KONINKLIJK NEDERLANDS

METEOROLOGISCH INSTITUUT

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Preliminary results on a comparison of shallow
water wave predictions.

De Bilt 1980

PRELIMINARY RESULTS ON A COMPARISON OF SHALLOW WATER WAVE PREDICTIONS

E. Bouws[1], B.W. Golding[2], G.J. Komen[1],

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Abstract: Predictions from two different wave models on wave height, low frequency wave height, wind speed and wind direction, are compared with observations. The comparison is made for the month of December 1979 and for three different locations in the southern North Sea.

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De Bilt, April 1980.

1. Introduction

In recent years interest in accurate wave predictions has been increasing steadily. This interest has been stimulated by demands from the offshore industry. In the Netherlands a special stimulus came from the envisaged construction of a storm surge barrier in the Oosterschelde estuary, which should start by 1982.

At present a large number of wave prediction models is available [1,2]. Although many of these are used for hindcasting studies, few are actually used for operational forecasts on shallow water (depth < 0.2 wavelength). Two such models are the Met Office model (Golding[3]) and the KNMI model GONO (Sanders[4]). The latter model has been extended to take certain bottom effects into account. The former considers refraction as well. The Met Office model makes use of two different grids, a coarse one covering most of the North Atlantic and a finer 50 km grid for the North Sea (Fig. 1a). It gives wave predictions every 12 hours: a 12 and 24 hour forecast, as well as a calculation based on the analysed weather map. GONO gives similar predictions every 6 hours. Its 75 km (Fig. 1b) grid extends quite far to the North (75° N). It covers only a small part of the Atlantic Ocean.

In order to monitor the over-all quality of these predictions it was decided to compare the output of both models with each other and with available observational data. The comparison started on the first of December 1979. Predictions for 5 different locations were selected for the comparison. These positions are

				depth	
0	EURO	51°59'N	3°30'E	20	m
1	IJMUIDEN	52°34'N	4°03'E	25	m
2	PENNZOIL	53°13'N	3°13'E	22	m
3	EKOFISK	56°33'N	3°13'E	60	m
4	OWS MIKE	66°00'N	2°00'E	∞	

The comparison is to cover the period until at least April 1980. It is hoped that results from the NORSWAM[5] model for the month of March 1980 and from the Manual Method used by KNMI (Kruseman[6]) can be included in the comparison. The present report will cover preliminary results for December 1979 and for the first three stations only.

Wave data were obtained with the help of waverider measurements. The data from EURO and PENNZOIL came to us via Rijkswaterstaat, Directie Noordzee; the IJMUIDEN data have been taken with the KNMI waverider.

The models involved predict wave spectra. In principle, these could be compared with the observed spectra. However, because of the large amount of data involved it was considered more useful to concentrate on a comparison of the significant wave height

$$H_S = 4 \left(\int_0^\infty E(f) \, df \right)^{1/2} \tag{1}$$

where $E(f)$ is the variance spectrum whose integral over all positive frequencies f gives the mean square surface displacement. As there is a special interest in the low frequency part of the spectrum an additional comparison was made of the low frequency (period > 10 s) energy. To this end a "low frequency wave height"

$$H_{S,10} = 4 \left(\int_0^{0.1} E(f) \, df \right)^{1/2} \tag{2}$$

was introduced.[*]

Since the atmospheric input to the models is important, we also made a comparison of calculated and measured wind vectors. Wind data for EURO were taken from the nearby light platform Goeree,[**] for IJMUIDEN from a nearby coastal station and from PENNZOIL from the oil rig itself.

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[*] At KNMI the quantity E_{10} has also been used as a measure of the low frequency energy. Its relation to $H_{S,10}$ is $E_{10} = \left(\frac{1}{4} H_{S,10} \right)^2$.

[**] If missing, Hook of Holland data were used.

It should be understood that the present comparison is mainly of interest as a test for the accuracy of the actual predictions. A search for weak points in the steps that lead to the predicted values would require a different approach.

As stated, the results and conclusions presented in this paper refer only to the month of December 1979. They should not be taken to imply that the models will always perform in this manner. In particular, both models have been revised since that time.

2. December time series

The two models have been compared in detail at three locations, EURO, IJMUIDEN, and PENNZOIL for the month of December 1979. Data for EKOFISK and O.W.S. MIKE were also examined but were incomplete and are not presented. Two quantities are compared in the time series, H_S the significant wave height, and $H_{S,10}$ a measure of the low frequency wave energy expressed as a height. In this section, the significant features of the time series are described. The comments should be read in conjunction with the time series diagrams (Figs 2a-f). The models will be referred to as model M for the Met Office model and GONO for the KNMI model.

A general conclusion from all the stations is that model M over-estimates $H_{S,10}$ by about 0.5 metres. This may be caused by too little dissipation in the model, a problem which has recently been corrected. However, it is also thought that a large directional spread in waves generated North or West of Scotland may be resulting in too much swell entering the North Sea according to the model.

(i) EURO

On the 1st, 3rd and 5th, GONO generates peaks in $H_{S,10}$ which did not occur. H_S is also too large at these times. The error appears to be due to the winds being too strong. Model M data were only available from 4th. It correctly predicts H_S on 5th but, like GONO, has a peak in $H_{S,10}$ which did not occur. The reduction of height after 5th is badly forecast by model M but well handled by GONO. On the 13th GONO's analysed and predicted H_S is too high. The analysis error is due to winds being too strong. However, in the 12 and 24 hour forecasts an error in wind direction appears to be the cause since the wind should be from the land but is predicted to be from the sea. Model M overpredicts the 24 hour forecast winds and H_S.

The 14th is a particularly interesting example. Model M has correct winds but H_S is too low. GONO has winds too high and incorrect H_S. Two possible explanations may be offered. One is that neither model can simulate the steep rise in the wave height that was observed in the preceding 12 hours. The other is that linear interpolation in time of the wind speeds may have resulted in the winds being too light for much of that time.

On the 17th incorrect wind forecasts result in both models overestimating H_S and $H_{S,10}$. On 27th/28th, GONO increases the winds too fast leading to H_S being too large. The 24 hour forecast winds are too low and so is H_S. Model M performed well during this period.

(ii) IJMUIDEN

On the 10th model M is about right but GONO has H_S too high. The wind speed is correct and the error appears to be due to a slight discrepancy in the wind direction which is almost parallel to the coast. On 14th, the wind at 0600Z was blowing off the coast. In the following 6

hours it veered and increased rapidly. GONO overestimates H_S which actually increased rather later than predicted. This example of an error due to a time lag in the wave response is expected to cause difficulties in the statistical analysis of errors. Model M has wind speeds too high in the 24 hour forecast and this results in H_S being too high.

The 18th is a particularly interesting case at this location. Both models approximate H_S correctly while both badly underpredict $H_{S,10}$. At PENNZOIL and EURO both models correctly predict $H_{S,10}$ as well as H_S. The reason may be indicated by the observed spectral shapes (Fig. 3). At PENNZOIL, a single narrow peak, typical of a wind driven sea, is shown. However, at IJMUIDEN the spectral peak has been flattened by some process which may be a reduction in wind speed or a shallow water effect. Whatever the reason, this shape of spectrum is not one that either model will permit. The likely result is that the models will actually have a more peaked spectrum with a higher peak frequency, thus losing the low frequency energy in $H_{S,10}$. Recent modifications to GONO may improve its representation of these processes and it is hoped that a rerun of this period will be possible using the new version.

On 28th GONO is too high as at EURO because of wind speed errors.

(iii) PENNZOIL

On 5th model M behaves as at EURO with $H_{S,10}$ too high and the reduction in H_S too slow. GONO also analyses H_S too high although the winds are correct. The forecasts of H_S are correct but with winds that are too low. On 11th GONO underestimates $H_{S,10}$ although H_S is a little high. The error may be connected with the northerly winds prevailing at the time. Both models perform very well for the 18th-20th and 26th/27th. However GONO underpredicts H_S in the 24 hour forecast on 26th/27th due to a poorly predicted wind speed.

