CHAPTER 89

MIGRATION OF LONGSHORE BARS

by

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ABSTRACT

It is known that nearshore areas occupied by longshore bars constitute a zone of active migration of bottom deposit due to agitation by breaking waves and wave-induced on-/offshore currents and longshore currents. So far there is still a lack of actual data from the field itself concerning the magnitude and variability of single parameters involved in the stability and migration of longshore bar features.

This paper summarizes data collected from a comprehensive field study in the years from 1976 to 1979 when grain size distributions were obtained from a narrow grid of core samples and repeated soundings and continuous measurements of waves and wave-induced currents were carried out. With regard to the characteristics of different longshore bar feature relationships e. g. in between bottom gradients and mean grain sizes are analyzed. Furthermore distinct types of topographic response within the submarine belt occupied by longshore bars depending upon the variable intensity and position of breaking waves and the resulting magnitude and variability of wave-induced currents are pointed out and presented for discussion as a contribution towards a general understanding of longshore bar characteristics and changes.

1. Introduction

Sand bars extending mostly parallel to the shoreline are generally known as longshore bars. They are characteristic features of sandy beaches all over the world. Although varying considerably in size and form longshore bars belong to one of two general types; one type is predominant on non-tidal beaches and the other on beaches with a considerable tidal range.

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Longshore bars common to tidal seas are mostly fully developped and mainly located several hundred meters distant from the shoreline at the breaking position of large plunging breakers (see e. g. DETTE, 1980). Earlier it was proposed by KING and WILLIAMS, 1949) that this type of longshore bar might be referred to as "ridge and runnel" beach in order to distinguish this feature from that type of longshore bars predominant in non-tidal seas which should be referred to as "barred beaches".

Longshore bars in non-tidal seas occupy a definite belt on the submarine slope which KING and WILLIAMS (1949) defined as the nearshore area lying in between the waterline and the two-fathom line (approx. MSL - 3.5 m). Beach gradient figures since then mostly refer to that zone.

The belt covered by longshore bars usually extends over a third to a half of the total width of the submarine slope. ZENKOVICH (1967) concluded from extensive field observations in the Anapa region of the Black Sea that the lateral movement of material is fairly intensive in the bar zone. In regions in which longshore bars are well developped there may be up to four, five, or even six of them. Most frequently, however, there will be two, or even only one, which will be fairly close to the shore in relation to the total width of the nearshore area.

So far very few quantitative data are available on the relationships between wave action and topographic response of longshore bars. This study carried out in the non-tidal western part of the Baltic Sea (Kiel Bight) is an analysis of:

1. Grain size distribution obtained from core samples taken in a narrow grid within the area of investigation (12 kilometers in length and more than 1 kilometer distant from the shoreline)

2. Repeated soundings and beach levellings in the area of investigation

3. Longterm measurements of waves and wave-induced on-offshore and longshore currents at different points

within a selected submarine profile which is considered to be characteristic for the area of investigation

The data revealed two distinct types of topographic response within the belt occupied by longshore bars.

1. Changes that involve only shifting of the bed material in on-/offshore direction because, due to normal water levels, the breaker position of the highest breakers is located at the seaward slope of the outer bar. Only small waves ($H < 1.0$ m) pass over the bars and cause only weak longshore currents which in relation to the present grain size are not able to displace considerable amounts of material alongshore.

2. Changes that involve besides on-/offshore shifting major alongshore displacement of material. This process is connected with storm surge conditions occurring with a return period of approx. 5 years. During such events due to wind set-up, the still water level is increased by more than 1.5 m. Lasting sometimes for more than 100 hours the breaking position of the large breakers is shifted landward into the longshore bar belt. According to the water level increase higher waves pass over the bars and bring higher wave energy loads to corresponding points in the submarine profile compared to wave energy loads occurring with normal water levels. Due to the higher "breaking loose forces" (BRUUN, 1966) the longshore currents in response are increased considerably above the boundary values known for the initiation of sediment motion alongshore.

