group B (Fig. 1b), the wave frequency decreases with time. This decrease is caused by successively higher reflection levels in the thermosphere from about 100 to 125 km for ray paths having slightly varying vertical angles of propagation.

The scientific value of the sonic booms from supersonic planes lies in the fact that they can be used as a probe of the upper atmosphere. The frequency of the received signal is an indication of the reflection height, and the observed trace velocity gives the sound velocity at this reflection height when corrected for the effects of nonlinearity resulting from the overpressure of the impulse. Thus we are in a position to determine the sound velocity from one or more reflection heights (depending on the number of signals received) in regions that are extremely difficult to observe otherwise. The Concorde flies a known route on a regular basis, thus providing sound sources at known positions in time and space. The great variations in amplitude, frequency, velocity, and arrival times of the recorded acoustic signal are all caused by the daily variations in the temperature-wind profile of the atmosphere. To determine these parameters we intend to use data from the present Lamont-Doherty array as well as from other arrays to be installed at critical locations.

Because signal is being generated continuously along the flight path, increased instrumental monitoring at judicious locations will provide greatly increased information about the atmosphere. For example, data from the Durham array show characteristics different from those recorded at Lamont-Doherty [note the four-part wave group A recorded at Durham (Fig. 1e)]. Also, acoustic impulses from the shock waves generated during the return trip of the Concorde to Europe have been regularly received at Durham and not at Palisades. (During the return journey, the shock wave, after the plane becomes supersonic, is directed away from Palisades and no signal is recorded.) The shock wave has a velocity component toward Durham so that impulses are detectable there (6).

NAMBATH K. BALACHANDRAN
Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964
WILLIAM L. DONN
Lamont-Doherty Geological Observatory and *City College of New York, New York 10031*
DAVID H. RIND
Lamont-Doherty Geological Observatory

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Shoreline Forms and Shoreline Dynamics

Abstract. *Atlantic coast barrier-island shorelines are sinuous in plan view, with curvatures ranging in size from cusps to capes. The orientation of shoreline segments within the larger of these sinuous features (10 to 15 kilometers between apexes) is significantly related to shoreline dynamics.*

Atlantic coast sandbeach and barrier-island shorelines are seldom long and straight, when viewed in plan, but rather sinuous in form. Some of the along-the-shore variation is in the form of organized patterns ranging in size from beach cusps to very large shoreline arcs. Crescentic coastal landforms are products of varying sea states, tides, and sea levels. The smaller features appear, disappear, and migrate along the shoreline; the larger ones establish the spatial context for along-the-shore processes, including the distribution of erosion and storm-

