CHAPTER 142

LONG TERM CHANGES IN WIND AND WAVE CLIMATE ON THE NORTH SEA

The Dutch Coast: Paper No. 3

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Introduction

This paper presents the first results of a study on the wind and wave climate along the Dutch coast of the North Sea. The analysis of time series of wind force, wave height, wind direction, etc, identifies the occurrence of long term changes in wind and (wind)wave climate. In the Dutch Coastal Defence Study, the results of these climate analyses were used to develop the so called "unfavourable hydro-meteorological scenario" with which an evaluation was made of the extreme impact of the shore line retreat of the Dutch coast. The wind and wave climate study is part of a project that examines the relation between changes in the regional wind and wave climate and the long term and large scale morphological development of the Dutch coast.

Method

For the study concerning coastal behaviour in relation with climatic changes, continuous time series of meteorologic and oceanographic data are of paramount importance. The available time series of wind waves in the Dutch part of the North Sea, cover a rather short period. To gather information over longer periods supplementary sources have to be found (for the period that wind wave data is lacking). Wind data of light vessels off the Dutch coast confirm to the requirements.

Between 1859 and 1982 various light vessels were stationed off the Dutch coast (Figure 1) to collect meteorological data such as; temperature, wind force and wind direction. As from 1926, the data collected included details of wave conditions and as from 1949 sea-state as well as swell (far field effect) were recorded separately. From that year onwards wave direction, wave period and wave height are available. The climate analysis of this study covers the period 1907-1980 and is in the first part of the project concentrated on wind data.

Analysis of this meteorologic and oceanographic data is concentrated on the time series of mean annual values of wind velocity,

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wind percentage and wind direction. Trends in the mean climatologic data indicate long term changes. To identify these trends linear regression techniques were applied. Apart from these trends the time series also seem to contain periodic changes. Since the period of these changes is rather large with respect to the length of the time series, determination of this feature is difficult. Since data of more than one light vessel is available for the same registration period, variations along the coast can be determined. The wind climate analysis is executed for several wind fields (see Figure 1):
1. The total wind rose which covers 360 degrees.
2. A division of the wind rose in two wind sectors WEST and EAST.
3. A subdivision of sector WEST into 4 sub sectors WEST-1 to WEST-4.

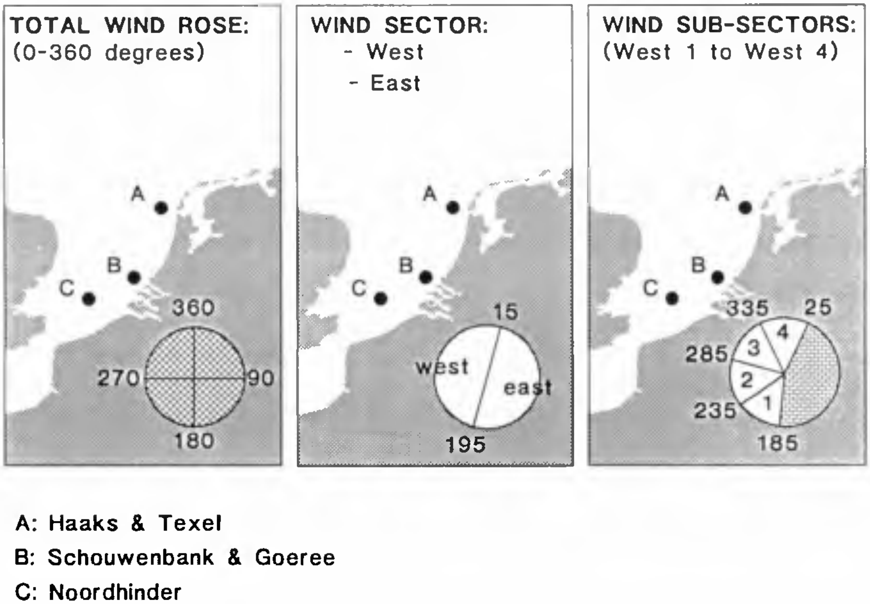

Figure 1 Wind field division and position light vessels

Results

Wind direction:
Changes in wind and wave climate of sector WEST [195-015°] in the Dutch part of the North Sea do occur. Figure 2 shows the mean annual wind direction measured at three Dutch light vessels of wind sector WEST. The figure shows a backing of the wind for period 1907-1924, a veering of the wind for period 1925-1938 (no high registration density between 1939-1948) and a more or less steady wind direction for the period from 1949 onwards.

