout also have very different geologic sequences. Core Banks is characterized by a transgressive stratigraphy with barrier island sands overlying finer lagoonal and backbarrier sediment (McNinch, 1997). In contrast, Shackleford Banks is characterized almost entirely of inlet fill deposits and has been relatively stable over the past several thousand years (McNinch, 1997). Importantly, sub-bottom seismic profiles and cores show that the underlying geology of the Cape Lookout cusped foreland does not have a geologic

control on the modern sedimentary processes of the cape point and cape-associated shoal (McNinch, 1997).

Subaerial Cape Point

The subaerial cape point is the sandy, non-vegetated region extending seaward from the vegetated dunes to local mean sea level, and is characterized by a dynamic, ephemeral seaward-most tip, transient seawater ponds, small scarps, and overwashes (Figure 5). Both features and the overall shoreline orientation and morphology can vary significantly in time and space. The entire subaerial cape point at Cape Lookout has a southerly orientation at approximately 180 degrees, while the orientation of the seaward-most tip can vary drastically. The eastern, or Core Banks, side of the subaerial cape point has a more linear shoreline and a dissipative beach that has an average elevation of 1.3 to 2.0 m (NAVD88) and an average slope of 4 to 5 degrees (Figure 6). The western side of the cape point has a shoreline with rhythmic features approximately 100 meters long and a dissipative beach (Komar, 1976). The west side of the cape point has an average elevation of 0.6 to 1.2 m (NAVD88).

Cape-Associated Shoal

The subaqueous cape-associated shoal at Cape Lookout extends 16 km seaward from the subaerial cape point to the south-southeast. The shape of the shoal is defined well by the 10-meter isobath and averages 3.5 km in width and 4 m in depth (Figure 7). The surrounding shelf depth ranges from 18 to 25 m (McNinch and Wells, 1999). The landward-most portion of the cape-associated shoal averages 1 to 3 m in depth and has a channel approximately 500 m from the cape point. This portion of the shoal, especially just seaward of the cape point, is a very shallow tide and wave-dominated area in which

sand is often exposed at low tide. Seaward of the channel a large subaqueous ridge, locally called Shark Island, is exposed at low tides (Park, 2000). The middle section of the shoal has average depths from 3 to 6 m. The seaward portion of the shoal, from about 10.5 to 16 km from the cape point, has a more varied bathymetry that ranges from 3 to 10 m in depth. The shoals have a distinct break in slope that occurs at the 10-meter isobath along the side margins and seaward end of the shoal. The surrounding shelf has a very gradual slope away from the feature, whereas the active region above the 10-meter isobath has slopes in excess of 20 degrees, particularly along the seaward end (McNinch and Wells, 1999).

Cape Fear

Cape Fear lies at the southeast corner of Bald Head Island (Figure 4). Bald Head Island beaches are exposed to the Atlantic Ocean on the east and south. Frying Pan Shoals extends southeast 32 km from the cape point. On the west Bald Head Island is separated from Oak Island by the Cape Fear River. Prior to the early 1990's East Beach extended north about 5 km to Corncake Inlet which separated Bald Head Island from Fort Fisher and Wrightsville area beaches.

South beach has experienced chronic erosion since the 1970's which has been attributed to a variety of natural and anthropogenic causes. For example, Denison (1998) suggests that erosion is exacerbated by the maintenance of the navigation channel into the Cape Fear River. Since then, short-term solutions to this erosion have included nourishment and construction of large geo-textile material tubes serving as groins. South Beach has narrow beach and re-constructed primary dune approximately 4 m in elevation. West Beach morphology is dominated by the Cape Fear River. It is part

of a large spit complex nourished by the eastern segment of an ebb delta immediately south of South Beach (Cleary et al, 2001). East Beach morphology is influenced by strong south-flowing longshore currents and has a narrow and steep beachface.

Together, the two capes provide an opportunity to compare and contrast morphologic response to bimodal wind, wave and current regimes under nominally similar conditions.

Subaerial Cape Point

The entire subaerial cape point at Cape Fear has an east-southeasterly orientation and is approximately 5 times smaller in length than the Cape Lookout point (Figure 6). Likewise, the seaward-most tip can vary drastically. The eastern side of the Cape Fear point also has a more linear shoreline and dissipative beach. Similar to the west side of the Cape Lookout point the southern side of the Cape Fear point has a shoreline where rhythmic features are commonly present.

Cape-Associated Shoal

The subaqueous cape-associated shoal at Cape Fear, Frying Pan Shoals, extend to the southeast approximately 32 km. Where as almost no field work has been done at Frying Pan Shoals, little is known about the geometric and sedimentary properties of the shoals. The landward most portion of the Frying Pan Shoals is the shallowest portion of the shoals, with large piles of sand commonly exposed just seaward of the cape point. Similar to the Cape Lookout Shoals, a channel resides just seaward of the cape point.

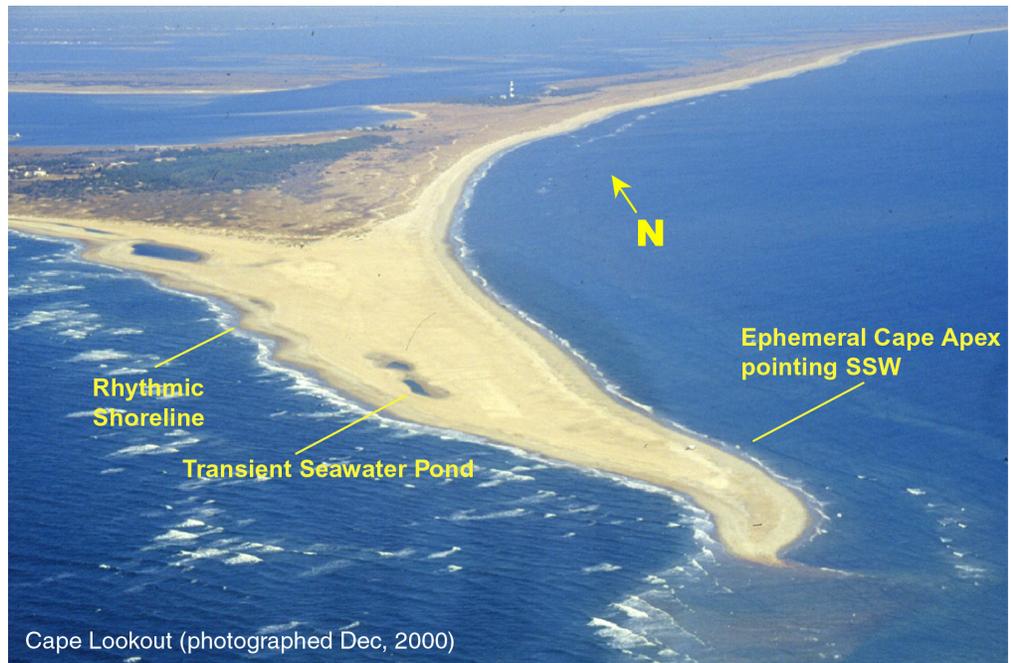


Figure 5. Prominent geomorphic features of the North Carolina capes. (Top) Transient seawater ponds and a rhythmic shoreline on the western side of the Cape Lookout point. In December 2000, the cape apex pointed south-southwest and waves from the south dominate the cape point morphology. (Bottom) Sand piles in the transition zone from the cape point at Cape Fear to the shoals and wave energy propagating from the north.

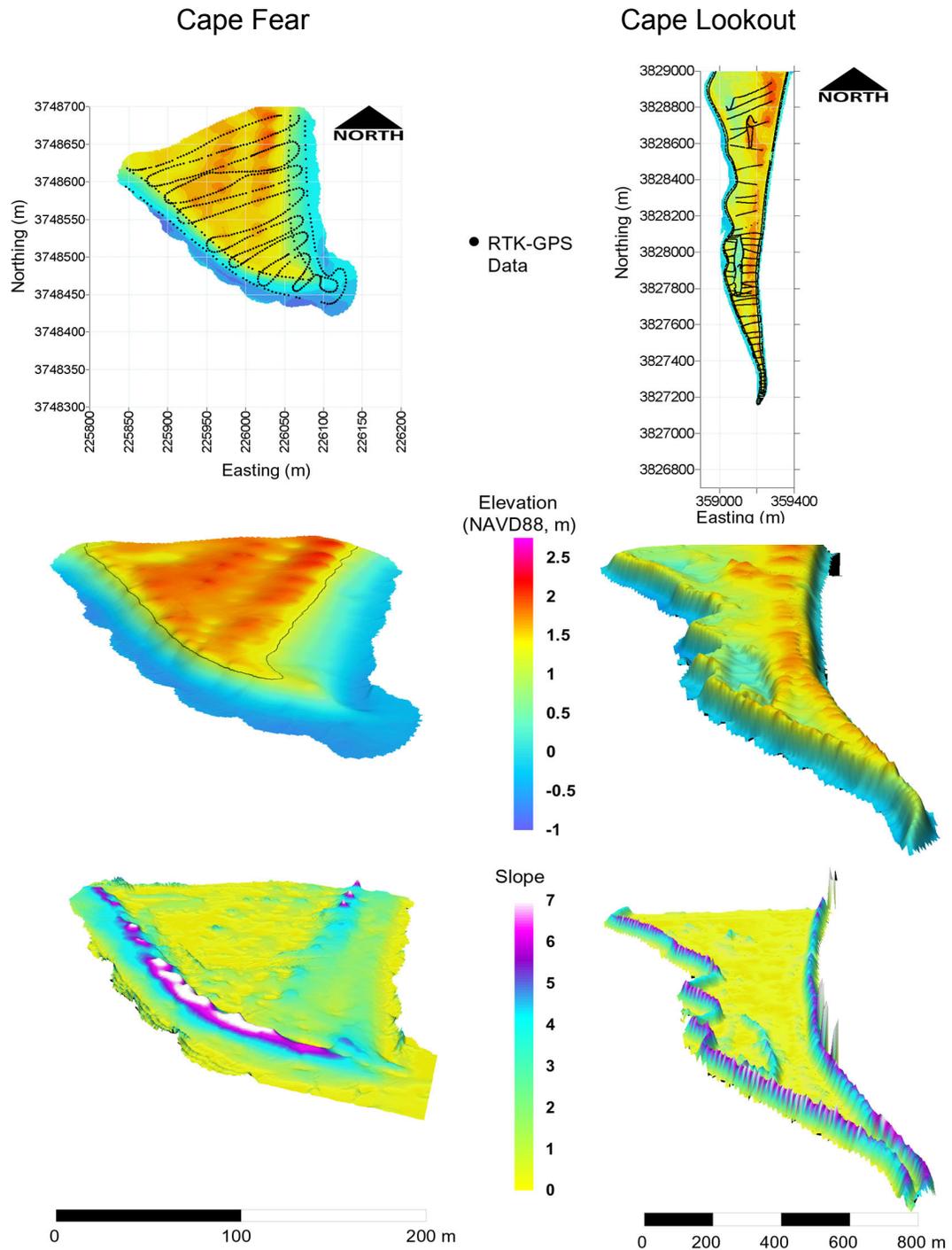


Figure 6. Topographic maps of Cape Lookout and Cape Fear created from RTK-GPS data (top). 3-Dimensional topographic surface showing the distribution of elevation and morphology across the Cape Lookout and Cape Fear points (middle). 3-Dimensional surface showing the distribution of slope across the Cape Lookout and Cape Fear points (bottom). Note: change in scale.

