CHAPTER 277

Transverse Bars in Duck, North Carolina

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Abstract

In 1985, unusual streaks were first seen in time exposure images of nearshore wave breaking. These features were persistent from image to image and ran perpendicular or oblique to the shoreline. They have been observed both between the shoreline and inner bar and offshore of the inner bar, and have a typical longshore wavelength of ~40-130 m, substantially shorter than normal sand bar length scales. Comparison with bathymetric data collected by the CRAB showed the bands to be bathymetric ridges with a relief of 0.3-0.5 m.

Both intensity transects as well as geometrically rectified images were used to determine the length scales of the bars. Longshore length scales of offshore bars (mean spacing of 131 m) were typically three times the spacing of trough bars (mean spacing of 41 m). The offshore limit of the visible features in the trough varied from as short as 5 m to a maximum of 35 m.

Frequency of occurrence statistics for the bars were determined by viewing Argus data from 1987-1995. Trough bars appeared in the images an average of 62 days/year while offshore bars appeared 41 days/year although there was substantial interannual variability. Offshore bar occurrence is more frequent in the winter, and trough bar occurrence is more frequent in the summer.

Introduction

The classic model of a sandbar is a large-scale feature aligned parallel to the shoreline. Sandbars that are oriented slightly oblique to the shoreline have also been observed and are called welded bars. In 1952, Shephard described a feature oriented perpendicular or at a high angle to the shoreline with a relatively short length scale that he called a transverse bar. Only a few studies have been done on these transverse bars, including Barcilon and Lau's (1973) and Niedoroda and Tanner's (1970) work on transverse bars off the coast of Florida.

In 1985, similar features were first observed in time exposure images off the coast of Duck, North Carolina. Figure 1a shows an oblique snapshot from January 10, 1994. The vegetated dunes, dry beach, and shoreline are evident, as is the pattern of breaking waves in the nearshore. By contrast, Figure 1b shows an oblique ten-minute time exposure. The time-averaged breaking waves now show up as smooth bands, clearly delineating the shoreline (from the shorebreak) and the

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Figure 1. Images from Duck, NC. a). Snapshot from January 10, 1994. b). 10-minute time exposure from January 10, 1994. Transverse features are evident in the trough as well as offshore of the shore-parallel bar. Box shows area rectified in Figure 2.

offshore bar (Lippmann and Holman 1989). Intermediate-scale white bands, oblique to the shoreline, are also obvious in the trough, as well as offshore of the shore-parallel bar. Research has been carried out on these features to first determine whether or not the oblique bands in the video images are real bathymetric features or simply an artifact of the imaging technique. Statistics of the features, such as their frequency of occurrence and longshore and cross-shore lengths were then calculated.

Methodology

The data were taken at the Field Research Facility (FRF) at Duck. Duck is a dune-backed beach located on one of the barrier islands of the Outer Banks. It is a low-energy, intermediate to reflective beach that is barred. An inner bar is located at ~125 m offshore and an outer bar is also present at times. The spring tide range is 1.6 meters and the mean water level is 0.35 m above NGVD. The average annual breaker height is 88 cm (Birkemeier1981). The study area for our research was a 1700 meter stretch along the beach.

The data were collected automatically as part of the Argus program. An Argus station is a video camera operated by a personal computer. Every hour, both a snapshot and a ten-minute time expose are taken of the nearshore region. These images are sent back to the Coastal Imaging Lab at Oregon State University every night. A data set of images sampled with Argus is available for Duck spanning 10 years (1986-1996).

A great deal of information can be extracted from time exposures such as the one shown in Figure 1b. Since the geometries of the video camera are known, the exact location on the ground for each pixel in the image is also known. The coordinate system that is used for the images is the FRF coordinate system. The video camera is located at x=32.54, y=585.78, with x and y increasing positively offshore and away from the camera, respectively.

One method of determining length scales and positions of the features is to use geometrically rectified images (plan views) of the study area. Knowledge of the camera geometries allows a rectification of a region on an oblique image to be made. (Figure 2). Measurements such as longshore length spacing, cross-shore position and cross-shore length can be manually made from such rectifications. Transects can also be taken along the rectification, or along the oblique images, to measure intensity. Intensity data were compared with bathymetric data that were collected using the FRF's Coastal Research Amphibious Buggy (CRAB) to determine if the features have a bathymetric nature.