Wind velocity:
Analysis of the mean wind velocity shows an increasing wind velocity when period 1907-1940 is compared with period 1950-1980.

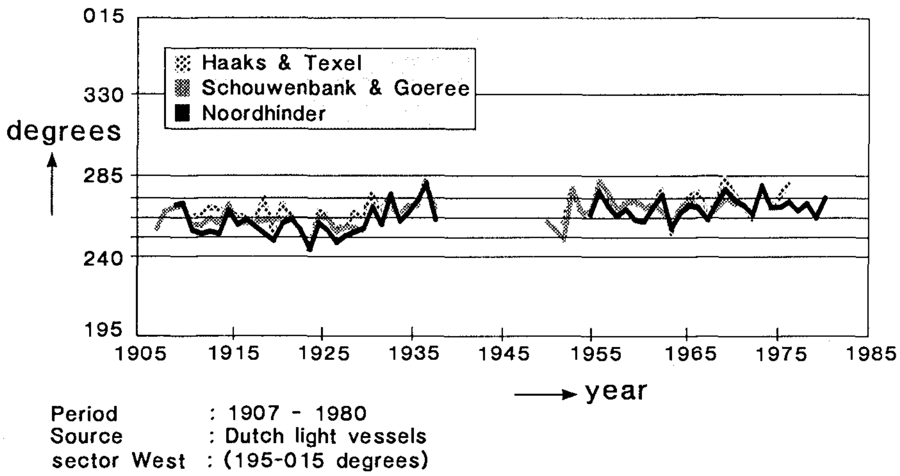

Figure 2 Mean wind direction

Figure 3 shows the mean annual wind velocity measured at three Dutch light vessels supplied with wind data of coast station Den Helder (situated in the north of Holland near light vessels Haaks/Texel) and a German light vessel/-station Scharhorn and Elbe-1 (situated in the estuary of the river Elbe).

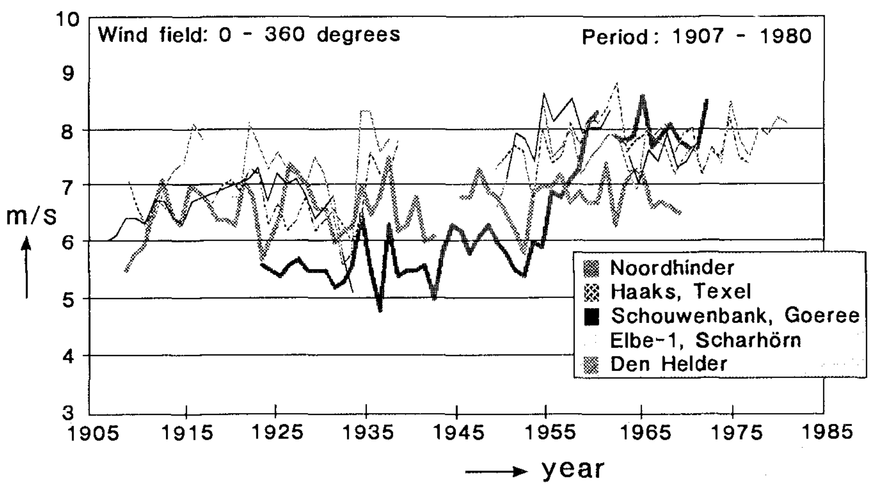

Figure 3 Mean wind velocity

Figure 4 shows the mean annual wind velocity of light vessels Haaks & Texel for the four sub sectors separately. The diagram shows an identical increase in time as figure 3, but far more important are the differences between the sub sectors. Sector West-4 contains the lowest mean wind vector increase and the three other sub sectors, especially sub sector West-3, contain the highest increase.

