

CHAPTER 22

DIRECTIONAL SEA STATE NEAR THE ISLAND OF SYLT

by

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Abstract

In the scope of a joint research program dealing with erosion problems of the island of Sylt in the North Sea, wave measurements with two pitch-and-roll buoys are carried out in order to obtain more detailed information on the sea state with regard to wave dependent morphological processes.

The instrumentation is described. Results from the directional analysis of closely spaced buoys are compared, showing good agreement in significant parameters and in distributions in the frequency range. Differences between wave and wind directions are discussed. A method of separating double peak spectra by fitting theoretical shallow water spectra to the measured energy density distributions is presented.

1. Introduction and scope of investigations

The island of Sylt is one of the North Frisian Islands, located in the southeastern part of the North Sea (fig.1). The main dimensions are about 40 km in north-south direction and 1 to 4 km in east-west direction, except the central part. The main wave directions are from the west, striking the islands broadside.

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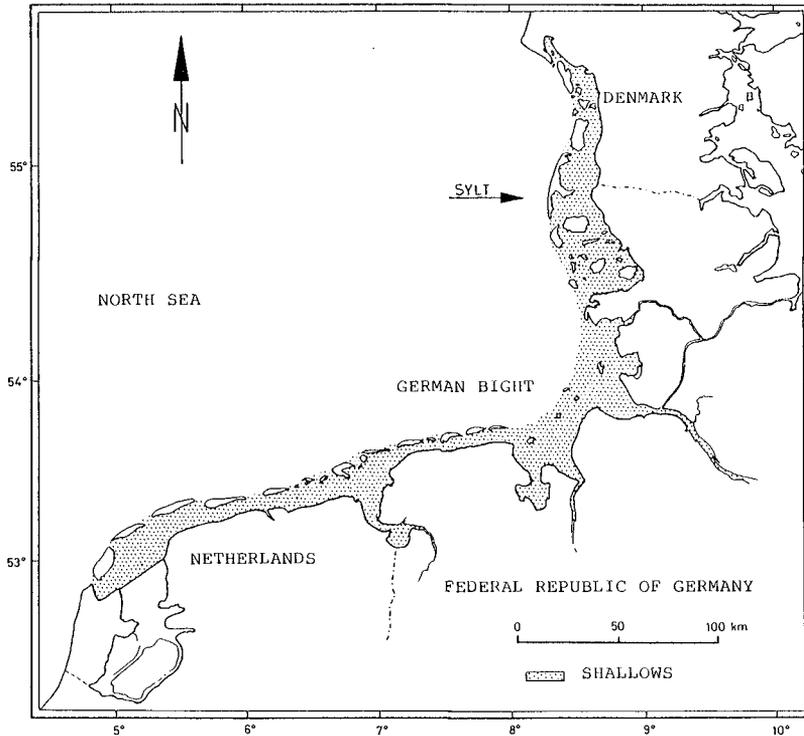


Fig.1:

Location of the island of Sylt in the North Sea

Due to the exposed site of the island the erosion has been a serious problem for centuries. This could not be stopped even with intensified shore protection works, e.g. the construction of groynes and revetments started in 1865 and by beach nourishments since 1972. During the last 35 years the island lost an area of about 2.50 km^2 equivalent to a quantity of some $50 \cdot 10^6 \text{ m}^3$ material.

In 1985 a joint research program was created to deal with the problems of the island and work towards an optimization of coast protection measures. Scientists from various German universities and the Amt für Land- und Wasserwirtschaft Husum (local technical authority) are participating in this project.

One part of this research program realized by the Franzius-Institut is to carry out measurements with two pitch-and-roll buoys in order to obtain directional wave spectra.

The main task of these measurements is to provide more detailed information on the sea state as a basis and reference for the wave related investigations within this

research program. Especially the directional information, essentially important for the judgement of longshore sediment transport processes, was not available up to now and had to be estimated on the basis of wind information.

In this contribution the following topics are treated:

- description of the instrumentation
- comparison of results from closely spaced Wavec buoys
- comparison of wind versus wave direction
- treatment of double peak spectra.