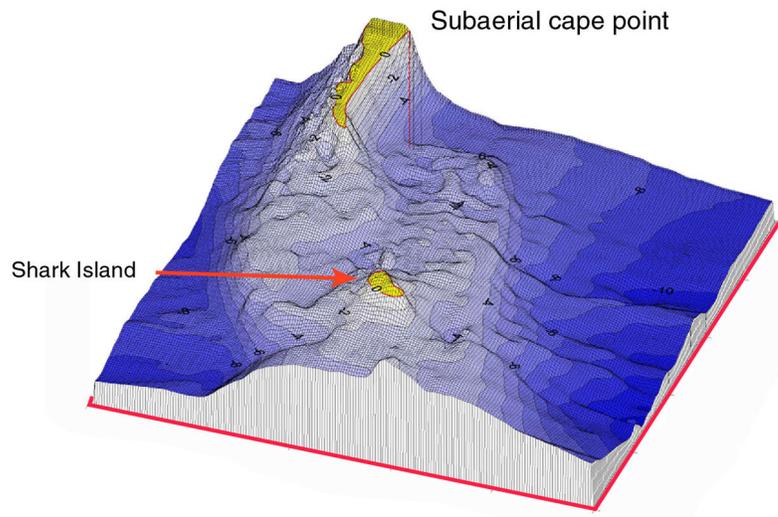
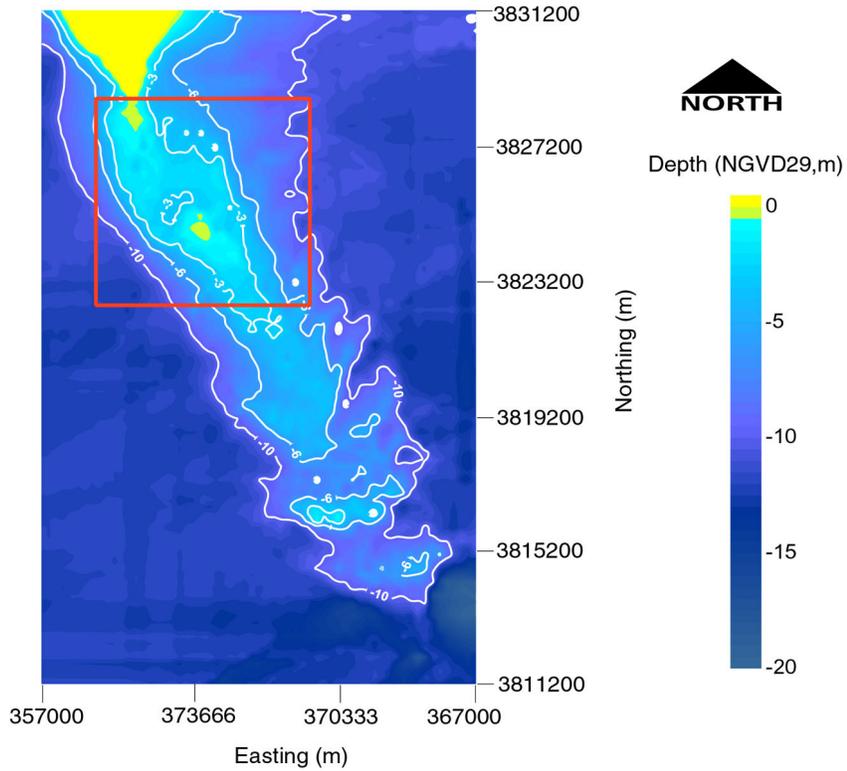
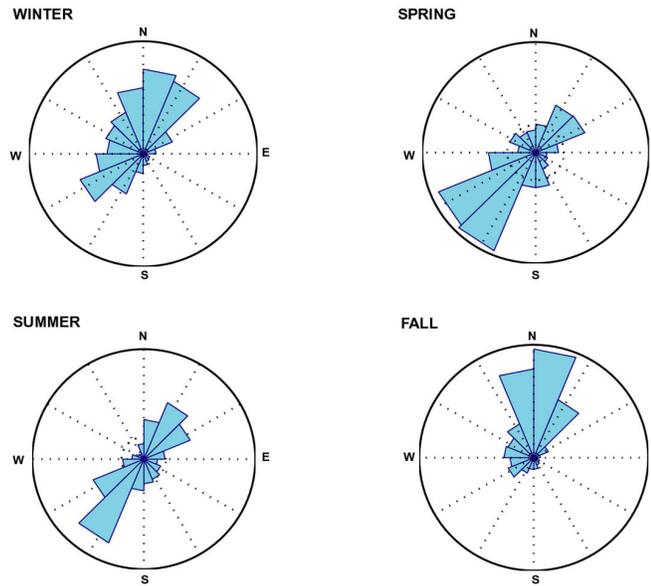


Figure 7. Bathymetry of the Cape Lookout cape-associated shoal. (from McNinch (1997) and McNinch and Wells (1999)). The subaqueous cape-associated shoal extends from the cape point. Transitional zone between the seaward end of Cape Lookout point and landward-most portion of the cape-associated shoals, including Shark Island, often exposed at low tide.

Wind and Waves

Cape Lookout and Cape Fear cusped forelands lie in a wind and wave energy regime that has both a seasonally bimodal character and a storm-driven bimodality that can vary on a weekly or even daily time scale. In general, the spring and summer can be characterized by southerly wind and wave energy which is typically less energetic, whereas the fall and winter can be characterized by more energetic northerly energy and significant events such as Nor' easters (Pietrafesa *et al.*, 1985). Figures 8 and 9 show wind and wave hindcast information developed by the USACE WIS (1997) at station No. 47 located at Cape Lookout Shoals at a depth of 9 m and approximately 13 km from the cape point. North to northeast winds dominate during the fall and winter and southwest winds dominate during the spring and summer.

WIND ROSE DIAGRAMS FOR SURVEY PERIOD (AUGUST 2000 - AUGUST 2001)



WIND ROSE DIAGRAMS FOR 10 YEARS (1986 -1995)

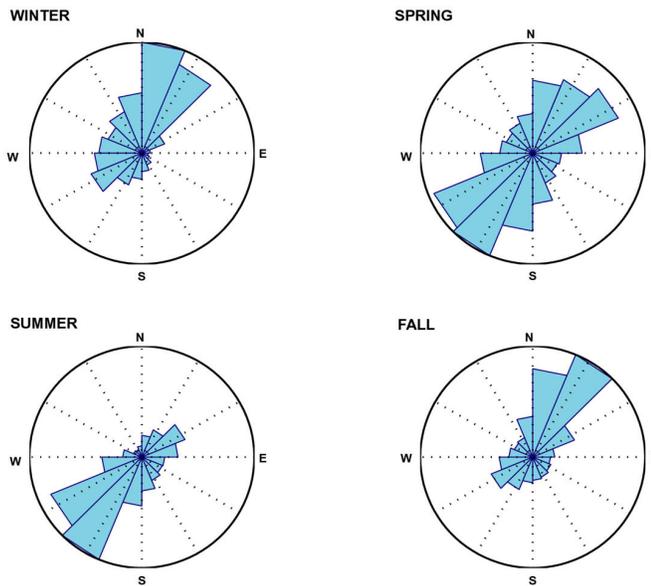


Figure 8. Wind rose diagrams in the Cape Lookout point region for August 2000-August 2001 from the National Weather Service Coastal-Marine Weather Service Automated Network station CLKN7 located at 34.62 N 76.52 W. Wind rose diagrams in the Cape Lookout Shoal region for 1986-1995 from hindcast station 47 of Unites States Army Corp of Engineers Waterways Experiment Station. North to northeast winds dominate during the fall and winter and southwest winds dominate during the spring and summer based on 10 years of data from 1986 to 1995, although the winds were frequently from the northeast (Park, 2000). Seasonal wind data collected at the CLKN7 C-MAN station on Cape Lookout for the survey period of August 2000 to August 2001 show similar trends.

WAVE ROSE DIAGRAMS FOR 10 YEARS (1986 - 1995)

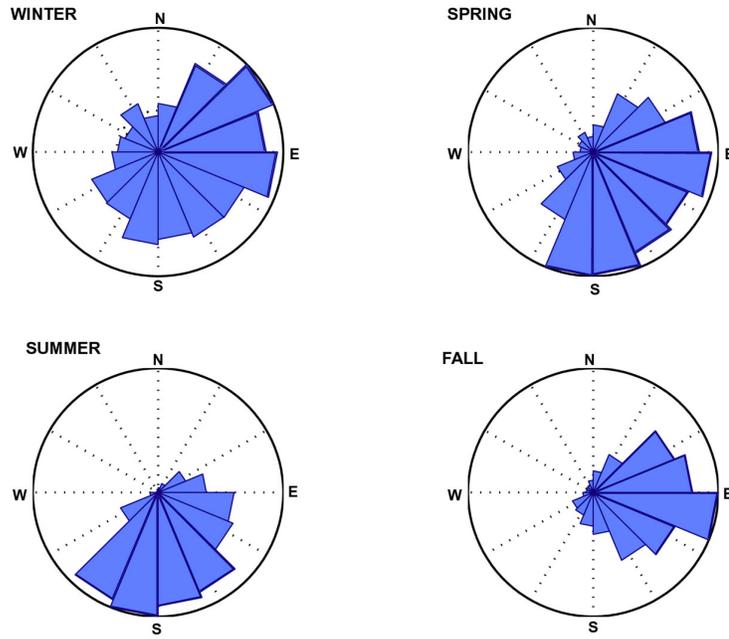


Figure 9. Wave rose diagrams in the Cape Lookout Shoal region for 1986-1995 from hindcast station 47 of United States Army Corp of Engineers Waterways Experiment Station. Wave patterns show that northeast to east waves dominate during the winter, east to south waves during the spring, south to southwest waves during the summer and east to northeast waves during the fall (Park, 2000).

FIELD METHODS

Surveys document the morphologies of the cape points at Cape Lookout and Cape Fear, beginning in August 2000, and ending August (Figure 10). A Real-Time-Kinematic (RTK) Global Positioning System (GPS) mounted on an all-terrain vehicle allowed rapid and efficient acquisition of topographical data which was acquired at or near low tide (Figure 11). Topographic data (latitude, longitude, and elevation) were generated every second or when the GPS antenna moved at least one meter from the previous position. The GPS basestation for Cape Lookout surveys was located at the TOWER benchmark (34°36'44.06731 N latitude, 76°31'48.95099" W longitude, 2.152 m, NAVD88). The GPS basestation for Cape Fear surveys was located at the PAN benchmark (33°50'45.62890 N latitude, 77°57'58.98045" W longitude, 13.278 m, NAVD88). Coordinates for latitude and longitude are referenced to the Universal Transverse Mercator datum (UTM zone 18) and elevations are referenced to the North American Vertical Datum (NAVD88). Horizontal errors in the GPS locations are typically on the order of 3 to 6 cm while errors in the vertical locations are slightly larger and range from 5 to 10 cm. Figure 12 illustrates differences between NAVD88 and several elevation datums at Cape Lookout and the Cape Fear area. Errors in elevation due to changes in vehicle weight and beach conditions are negligible. Likewise, the changes in location due to beach slope are typically less than 5 cm and can thus be safely ignored.

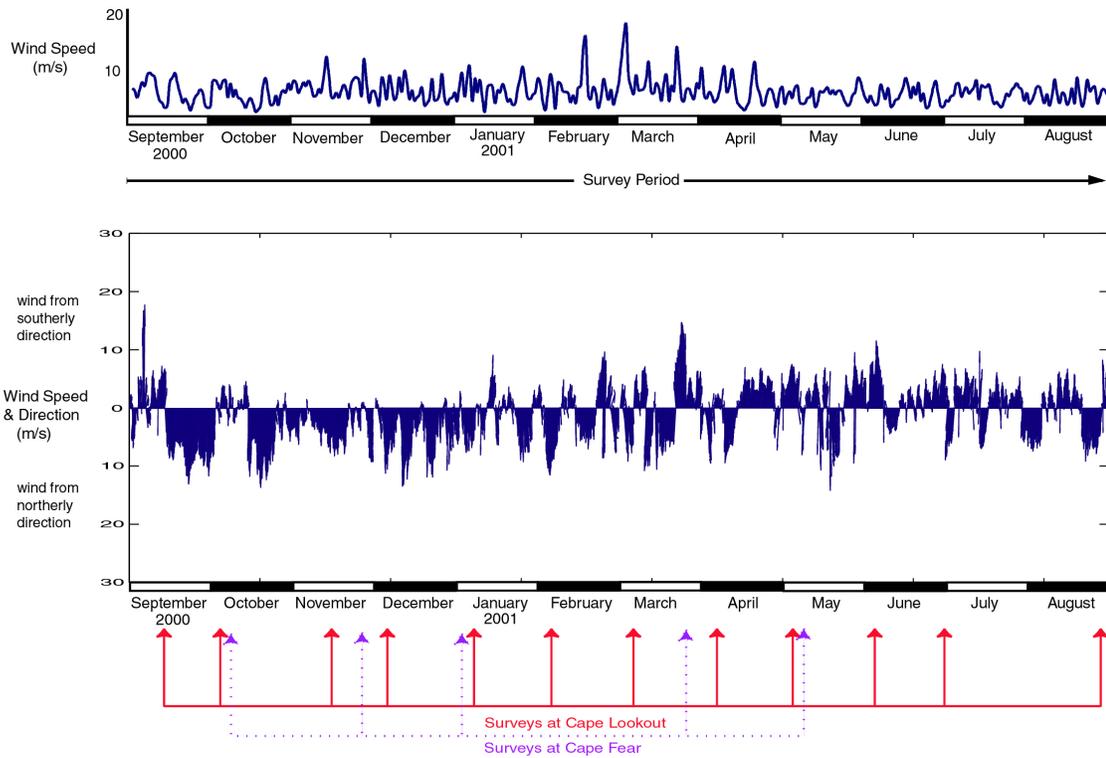


Figure 10. Timeline illustrating the survey period at (top) from September 2000 to August 2001 and the daily average wind speed at Cape Lookout . Timeline illustrating the survey period, daily average wind speed and direction (bottom). Surveys at Cape Lookout and Cape Fear area indicated throughout the study period.