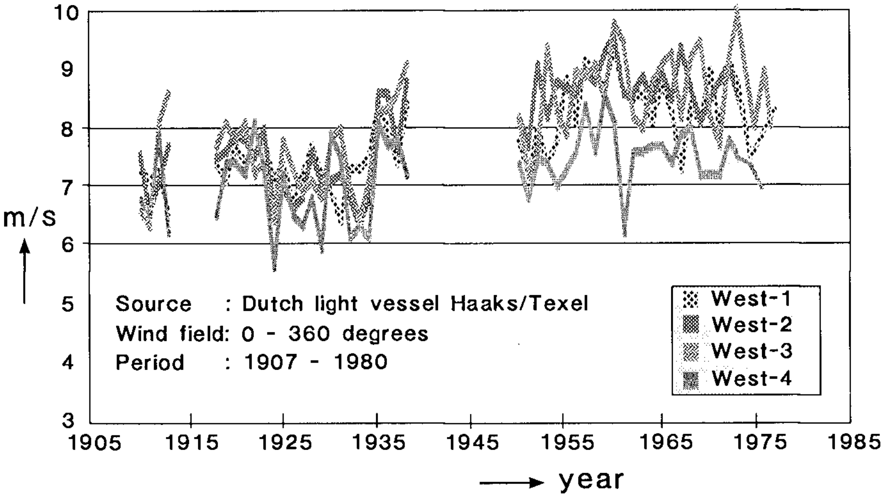

Figure 4 Mean wind velocity

Figure 5 shows the percentage of each Beaufort class of the total wind field for two periods: from 1922 to 1933 and from 1950 to 1980. The histogram shows an increasing force when the two periods are compared. Beaufort class three shows the highest percentage for the period between 1922 and 1933, but this mode has changed into Beaufort class four for the period between 1950 and 1980.

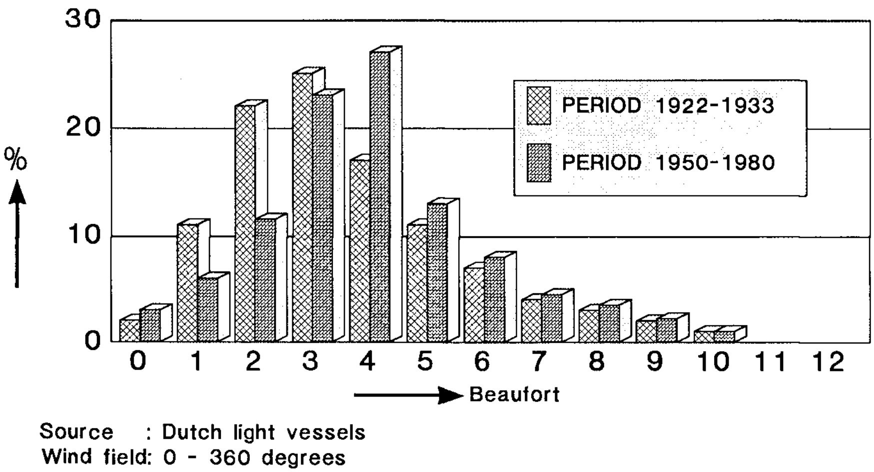

Figure 5 Frequency distribution scale numbers of Beaufort

Frequency of wind:

A third wind parameter, the frequency of wind in a sector, shows a decreasing frequency of wind in sector WEST.

Conclusions based on wind analyses:

It can be concluded that the wind climate along the Dutch coast has changed in the period 1960-1980: a veering of the wind direction, an increasing wind velocity and a decreasing wind percentage in sector WEST. Significant spatial differences in wind climate between the several light vessels along the coast could not be found.