2. Instrumentation

For the investigations it was decided to procure the Datawell wave direction measuring system (fig.2). The buoy has a total weight of 700 kg, its diameter is 2.50 m. The mooring system consists of a mooring cross, 30 m rubbercord with a safety line (maximum load 8 t) and a 2 t heavy chain as an anchor weight.

The buoy measures vertical acceleration (heave) and pitch and roll angles against buoy defined x- and y- directions.

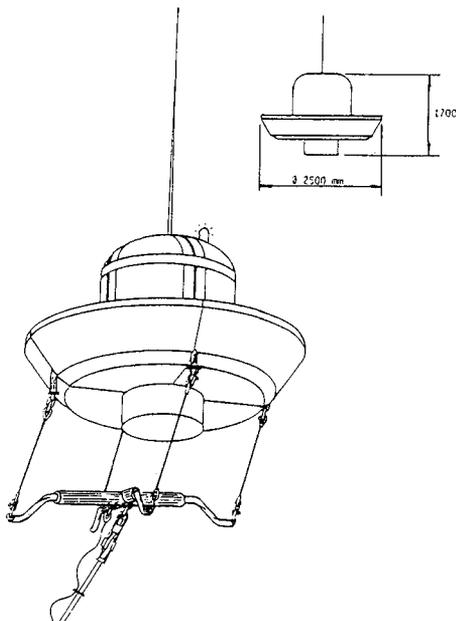


Fig.2:
Wavec pitch-and-roll buoy

The land station on Sylt consists of a Direc receiving station, a HP85 deskcomputer and a HP winchester disc for each buoy. The data are decoded and analysed by the Direc and then plotted and stored by the HP85 and the winchester disc. In the standard mode every 4 hours a 30 min series of data are processed and stored. The main computer in Hannover, 400 km southwards, is connected by telephone data line for

- transmission of the measured data
- function control
- change of the measuring mode.

For the processing of the measured time series, the Datawell standard package is used to calculate

- energy density spectrum
- mean direction for each frequency
- beam width of directional distribution

according to the methods established by LONGUET-HIGGINS et al. (1963).

3. Comparison of results from closely spaced buoys

It was decided to have one bouy at a permanent position as a basis and reference for the long term wave statistics. The second buoy is assigned for measurements in areas of special investigations along the island, but also for investigations of variations of the sea state, including shoaling and refraction. In a first measurement series, the buoys were located for a period of about 7 month in a distance of less than 1000 m (water depth of about 13 m below MSL) for the assessment of the reliability of the measuring system and the homogeneity of the wave field.

Significant parameters

$$\begin{aligned}
 H_S - \text{significant wave height} &= H_{m_0} = 4 \cdot \sqrt{m_0} \\
 & m_0 = \int_0^{\infty} S(f) \cdot df \\
 T_Z - \text{significant wave period} &= T_{0,2} = \sqrt{\frac{m_0}{m_2}} \\
 & m_2 = \int_0^{\infty} S(f) \cdot f^2 \cdot df \\
 \bar{\theta} - \text{overall mean direction} &= \frac{1}{m_0} \cdot \int_0^{\infty} S(f) \cdot \theta_m(f) \cdot df
 \end{aligned}$$

were calculated and the results for October 1987 compared in fig.3 as scatter diagrams.