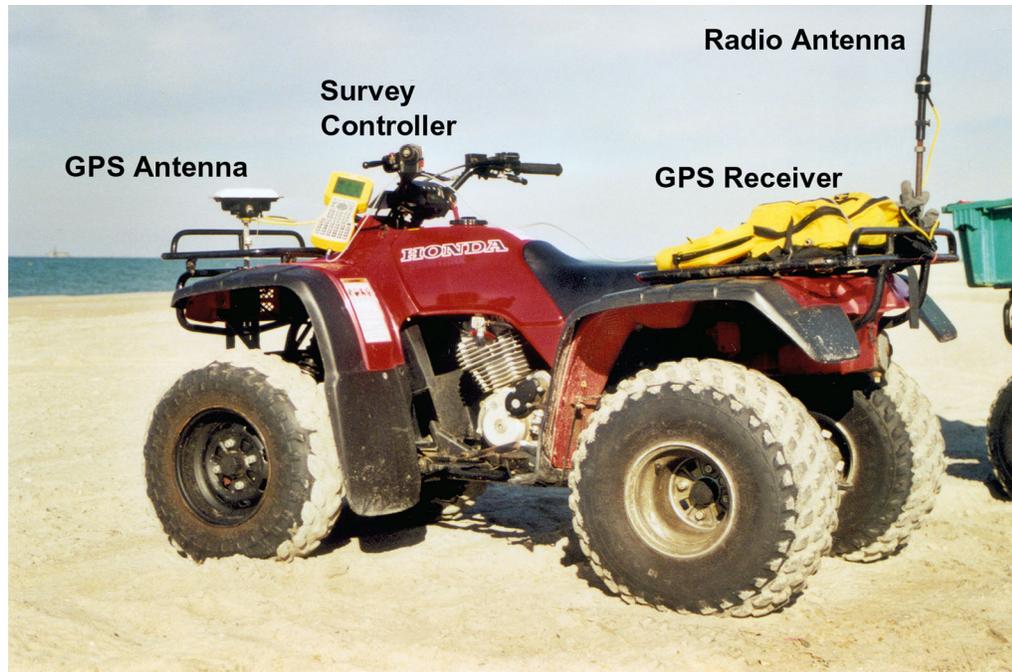
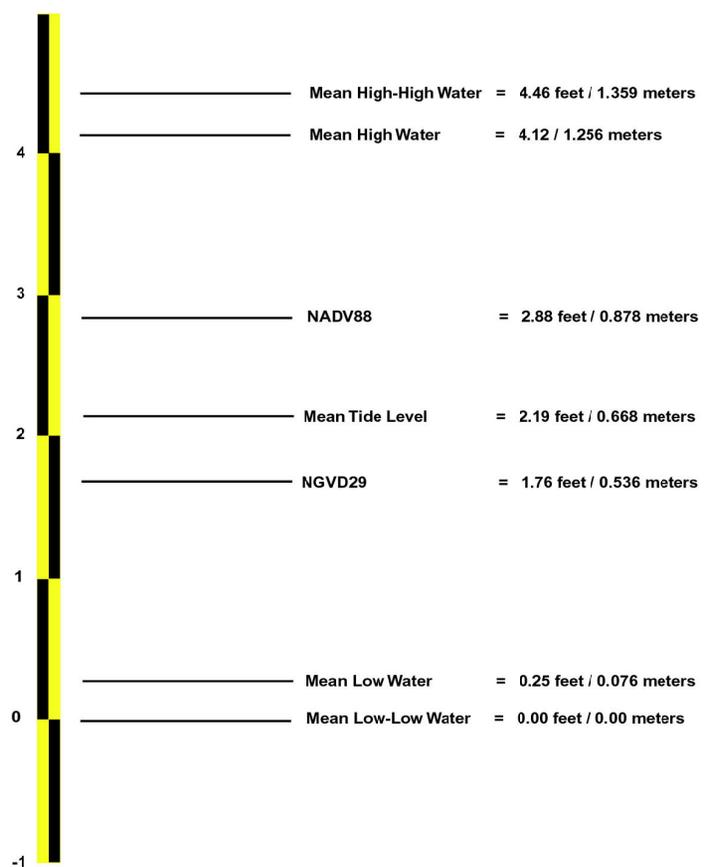


Figure 11. Real-Time-Kinematic (RTK) Global Positioning System (GPS) mounted on an all-terrain vehicle allowed rapid and efficient acquisition of topographical data. An x,y,z data point was generated every one second or one meter traveled. Typical GPS errors in horizontal location are 3 to 6 cm; and 5 to 10 cm in the vertical.

Cape Lookout

Elevation Information for PID = EA0197
 (Tidal benchmark nearest **Cape Lookout** with accurate tidal datums located at 3830037.078 N, 358634.329 E)



Cape Fear

Elevation Information for PID = EA0672
 (Tidal benchmark nearest **Cape Fear** with accurate tidal datums located at 3768253.000 N 232444.518 E)

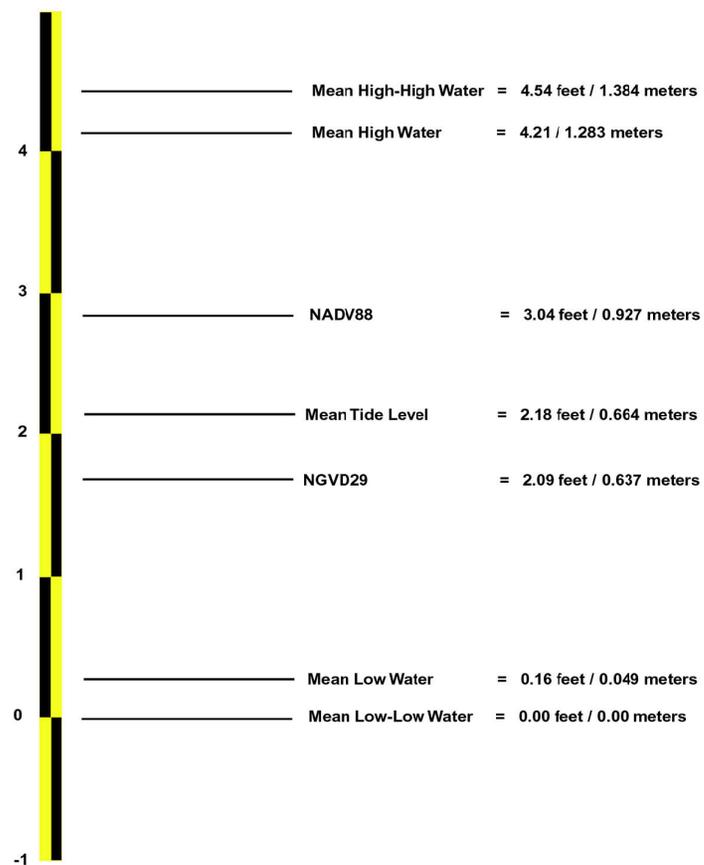


Figure 12. Relationship between commonly used vertical elevation datums at the NGS tidal benchmark nearest the Cape Lookout (left) and Cape Fear (right) study sites (<http://www.ngs.noaa.gov>). All elevations in this study use the NAVD88 datum.

Topographic Mapping and Volume Calculations

Digital elevation maps (DEM) were generated from GPS survey data (Figure 13). Kriging was used to interpolate a surface with a grid cell size of 2 meters, and determine the volume of cape sand measured from the 0 meter contour to the interpolated surface (Figure 14). Volume change from survey to survey was calculated for the entire subaerial cape point and in three sections: the landward-most, middle, and seaward-most portions of the cape. Dividing the subaerial cape point into sections to determine volume change allowed for a spatial analysis of the sediment volume change across the cape point.

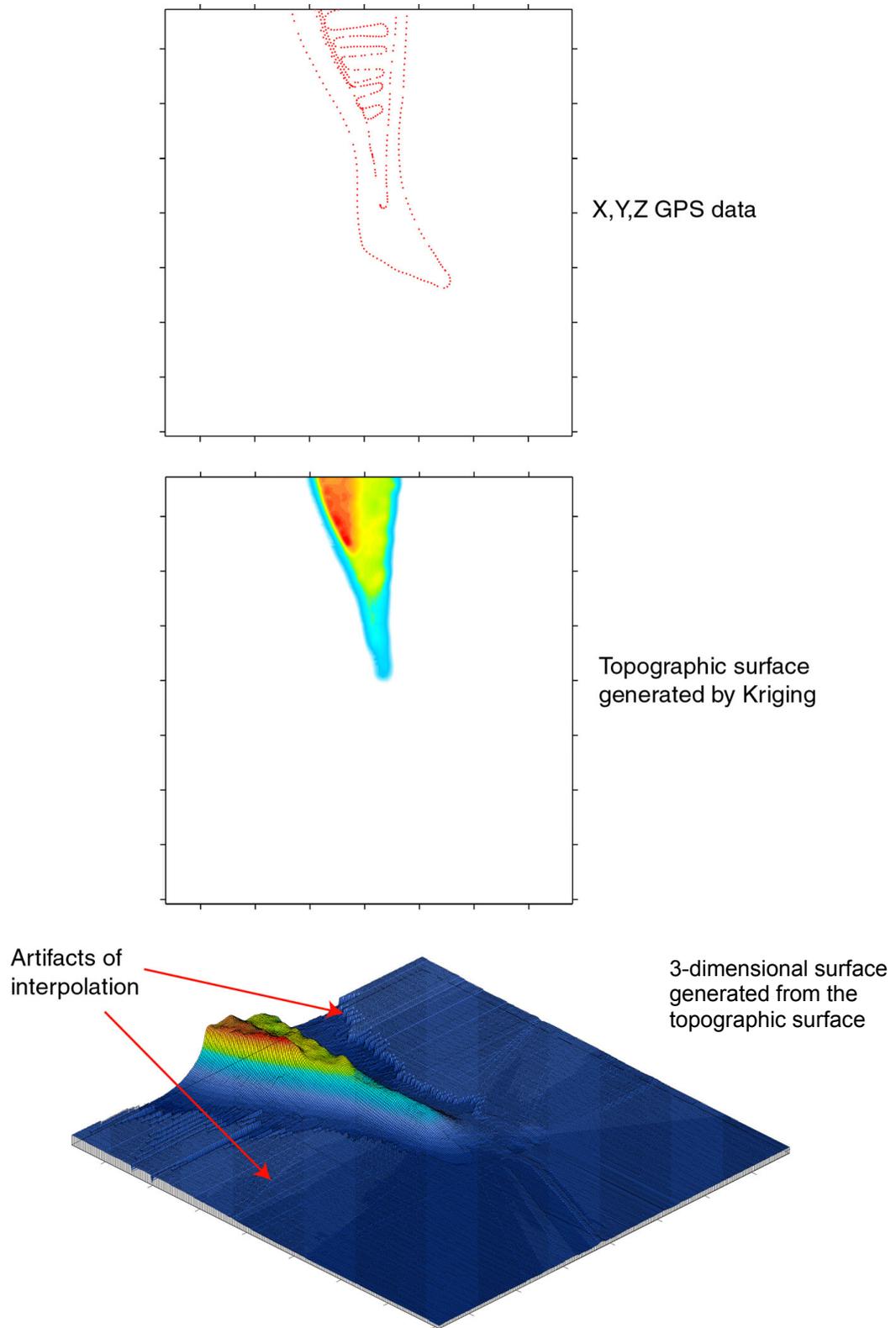


Figure 13. Processing steps for generating a detailed 3-d representation of the topography of the subaerial cape point used for volumetric and morphologic analysis.