Wave height:

Parallel to wind observations, the visual wave height ($H_v \approx H_s$) has been estimated between 1949 and 1982. These observations are less reliable than the time series of wind parameters. Figure 6 shows the mean annual significant wave height measured at three Dutch light vessels. For comparison this figure also shows the series of light vessel Seven Stones (south-west England).

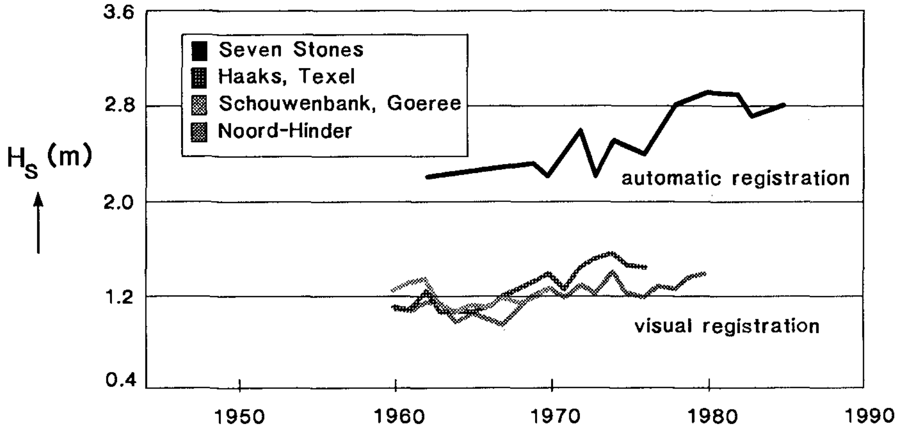

Figure 6 Mean annual significant wave height measured at Dutch and English light vessels

In the Coastal Defence Study the effects of three hydro-meteorologic scenarios have been investigated. The major factor in these scenarios is a sea level rise. The first two scenarios only concern a sea level rise (the present-day sea level rise of 20 cm/century, the expected scenario of 60 cm/century). In the third scenario, which was supposed to present an unfavourable development of hydro-meteorologic conditions, also changes in wind and wave climate were included (a veering of the wind direction of 10° in the most unfavourable direction and an increasing wind velocity of 10%). An indication of the magnitude of these changes expressed in this unfavourable scenario was derived from rough wind data analyses. In the present study the wind parameters are statistically determined. The related values of the wave climate and wave and wind setup are derived by model analysis. Since the Dutch coast is mainly exposed to the west this analysis is focused on the sector West. The results are presented in Figure 7. The values in the centre column present the mean climate of the period 1907-1980. Column "DEVIATION + 2σ" corresponds to the unfavourable scenario.

PARAMETERS	DEVIATION (-2 σ)	HYDRAULIC SCENARIO	DEVIATION (+2 σ)	DIM
Mean Wind Velocity	6.6	8.0	9.4	m/s
Mean Wind Direction	250	265	281	o
Mean Wave Height	1.0	1.3	1.7	m
Mean Wave Frequency	0.25	0.22	0.19	Hz
Mean Wave Direction	250	265	281	o
Mean Wave Setup	3	10	13	cm
Mean Wind Setup	5	11	21	cm

Figure 7 Effect of variations in westerly winds (195-015 degrees) on hydraulic parameters

Further research

Time series of the above mentioned wind parameters will be used as input variables for wave and transport models. With these models the effect of climatic changes on the hydraulic conditions can be analyzed as well as the impact on the large scale development of the Dutch coast (e.g. coastal erosion or accretion).

There is a relation between the regional climate on the North Sea and the mondial climate of the Northern hemisphere. Changes in the mondial climate have a direct (e.g. displacement of depressions to the north) as well an indirect effect (e.g. far field effect on height of swell). If possible, a simple relation has to be found between the mondial and regional climate in which the far field effect will play an important role.

In the course of time, several authors have given a relation between changes in wind direction, seasonal temperature amplitudes, stability of air masses on sea level, coastal behaviour, etc. The above mentioned meteorologic, oceanographic and morphometric time series will certainly contribute to the knowledge of coastal behaviour as a response to changes in climate.

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