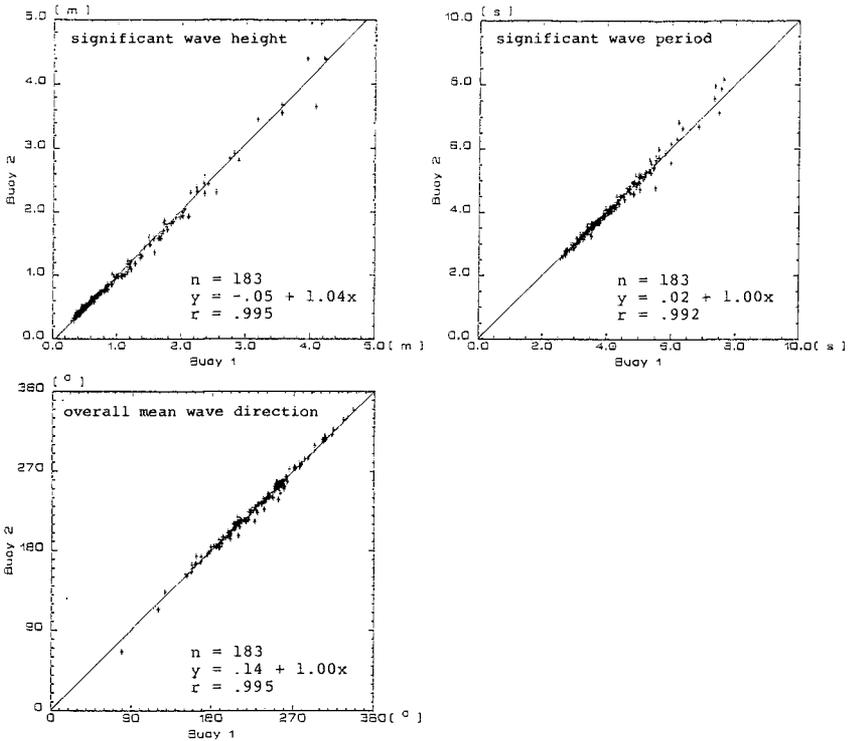


Fig.3:

Comparison of two closely spaced buoys, October 1987
 linear regression

-significant wave height H_s [m]
 -significant wave period T_z [s]
 -overall mean wave direction $\bar{\theta}$ [°]

From the figures a good agreement can be seen. The correlation coefficient for all significant parameters is near to one.

In addition, the distribution in the whole frequency range was compared. Two examples are plotted, one with nearly identical significant parameters (fig.4) and one with some differences in the parameters (fig.5). In both cases the deviations are not too serious.

These results are in accordance with data presented by other authors (e.g. v.d.VLUGT, 1984).

4. Comparison of wind versus wave direction

One main part of this research program is to get better directional information and to check this against the wind direction, which was the up to now deepwater reference for the calculation of sediment transport rates.

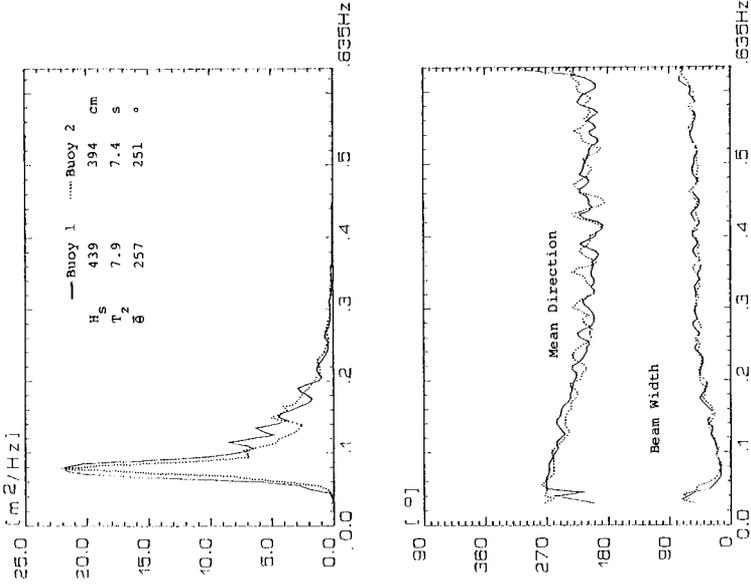


Fig.5:

Comparison of directional spectra of two closely spaced buoys (16.10.1987, 15.30)