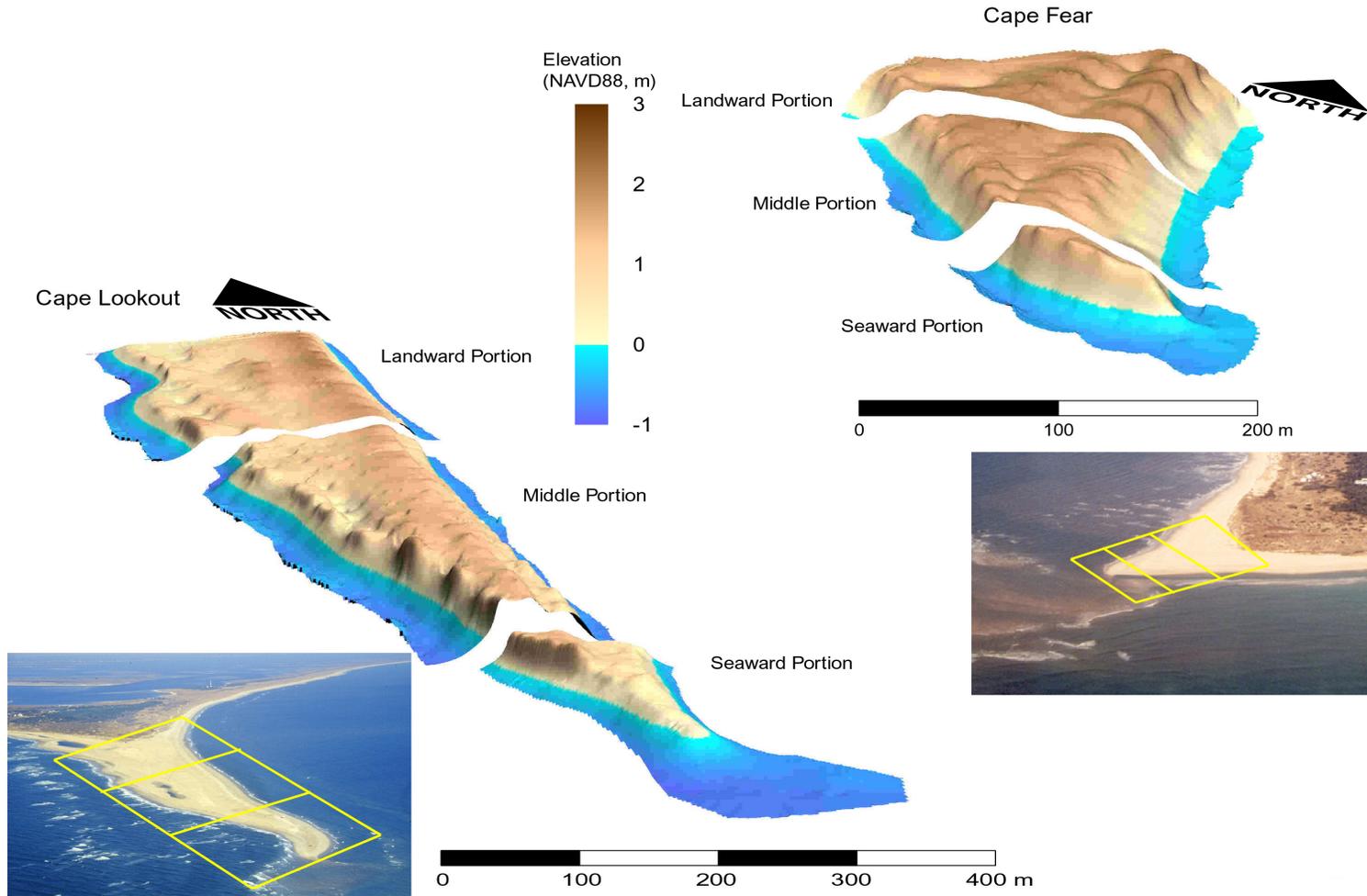


Figure 14. Spatial dissection of the Cape Lookout and Cape Fear subaerial cape point for volumetric calculations and analysis. Volume is calculated above the 0 m contour. Dividing the subaerial cape point into such partitions to determine volume change allows analysis of the sediment volume change across the cape point.

Shoreline Mapping

The shoreline is defined as the horizontal location of the Mean-High-Water Contour (MHWC) (NAVD88). This datum-derived shoreline position indicator was chosen mainly because it serves an objective shoreline change indicator. The MHWC, or the 0.378 m contour, at Cape Lookout has been derived from the closest tidal station (NGS station PID, EA0197) relating the NAVD88 datum to other vertical datums. The MHWC at Cape Fear, or the 0.357 m contour, has been derived from the closest tidal station (NGS station PID, EA0672) relating the NAVD88 datum to other vertical datums (Figure 12). The position of the MHWC is determined from GPS survey data by extrapolating the MHWC contour from two nominally parallel survey lines driven immediately adjacent to and parallel to the swash line. This technique assumes that the survey lines and MHWC contour all lie in a common plane so that linear extrapolation from the upslope line along the line of steepest descent determines the shoreline (Figure 15). Under most conditions the beach slopes at Cape Lookout and Cape Fear are approximately planar, however, when scarps or other irregular topography were present, more survey lines were acquired to improve the estimate of shoreline location. Typical errors in shoreline location were determined by surveying the same shoreline a number of times; the resulting rms error in shoreline location is about 0.5 m. GIS software was used to analyze changes in shoreline orientation and position. Measurements of shoreline position at Cape Lookout were made from an arbitrary cape point baseline which extends south (approximately 180 degrees) from the seaward-most point of vegetated dunes on the subaerial cape point. At Cape Fear, measurements of shoreline

position were made from an arbitrary cape point baseline which extends south-southeast (approximately 150 degrees) from the seaward-most point of vegetated dunes on the subaerial cape point.

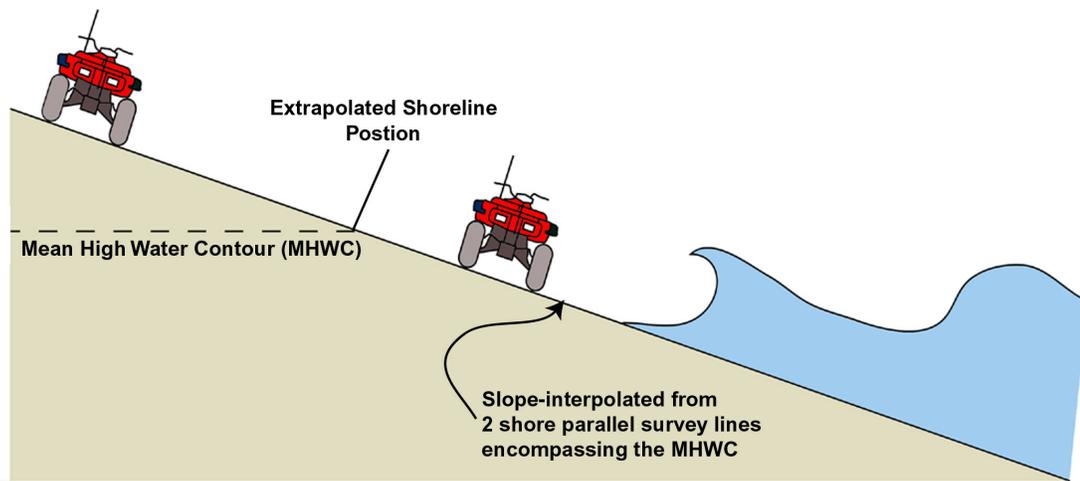


Figure 15. Shoreline position, defined here as the horizontal position of the Mean High Water Contour (MHWC). Two nominally parallel survey lines driven immediately adjacent and parallel to the swash line provide x,y,z data from which the MHWC was extrapolated. Typical horizontal shoreline location errors are 0.5 m. The MHWC for Cape Lookout = 0.378 m. The MHWC for Cape Fear = 0.357 m.

Wind and Wave Data

Continuous and historical wind data from the CLKN7 C-MAN station at Cape Lookout, North Carolina was used to associate the spatial orientation and morphological changes of the subaerial cape point with nearshore wind and wave energy. Since no wave gauges or buoys are in permanent deployment near Cape Lookout nearshore wave energy is not straight forward. Although several years of hindcast wave information from USACE WIS exists, it does not provide as much insight as to the nearshore wave energy affecting the morphology of Cape Lookout or Cape Fear. Figure 1 illustrates the location of the USACE WIS station #47, and the NOAA NWS CLKN7 CMAN station from which wind and wave data was gathered.

Lidar Analysis

The morphology of the cape point was also analyzed using Light Identification Detection And Ranging (Lidar) data gathered on an infrequent basis by the United States Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautic and Space Administration (NASA) from October 1996 to present. Lidar data are collected using an aircraft-mounted, GPS-corrected laser system to provide beach surface elevations with a data density with several points per m² having a vertical accuracy of ± 20 cm on flat sandy surfaces. Lidar can be used to measure bathymetry when the optical water clarity is high, which is rarely the case in either of the study areas. Reliability of depths less than

-1 m (NAVD88) for this study are uncertain and were eliminated from the analysis presented here. The subaqueous lidar data are useful in describing the behavior of the very seaward-most tip of Cape Lookout point and the clippings residing just off the cape point, as well as allowing determination of the volume of sediment piles. Volume of sediment piles was quantified, and profiles from the cape point extending offshore, through the “clippings”, were extracted. (for more information on LIDAR beach mapping see (Quinn, 2000; Armstrong, 1996).

RESULTS

Surveys show morphologies of the subaerial cape points evolve substantially on time scales of at least months. Exposure of the capes to a bimodal wind and wave energy regime and in particular, changes in wind and wave direction activate a sequence of morphologic changes that result in abrupt transitions in cape point orientation and extent. A mechanism called *clipping* provides the means for rapid changes in the configuration of the cape point. In a period as short as a few hours, the extended, narrow tip of the cape point can be clipped by waves and wave-generated alongshore-currents that breach the narrow cape point extension, removing tens to hundreds of meters from the cape point, and isolating large volumes of sand that are inferred to move into the shoals transport system. The following sections detail observations of changes in cape point morphology based on GPS surveys.

Shoreline Change

At Cape Lookout, changes in orientation and extent of the cape point can be related to changes in the nearshore wind/wave energy. Figures 16 show the shoreline configuration, the time series of wind speed and direction for the period preceding the survey, and other data used to explain important phenomena and relationships.

Wind/Wave influence on shoreline change at Cape Lookout point is illustrated by a comparison of surveys from 6 December 2000 and 12 January 2001. At the time of the December survey, the apex points south-southwest at approximately 189 deg and lies 22 meters west of the survey baseline. The dominant wind direction between surveys is northerly, with infrequent occurrences of west and west-southwest winds.

The January survey (Figure 16b) documents the apex pointing southeast at approximately 150 deg and lying 65 meters east of the cape baseline; a net migration of about 87 m to the east and a distinct change of about 39 deg. From the December 2000 survey to the January 2001 survey, the shoreline position of the apex of the cape point had meandered to the southeast by approximately 87 meters. The dominant wind frequency and direction for the month prior to the January survey, seen in Figure 16d, is northerly, with less occurrence of southwest winds. Figure 16d, shows winds 1 day prior to the survey with a dominant southwesterly frequency and direction and three days prior to the survey with a dominant west and northwest frequency and direction. Five days prior to the January survey winds had a dominant southwest and westerly frequency and direction. Recalling frequency and occurrence of southerly events between the December 2000 and January 2001 surveys, 5 notable events had influenced the cape point, thus revealing that changes in the direction and magnitude of wind/wave energy can significantly change the orientation and position of the seaward-tip of the cape point on time scales of months or less.

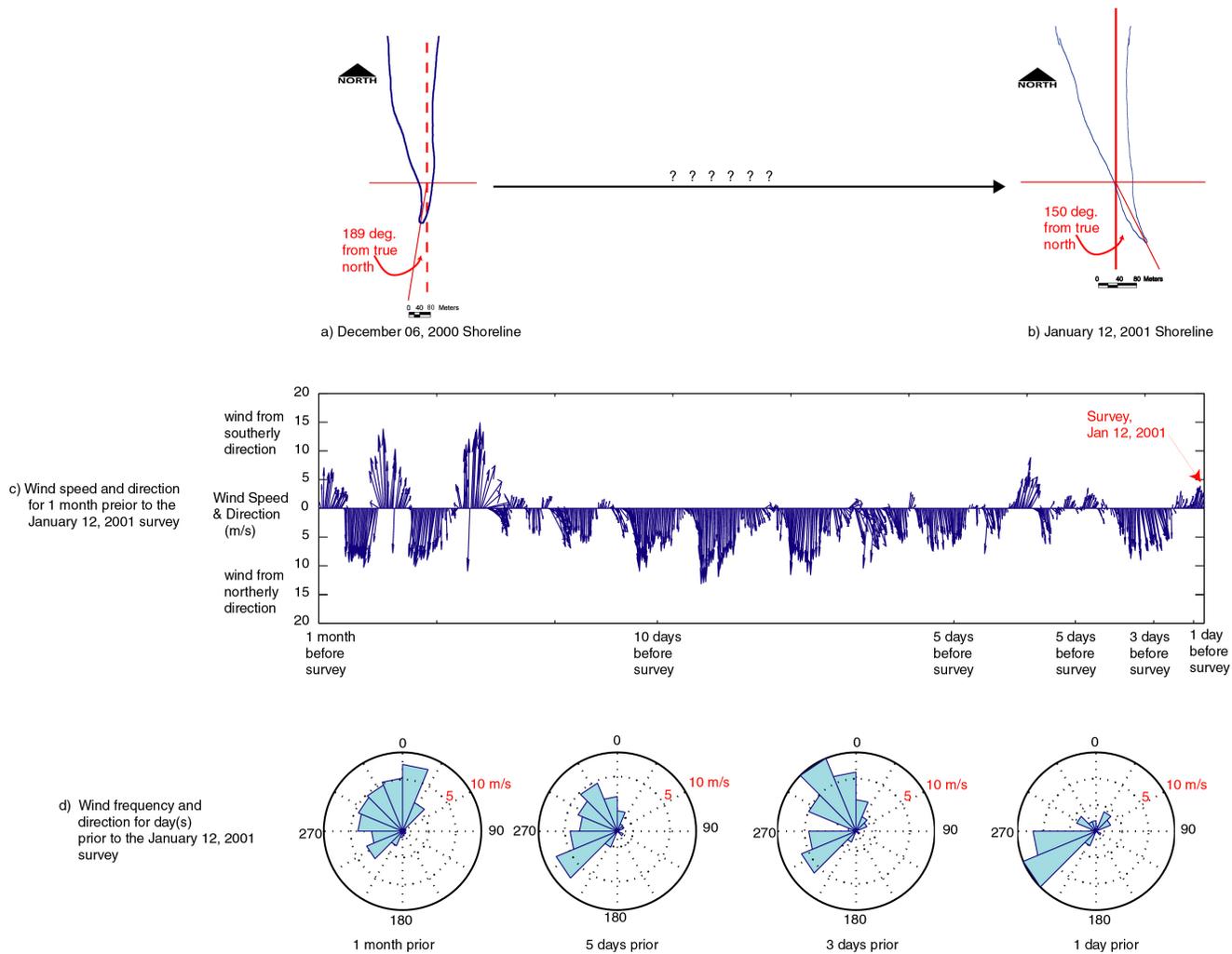


Figure 16. a) Shoreline orientation and extent of the Cape Lookout point from the December 06, 2000 and January 12, 2001 surveys, b) wind speed and direction at the Cape Lookout point for 1 month prior to the January survey, and c) wind frequency and direction for days(s) prior to the January survey.