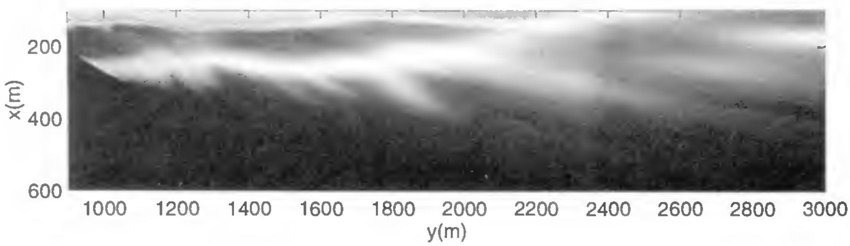

Figure 2. Rectification of boxed area in Figure 1b. Measurements can be made manually from the rectification.

In order to determine the frequency of occurrence of the bars, 8 years of Argus images (1987-1994) were viewed. One image from each day was studied for a total of 2600 images There were some days when no data was available due to equipment failure, bad weather, or other reasons that an image could not be obtained. In order to quantify the presence/absence of transverse bars, each image was given a rating on a scale of 0-5, with 0 being no evidence of transverse bars and 5 being a clear indication of multiple transverse bars. A rating was given both for the *trough bars* (transverse bars found in the trough) as well as *offshore bars* (transverse bars found offshore of the shore-parallel bar). Figure 3 shows examples of images that were given ratings of 1, 3, and 5.

All the images were separated into two categories. An image that was given a rating of 3, 4, or 5 was considered a day in which bars were present. Images that received a rating of 0, 1, or 2 were considered as days in which bars were not present.

Results

The first objective of this study was to determine the persistence of the intensity streak features to insure that they are not random processing features. Longshore intensity transects were taken along a line at x=145 m, from y=790 to 1060 m, for a series of 4 hours (5 images) for January 10, 1994 (Figure 4a). From Figure 4b, it is evident that there was a peak in intensity where there was a white band in the time exposure. This figure also shows that intensity peaks were persistent over substantial periods, including tidal variations, suggesting that these features are not a random artifact of the image processing. Figure 5 shows intensity transects that were taken across a set of offshore transverse bands for 3 consecutive days in November of 1993. Transects were taken at x=300 m, from y=1200 m to 1700 m. The intensity maxima and corresponding white bands in the video images persisted for a period of days, supporting the fact that these features are real, not artifacts.

On July 18, 1995, a detailed CRAB survey was carried out to determine if the white bands in the images are real bathymetric features. Figure 6a shows a transect along which intensity data were taken and also shows the transect along which bathymetric data were collected. Intensity and depth along the transects in Figure 6a are shown in Figure 6b. It is evident that intensity maxima correspond to bathymetric highs and intensity minima correspond to bathymetric lows, proving that the oblique bands in the video images are ridges. The bathymetric data showed the relief of these bars to range from 0.3-0.5 m.

Length scales and positions for both the trough and offshore bars were calculated from intensity plots and rectified images. The mean longshore length spacing (distance between two consecutive bars), distance offshore (offshore extent of bars as measured from the shoreline), and cross-shore length of the bars, were determined. Longshore length spacing was determined using 18 images for trough transverse bars and 33 images for offshore transverse bars. Five images (up to 3 bars per image) were used to determine the distance offshore and cross-shore length for trough bars, and 7 images (up to 3 bars per image) were used to calculate those statistics for the offshore bars. These data are summarized in Tables 1 and 2 for trough and offshore bars, respectively.

Figure 3. Examples of ratings on a scale of 0-5 that were given to images. a). Time exposure from November 13, 1993. Trough bars were given a rating of 1. b). Time exposure from November 11, 1994. Trough bars were given a rating of 3. c). Time exposure from February 9, 1993. Both trough and offshore bars were given a rating of 5.