2. Presentation of data

2.1 About the study site

The field studies concerning the wave energy dissipation and magnitude of wave-induced currents as the impact forces and the topographical configuration of the submarine slope as the response factor were carried out in the Kiel Bight (Fig. 1) located in the western part of the Baltic Sea which can be regarded as an enclosed sea in which waves are generated locally and have only little space in which to disperse before reaching a shoreline. The result of intermittent storm wave action typical for enclosed seas is a more or less distinct system of longshore bars because swell does not occur in order to sweep the bars back to shore. The longshore transport is almost completely confined to the surf zone which necessarily is wider than the surf zone on an oceanographic coast averaged throughout the year (SILVESTER, 1974).

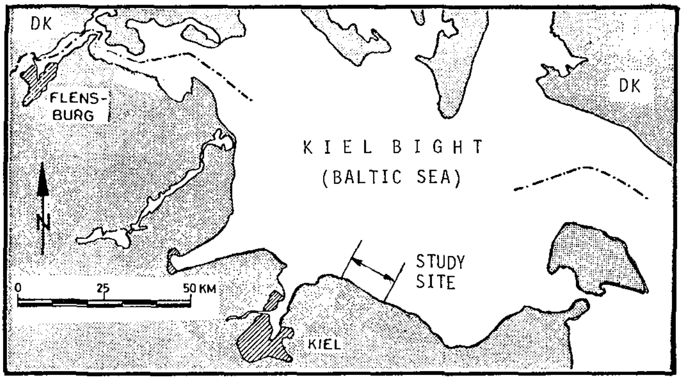

Figure 1: Location of the study site

Like in other enclosed seas, storm waves within the Baltic Sea are occurring mostly from a fairly narrow sector (DETTE and STEPHAN, 1979) so that a resultant vector applicable to any point on the coast can be derived and a predominant uni-directional alongshore transport can be assumed.

Figure 2 shows in more details the area of investigation which can be regarded as a physiographic unit consisting of an eroding feeder cliff which lies approx. 5 kilometers south-east of point 11 marked on the shoreline and an area of accretion located south-west of point 3. The zone between point 11 and point 3 can be considered as the transition area concerning alongshore transport.