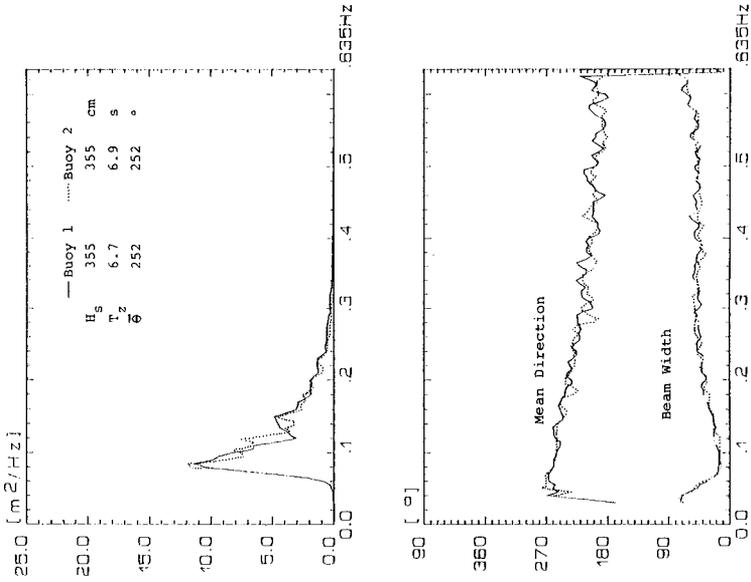


Fig.4:

Comparison of directional spectra of two closely spaced buoys (16.10.1987, 19.00)

The wave and wind direction, together with the wave height and the wind speeds are compiled in monthly plots. In fig.6 the data for October 1987 are shown.