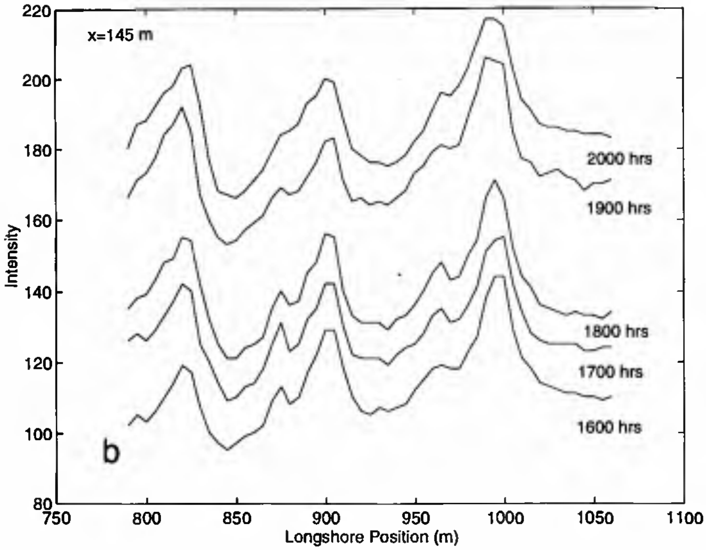

Figure 4. a). Time exposure from January 10, 1994 showing transverse bars in the trough. Transects along which intensity data were collected for 5 consecutive images are also shown. b). Intensity vs. longshore length from 1600-2000 hours along transect shown in a). This graph shows that the bars remain fixed over a period of 4 hours.