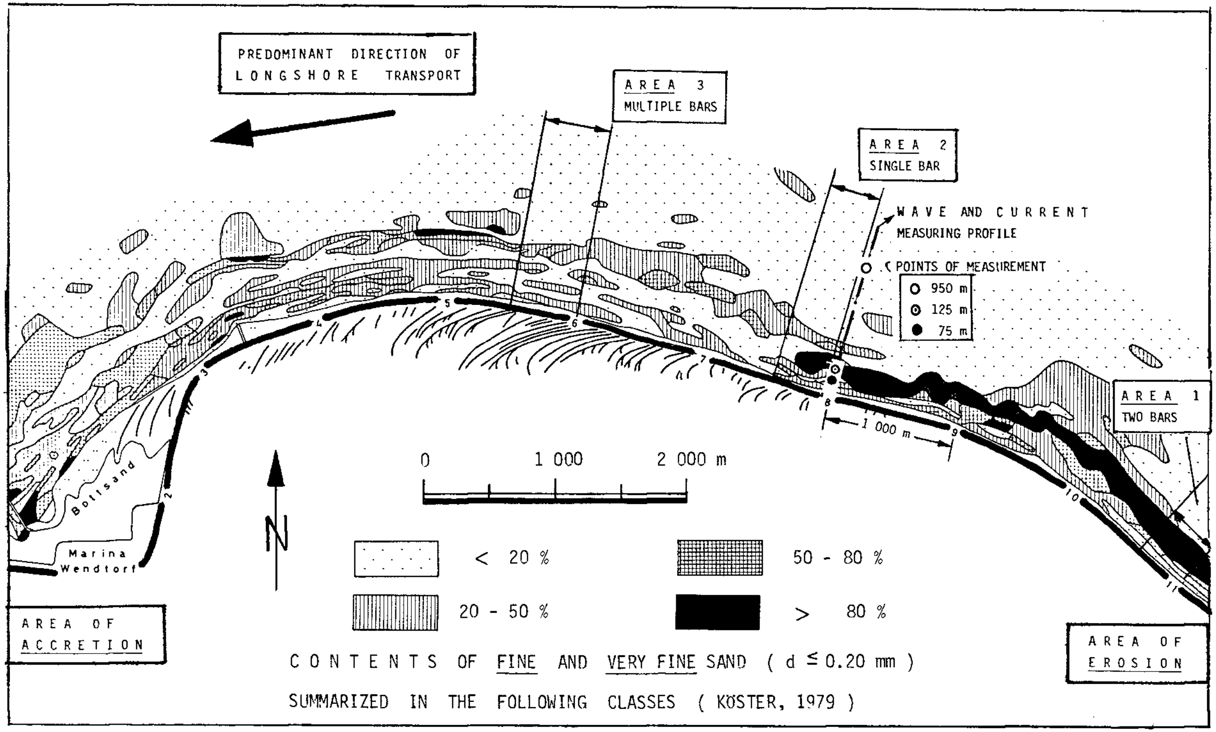

Figure 2: Plan view of the study site with indication of selected study sections (Area 1 to 3) and points of wave and current measurements in the nearshore zone (Position 75 m, 125 m, and 950 m)

In the study area storm waves approach from the sector North-East causing a predominant longshore transport in Western direction.

2.2 Characteristics of longshore bar features in relation to the grain size distribution

Within the study site, which can be considered as a physiographical unit of beach section, a system of different longshore bar features exists,lying generally upon silty clay and sometimes above troughs filled up in recent times. The bars consist of ridges with heights up to more than 1.0 m, widths of several meters and in length they sometimes extend over miles.

The topography of the submarine zone within the study site can be described by mean profiles which are found in Area 1, 2. and 3 (Fig. 2) and correlated with grain size distributions which have been analyzed by KÖSTER, 1979. In Figure 3 three different longshore bar features typical for this area are shown.

Within the eastern part of the study site represented by the mean profiles found in Area 1 and Area 2 (Fig. 2) where the sand transported alongshore is originating from a nearby cliff, mainly one or two bars can be detected. They are located fairly close to the shore in relation to the total width of the nearshore zone.

The inner bar here predominatly consists of sand with maximum grain sizes between 0.18 mm to 0.25 mm (find sand). The outer bar in this area, however, has maximum grain sizes below 0.18 mm (very fine to fine sand). In the troughs, however, coarser sediments are found.

In Area 2 (Fig. 2) a 'geological boundary' is obvious. This was detected by KÖSTER (1979) after plotting the band of sediment distribution containing more than 80 percent of grain sizes between 0.06 mm and 0.20 mm (Fig. 2). This band is connected with that part of the study site where one or two bars have been found to be the typical features.

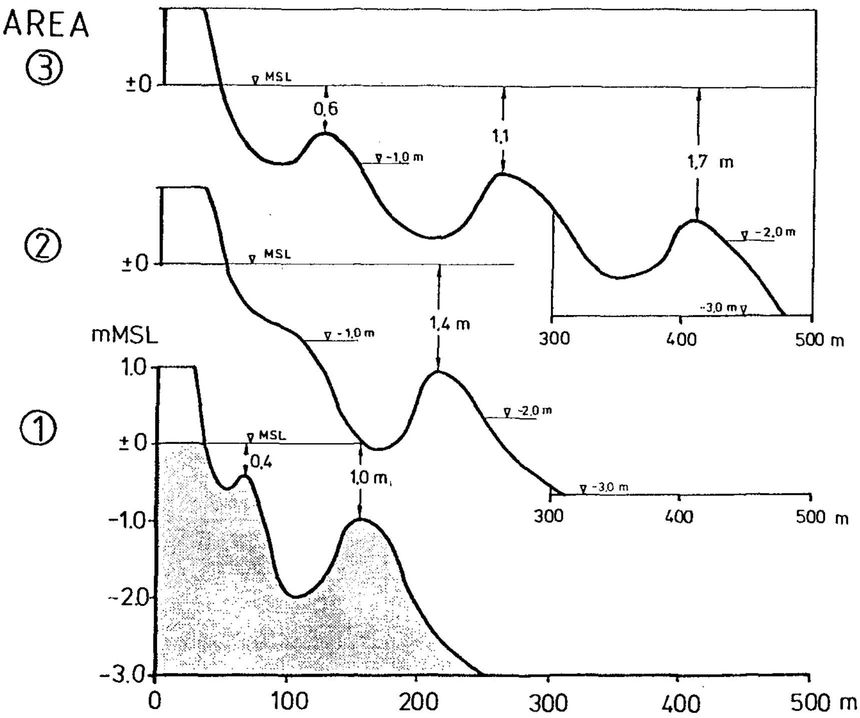

Figure 3: Mean longshore bar configurations within the study site (Area 1, 2, 3 - see Fig. 2)

Towards the west from this boundary, that is in the direction of predominant longshore transport, a splitting-up of the longshore bar system into a multiple bar system takes place as is shown by the representative mean submarine profile for Area 3 (Fig. 2) in Fig. 3.