3. Statistics

Two forms of presentation were selected for the statistical ana-
lysis. Firstly, summary tables of the errors for the whole month; and
secondly contingency tables and scatter diagrams were prepared. In the
discussion which follows the Met Office model is referred to as model
M while the KNMI model is called GONO. Tables for the verification of
wind direction and speed, H_S and $H_{S,10}$ are shown. Tables are given
with the analysis and the 24 hour forecast. They show location,
number of observations, average of the observed values, average error,
RMS error, number of cases overpredicted and number of cases underpre-
dicted for each of the given locations. (Fig. 4). For the analysis of
wind direction errors, cases with a wind speed less than 10 knots are
omitted. As before, no discussion is given for stations EKOFISK and
O.W.S. MIKE because of incompleteness and unreliability of the data.

(i) Wind direction

Model M wind-analyses include observations and so it is not valid
to compare the errors at this time. In the forecasts both models show
an average positive error indicating that forecast directions are
veered from the observations. The GONO forecast errors deteriorate with
length of forecast more quickly than in model M.

(ii) Wind speed

The analyses again cannot be compared because of the inclusion of
observations in model M. GONO overestimates the wind-speed on average.
The forecasts by model M have substantially lower errors than these from
GONO. In particular, the 24 hour forecast GONO winds are too low on ave-
rage.

(iii) H_S

Model M gives better analyses than GONO. At 12 hours the GONO RMS errors are actually smaller than in the analyses. The 24 hours forecasts by GONO are too low on average. This is consistent with the average wind speed error noted above.

(iv) $H_{S,10}$

Model M is consistently about 40 cms too high both in analyses and forecasts. GONO estimates this quantity much more accurately on average. The accuracy does not deteriorate significantly with increasing forecast time. However, the RMS error is of similar size to the average observed value so it is necessary to look in more detail at the distribution of errors. This can be done by looking at the scatter diagrams of which an example from each model is presented (Fig. 5). This example is for station EURO for the analysis and 24 hour forecast. The area of the diagram bounded by 50 cms observed or predicted $H_{S,10}$ is important because this height is critical for the entry of supertankers into EUROPOORT. The axes are labelled in cms, observed height on the vertical axis, and predicted height on the horizontal axis. Cases are grouped into bands of the labelled height $\pm$ 5 cms. This presentation confirms the overprediction of $H_{S,10}$ by model M. The points within the boundaries at the upper left indicate the "safe area" where both observed and predicted values are below 50 cms. The cases in the lower left part of the diagram are underpredictions and need to be minimised for a safe forecast. It should be noted that strong serial correlations exist in the data and that many entries may refer to the same "event".

In order to investigate the correlation of wave height (H_S) errors with wind speed errors, the summary diagrams were recalculated with all

cases removed from the H_S, $H_{S,10}$ calculations when the wind speed error

was greater than 7.5 knots. The resulting diagrams for 24 hour forecasts

are shown. Both models' results are substantially improved. However, the

improvement to GONO is greater leading to very similar errors between

the two models. This supports the view that the differences in wave height

errors are primarily due to the different wind errors.

4. Conclusions

Both models performed rather well during December 1979.

However, the following weak points were observed:

1. The Met Office model overestimates $H_{S,10}$ by about 0.5 metres.

2. The observed large $H_{S,10}$ at IJmuiden during the night of 17/18 December is not given by either model.

3. Most of the discrepancy between calculations and observations is attributable to errors in the wind input. This is a qualitative statement, which we intend to quantify later.

4. For the period and locations considered, the Met Office winds were better than the KNMI winds.

The first point may be due to do incorrect handling of dissipation

or by an overestimate of the angular spread, which takes waves from the

ocean into the southern North Sea. The cause for the second point may

be found in the observed spectral shape, which is not allowed by either

model. It is hoped that more recent versions of both models score better

on these points.

Acknowledgements

References

1. Turbulent fluxes through the sea surface, wave dynamics, and
    prediction, edited by A. Favre and K. Hasselmann. Plenum, New
    York, 1978.

2. Ocean wave climate, edited by M.D. Earle and A. Malahoff,
    Plenum, New York, 1979.

3. B.W. Golding: A depth-dependant wave model for operational
    forecasting, in Ref. 1, p 593 - 606.

4. J.W. Sanders: A growth-stage scaling model for the wind-driven
    sea, DHZ 29 (1976) 136 - 161.

5. H. Günther, W. Rosenthal, T.J. Weare, B.A. Worthington, K. Has-
    selmann and J.A. Ewing: A hybrid parametrical wave prediction
    model. J. Geophys. Res. 84 (1979) 5727 - 5738.

6. P. Kruseman: Twee practische methoden voor het maken van ver-
    wachtingen van golfkomponenten met perioden tussen 10 en 25
    seconden nabij Hoek van Holland. KNMI report WR 76-1 (1976).

Figure Captions

1a.   Grid of the Met Office Model.

1b.   Grid of GONO.

2.   Time series diagrams for December 1979. The upper part shows
       H_S as a function of time (4 times a day for GONO, twice a day
       for model M), the middle part gives $H_{S,10}$, the bottom part
       gives wind arrows. "Meting" and "0" refers to observations,
       "kaart analyse" and "1" to calculations based on analysed
       weather maps. The 12 hour forecast is indicated by "+" for
       the wave heights and by "2" for the winds, while 24 hour fore-
       casts are indicated by "x" and "3". Wave heights are in metres,
       wind arrows follow standard convections. "GOLDING" refers to the
       Met Office model.

3.   a) Wave spectrum on the 18th at 00.00Z at IJMUIDEN. Note the re-
          latively broad spectral peak at about 0.1 Hz.
       b) For comparison the spectrum measured at PENNZOIL at the same
          time.

4.   Summary tables, giving results for wind direction, wind speed, H_S
       and $H_{S,10}$ (from top to bottom). Given are resp. location, number
       of observations, average of the observed values, average error,
       RMS error, number of cases overpredicted and number of cases un-
       derpredicted. The following summaries are given a) GONO, analy-
       sis b) Met Office model analysis c) GONO, 24 hour forecast
       d) Met Office model 24 hour forecast.

5. Scatter diagrams giving number of cases for a given calculated
    value of $H_{S,10}$ (horizontally) and a given observed value of $H_{S,10}$.
    The height is in cm, location is EURO, a) refers to GONO analysis,
    b) Model M analysis, c) GONO 24 hour forecast, d) Model M 24 hour
    forecast. The 50 cm level is critical for the entry of supertan-
    kers into EUROPOORT ($H_{S,10}$ = 50 cm $\leftrightarrow$ E_{10} = 150 cm^2).