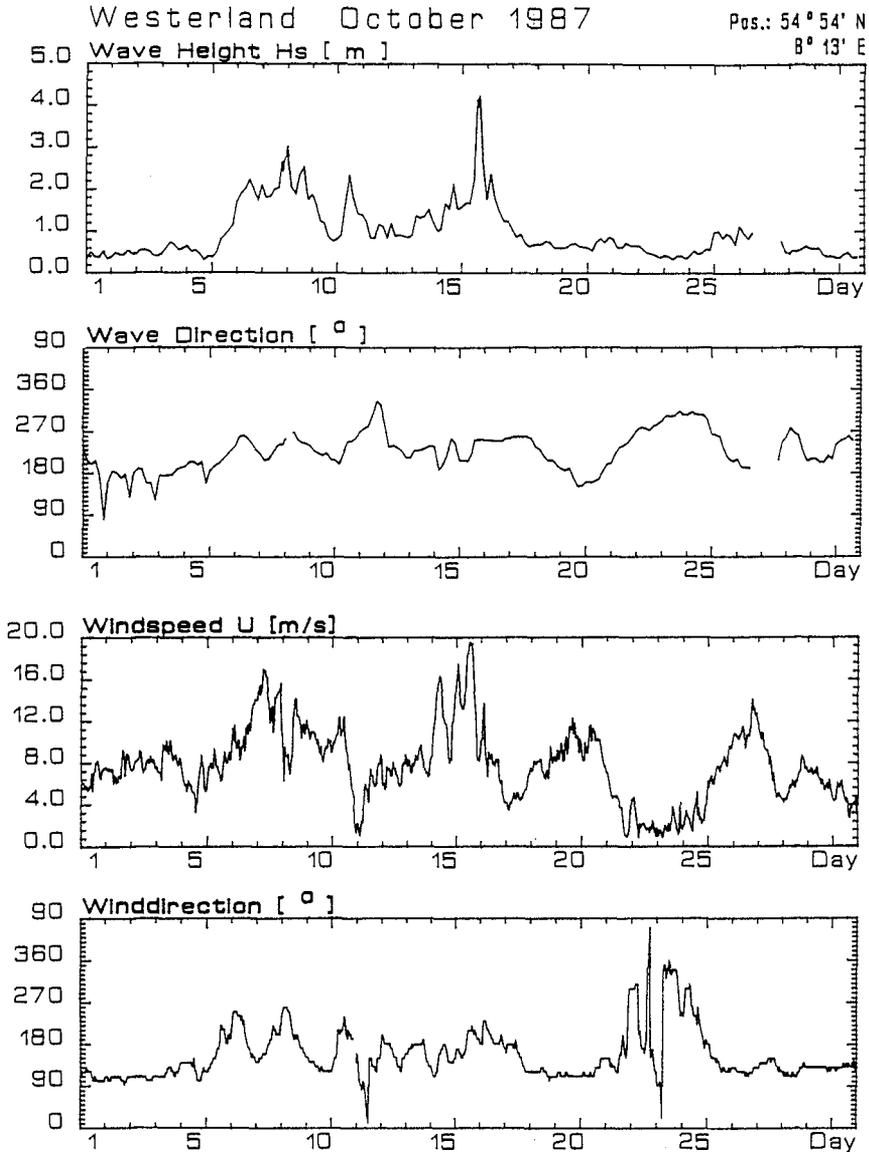


Fig.6:
Compilation of wave and wind parameters, October 1987

It is the general tendency, that fluctuations in wind direction are accompanied by minor fluctuations in wave direction. For easterly wind directions, i.e. wind from the land, no significant relationship can be expected, due to the still existing swell and wave heights below 0.5 m.

To investigate typical deviations, the wave directions were plotted directly against the wind directions for the period November 1987 to March 1988 (fig.7 a-c). The plot was restricted to events with westerly wave directions

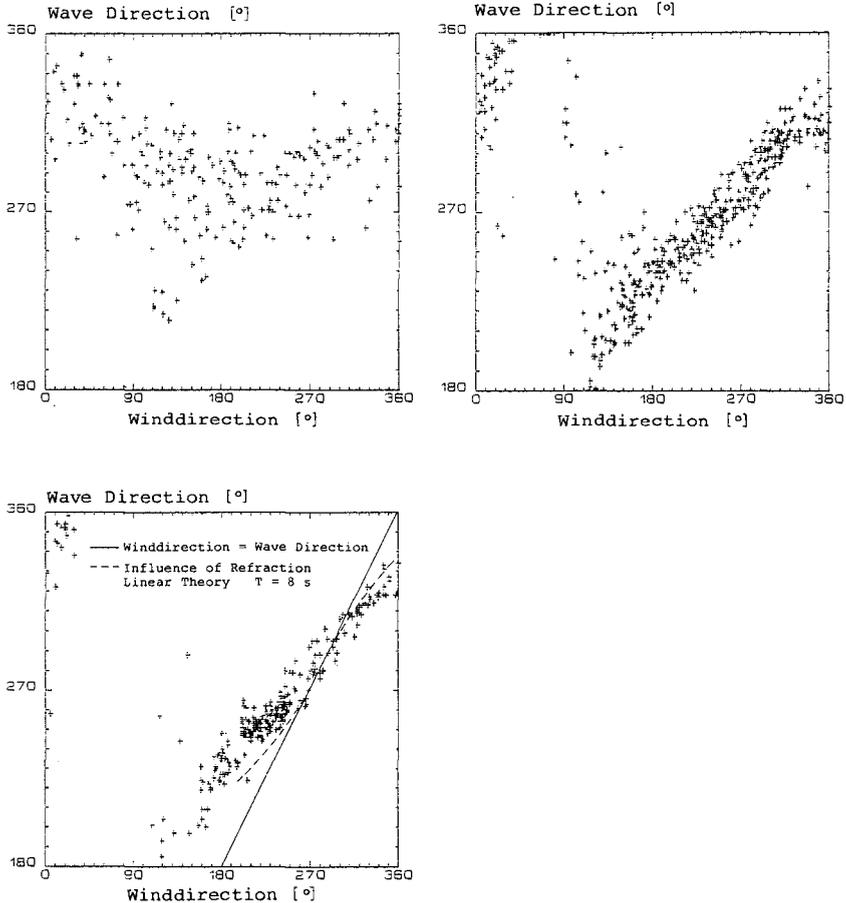


Fig.7:
Comparison of wind and wave direction
November 1987 - March 1988

a)	$u < 5$ m/s	$n = 281$
b)	$5 \text{ m/s} < u < 10$ m/s	$n = 430$
c)	$10 \text{ m/s} < u$	$n = 288$

between 180° to 360° . Besides that, a distinction was made between different groups of wind speeds (wind speeds and pertinent wind directions are 4 h averages of data preceding the wave measurements). Fig 7a shows a wide scatter, among others due to a great variety of wind direction at low wind speeds. In fig. 7b (wind speeds between 5 m/s and 10 m/s) a general tendency already appears in outlines, but still some remarkable scatter is left, due to influences from former events. In fig 7c the comparison is shown for wind speeds of more than 10 m/s. A distinct relation of the wave direction to the wind direction is now obvious.