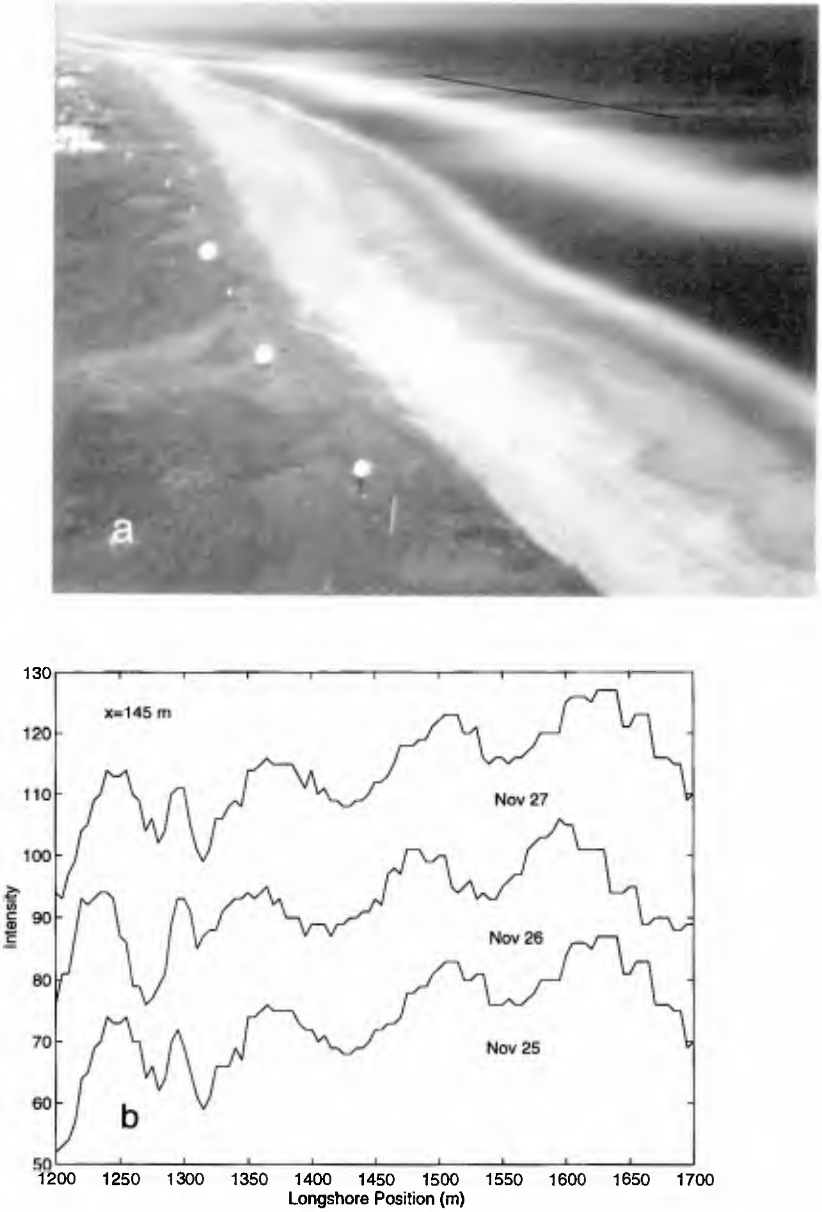

Figure 5. a). Time exposure from November 27, 1993 showing transverse bars offshore of the inner bar. Transects along which intensity data were collected are also shown. b). Intensity vs. longshore position for November 25, 26, and 27, 1993 along transects shown in a). This graph shows that most of the bars remain fixed over a period of days.

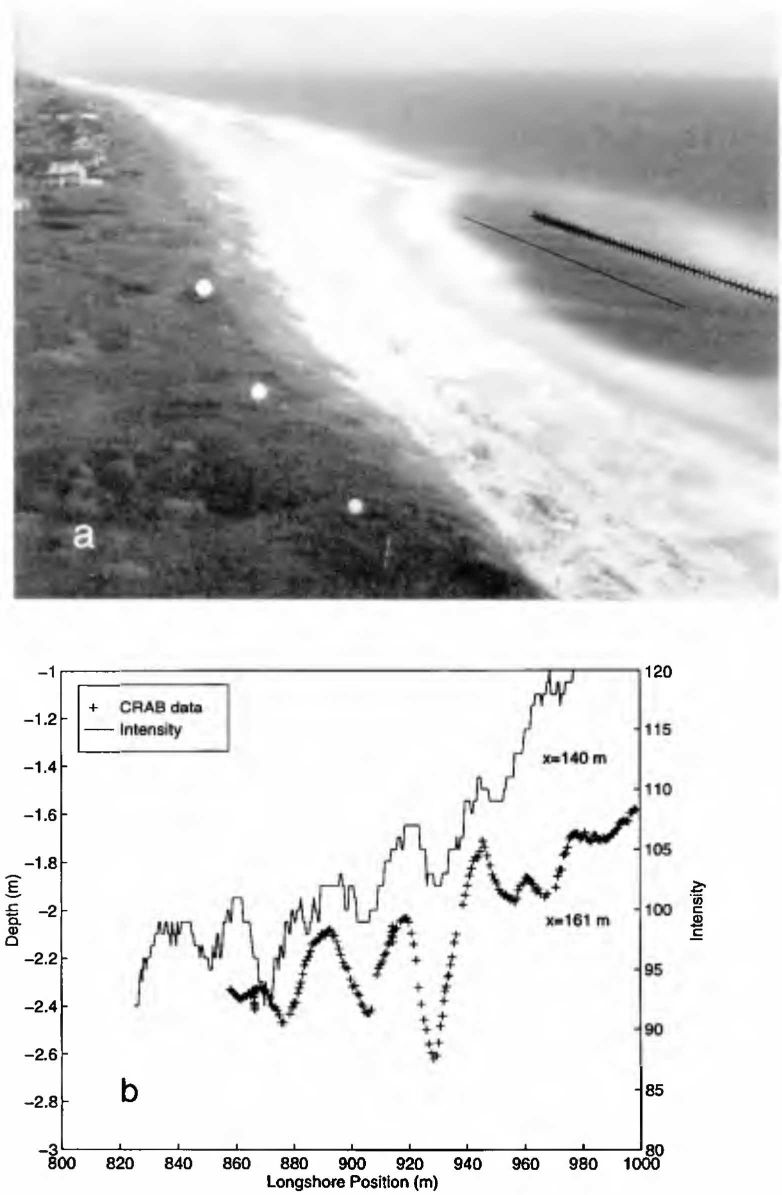

Figure 6. a). Time exposure from July 18, 1995 showing transverse bars in the trough. Transects along which intensity and bathymetric data were collected are shown. b). Comparison between intensity vs. longshore position and depth vs. longshore position for transects in a). This figure clearly shows that there is a correlation between the high pixel intensity in the video images and topographic highs.