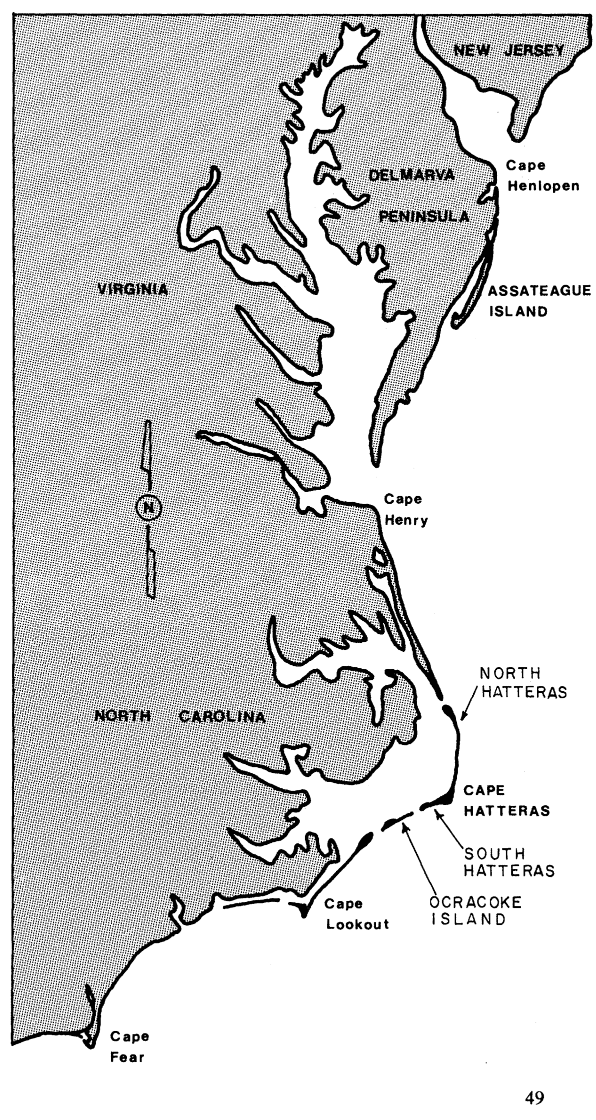


Fig. 1. Mid-Atlantic coast from New Jersey to North Carolina, where the relationship between coastal processes and coastal configuration is being investigated. Data on historical coastal erosion and current coastal orientation have been collected and analyzed for Assateague Island, Hatteras Island, and Ocracoke Island.

overwash processes (1). The larger features may be coupled with the subaqueous topography seaward of the inshore zone and storm-generated "coastal jets" associated with variations in the angle of wave attack (2, 3).

Although efforts are under way to formulate a theoretical framework for the processes responsible for longshore topographic variation (4), empirical research is still needed to characterize shoreline features in terms of their distribution in time and space. We have developed a monitoring system based on Landsat II imagery and aerial photography that provides excellent spatial and temporal data on large-scale crescentic shoreline features of the mid-Atlantic coast (Fig. 1). We now report a strong relationship between shoreline orientation and rates of shoreline change.

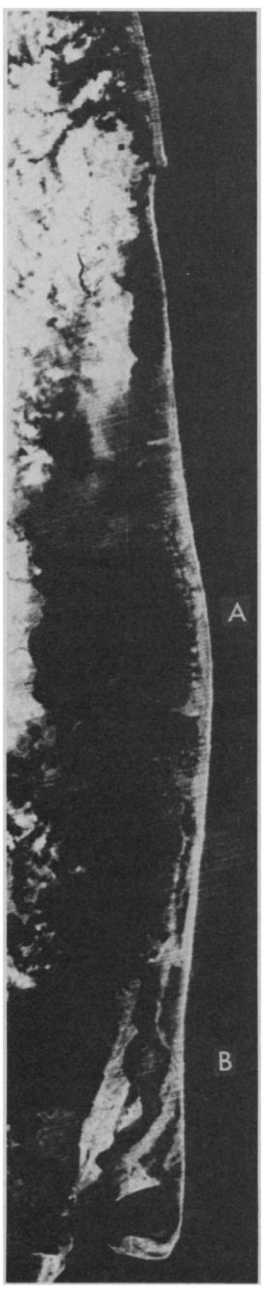
With recent developments in nearshore hydrodynamics, there has been renewed interest in longshore variations of inshore processes and their relationship to rhythmic and crescentic beach morphology, shoreline erosion, and overwash processes (5). Along the mid-Atlantic coast these crescentic forms included small cusps only 1 m across; larger beach cusps up to tens of meters; giant beach cusps, or shoreline sand waves, from 100 to 3000 m long; secondary capes; and capes (6). The larger of these forms are the most important in determining where sandbeaches and barrier islands change most rapidly (7). Our investigation was designed to test whether the orientation of shoreline segments within larger sinuous features (up to 10 m long) are correlated with shoreline change.

The orientation of the arcuate shoreline segments along Assateague Island (60 km) and the Outer Banks of North Carolina (130 km) was measured from Landsat II imagery at scales of both 1:80,000 and 1:250,000 and from high-altitude aerial photography at a scale of 1:130,000 (see Fig. 2). Long-term trends in coastal dynamics were determined by mapping trends in shoreline erosion and storm-surge penetration changes from historical aerial photography spanning four decades.

Using an orthogonal grid system with transects at 100-m intervals along the coast, we recorded, to the nearest 5 m, each point at which the shoreline and the storm-overwash penetration line intersected the across-the-shore transects. This step was repeated up to seven times with aerial photographs dating from 1934 to 1974. To determine the orientation of shoreline segments within the larger crescentic forms, we used Landsat II imagery at 1:80,000 and 1:250,000. By experimenting, we have developed a simple method for determining orientation along the coast which does not require digital processing of raw Landsat data.

A straightedge is placed along each relatively straight segment of the coast within the larger arcs and a line is drawn on an overlay. The point where adjacent lines intersect, termed a "node," marks the place where the angle of the coast changes. The lengths of these segments are measured and their orientations relative to a north-south or northeast line are then recorded (Fig. 3). Each node is located by the nearest 100-m transect of our historical data. There is some subjectivity in this method; therefore we repeated the process at least five times. These data were then put into a digital form compatible with a computer program written for historical shoreline analysis.