The bar pattern in the total study site furthermore can be evaluated from Fig. 2 by considering the areas representing contents of fine sand (0.06 mm to 0.20 mm) between 20 to 50 percent.

A typical phenomenon of the western study site is a considerable increase of the longshore bar belt in width compared with that in the Eastern part. This feature is directly related to an increase in grain size within the longshore bar belt up to a maximum between 0.25 mm and 0.35 mm which means medium sand without fine particles whereas grain sizes below 0.18 mm can be considered to be representative for the bar belt in the Eastern site.

Additionally to the investigations of fine and very fine contents of sand ($d \leq 0.20$ mm), KÖSTER (1979) analyzed the distribution of mean grain sizes (d_{50}) in different classes between $d < 0.18$ mm und $d > 0.5$ mm. Fig. 4 shows part of the results for the areas 2 and 3 which are representative of the two different longshore bar features; the crest positions of the single bars in Area 2 and 3 are marked for the purpose of orientation.

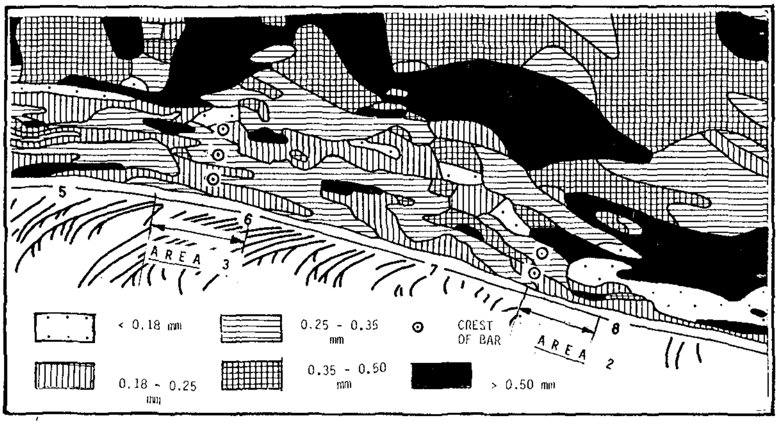

Figure 4: Distribution of mean grain sizes (d_{50}) summarized in five classes by KÖSTER (1979)

With regard to relations between longshore bar characteristics and grain size distributions within the study, the most important parameters are compiled in Table 1. From the results it can be concluded that a longshore bar system is characterized by a narrow range of materials and bottom gradients.

Table 1: Compilation of longshore bar characteristics and grain size distribution within the study site

		Area (see Fig. 2 and 3)		
		1	2	3
Bottom Gradient	A *)	1 : 75	1 : 90	1 : 150
	B **)	1 : 110	1 : 125	1 : 220
Distance of outer bar from MSL		110 m	220 m	370 m
Crest height of outer below MSL		- 1.0 m	- 1.4 m	- 1.7 m
Mean grain size at outer bar		< 0.18 mm	< 0.18 mm	0.25 - 0.35 mm

*) Bottom gradient between MSL and MSL - 3 m

**) Bottom gradient between MSL and crest of the outer bar

The bottom gradients can be expected in the range between 1 to 50 and 1 to 200 (between MSL and the seaward boundary of the nearshore belt). When the gradient is slight, the number of bars increases. The bottom gradients are in turn connected with the nature of material. Longshore bars rarely will be found in areas where the mean size of the sand particles is greater than $d_{50} = 0.5$ mm and hardly ever found when particle sizes are smaller than $d_{50} = 0.1$ mm.

These findings are in good agreement with the investigations carried out in the Black Sea (ZENKOVICH, 1967).