Table 1. Length scales and locations for ***trough bars.***

	longshore length spacing (m)	*distance offshore (m)*	*cross-shore length (m)*
mean	45.0	20.0	23.8
std dev.	21.4	9.2	15.5
range	12-87	5-35	5-50

Table 1. Length scales and locations for ***offshore bars.***

	longshore length spacing (m)	*distance offshore (m)*	*cross-shore length (m)*
mean	130.7	249.1	180.0
std dev.	62.9	37.4	117.9
range	45-325	175-300	75-400

Offshore transverse bars are larger scale features than trough transverse bars. Their longshore length spacing is almost 3 times as large and their cross-shore length is up to an order of magnitude longer than the trough bars.

From the extensive Argus database, presence/absence data for the transverse bars were determined. We calculated the number of days transverse bars were observed annually and the average number of days transverse bars were observed per month. One problem that was encountered when calculating the statistics was the fact that there were many days for which no image was available. Taking this into consideration, the frequency of occurrence of transverse bars was determined as follows:

For annual statistics: $$N_{annual} = \frac{N_{obs}(yr)}{N_{images}(yr)} * 365$$

For monthly statistics: $$\overline{N}_{month} = \frac{N_{obs}(month)}{N_{images}(month)} * N_{days}(month)$$

where N_{obs} is the number of images in a year or month in which transverse bars were present, N_{images} is the number of images available for that month or year, N_{annual} is the number of days transverse bars were observed annually, and $\overline{N}_{month}$

is the average number of days transverse bars were observed per month. If less than 20 images were available for a given month, that month was excluded from the monthly statistics because a representative average could not be determined.

The average number of days trough and offshore transverse bars appeared in the video images each month for the 8 years varies greatly (Figure 7). Trough bars were observed from 3 to 7 days/month and offshore bars were observed less frequently (~1 to 5 days/month). Trough bars were most frequently observed in the summer while offshore bars seem to follow a seasonal cycle, appearing in the video images more frequently in the winter than in the summer.

Each year, trough bars were observed more frequently than offshore bars (an average of 62 and 41 days/year, respectively), and there was an interannual variability in the statistics as well (Figure 8). There is a positive correlation between trough and offshore bars for most years and there seems to be an increasing trend for both sets of bars.

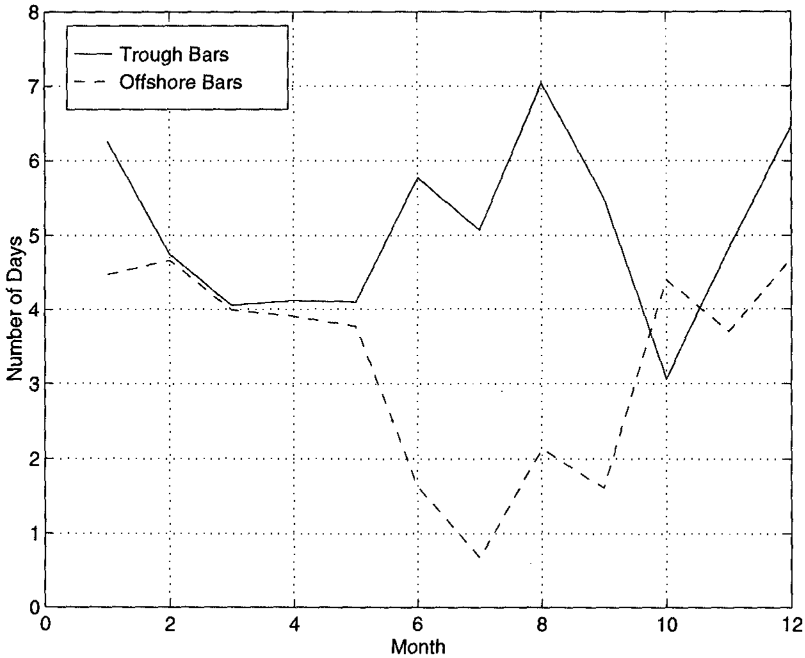

Figure 7. Average number of days transverse bars are observed per month.