Figure 3 illustrates the magnitude of shoreline change along Assateague Island from Chincoteague Inlet to Ocean City Inlet and shows the mean rate of recession plus 1 standard deviation (S.D.) measured from aerial photography. Coastal sections with high erosion and storm-surge penetration are represented by peaks, which consequently also indicate points of high vulnerability to future storm-surge penetration. Figure 3 also shows the shoreline form or orienta-



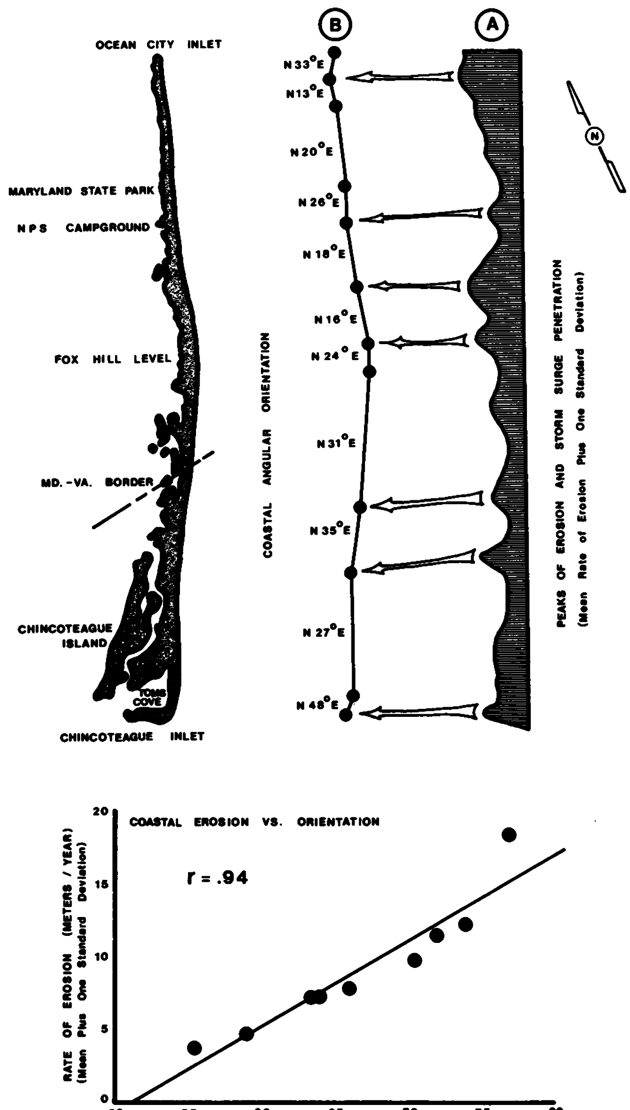


Fig. 2 (left). Assateague Island. Even this small-scale Landsat II image of Assateague Island shows several broad arcuate trends in the shoreline. (A and B) The sections of the island with the greatest variability of shoreline erosion and storm-surge penetration. Fig. 3 (right). Coastal orientation and coastal erosion for Assateague Island. High correlations have been found between coastal orientation and rates of erosion on Assateague Island when the shoreline is examined in the mesoscale range (the mean length of segments of the coast is 5 to 10 km).

tion measured on the Landsat imagery. Each break in the line represents a point along the coast where relatively straight trends within one of the larger arcs intersect.

The distribution of rates of shoreline change and orientation (Fig. 3) indicates that the erosional and storm-overwash areas are associated with the configuration of the island. In most cases, the closer the shoreline trends approach a north-south orientation, the greater the recession rates. We further tested with correlation the relationship between orientation of segments and mean recession rates for each segment. We were able to define 15 segments along Assateague from a Landsat II imagery enlargement of 1:80,000. The correlation coefficient (r) between coastal orientation (degrees north of east) and shoreline recession (mean + 1 S.D., meters per year) was .44. When nine segments were defined from a smaller-scale enlargement of 1:250,000, r increased to .94 (Fig. 3). It is clear that when the scale of a Landsat enlargement is increased, smaller crescentic features appear which are not related to the mesoscale processes and the correlation coefficient is reduced.