2.3 Incoming waves and wave-induced currents in the nearshore zone

For the western part of the Baltic Sea within the Kiel Bight (Fig. 1) two typical storm conditions accurring intermittently were found out during the longterm field measurements:

1. Storm winds without causing considerable wind set-up (below + 1.0 m MSL)
   - Wind speeds: 20 to 30 knots
   - Wind direction: E to NE
   - Wind duration: Hours up to several days
   - Wave heights: $H_{max} < 3.0$ m
   - Wave periods: $T_m = 3.0$ to 5.0 secs
   - Return period: 5 to 10 times per year

2. Storm winds causing storm surge conditions with considerable wind set-up (above + 1.5 m MSL)
   - Wind speeds: 30 to 50 knots
   - Wind direction: E to NE
   - Wind duration: Up to several days
   - Wave heights: $H_{max} = 3.0$ m to 4.0 m
   - Wave periods: $T_m = 4.0$ to 5.5 secs
   - Return period: Once in 5 to 10 years

The time history of a storm surge event which lasted for more than 100 hours from December 28th, 1978 up to January 1st, 1979 is plotted as an example (Fig. 5). Measurements of wind and wave conditions were carried out during that event at intervals of 2 hours.

Storm events lasting for more than 100 hours but blowing with minor wind speeds and thus causing only negligible wave set-up also occurred during the period of measurements and were recorded.

For the two distinct events mentioned above, two representative records of wave heights and wave-induced on-/offshore currents and longshore currents measured at two locations within the surf zone are presented.

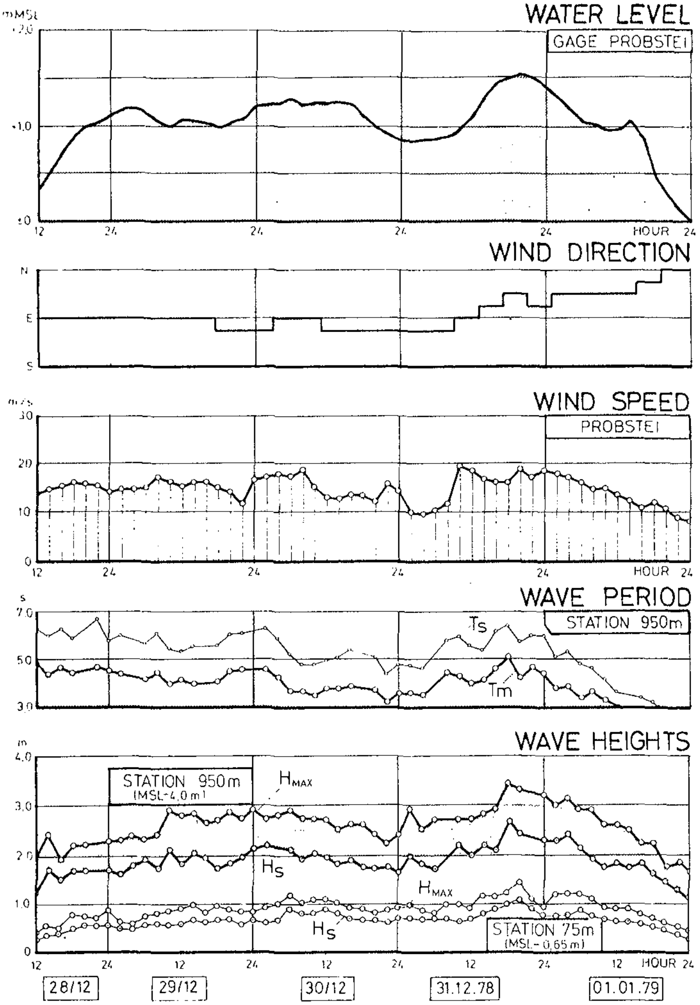

Figure 5: Time history of a storm surge event with wave set-up to + 1.5 m MSL with regard to water level, wind, and wave conditions

Figure 6 is an example of storm winds causing negligible wave set-up and Figure 7 is an example of a storm surge event with wave set-up of 1.5 m above MSL.

By comparing Fig. 6 and 7, the location and width of the surf during both events appear to be more or less identical. The incoming waves break at identical locations of the submarine profile, but, are very much different because the water level increases up to 1.5 m above MSL and approx. 1.0 m higher breakers occur during storm surge conditions in comparison to the normal storm conditions.