6. Summary tables of 24 hour forecasts for a) GONO and b) Met
    Office model, however, with all cases removed from the calcula-
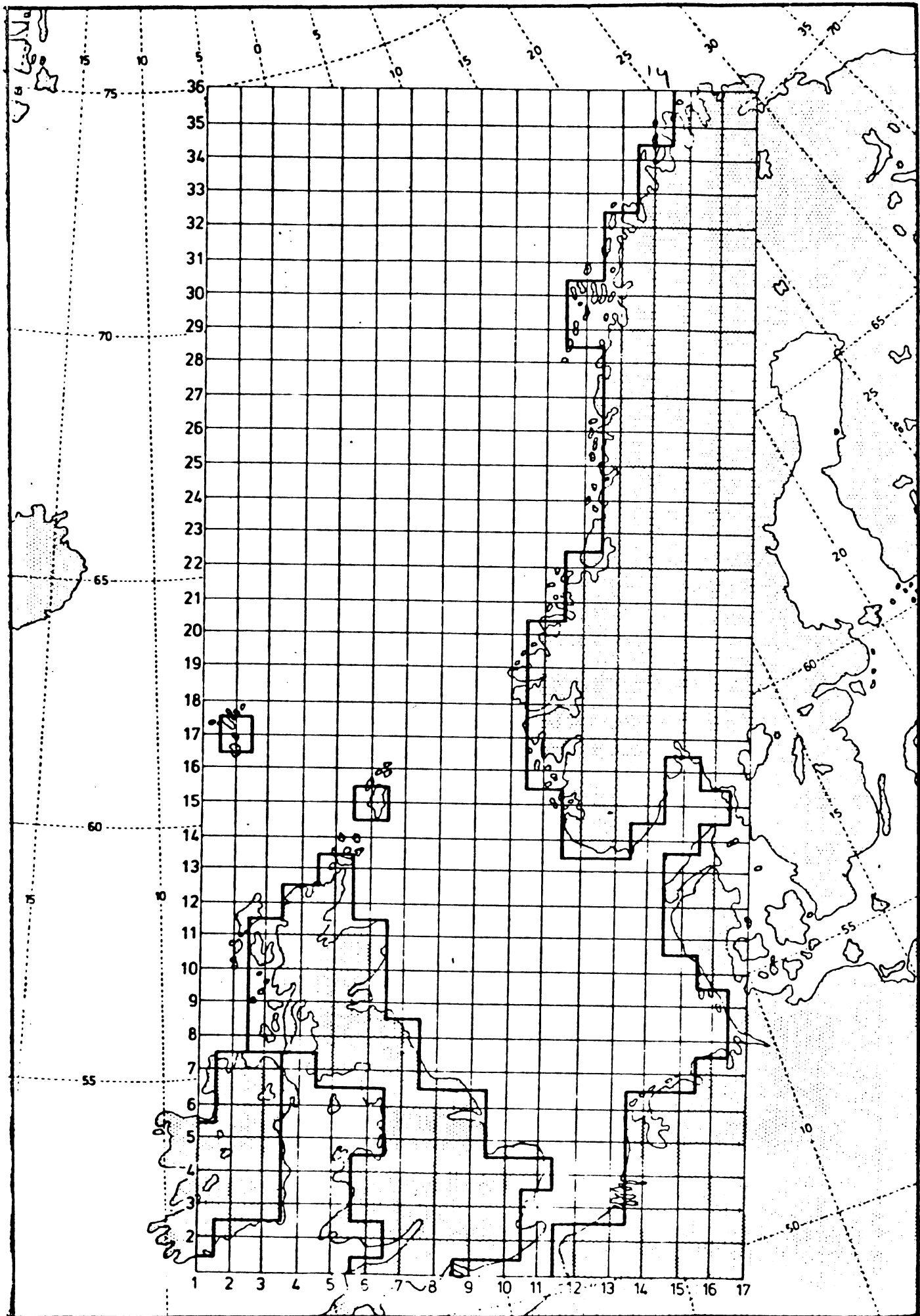   tion when the wind speed error > 7.5 knots.
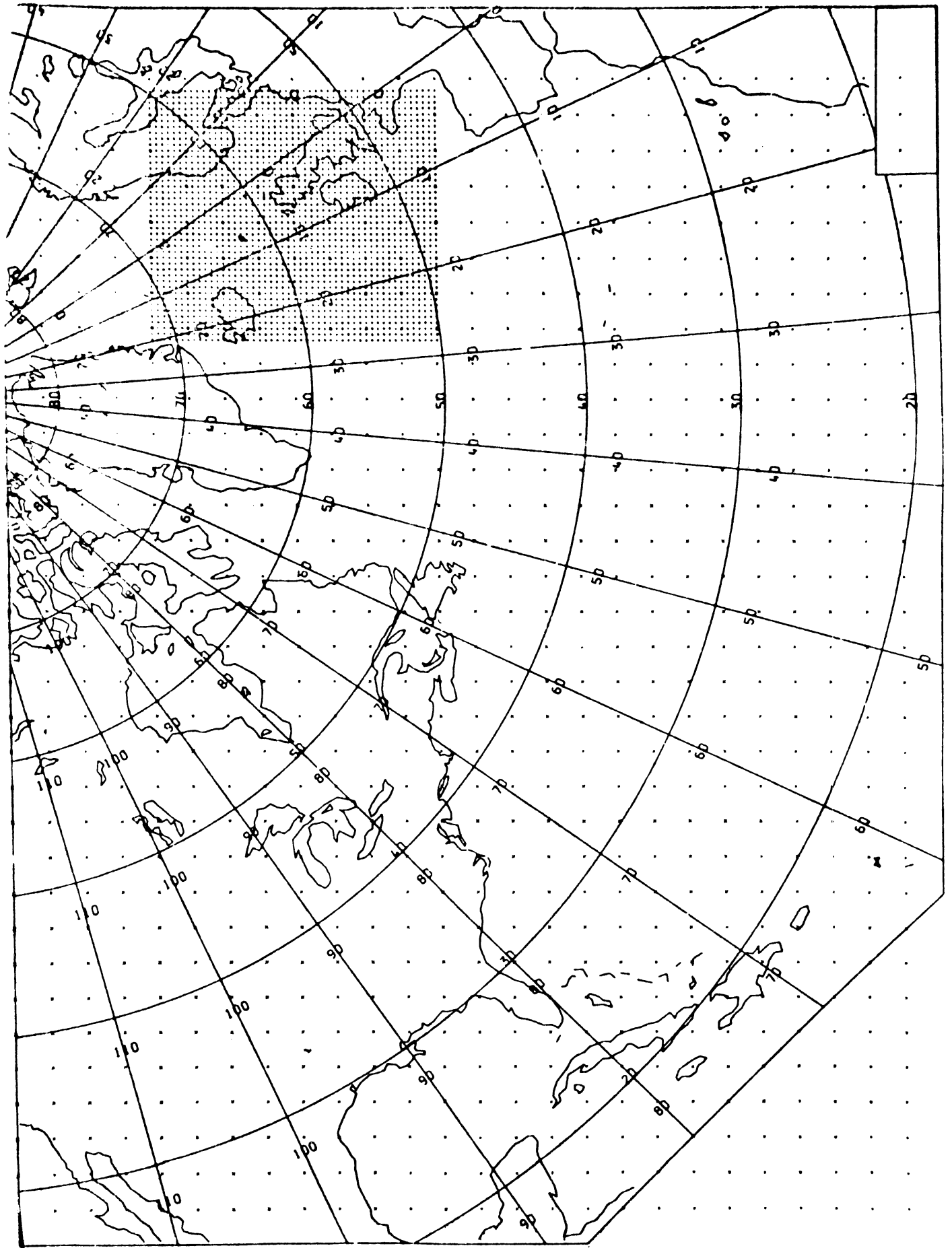
Fig. 1a