Discussion

Transverse bars seem to be a common feature in the nearshore at Duck. They persist in the video images for periods up to days. There were, however, many instances when they were seen for consecutive days, "disappeared" from the images for a few days and then returned to what seems to be the exact location in which they

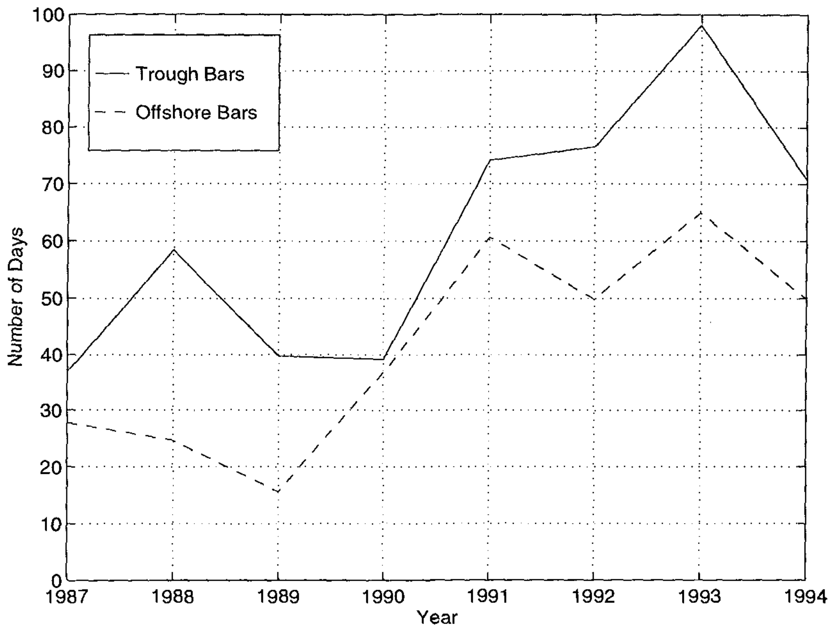

Figure 8. Number of days transverse bars are observed annually. Trough bars are observed more frequently than offshore bars.

were previously seen. This appearance/disappearance may be due to fluctuations in wave height. The bars are only seen in the images on days in which the waves are high enough to be breaking. Although they may "disappear" from the images when the wave height is lower and no breaking is taking place, they may still be present, but not observable. Wave height has not yet been taken into consideration in the calculation of bar statistics. Images in which no bars were seen were given a rating of 0 even when wave height was low. Wave height data from 1987-1995 will be studied to determine whether or not bars were always present during conditions of high wave height. This information will be used to better determine the statistics of the bars, as only days in which waves are breaking will be included in the statistics.

The mechanism for transverse bar formation is unclear. Their presence may be attributed to strong longshore currents and they may be formed in the same way that bedforms in a river are created. While longshore currents could perhaps be the mechanism for trough bar formation, it is not clear that they will be strong enough to locally form offshore bars.

Research will continue on the transverse bars at Duck. More complete statistics will be calculated for bar lengths and positions, and images from 1995 and 1996 will be viewed to augment the existing database. The movement, if any, of the bars will be determined, and an attempt will be made to understand the environmental conditions that are conducive to transverse bar formation. Finally, the Argus database for other beaches will be searched to determine if this process is unique to Duck.

Conclusions

Time exposures from Duck frequently show white bands perpendicular or oblique to the shoreline. These bands, which have been observed both in the trough and offshore of the shore parallel bar, persist for periods of hours up to days. Ground truthing has shown that they are transverse ridges with a relief of 0.3-0.5 m. Trough transverse bars (ridges in the trough) are a smaller scale feature than offshore transverse bars (ridges offshore of the shore-parallel bar). Their mean longshore length spacing is 3 times smaller than that of the offshore bars (44 m and 131 m, respectively). Trough bars obliquely extend up to 35 m from the shoreline while their actual cross-shore lengths may be up to 50 m. Offshore bars obliquely extend up to 300 meters from the shoreline with actual lengths up to 400 m. It appears that the cross-shore length of trough bars is constrained by the shore-parallel bar.

Trough transverse bars appear in the video images an average of 62 days/year and offshore transverse bars appear in the images an average of 41 days/year. There is an interannual variability in the statistics and a seasonal cycle. Offshore bars appear more frequently in the winter and trough bars appear most often from June-August and in December and January.

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