The consequences of the large breakers and set-up are demonstrated by the rapid increase in the mean longshore velocities as well as the peak velocity components during a 10 minute record. During normal conditions (Fig. 6), the mean longshore current velocities are below $\overline{V}_L$ = 0.3 m/sec which can be considered as the boundary value for the initiation alongshore transport of sediments found within the study site. Due to the higher breakers during storm surge conditions (Fig. 7) the mean longshore current velocities are increased considerably and reach mean velocities up to $\overline{V}_L$ = 0.8 m/sec; accordingly a large alongshore flux of sediments can be assumed.

The changing and shifting of the longshore bar characteristics during periods without wave set-up (= normal conditions) and after a storm surge event with a return period of 5 to 10 years is demonstrated by comparing echo-sounded submarine profiles at distances of 100 m within Area 3 (Fig. 2).
The erosions and accretions are plotted in Figure 8 (left side for a period without wave set-up and right side for a period with wave set-up over + 1.0 m MSL at a total of more than 100 hours).

3. Discussion

It is obvious that there exists a close relationship between the special longshore features, which may consist of one bar or multiple bars, and the grain size distribution.

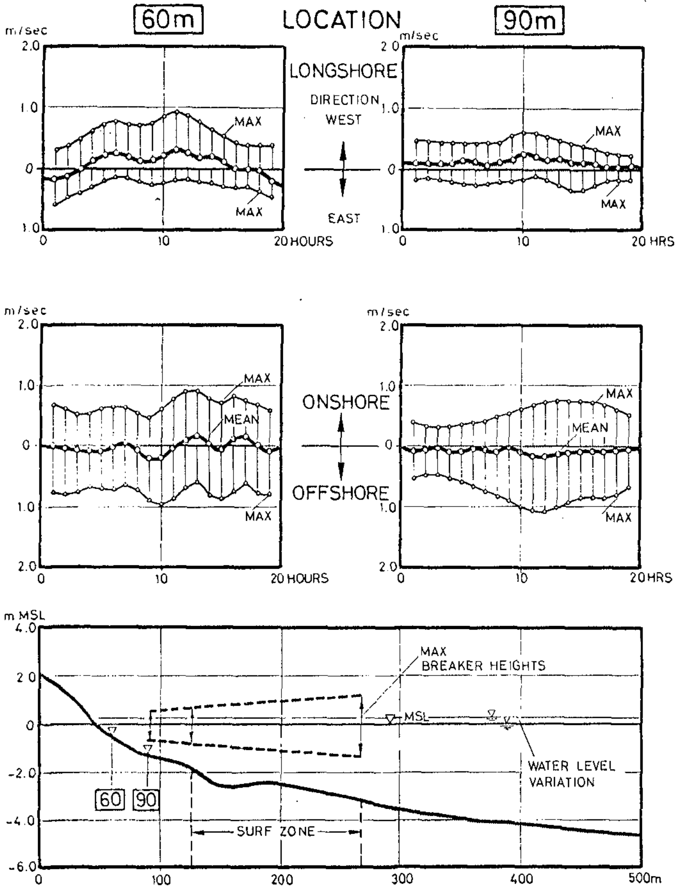

Figure 6: Location of the surf zone, envelope of max. breaker heights and wave-induced currents during normal storm winds causing negligible wave set-up