Trends in Shoreline Variability: Cape Lookout and Cape Fear

Variability in the location of the subaerial cape point is a strong function of distance along the point, increasing monotonically from the vegetated shoreward end of the cape to the highly variable cape point. The change in variability with distance from the shoreward base appears to be roughly linear with distance to a point near the seaward tip of the cape point where variability increases dramatically. The variability is the maximum change in shoreline position (Δy) measured perpendicular to the long-term average axis of the cape point. Shoreline variability of the east side of the Cape Lookout point differs significantly from the west side. The west side of the cape point has an envelope of change, ranging from 120 m at the landward-most area to 40 m in the middle portion and increasing to 157 m over the seaward-most 200 m of the point. The east side of the point, on the other hand, has a linear trend in shoreline variability from the landward-most portion to the seaward-most portion and a smaller envelope of change (Figure 17).

Shoreline variability at Cape Fear point is similar to the Cape Lookout point in that the opposing sides of the Cape Fear point also show a distinct difference in the amount and trend of shoreline variability (Figure 18). The south side of Cape Fear point has a linear trend in shoreline variability from the landward-most portion to the seaward-most portion ranging from 11 m in the landward-most portion to 48 m in the seaward-most portion. The east side of the cape point varies more, with changes ranging from 41 m to 86 m. Like Cape Lookout point, variability in the seaward direction increases throughout the last 50 m on both sides of the Cape Fear point.

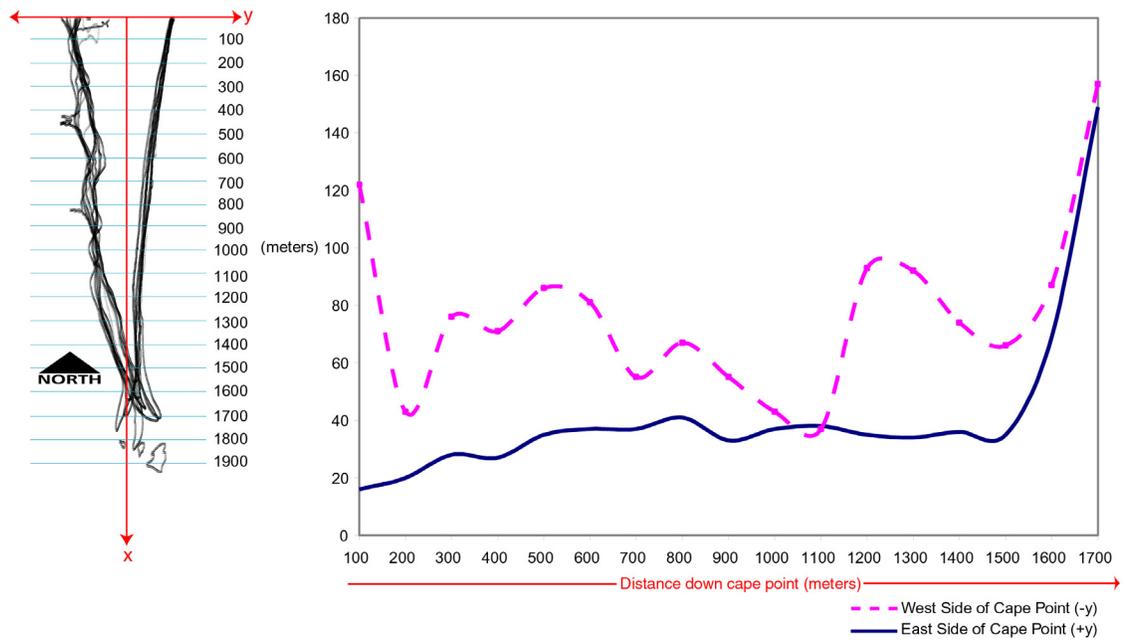


Figure 17. Shoreline variability at Cape Lookout point differs significantly on the west and east sides of the cape point. Variability increases dramatically over the seaward-most 200 m of the point.

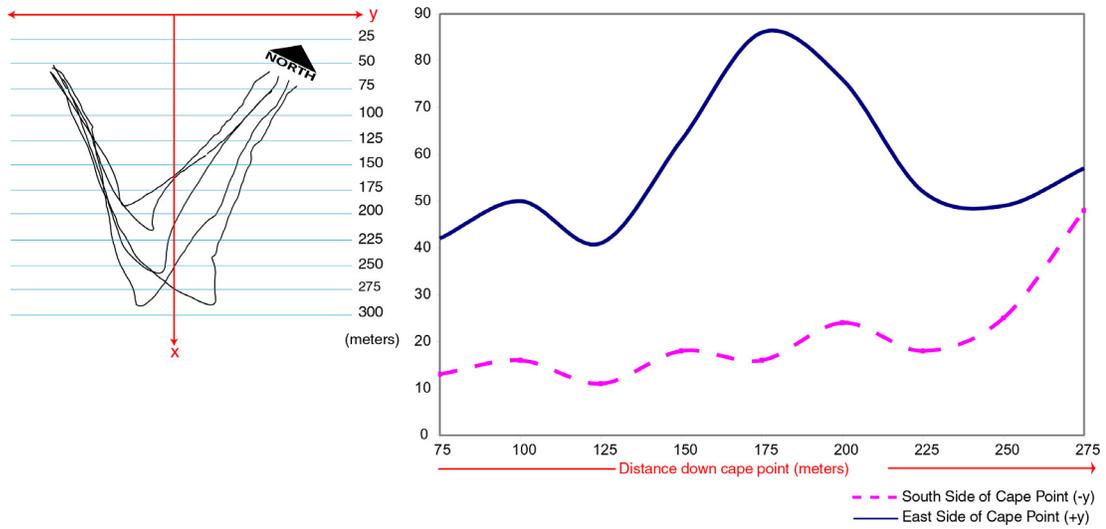


Figure 18. Shoreline variability at Cape Fear point differs significantly on the south and east sides of the cape point. Variability increases dramatically over the seaward-most 50 m of the point.

Volumetric and Morphologic Changes

Topographic surveys can be used to estimate the total volume of sediment comprising the subaerial cape points by integrating the elevation over the surface area of the capes. The cape points were arbitrarily divided into three regions to assess spatial variability in morphologic change, which was hypothesized to increase with distance seaward along the cape point. Figures 19 and 20 illustrate volume changes for the Cape Lookout and Cape Fear points from survey to survey in the three regions.

Cape Lookout

The volume of the Cape Lookout subaerial cape point increased approximately 15% over the study period. Volume changes appear to vary seasonally, typically increasing during the spring and summer and decreasing at other times (Figure 19a). Average monthly volume change for the entire cape point is 1.7%, while the largest change is almost 10% (December 2000 to January 2001).

Variability in volume change at the Cape Lookout point increases with distance from the nominally fixed landward end of the cape. The landward portion comprises approximately 60% of the total volume, the middle portion 30%, and the seaward-most portion approximately 10%. The seaward-most portion of the Cape Lookout cape point experiences the greatest variability, as expected. During the study period the seaward portion lost 61% of its initial volume; superposed on this trend are gains and losses of the same magnitude as the initial volume itself (Figure 19d).

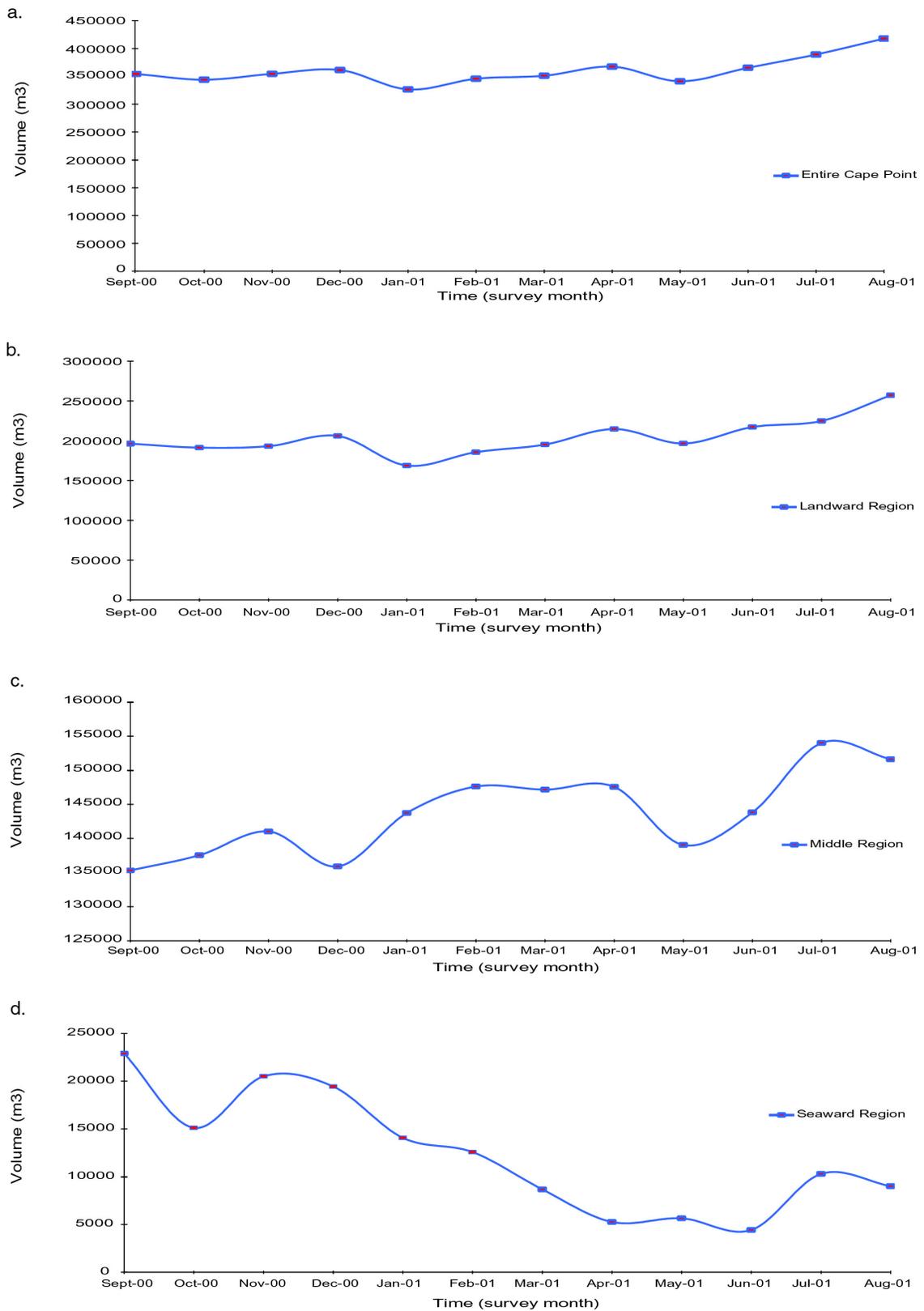


Figure 19. Volume (m³) change for the Cape Lookout subaerial cape. Volumetric curves for (a)the entire cape point, (b)landward portion, (c)middle portion and (d) seaward-most portion show the variability in volume change throughout the subaerial cape point over the survey period. Note: change in scale.