Fig. 1b

Fig. 2a

EURO
GOLDING
DECEMBER 1979
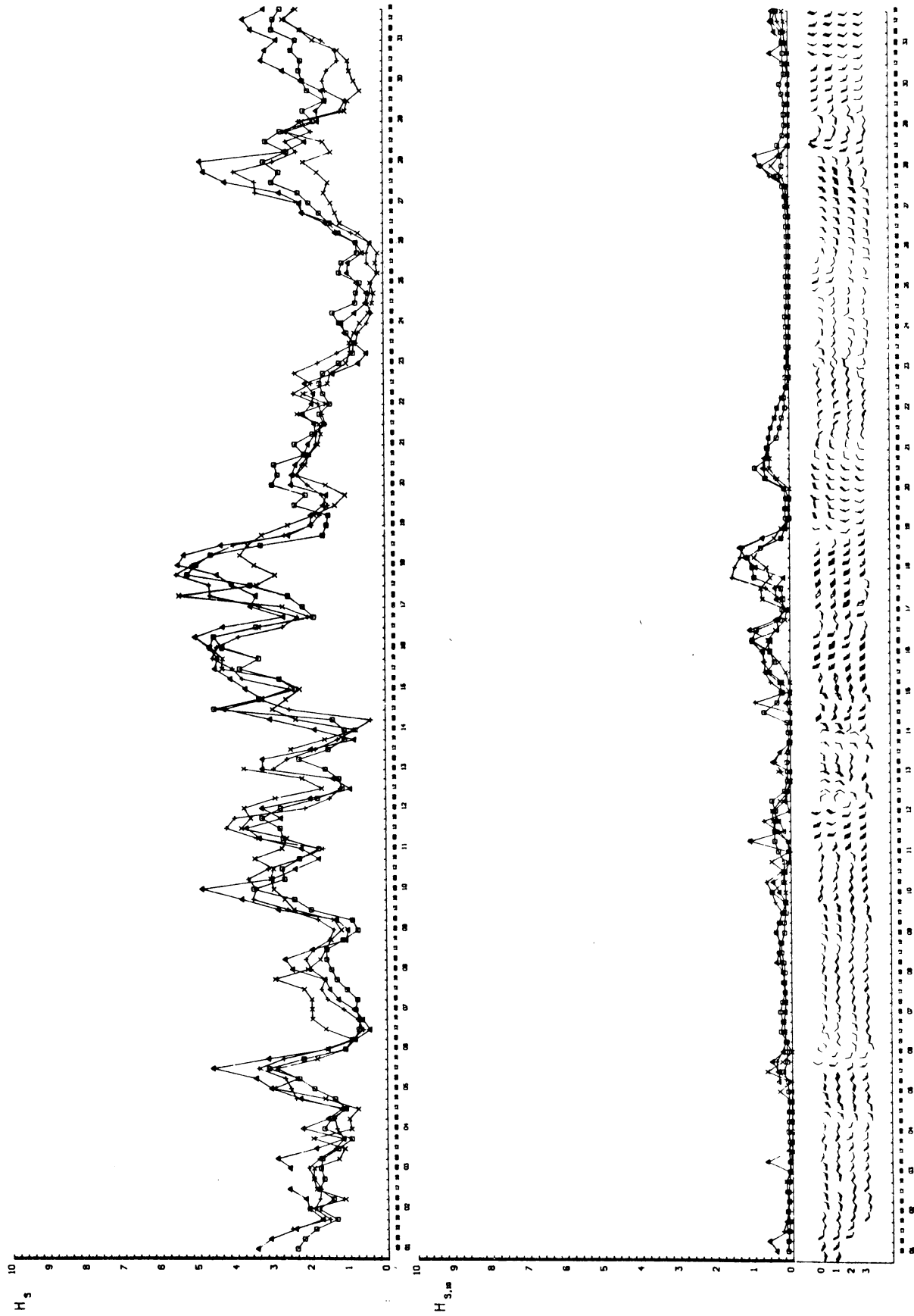
METING
KAART ANALYSE
12 UUR FORECAST
24 UUR FORECAST
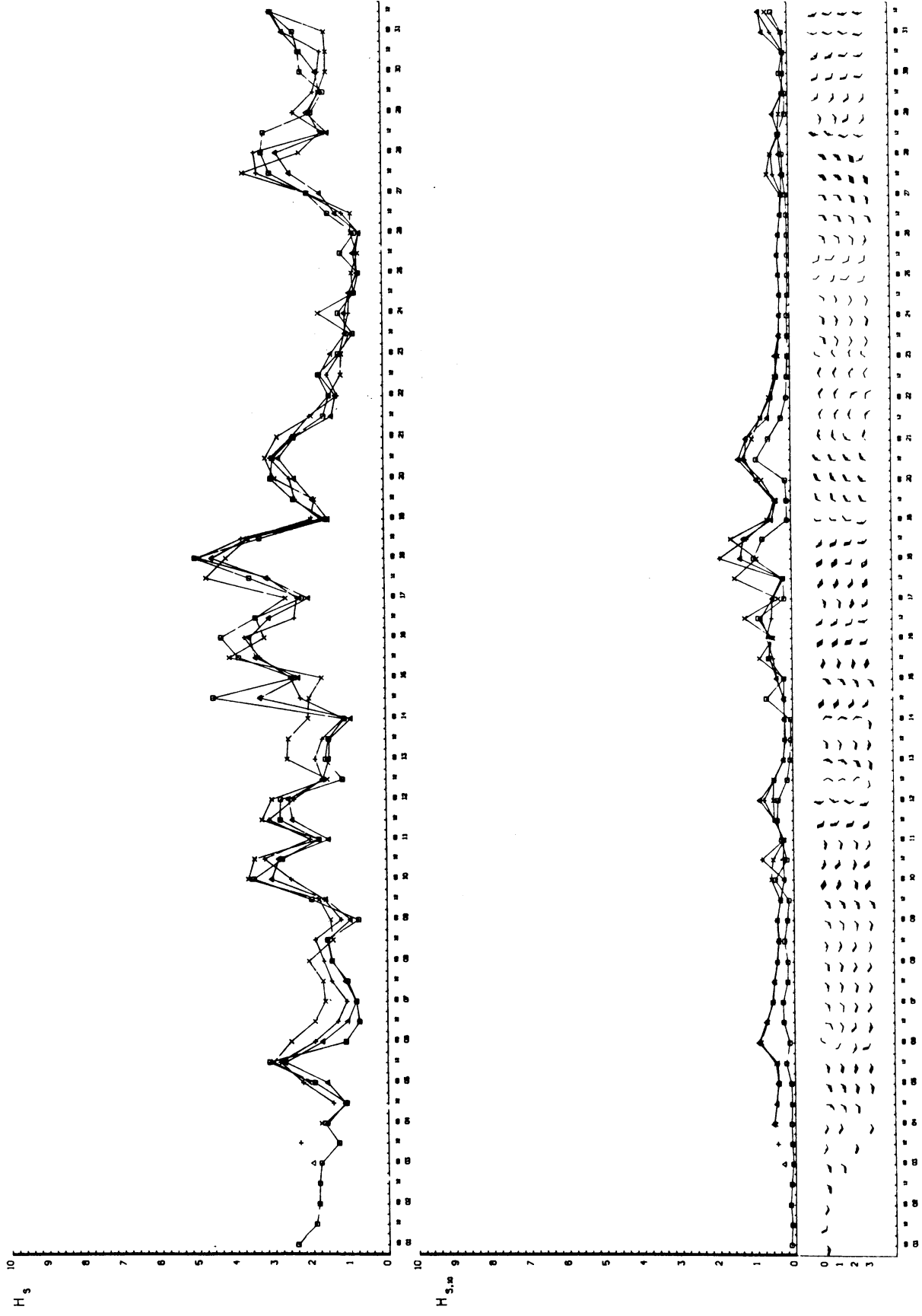
Fig. 2b

IJMUIDEN
GONO
DECEMBER 1979

METING
KAART ANALYSE
12 UUR FORECAST
24 UUR FORECAST
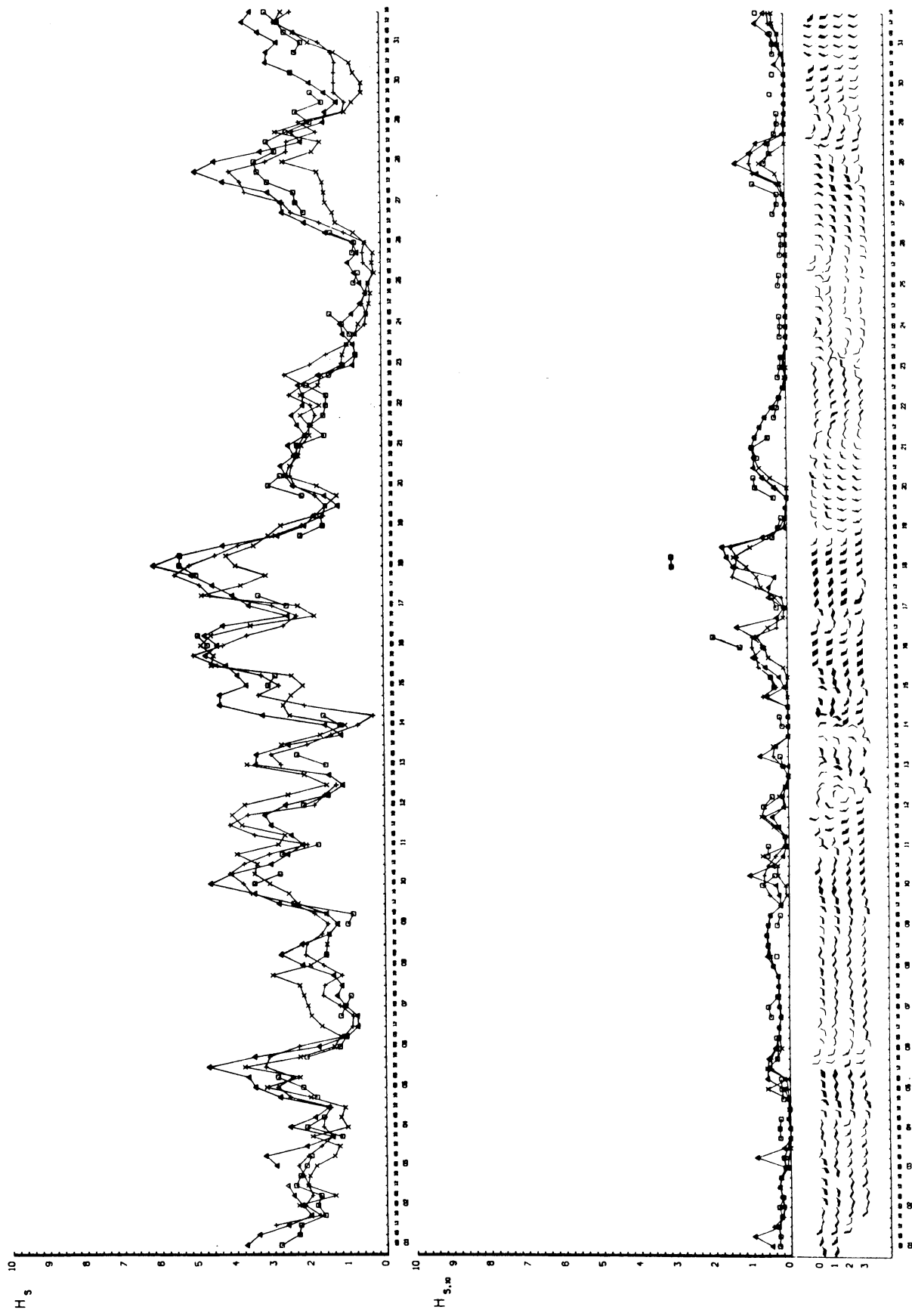
Fig. 2c