Refraction influences were estimated with a regular wave model on the basis of linear wave theory, assuming parallel depth contours (strand orthogonal: 273° south part of the island, 290° north part of the island). According to the measurements, for wind speeds around 10 m/s a characteristic wave period of $T = 8$ s was used as input parameter. The result is plotted in fig. 7c for comparison (dotted line). Although the tendency of the results corresponds with the general trend of the deviation, this is not sufficient for application in design methods. A better agreement is expected from more sophisticated refraction models and considering results from measurements in deeper water with the second buoy.

5. Treatment of double peak spectra

It occurs, due to changing wind conditions, that a swell is superposed by a new generated wind sea. In the frequency domain, this may result in double peak spectra. The calculation of overall significant sea state parameters seems not to be sufficient in these cases (example see fig.8).

One way to identify these spectra and to separate for further working with significant wave parameters is to fit theoretical spectra, e.g. of the JONSWAP type, to the measured energy density distributions.

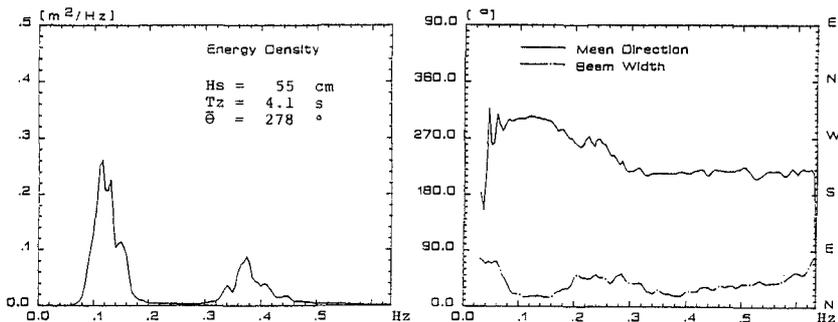


Fig.8:
Double peak spectrum 08.01.1987 00.30

As the JONSWAP shape is valid for deep water conditions, whereas the location of measurement is in a water depth of about 13 m below MSL, shallow water influences should be considered. To estimate the shape of the shallow water spectrum, the self similarity criteria as published by BOUWS et al. (1985), meanwhile well known as TMA shallow water spectrum (fig.9), were utilized.

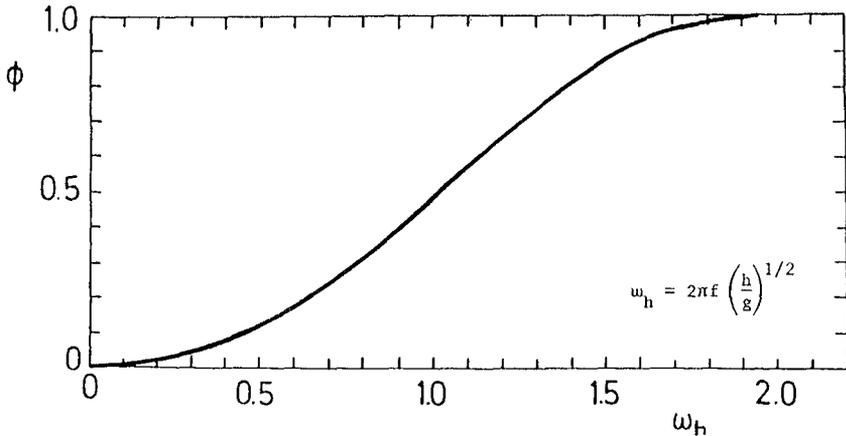


Fig.9:
KITAIGORODSKII et al.'s ϕ as a function of ω_h
(after BOUWS et al. 1985)

By this method, it is possible to calculate a shallow water spectrum from a deepwater JONSWAP spectrum, using a transformation factor, which is a function of water depth and frequency. Using the TMA spectrum for the pertinent water depth a relatively good approximation to the measured spectrum was achieved (fig.10) by varying the PHILLIPS constant α and the peak enhancement factor γ . There is still some scatter, but the difference in significant wave heights is less than 5% in this example (4.5 m measured to 4.6 m calculated).