Cape Fear

Volume changes at the Cape Fear point are related to nourishment of Bald Head Island during the period January 2001 to June 2001. The volume of the Cape Fear point was relatively stable from October 2000 to January 2001. From January 2001 to March 2001 the volume of the entire cape point increased by approximately 47% of its volume in January 2001. During the remainder of the study period the volume of the cape point increased about 6% (Figure 20a). Taken as a whole, the average monthly volume change for the entire cape point is 13%. Throughout the study period the Cape Fear point has almost doubled in volume. Spatial variability in volume change at the Cape Fear does not follow the trends at Cape Lookout. While the landward-most portion experienced both gains and losses over the study period, the middle and seaward portions consistently gained volume (Figure 20).

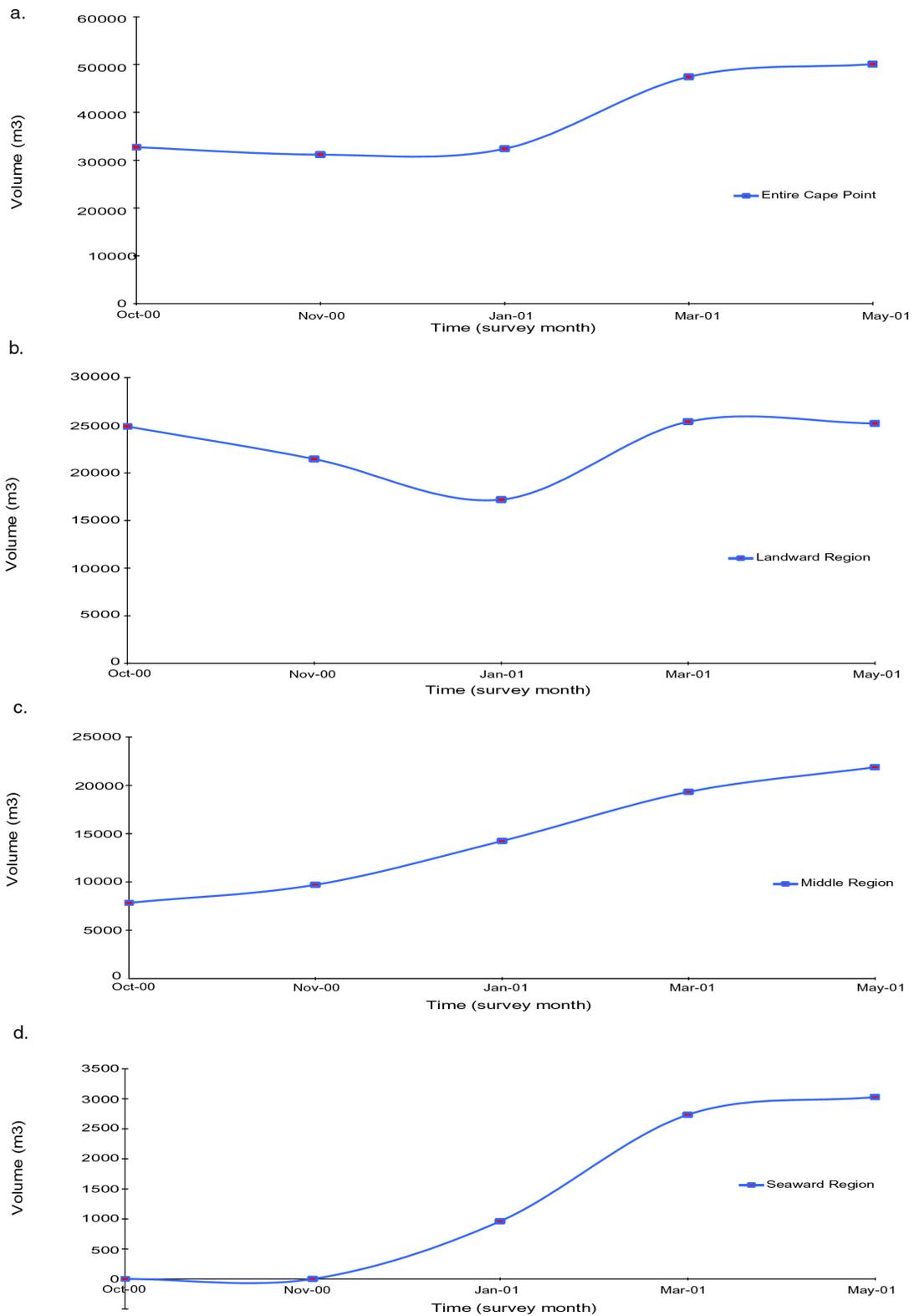


Figure 20. Volume (m³) change for the Cape Fear subaerial cape. Volumetric curves for (a)the entire cape point, (b)landward portion, (c)middle portion and (d) seaward-most portion show the variability in volume change throughout the subaerial cape point over the survey period. Note: change in scale.

Cape Point Clipping Mechanism

Evolution of the seaward-most portion of subaerial cape points at Cape Lookout and Cape Fear depends on both subaerial and subaqueous processes, and is therefore difficult to observe and document with a single mapping technique. Aerial photography, LIDAR and RTK-GPS data document a sequence of morphologic events that appear to provide the dominant mechanism transporting sand from the subaerial cape point to the subaqueous shoals. Figures 21 and 22 describe a typical occurrence of clippings, or large piles of sand just seaward of the cape apex, at Cape Lookout and Cape Fear points. Aerial photos indicate complex bathymetry around the cape point and a channel of deeper water separating the tip of the cape point from a large pile of sand. At low tide bedforms are often visible in the transitional zone between the cape tip and shoals, providing evidence of currents crossing the tip of the cape point that can isolate the bodies of sand at high tide. RTK-GPS and LIDAR data from the region just seaward of the cape point indicate large amounts of sand that was previously of the subaerial cape point. Changes in nearshore wind and wave energy altered the extent and position of the cape point.

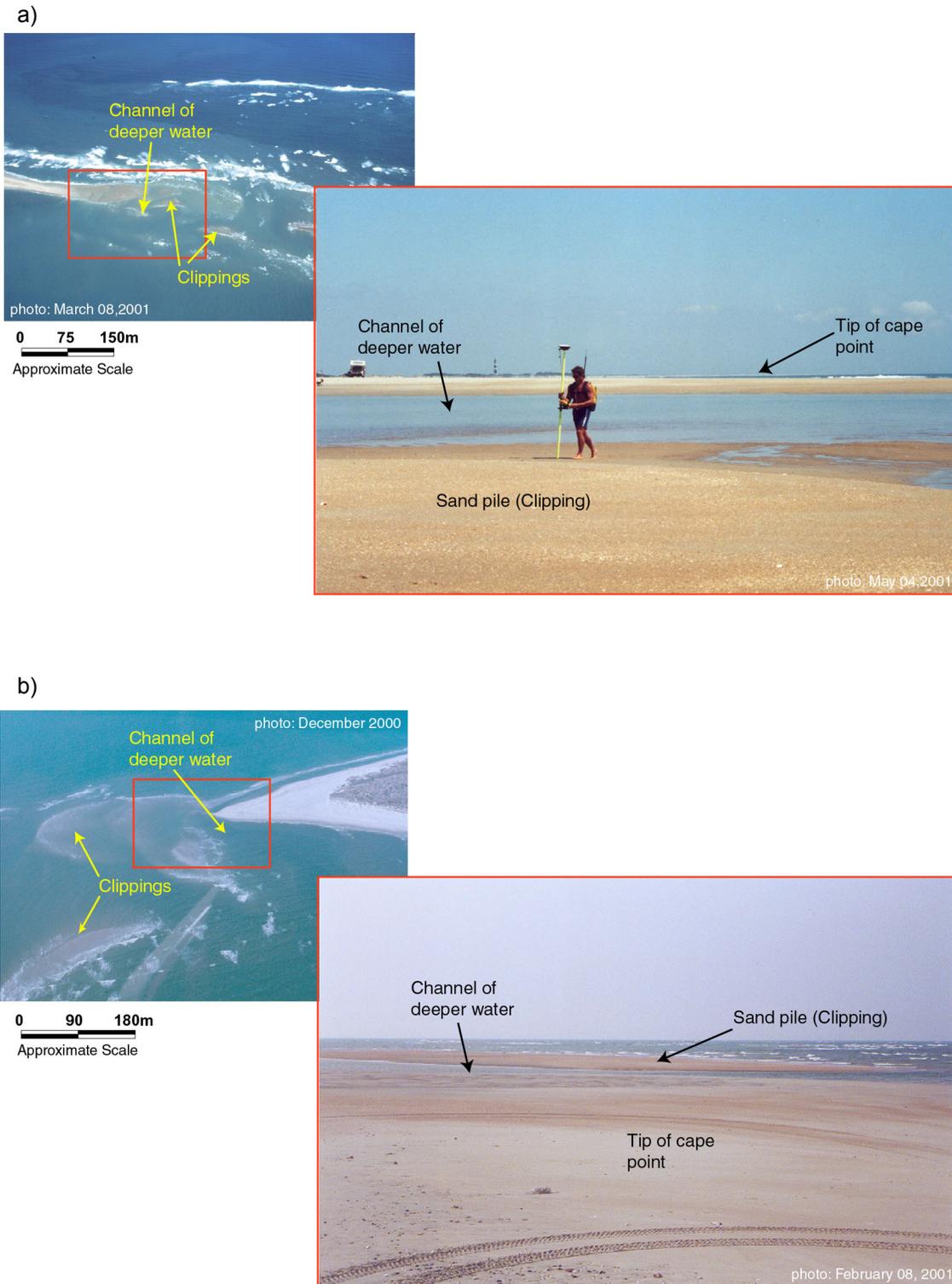


Figure 21. (a)Cape Lookout transitional area at the seaward-most tip of the cape point. Complex bathymetry surrounding the cape point and large piles of sediment separated from the cape point are features that exemplify the clipping mechanism. (b)Cape Fear transitional area at the seaward-most tip of the cape point. The Cape Fear transitional area has similar features to Cape Lookout, illustrating the clipping mechanism at both capes.

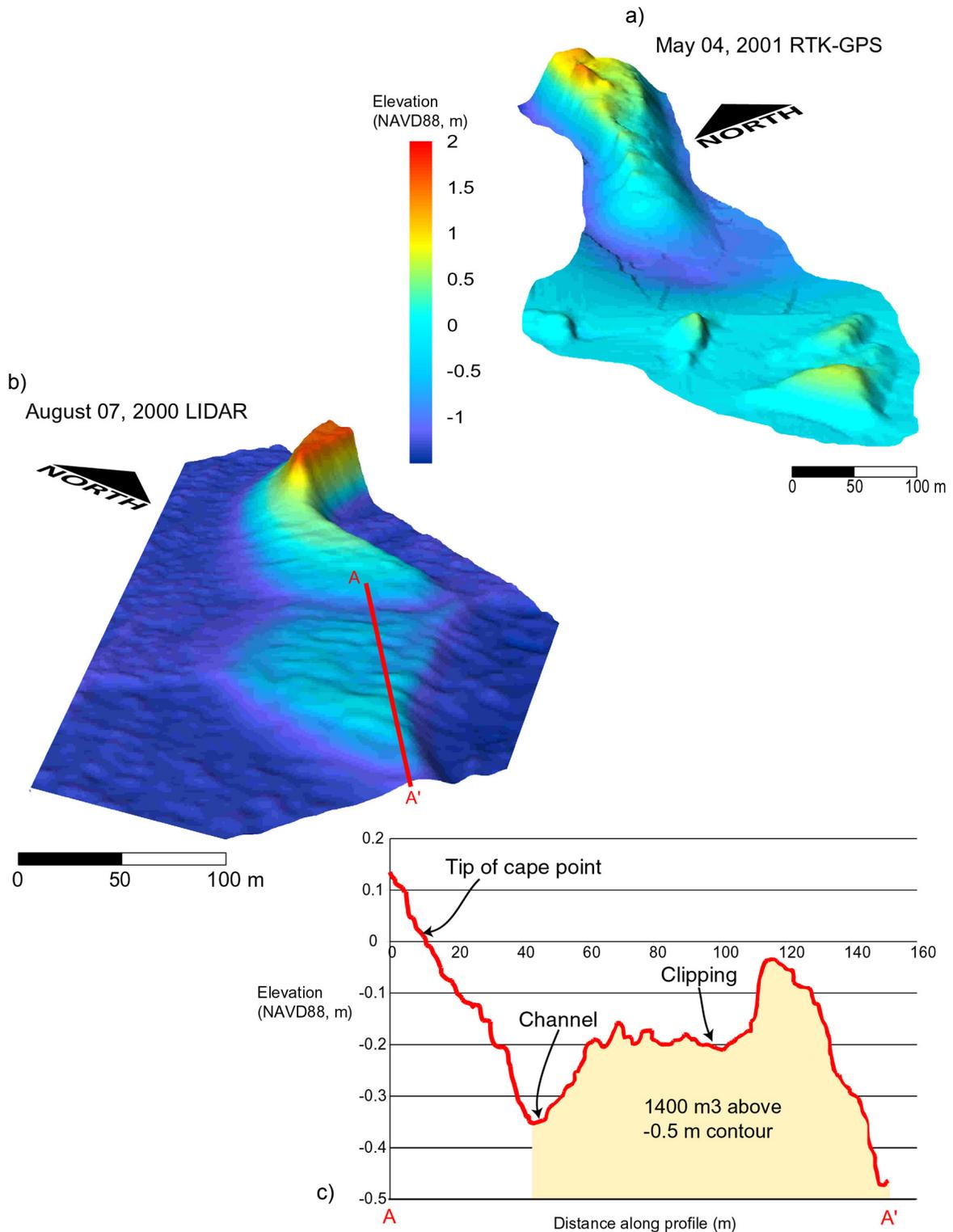


Figure 22. Subaerial topography of the transitional area at the seaward-most tip of the Cape Lookout point from the (a) RTK-GPS survey (May 04, 2001) and (b) LIDAR survey (August 7, 2000) by the National Oceanographic and Atmospheric Administrations Coastal Services Center. (c) Topography and profile slice from A to A' indicates a large clippings just seaward of the cape point and separated from it by a deeper channel.