IJMUIDEN
GOLDING
DECEMBER 1979
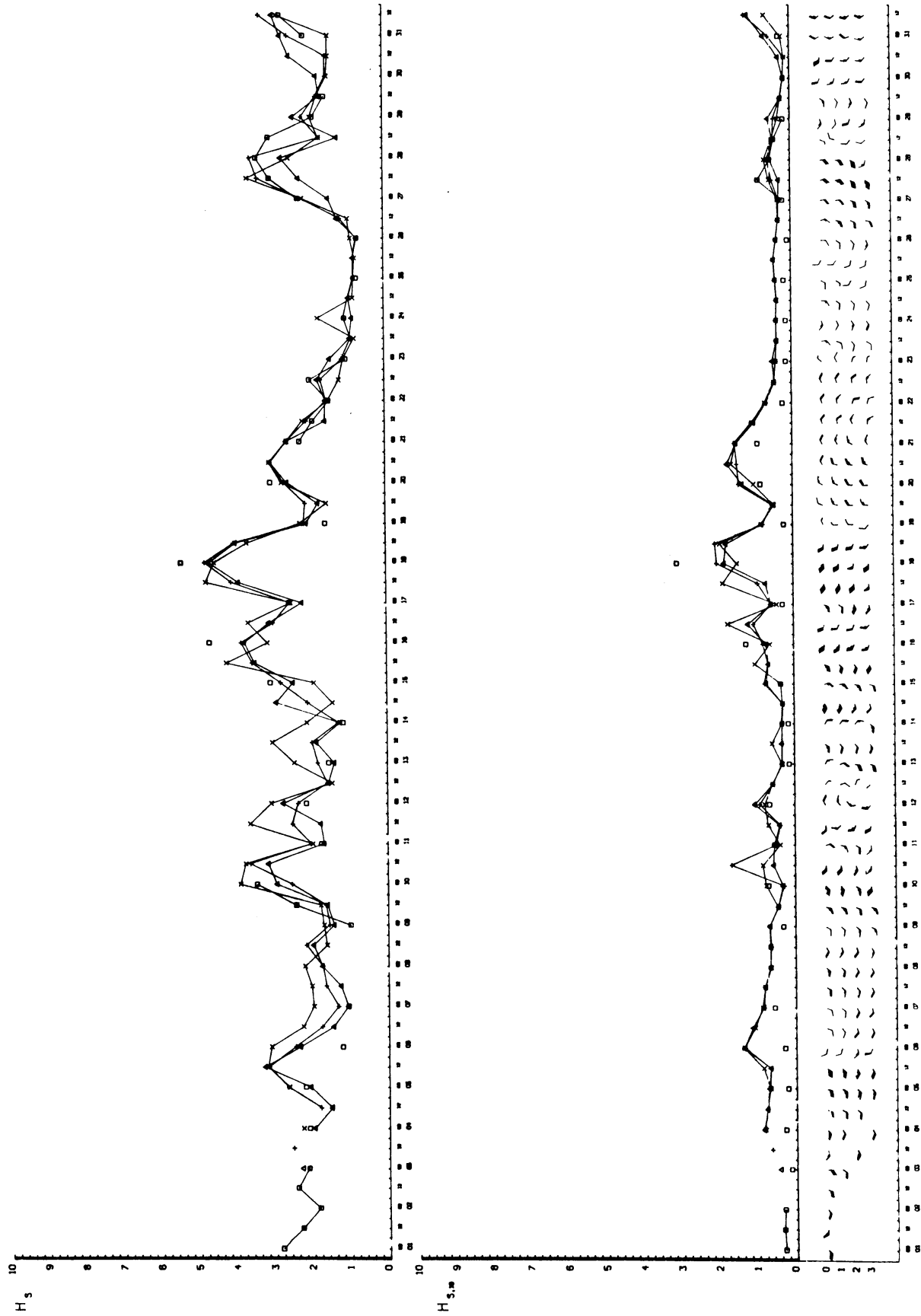
Fig. 2d

PENNZOIL
GONO
DECEMBER 1979

METING
KAART ANALYSE
12 UUR FORECAST
24 UUR FORECAST

H_s

$H_{s,\infty}$
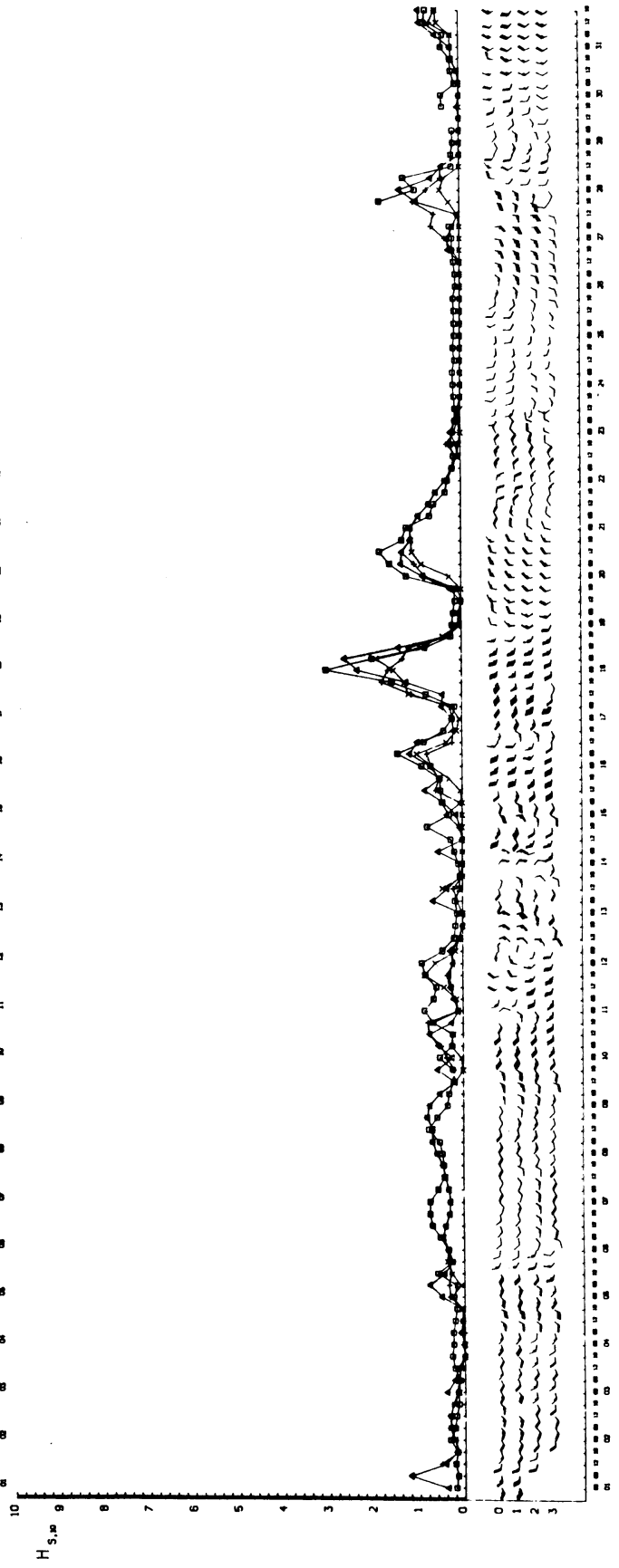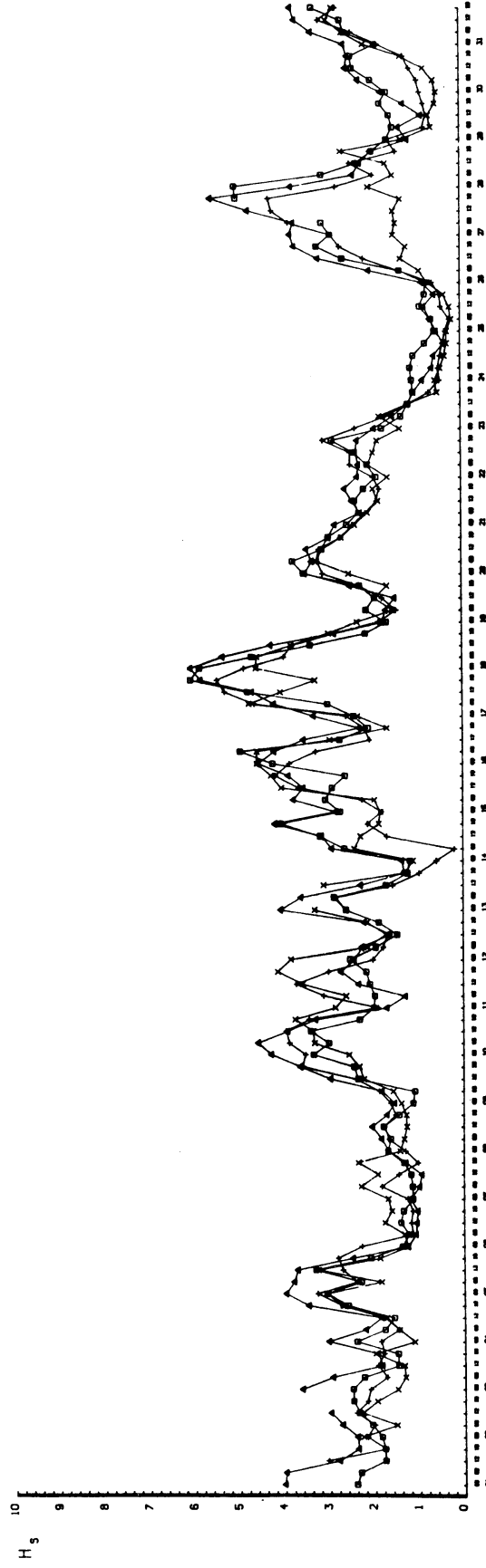
Fig.2e