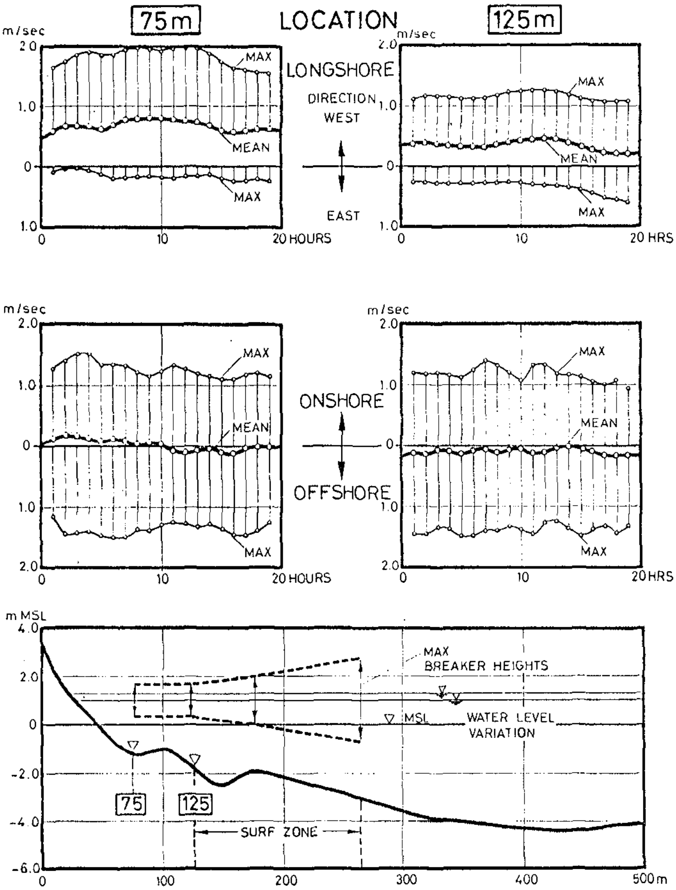

Figure 7: Location of the surf zone, envelope of max. breaker heights and wave-induced currents during storm surge conditions with a wave set-up of 1.5 m above MSL (see Fig. 5, measurements starting at 08.00 HOURS DEC. 29, 1978)

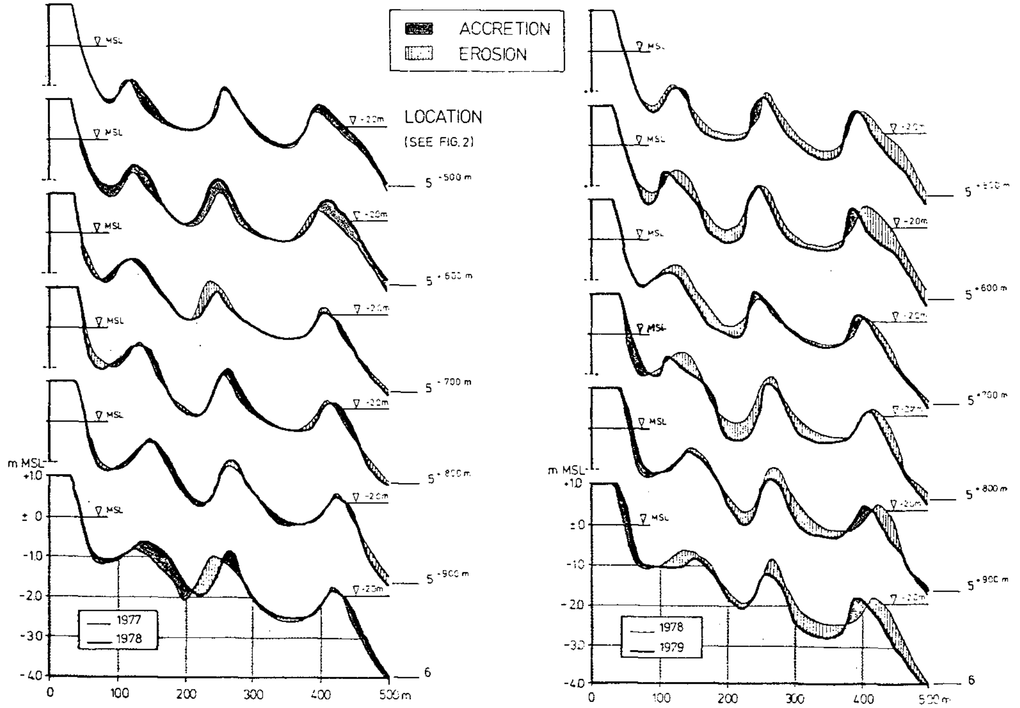

Figure 8: Changes and shiftings of the longshore bar characteristics after periods with normal storm conditions only (left side) and with storm surge conditions (right side)

With regard to the interactions of breaking waves and wave-induced currents, it can be concluded from the field study that the primary, or initial, effect on longshore bar formation and deformation is the breaking wave energy which causes the more intense on-/offshore oscillatory currents and greater magnitude and variability of longshore currents. Further investigations are necessary in order to study in more detail for example the different wave-induced currents in the vicinity of a bar trough or the bar crest. The present paper is thought as a contribution towards the collection of reliable data from the field itself as input data for further theoretical treatment of the problems.

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