Figure 23 illustrates a typical clipping event. A less energetic south-southwesterly wind and wave condition can influence the orientation and shape of the cape point by extending the point to the opposing direction, and building the volume (Figure 23-1,2). As a rapid change in the wind and wave direction and magnitude occur, now a more energetic northerly wind and wave energy changes the dominant longshore transport direction to the south along the opposite side of the cape point (Figure 23-3). The seaward-most tip of the cape point can then be clipped off, revealing a retreated cape point, deeper channel of water, and a large pile of sand just seaward of the cape point (Figure 23-4,5). It is then speculated that the clipping and then fate of the sand pile appears to be controlled by the wave generated longshore currents influencing the cape point, and the tidal residual currents flowing around the tip of the cape point. This pile of sand, or clipping, is then in the transitional area between the subaerial cape and cape-associated shoals, and may then be reworked and introduced to the active sedimentary processes of the cape shoals or leaked around the cape point.

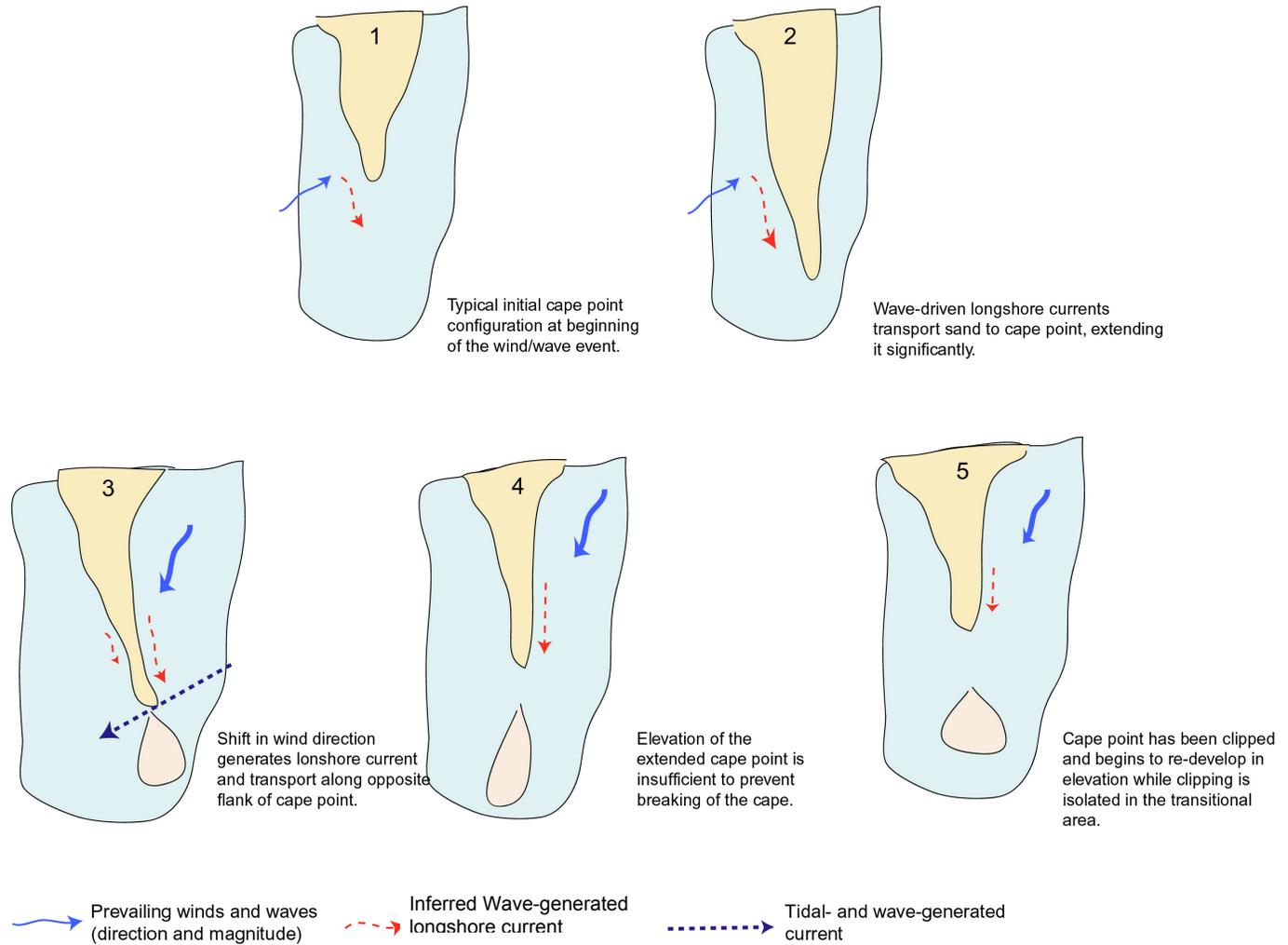


Figure 23. Schematic diagram of the clipping mechanism by which sand moves from the longshore transport system of the cape point shoreline to the subaqueous shoals.

DISCUSSION

Surveys suggest that the subaerial cape point responds directly to changes in the nearshore wind and wave energy. Furthermore, documentation of the changing morphology of the Cape Lookout and Cape Fear points reveal a general mechanism for transporting sand from the subaerial cape point to the shoals; a mechanism called clipping. Three conclusions can be drawn from the surveys and analysis of Cape Lookout and Cape Fear: 1) Changes in shoreline orientation and extent result from changes in the bi-modal nearshore wind and wave energy; 2) variability in shoreline position and morphology increases with distance from the landward end of the cape to the seaward tip; and 3) the seaward-most portion of the subaerial cape point responds strongly to changes in the nearshore wind and wave energy and plays a key role in sediment exchange between the subaerial cape and cape-associated shoal.

Shoreline Change

The shorelines of the cape points vary in orientation and extent on time scales as short as days. At Cape Lookout, the Core Banks or eastern side of the cape point varied little during the survey period compared to the western side of the point. At Cape Fear, the southern or opposing side shows less variation than the eastern side of the cape point. One can speculate that the more stable flank of the cape point is linear due to a relatively consistent and dominant transport direction. Shoreline changes at Cape Lookout and Cape Fear have indicated that the seaward-most portion of both capes is far more variable than the rest of the cape, and this portion is easily influenced.

A particularly rapid change in the orientation and position of Cape Lookout point occurred between the December 2000 and January 2001 surveys and illustrates the

effects of a number of events on the cape point morphology. A northerly wind prior to the December survey generated southerly longshore transport along Core Banks, forcing the seaward tip of the cape point into a south-southwesterly orientation. Although the dominant wind energy from the December survey to the January survey was predominantly northerly, five notable southerly events, one ending at the time of the survey, appeared to have changed the orientation of the cape point into a southeasterly orientation. This rapid change in shoreline position reveals 1) although it is uncertain which of the events caused the changes observed in the survey, the mechanisms responsible for re-orienting the shoreline position work on time scales as short as days to weeks, and 2) the seaward tip of the cape point responds readily to events of minimal magnitude.

Topographic Evolution

The topography of the subaerial cape points at Cape Lookout and Cape Fear is modified in response to wind-and wave-driven longshore currents. Volumetric change calculations for the landward, middle, and seaward-most portions of the cape points show distinct spatial variation of volume change. For both Cape Lookout and Cape Fear, the volume change of the landward portion of the cape points closely resembles the volume change of the entire cape point, as this region contains most of the volume of the cape point. At Cape Lookout, the middle portion of the cape point fluctuates in volume, but steadily increases over the study period. The middle portion of the Cape Fear point also steadily increases over the study period. Variability in volume change compared to the rest of the cape is greatest in the seaward-most portion of the subaerial cape points. The seaward-most portion of the Cape Fear point experienced an overall

positive change in volume, and the seaward-most portion of the Cape Lookout point experienced an overall negative change in volume. These large episodic variations suggest that the seaward-most portion of the cape points is a region of significant and largely one-way transfer of sediment from the cape point to the cape-associated shoals.

Clipping Transport Mechanism

Provided the results of RTK-GPS surveys, LIDAR survey, and aerial reconnaissance surveys of the seaward-most portion of the cape points, documentation of sediment exchange, in a shedding and clipping trend, from the cape point to the cape-associated shoals suggest a particular pathway or mechanism by which the sedimentary processes of the subaerial cape intermingle with the sedimentary processes of the cape-associated shoals. This phenomenon has not only been documented at Cape Lookout, NC but also Cape Fear, NC. Although the Cape Fear point is smaller in size and evolves slightly different, it behaves similar to the Cape Lookout point. Similar interpretations of the clipping mechanism of sediment transport are valid at Cape Fear. Provided the unique behavior of the seaward-most portion of both capes and similarities in documentation of the transitional areas, a mechanism of sediment transport is suggested.

CONCLUSIONS

Repeat surveys of the shoreline position and topography of the subaerial cape point at Cape Lookout and Cape Fear, North Carolina for the period September 2000 to August 2001 show that orientation of the shoreline position and morphology of the cape point respond to changes in the local wind and wave conditions. Correlation of changes in the local wind direction and magnitude to shoreline position clearly indicate that the mechanisms responsible for re-orienting the cape point work on monthly time scales, however, the relationship did not materialize for lesser time scales, probably due to data insufficient to define trends with high intrinsic variability. These changes, working on a relatively short time scale, mimic the long-term synoptic changes of retreat and progradation of the cape points that have been previously documented.

Variability of the cape point morphology increases in the seaward direction. The seaward tip and transitional area of these cusped forelands is a complex area that plays a key role in sediment exchange between the subaerial cape and the cape-associated shoals. While previous research indicates that sedimentary processes in adjacent littoral cells are largely independent of one another and that sediment exchange is limited between the cells, the mechanism by which cape-associated shoals receive sediment from the littoral cells and remove it from the active beach sediment budget has not been previously explained. The clipping mechanism by which sediment is introduced to the cape-associated shoals from the subaerial beach has a significant effect on the evolution of the cape and the adjacent beaches. Furthermore, this mechanism of transport influences the morphology and volume of sediment distributed across the cape and

adjacent beaches. Thus, the evolution of these capes can provide insight to the long-term evolution of the barrier system in which they reside.

Suggestions for Future Work

This reconnaissance study of morphologic evolution suggests a number of interesting questions that should be addressed in future studies. Better correlation of nearshore wave energy to the geomorphic response of the cape point would provide an improved understanding of the factors that drive changes in cape point position and shape. Time-lapse photography or video imagery acquired by a camera looking down at the cape point would allow high temporal resolution studies of the processes by which the cape point meanders and is clipped off, including insight into transport in the channel of water separating the tip of the cape from the ephemeral sand piles at the landward-most end of the shoals.

More detailed surveys of the transitional zone, topographic and bathymetric, could lead to a better understanding of the mechanisms that influence the clipping of the cape point. This aspect of future might focus on whether the orientation changes and clipping evolution at the cape are an example of a self-organized system in a critical state (Bak, 1997).

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Appendix

Metadata Development for Coastline Surveys

Since a generous amount of this particular type of field data was collected over the survey period, the demand for detailed field notes and survey processes documented in the form of metadata was necessary. The Federal Geographic Data Committee approved the Content Standard for Digital Geospatial Metadata (FGDC-STD-001-1998) in June 1998 (<http://www.fgdc.gov/metadata/metadata.html>). Throughout this project the metadata team at the NOAA Coastal Services Center (Charleston, South Carolina) has collaborated in an effort to develop an FGDC compliant metadata tool for surveys of this nature. A detailed description of the content, quality and condition of data, as well as the conditions while the data was being acquired and the instruments used is an integral part of a complete and organized data acquisition and management process.