PENNZOIL
GOLDING
DECEMBER 1979

Fig. 2f

a IJMUIDEN
7912180O

b PENNZOIL
7912180O

$E (m^2 s)$

$E (m^2 s)$

$f (Hz)$

$f (Hz)$
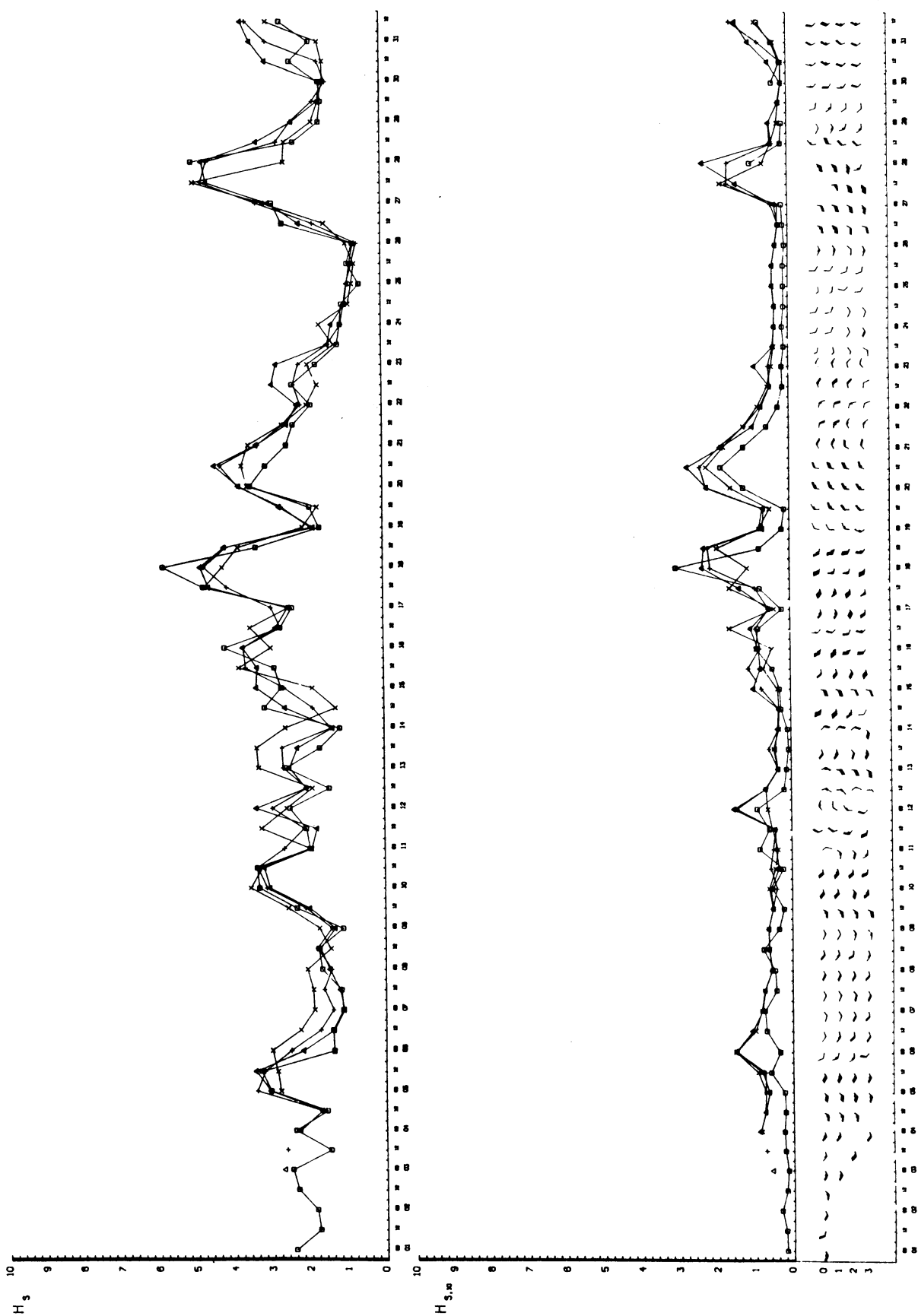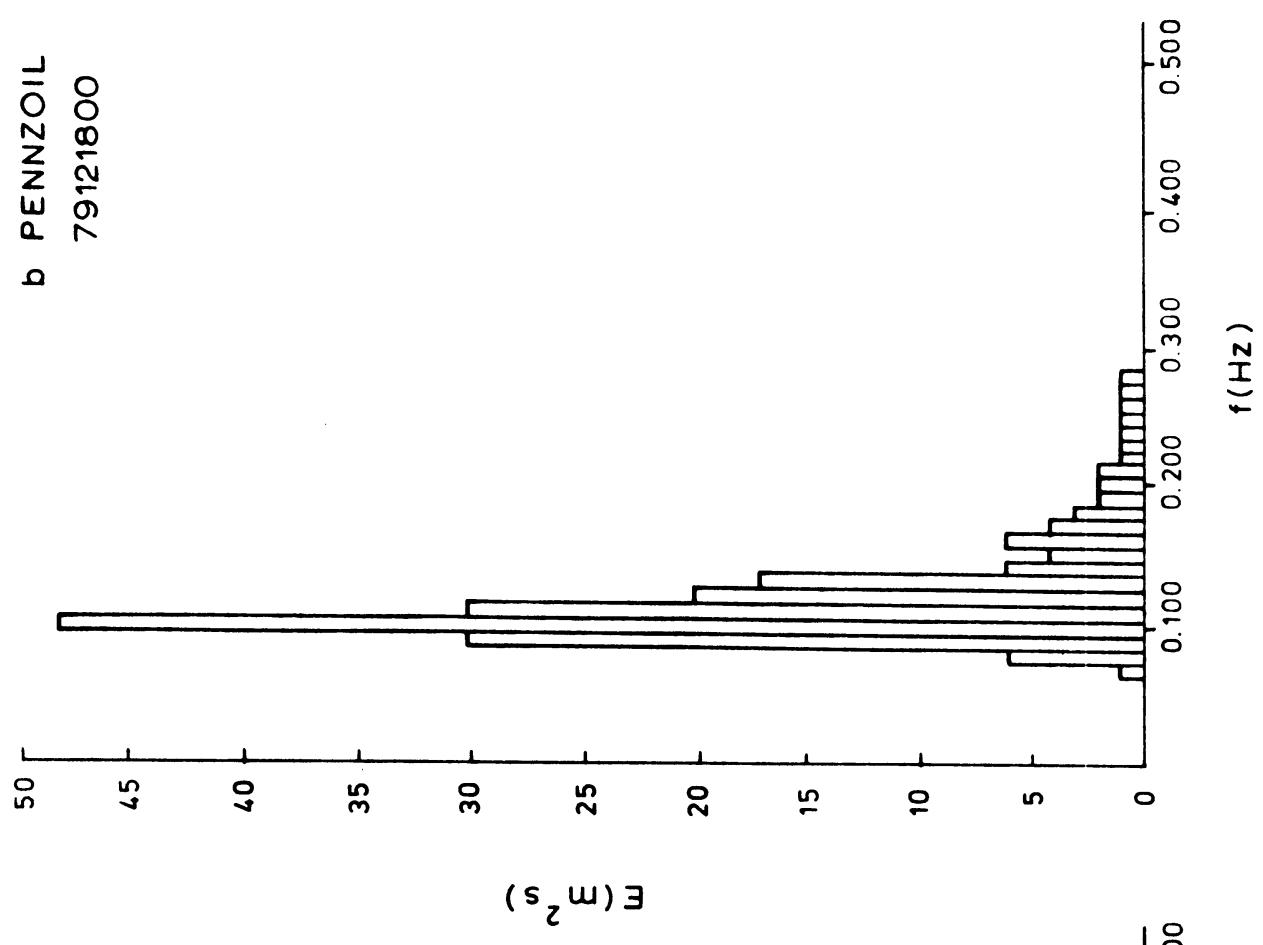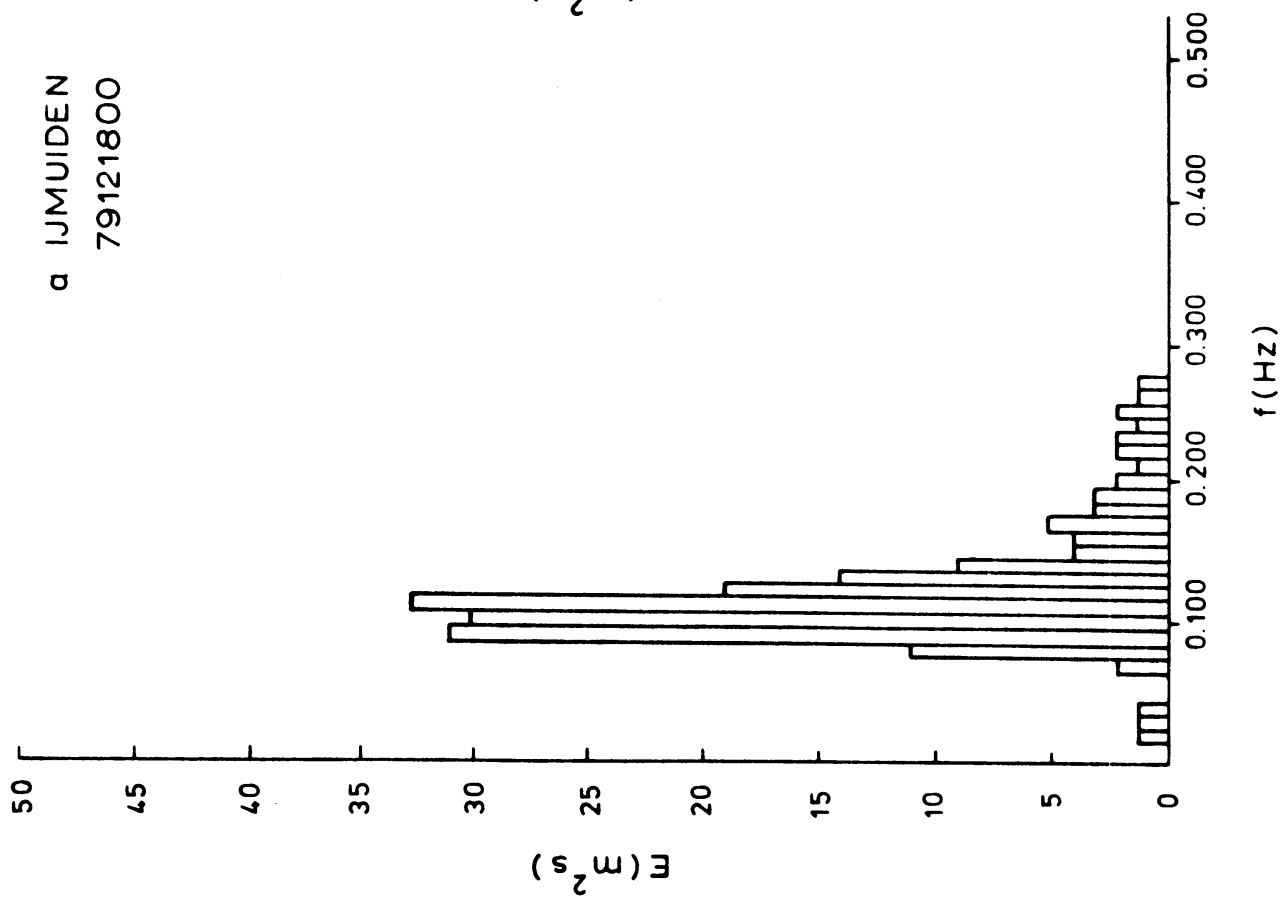
FIG. 3

WINDRICHTING IN GRADEN — ANALYSE GONO

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	RMS	PLUS	MIN
EURO 5	110	***	008	017	077	029
IJMUIDEN	104	***	014	026	081	023
PENNZOIL	107	***	-005	016	035	070
EKOFISK	078	***	-002	023	040	035
STATION M	098	***	-009	025	031	063

WINDSNELHEID IN DM/SEC — ANALYSE GONO

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	RMS	PLUS	MIN
EURO 5	123	106	006	030	073	048
IJMUIDEN	123	106	006	028	067	054
PENNZOIL	122	099	010	027	089	033
EKOFISK	105	114	-025	035	010	095
STATION M	118	120	-023	041	024	093

HS SIGN. GOLFHOOGTE IN CM — ANALYSE GONO

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	RMS	PLUS	MIN
EURO 5	123	205	037	071	085	036