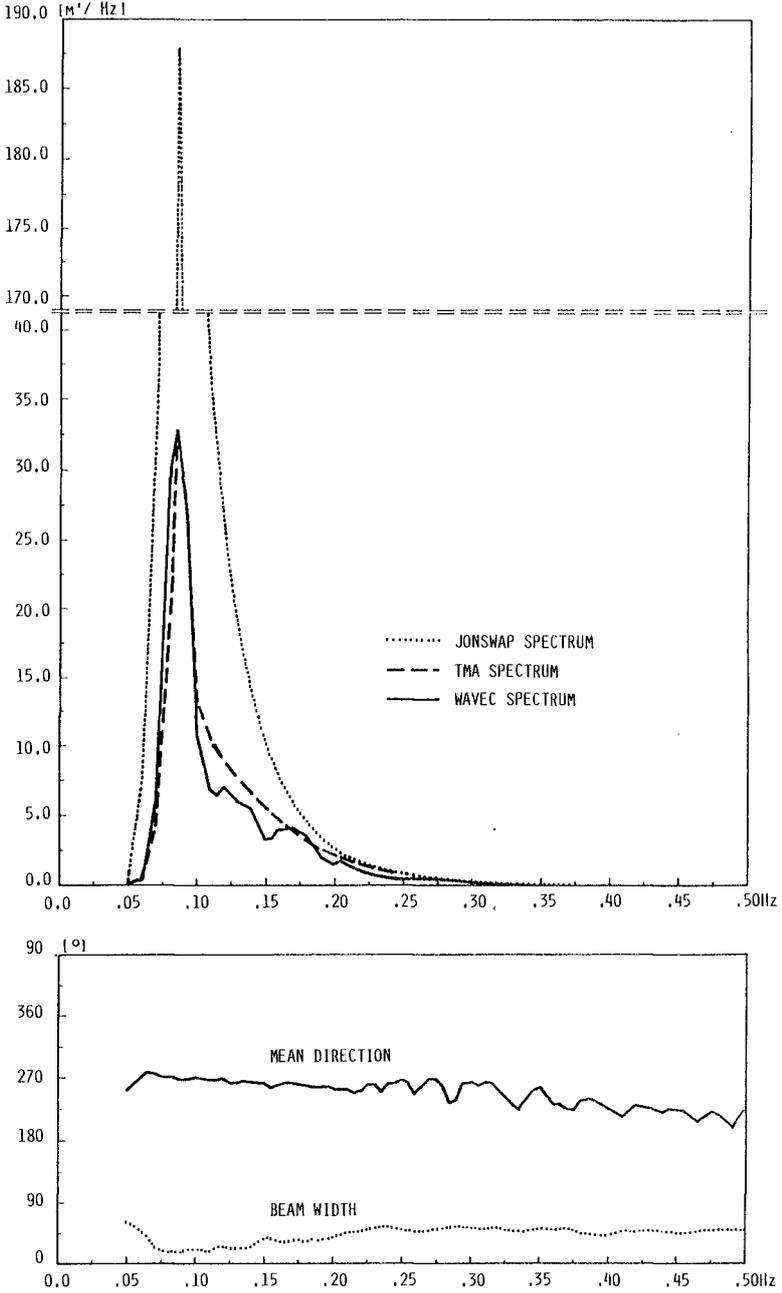


Fig.10:
Measured spectrum 10.2.1988 19.30 and pertinent TMA spectrum

For the separation and parameterization of a double peak spectrum, first the spectrum part with the lowest peak frequency is fitted by means of a TMA spectrum. The remaining part of the spectrum is then fitted by using the peak frequency of the second peak and the pertinent energy density reduced by the energy of the first spectrum at this frequency (example see fig.11).