As the demand for such metadata was discovered through this field-intensive study, a PC-based metadata tool was developed. The NOAA-CSC Metadata Builder has 2 main parts; the metadata builder and the templates. The templates can be modified to fit the users particular project. This tool allows the surveyor or scientist to create a detailed metadata file on a field-PC, while in the field or upon completion of a survey. Unique to this form of metadata are many input fields in the templates that describe the conditions under which the survey occurred. Figure 24 illustrates the metadata builder with a custom template designed for this study. As seen in figure 24, input fields such as weather conditions, ocean conditions, tides, additional notes and start/stop time of survey allow for a detailed record of conditions at the time of survey. An example of metadata generated for a survey at Cape Lookout can be found in Appendix A. As the

future of coastal science evolves, the methods and techniques used to collect meaningful data also evolve. The use of RTK-GPS has proven a very useful tool that aids in the acquisition of accurate elevation and position data. As RTK-GPS is used more frequently and commonly in coastal science, this tool can be very useful to surveyors, scientists, and data managers.

Field	Description
Date of Metadata creation :	Enter date of metadata creation (yyyymmdd)
Weather conditions - sky :	Enter conditions of sky at time of survey
Weather conditions - wind :	Enter wind conditions at time of survey
Weather conditions - temperature :	Enter temperature reading at time of survey
Weather conditions - precipitation :	Enter information on precipitation at time of survey
Additional notes on weather conditions:	Enter any additional weather info here
Ocean conditions - seas :	Enter condition of ocean at time of survey
Ocean conditions - wind :	Enter conditions of ocean winds at time of survey
Ocean conditions - swell direction :	Enter direction of swells
Time of a.m. low tide :	Enter am low tide time - (HHMM)
Time of p.m. low tide :	Enter pm low tide time - (HHMM)
Time of a.m. high tide :	Enter am high tide time - (HHMM)
Time of p.m. high tide :	Enter pm high tide time - (HHMM)
Additional notes:	Record any additional information on ocean conditions here.
Survey start time :	Enter the start time of the survey (yyyymmdd hhmm)
Survey end time :	Enter the end time of the survey (yyyymmdd hhmm)
Date of processing :	Enter the date of processing (yyyymmdd)
Date metadata generated :	Enter the date of metadata creation (yyyymmdd)
Date metadata reviewed :	Enter the date of metadata review (yyyymmdd)

Path/Name for new Record: C:/Metadata/output.met Build the Record

Figure 24. The NOAA-CSC Metadata Builder tool with a custom designed template for this study.

Metadata Sample

Identification_Information:

Citation:

Citation_Information:

Originator:

Department of Marine Earth and Atmospheric
Sciences, North Carolina State university

Publication_Date: 20020106

Title: RTK-GPS Survey

Geospatial_Data_Presentation_Form: Map

Publication_Information:

Publication_Place: Raleigh, NC

Publisher:

Department of Marine Earth and Atmospheric
Sciences, North Carolina State university

Larger_Work_Citation:

Citation_Information:

Originator:

Department of Marine Earth and Atmospheric
Sciences, North Carolina State university

Publication_Date: 20020108

Title: RTK-GPS Survey data

Publication_Information:

Publication_Place: Raleigh, NC

Publisher:

Department of Marine Earth and Atmospheric
Sciences, North Carolina State university

Other_Citation_Details:

This data is x,y,z of the beach collected with a Real Time
Kinematic GPS
system.

Description:

Abstract:

Capes and their associated shoals are part of several national parks and seashores on the North American coast. Capes often form important physical and ecological discontinuities in the coastline, yet their dynamics are poorly understood. Processes controlling the morphology of Capes Hatteras, Lookout and Fear along the coast of North Carolina involve both the submerged, cape-associated shoals and the subaerial cape headland. Direct observation of waves, currents and bathymetry on associated shoals is extremely difficult and often hazardous. Our field-intensive study at the Cape Lookout National Seashore uses the changing geometry of the subaerial point as an easily observed proxy for complex nearshore sediment transport processes at capes. Real-time-kinematic GPS mounted on an all-terrain vehicle was used to generate high-spatial and temporal resolution maps of Cape Lookout. Our long-term study objective is to relate these changes in morphology to nearshore wind and wave energy and direction, and infer sediment transport pathways between the subaerial cape and cape-associated shoals. Findings collected through this study can be conveyed to national seashore and coastal-zone managers and may be extremely relevant to possible beach nourishment projects on adjacent shorelines.

Purpose:
 Supplemental_Information:
 Weather/Survey Conditions:
 Land based observations:
 Sky:sunny
 Wind:SW at approx. 5-10 km\hr
 Temp:50-60s
 Precipitation:n\a
 Notes:Large Nor'easter just passed up the coastline

 Ocean based observations:
 Seas:8-10 feet
 Wind:SW 15-25 km\hr
 Swell Direction:NE long period swell
 Tides:
 low (am):1120
 low (pm):1203
 high (am):0552
 high (pm):0614
 Notes:Aerial photos of the cape were taken during this survey

 Time_Period_of_Content:
 Time_Period_Information:
 Range_of_Dates/Times:
 Beginning_Date: 20010308 0900
 Ending_Date: 20010308 0200
 Currentness_Reference: Publication Date
 Status:
 Progress: Complete
 Maintenance_and_Update_Frequency: Unknown
 Spatial_Domain:
 Bounding_Coordinates:
 West_Bounding_Coordinate: 76 32 58.98
 East_Bounding_Coordinate: 76 31 39.26
 North_Bounding_Coordinate: 34 36 35.14
 South_Bounding_Coordinate: 34 34 35.70
 Keywords:
 Theme:
 Theme_Keyword_Thesaurus: None
 Theme_Keyword: Shoreline
 Theme_Keyword: Beach Profiles
 Theme_Keyword: Beach Renourishment
 Theme_Keyword: Erosion
 Theme_Keyword: Beach Data
 Theme_Keyword: Nearshore Bathymetry
 Theme_Keyword: GIS
 Theme_Keyword: GPS
 Place:
 Place_Keyword_Thesaurus: None
 Place_Keyword: North Carolina
 Place_Keyword: Atlantic Coast
 Place_Keyword: Southeast Coast
 Access_Constraints: None
 Use_Constraints: Not for Navigational Purposes
 Point_of_Contact:
 Contact_Information:

Contact_Organization_Primary:
 Contact_Organization:
 Department of Marine Earth and
 Atmospheric Sciences, North Carolina State University
 Contact_Person: Dave Bernstein and/or Tom Drake
 Contact_Position: Research Specialist
 Contact_Address:
 Address_Type: mailing and physical address
 Address: 1125 Jordan Hall, NCSU Box 8208
 City: Raleigh
 State_or_Province: North Carolina
 Postal_Code: 27695-8208
 Country: USA
 Contact_Voice_Telephone: (919)515-7838
 Contact_Facsimile_Telephone: (919)515-7802
 Contact_Electronic_Mail_Address:
 dbernste@coastal.edu or
 drake@ncsu.edu
 Hours_of_Service:
 Monday-Friday, 8am-5pm, Eastern Standard
 Time
 Native_Data_Set_Environment:
 Data_Quality_Information:
 Attribute_Accuracy:
 Attribute_Accuracy_Report:
 GPS quality was determined through post-processing,
 Real-time accuracy checks of horizonatal and vertical RMS
 values
 Logical_Consistency_Report:
 GPS data was overlayed with
 previous B.E.R.M. data and aerial imagery to visualize
 logical consistancy.
 Completeness_Report:
 Positional_Accuracy:
 Horizontal_Positional_Accuracy:
 Horizontal_Positional_Accuracy_Report:
 Base station horizontal position was determined by a
 baseline solution from more
 than 3 known geodetic control benchmarks.
 Vertical_Positional_Accuracy:
 Vertical_Positional_Accuracy_Report:
 Base station horizontal position was determined by a
 baseline solution from more
 than 3 known geodetic control benchmarks.
 Lineage:
 Source_Information:
 Source_Citation:
 Citation_Information:
 Originator:
 Department of Marine Earth and Atmospheric
 Sciences, North Carolina State University
 Publication_Date: 2001
 Title: RTK-GPS Survey data
 Edition:
 Geospatial_Data_Presentation_Form: map
 Publication_Information:
 Publication_Place: Raleigh, NC

Publisher:
 Department of Marine Earth and Atmospheric
 Sciences, North Carolina State University
 Source_Scale_Denominator:
 Type_of_Source_Media:
 Source_Time_Period_of_Content:
 Time_Period_Information:
 Range_of_Dates/Times:
 Beginning_Date: 2000
 Ending_Date: 2001
 Source_Currentness_Reference: Publication Date
 Source_Citation_Abbreviation:
 Source_Contribution:
 Used to determine erosion rates,
 volumes, changing geometry of the beach
 Process_Step:
 Process_Description:
 Position and elevation survey data are aquired with a
 Real-Time-Kinematic Global Positioning Satellite (RTK-GPS)
 system.
 Process_Date: 20010308
 Process_Contact:
 Contact_Information:
 Contact_Organization_Primary:
 Contact_Organization:
 Department of Marine Earth and
 Atmospheric Sciences, North Carolina State University
 Contact_Person: Dave Bernstein and/or Tom Drake
 Contact_Position: Research Specialist
 Contact_Address:
 Address_Type: mailing and physical address
 Address: 1125 Jordan Hall, NCSU Box 8208
 City: Raleigh
 State_or_Province: North Carolina
 Postal_Code: 27695-8208
 Country: USA
 Contact_Voice_Telephone: (919)515-7838
 Contact_Facsimile_Telephone: (919)515-7802
 Contact_Electronic_Mail_Address: dbernste@coastal.edu or
 drake@ncsu.edu
 Hours_of_Service:
 Monday-Friday, 8am-5pm, Eastern Standard
 Time
 Spatial_Reference_Information:
 Horizontal_Coordinate_System_Definition:
 Planar:
 Grid_Coordinate_System:
 Grid_Coordinate_System_Name: Universal Transverse Mercator
 Universal_Transverse_Mercator:
 UTM_Zone_Number: 18N
 Transverse_Mercator:
 Scale_Factor_at_Central_Meridian:
 Longitude_of_Central_Meridian:
 Latitude_of_Projection_Origin:
 False_Easting:
 False_Northing:
 Planar_Coordinate_Information:

Planar_Coordinate_Encoding_Method:
 Coordinate_Representation:
 Abscissa_Resolution:
 Ordinate_Resolution:
 Planar_Distance_Units: meters
 Geodetic_Model:
 Horizontal_Datum_Name: North American Datum of 1983
 Ellipsoid_Name: WGS 1984
 Semi-major_Axis: 6378137
 Denominator_of_Flattening_Ratio: 298.257223563
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 Detailed_Description:
 Entity_Type:
 Entity_Type_Label: profiles, shoreface and nearshore
 Entity_Type_Definition:
 Entity_Type_Definition_Source:
 Overview_Description:
 Entity_and_Attribute_Overview:
 Entity_and_Attribute_Detail_Citation:
 Distribution_Information:
 Distributor:
 Contact_Information:
 Contact_Organization_Primary:
 Contact_Organization:
 Department of Marine Earth and
 Atmospheric Sciences, North Carolina State University
 Contact_Person: Dave Bernstein and/or Tom Drake
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 Contact_Address:
 Address_Type: mailing or physical address
 Address: 1125 Jordan Hall, NCSU Box 8208
 City: Conway
 State_or_Province: North Carolina
 Postal_Code: 27695-8208
 Country: USA
 Contact_Voice_Telephone: (919)515-7838
 Contact_Facsimile_Telephone: (919)515-7802
 Contact_Electronic_Mail_Address: dbernste@coastal.edu or
 drake@ncsu.edu
 Hours_of_Service:
 Monday-Friday, 8am-5pm, Eastern Standard
 Time
 Resource_Description: This data set is an RTK-GPS dataset
 Distribution_Liability:
 Users must assume responsibility to
 determine the appropriate use of these data.
 Standard_Order_Process:
 Digital_Form:
 Digital_Transfer_Information:
 Format_Name: x,y,z text format
 Digital_Transfer_Option:
 Offline_Option:
 Offline_Media: none
 Recording_Format:
 Compatibility_Information: unknown
 Fees: none
 Metadata_Reference_Information:

Metadata_Date: 20020106
Metadata_Review_Date: 20020106
Metadata_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization:
Department of Marine Earth and
Atmospheric Sciences, North Carolina State University
Contact_Person: Dave Bernstein and/or Tom Drake
Contact_Position: Research Specialist
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Address_Type: mailing and physical address
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City: Raleigh
State_or_Province: North Carolina
Postal_Code: 27695-8208
Country: USA
Contact_Voice_Telephone: (919)515-7838
Contact_Facsimile_Telephone: (919)515-7802
Contact_Electronic_Mail_Address: dbernste@coastal.edu or
drake@ncsu.edu
Hours_of_Service:
Monday-Friday, 8am-5pm, Eastern Standard
Time
Metadata_Standard_Name: FGDC CSDGM
Metadata_Standard_Version: FGDC-STD-001-1998