IJMUIDEN	088	215	040	069	067	020
PENNZOIL	122	229	026	061	084	038
EKOFISK	018	192	150	198	018	000
STATION M	117	281	088	156	092	025

H S,10 IN CM — ANALYSE GONO

LOKATIE	AANTAL	GEM-OBS	GEM CAL-CBS	RMS	PLUS	MIN
EURO 5	123	023	001	022	046	076
IJMUIDEN	080	045	-012	041	024	056
PENNZOIL	121	046	-006	030	044	076
EKOFISK	018	104	052	116	010	008
STATION M	000					

Fig. 4a

WINDRICHTING IN GRADEN

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	ANALYSE GOLDING RMS	PLUS	MIN
EURO 5	049	***	006	011	035	010
IJMUIDEN	045	***	010	019	035	009
PENNZOIL	052	***	003	014	030	019
EKOFISK	040	***	004	012	028	010
STATION M	052	***	015	021	051	001

WINDSNELHEID IN OM/SEC

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	ANALYSE GOLDING RMS	PLUS	MIN
EURO 5	057	109	-007	018	023	032
IJMUIDEN	057	108	-011	020	013	043
PENNZOIL	056	099	018	026	047	006
EKOFISK	050	109	-006	021	018	030
STATION M	055	121	003	017	028	024