We performed the same tests for the barrier islands of North Carolina; however, the shoreline trend of the Outer Banks changes abruptly at Cape Hatteras, so the islands were stratified into three reaches—Ocracoke, South Hatteras, and North Hatteras (Fig. 1). Ocracoke, like Assateague, shows very high correlation (r = .94) between orientation and shoreline recession. The correlation for South Hatteras drops to r = .49, and North Hatteras has the weakest correlation (r = .39).

These areas are all in the same climatic regime, so the process-response relationships should be similar. With the exception of an occasional hurricane, winter extratropical storms cause the most widespread coastal change along the mid-Atlantic. As these storms move northeast with wind fields circulating counterclockwise, the highest and most damaging waves approach the coast from the northeast. The mean orientation for North Hatteras is 183.5°, for Assateague 156.5°, for Ocracoke 121.5°, and for South Hatteras 107.6°, all degrees north of south. There appears to be a high-energy orientation window centered around the northeast. If segments of the mid-Atlantic coast have this orientation, the rate of erosion and distance of storm-surge penetration along those segments increase (Fig. 4).

Included within our test site are engineering structures that greatly alter the inshore sediment transport processes. For example, the northern 10 km of Assateague Island have been rapidly eroding since the Ocean City inlet jetties were built in 1933—the rate has been approximately 12 m/year since 1934. Since this island segment is not undergoing natural change, when it was eliminated from our tests r increased to .99.

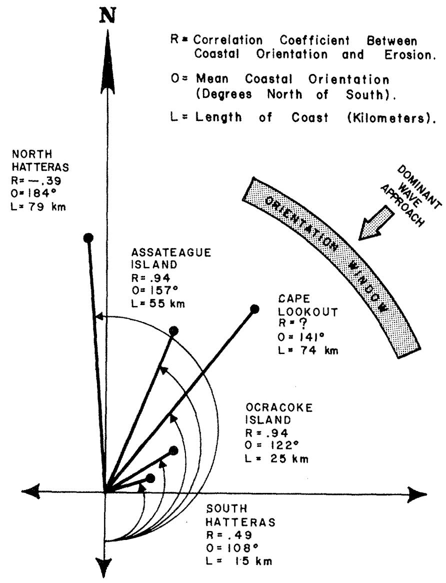


Fig. 4. Orientation and erosion statistics for five major segments of mid-Atlantic barrier islands. This polar coordinate plot of the mean orientation of the mid-Atlantic coast barrier islands suggests that there is an orientation window due approximately northeast. If the mean orientation of a large section of sedimentary coast is found, then the following relationship holds: as smaller straight-line segments of large crescentic or arcuate patterns of that coastal section approach a more north-south orientation (as they lie more perpendicular to the dominant wave approach) the rate of erosion increases.

We conclude that shoreline configuration is functionally related to organized mesoscale processes within the inshore zone and that the fluid motions responsible for large-scale crescentic shoreline forms are consistent along the mid-Atlantic coast. Our results are also consistent with Davies' (*3*) description of orientations in swell-dominated coasts. However, on complex storm-dominated coasts a greater along-the-coast variation in wave transformation processes appears to determine equilibrium configuration.

ROBERT DOLAN
BRUCE HAYDEN
JEFFREY HEYWOOD
Department of Environmental Sciences, University of Virginia, Charlottesville 22903
LINWOOD VINCENT
Waterways Experiment Station, U.S. Army Corps of Engineers, Vicksburg, Mississippi 39180

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Somali Current: Recent Measurements During the Southwest Monsoon

Abstract. *The Somali Current was measured at approximately maximum strength for the year during the southwest monsoon on 11 and 12 August 1975 (approximately 1 1/2 days) at stations spaced 20 to 35 kilometers apart. These measurements permit a nearly synoptic detailed mapping of the temperature structure of a major western boundary current.*

The Somali Current occurs seasonally, developing during the southwest monsoon in the Indian Ocean approximately between May and September each year. It flows northeast along the East African coast between about 4°S and 12°N and reaches its greatest velocity during July and August near 5°N to 10°N, where speeds of up to 350 cm/sec at the surface have been observed (*1*). The directly measured volume transport during that time was 62×10^6 m^3/sec in the upper 200 m across a section 350 km wide. Although the current is comparable to the Gulf Stream or the Kuroshio, it is relatively shallow (upper 200 to 400 m) and appears to be basically wind-driven. Surveys of the circulation off the Somali coast show that the current turns strongly offshore eastward and can be associat-