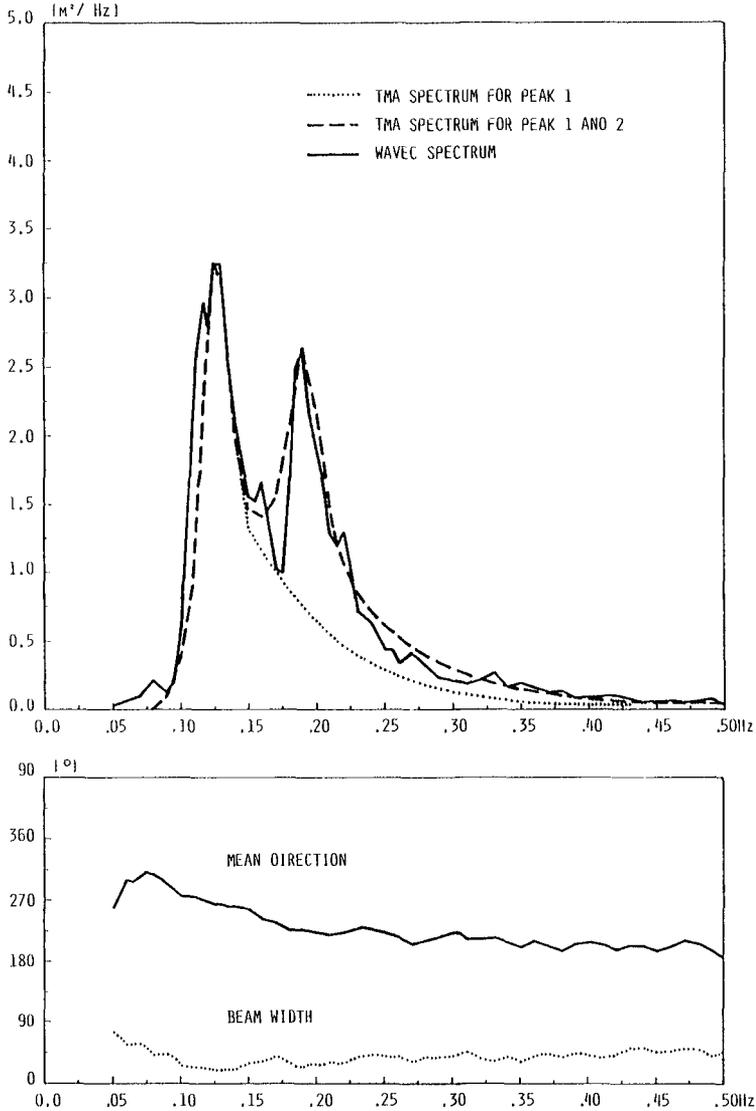


Fig.11:

Double peak spectrum 7.10.1987 16.30 and fitted TMA spectra

Using this parameterization approximate average wave directions could be calculated for each wave field. The wave parameters of the resulting TMA spectrum compared with the measured spectrum are as follows:

	H_s	T_z	T_p	$\bar{\theta}$
	m	s	s	°
measured spectrum	1.98	5.00	8.00	243
TMA 1	1.53		8.00	248
TMA 2	1.19		5.26	223

Fitting double peak spectra by this method has to be seen as a first attempt. In the scope of the project it is used to determine more reliable wave parameters for the estimation of longshore transport rates, e.g. by the CERC formula.

Assuming that both wave fields can be treated independently, two transport rates can be calculated and compared with the rate calculated from the overall parameters of the original spectrum. On a yearly basis $5.2 \cdot 10^6 \text{ m}^3$ are estimated from the first part of the spectrum (lower frequencies) and $2.4 \cdot 10^6 \text{ m}^3$ from the second part. The calculation with the overall parameters results in $9.8 \cdot 10^6 \text{ m}^3$. This is equivalent to a difference of about 25%.

6. Acknowledgement

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