HS SIGN. GOLFHOOGTE IN CM

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	ANALYSE GOLDING RMS	PLUS	MIN
EURO 5	057	211	-017	041	017	039
IJMUIDEN	034	218	-013	058	015	018
PENNZOIL	056	230	023	054	035	021
EKOFISK	009	204	176	213	009	000
STATION M	054	281	162	193	050	004

H S>10 IN CM

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	ANALYSE GOLDING RMS	PLUS	MIN
EURO 5	057	025	023	032	048	009
IJMUIDEN	029	050	020	048	024	005
PENNZOIL	055	049	035	051	049	006
EKOFISK	009	109	119	181	009	000
STATION M	000					

Fig. 4b

WINDRICHTING IN GRADEN

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	+24 GONO RMS	PLUS	MIN
EURO 5	103	***	011	039	067	033
IJMUIDEN	096	***	019	050	070	025
PENNZOIL	095	***	004	039	056	037
EKOFISK	072	***	-010	066	041	031
STATION M	088	***	-001	033	041	046

WINDSNELHEID IN OM/SEC

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	+24 GONO RMS	PLUS	MIN
EURO 5	119	107	-011	042	047	070
IJMUIDEN	119	106	-013	045	044	074
PENNZOIL	118	099	-010	041	041	076
EKOFISK	102	113	-036	056	018	084
STATION M	114	123	-035	053	018	094

HS SIGN. GOLFHOOGTE IN CM

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	+24 GONO RMS	PLUS	MIN
EURO 5	119	205	-006	085	055	062
IJMUIDEN	084	214	-013	083	035	048
PENNZOIL	118	229	-024	093	041	076
EKOFISK	018	192	031	078	013	005
STATION M	113	285	041	124	070	042

H S.10   IN CM

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	+24 GONO RMS	PLUS	MIN
EURO 5	119	024	-006	020	032	084
IJMUIDEN	076	045	-021	042	015	060
PENNZOIL	117	047	-018	035	026	091
EKOFISK	018	104	-034	067	003	015
STATION M	000					

Fig. 4c

WINDRICHTING IN GRADEN

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	+24 RMS	GOLDING PLUS	MIN
EURO 5	048	***	021	033	039	009
IJMUIDEN	048	***	025	044	039	008
PENNZOIL	047	***	007	036	023	022
EKOFISK	035	***	012	043	022	012
STATION M	049	***	013	038	031	013

WINDSNELHEID IN DM/SEC

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	+24 RMS	GOLDING PLUS	MIN
EURO 5	055	110	000	034	028	027
IJMUIDEN	055	107	-002	038	025	029
PENNZOIL	054	098	009	042	038	016
EKOFISK	048	108	-017	041	013	035
STATION M	053	120	-017	039	017	036

HS SIGN. GOLFHOOGTE IN CM

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	+24 RMS	GOLDING PLUS	MIN
EURO 5	055	213	005	071	031	021
IJMUIDEN	033	218	008	074	022	011
PENNZOIL	054	231	010	079	034	020
EKOFISK	009	204	154	212	009	000
STATION M	052	273	126	168	049	004

H S,10 IN CM

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	+24 RMS	GOLDING PLUS	MIN
EURO 5	055	026	025	036	047	008
IJMUIDEN	028	052	015	048	022	006
PENNZOIL	053	050	021	048	043	010
EKOFISK	009	109	111	195	009	000
STATION M	000					

Fig. 4d

PERIODE 79120100-79123112

ANALYSE GOMO   LOKATIE EURO

H S.10   IN CM

	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
0	1																				
10	36	9	6	3	1	3	1	1													
20	4	7	5	1	8	1		1	1	1											
30	2	1	3	2	2	2															
40			1	1		2		1				1									
50		1		1				1													
60						1	1	1													
70	1						1														
80														1							
90			1			1		1			1										
100						1				1											
110													1								
120																					
130																					
140																					
150																					
160																					
170																					
180																					
190																					
200																					

Fig. 5a

PERIODE 79120100-79123112

ANALYSE GOLDING   LOKATIE EURO

HS.10   IN CM

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200

	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
0																					
10		1	5	8	5	4	1		1												
20		1	2	2	3	4		1		1											
30			1	1	1		2		1												
40						1			1	1											
50			1				1														
50							1		1				1								
70		1																			
80									1					1							
90									1						1						
100															1						
110																					
120																					
130																					
140																					
150																					
160																					
170																					
180																					
190																					
200																					

Fig. 5b

H S.10   IN CM

	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
0	1																				
10	39	8	5	4																	
20	4	7	8	2	3	2		2	1												
30	3	1	4	2	1	2															
40		2	1	1	1	2															
50		1	1	1	1																
60	1	1				1	1														
70	1		1																		
80										1											
90					1	2	2														
100																					
110									1		1										
120																					
130																					
140																					
150																					
160																					
170																					
180																					
190																					
200																					

Fig. 5c

PERIODE 79120100-79123112

LOKATIE   EURO

+24 GOLDING

H 5.10   IN CM

	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
0																					
10		1	7	7	4	1	2			1						1					
20		1	2	1	1	7	1		1												
30			1	1	1		1	1	1												
40						2	1														
50						1	1														
60							1			1	1										
70			1																		
80																		1			
90														2							
100										1											
110																					
120																					
130																					
140																					
150																					
160																					
170																					
180																					
190																					
200																					

Fig. 5d

WINDRICHTING IN GRADEN

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	+24 GONO RMS	PLUS	MIN
EURO 5	119	***	007	042	072	044
IJMUIDEN	119	***	019	055	085	033
PENNZOIL	118	***	-002	045	063	053
EKOFISK	102	***	-006	070	055	047
STATION M	114	***	-005	044	050	063

WINDSNELHEID IN CM/SEC

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	+24 GONO RMS	PLUS	MIN
EURO 5	119	107	-011	042	047	070
IJMUIDEN	119	106	-013	045	044	074
PENNZOIL	118	099	-010	041	041	076
EKOFISK	102	113	-036	056	018	084
STATION M	114	123	-035	053	018	094

HS SIGN. GOLFHOOGTE IN CM

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	+24 GONO ꭓ RMS	PLUS	MIN
EURO 5	075	193	008	055	040	034
IJMUIDEN	050	189	-003	056	024	025
PENNZOIL	083	204	-018	061	028	054
EKOFISK	008	150	059	074	007	001
STATION M	061	252	074	137	045	015

H S.10 IN CM

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	+24 GONO ꭓ RMS	PLUS	MIN
EURO 5	075	022	-004	016	024	049
IJMUIDEN	045	037	-016	033	010	035
PENNZOIL	082	040	-015	027	018	064
EKOFISK	008	079	-019	030	000	008
STATION M	000					

ꭓ wind speed error < 7.5 knots

Fig. 6a

WINDRICHTING IN GRADEN

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	+24 GOLDING RMS	PLUS	MIN
EURO 5	055	***	018	037	042	013
IJMUIDEN	055	***	021	054	043	011
PENNZOIL	054	***	004	037	026	026
EKOFISK	048	***	-001	050	026	021
STATION M	053	***	012	037	033	020

WINDSNELHEID IN CM/SEC

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	+24 GOLDING RMS	PLUS	MIN
EURO 5	055	110	000	034	028	027
IJMUIDEN	055	107	-002	038	025	029
PENNZOIL	054	098	009	042	038	016
EKOFISK	048	108	-017	041	013	035
STATION M	053	120	-017	039	017	036

HS SIGN. GOLFHOOGTE IN CM

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	+24 GOLDING RMS	PLUS	MIN
EURO 5	045	202	005	051	025	018
IJMUIDEN	025	214	005	059	017	008
PENNZOIL	036	230	-000	053	021	015
EKOFISK	007	154	112	114	007	000
STATION M	034	251	148	187	032	002

H S,10 IN CM

LOKATIE	AANTAL	GEM-OBS	GEM CAL-OBS	+24 GOLDING RMS	PLUS	MIN
EURO 5	045	025	024	030	040	005
IJMUIDEN	021	050	013	045	017	004
PENNZOIL	035	052	018	050	028	007
EKOFISK	007	072	056	057	007	000
STATION M	000					

* wind speed error < 7.5 knots

Fig. 6b