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Operational WAMS statistics over the period December 1986 - March 1987

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Abstract

Wave heights predicted by a shallow water, third generation wave model (WAMS) and the wind fields from the European Centre for Medium Range Weather Forecasts (ECMWF) have been compared with observations. The comparison is made for the following elements : wind direction, wind speed, and wave height, for the period December 1986 until March 1987 inclusive for the following locations: LEG, IJMUIDEN and K-13 in the southern North Sea, EKOFISK in the central North Sea and BRENT in the northern North Sea.

Contents

I Introduction.

The WAMS model is a third generation ocean wave prediction model. It was jointly developed by the so-called WAMDI (Wave Model Development and Implementation) group (WAMDI, 1988). The model has been tested in a number of hindcasts.

To demonstrate its operational capabilities a regional version of the model was coupled to the atmospheric model of the European Centre for Medium Range Weather Forecasts (ECMWF) to produce daily 24-hour forecasts. The model was operated in the same way as for the Whist hindcast described in WAMDI (1988) : the grid (1/4° latitude, 1/2° longitude) covered part of the North Atlantic Ocean, the Norwegian Sea and the North Sea and the propagation time step was set at 15 minutes, within the stability limits of the first order, upwind advection scheme.

In the present publication we compare model results for a number of stations with observations. We made a similar comparison between GONO (the operational wave model at KNMI, for a description of which we refer to Janssen, Komen and de Voogt, 1985) and observations, so that we are able to assess the quality of the predictions. One should realize that this comparison does not only test differences between GONO and WAMS, but also differences in predicted wind fields: WAMS is driven by ECMWF surface fields (ECMWF winds); GONO is driven by winds derived from the pressure fields of the fine-mesh model of the Meteorological Office of the United Kingdom (GONO winds). The comparison is further complicated because GONO was run twice daily, whereas WAMS was run once every day. Our comparison is 6 hourly.

II The observations

In this report we will consider wind direction (DD), wind speed (FF) and significant wave height (H_S) only. Stations to be discussed are given in table 1.

NAME	POSITION		Depth (m)
LEG	51°54' N	3°36' E	30 m
IJMUIDEN	52°34' N	4°04' E	25 m
K-13	53°13' N	3°13' E	22 m
EKOFISK	56°30' N	3°12' E	60 m
BRENT	61°04' N	1°43' E	>100 m

Table 1 : Positions of stations

The positions are shown in figure 1.

All winds have been reduced to equivalent 10 meter winds.

The significant wave height (H_S) is defined as

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

where E(f) is the one-dimensional frequency spectrum.

The observations were supplied by various sources. The data from K-13 came to us via Rijkswaterstaat, Directie Noordzee; the IJMUIDEN data have been taken with the KNMI waverider. The rest of the observations have been taken via the Global Telecommunication System (GTS).

III Time series.

The time series have been presented in graphs, showing every 6 hours the wind direction (DD) in degrees, the wind speed (FF) in metres/sec, and the wave height (H_S) in metres. The time series graphs are labelled with the symbol FP = 0,6,12,18, where FP means forecasting period. For WAMS the 0 data are based on analysed winds, the 6, 12 and 18 are based on forecast. For GONO 0 and 12 are based on analysed winds; the 6 and 18 are based on forecast winds. Hence we see on the GONO graphs : FP = 0,6,0,6

We give a qualitative description of the main features of the time series. (see Fig. 2 to 41).

III.1 WAMS and ECMWF versus observations. (see Fig. 2 to 40 even numbered)

LEG (see Fig. 2, 4, 6 and 8)

The models performed well at LEG, only on December 5th the wind speed as well the wave height are overpredicted. In the period December 6th - 10th ECMWF overpredicted the wind speeds. And on December 19th and 20th WAMS underpredicted. ECMWF winds and the WAMS wave heights overpredicted on February 6th, 8th and 9th. On February 20th ECMWF calculated too low wind speed but WAMS performed better. On March 2nd WAMS underpredicted the wave height, the increase of wind speed and wave height was rather fast on that day.

IJMUIDEN (see Fig. 10, 12, 14 and 16)

WAMS performed also well at IJMUIDEN, the failures are on the same dates as LEG.

K-13 (see Fig. 18, 20, 22 and 24)

WAMS overpredicted several times, on December 23rd, 27th - 29th and on January 1st, 2nd, 14th - 16th and 26th the wave heights are underpredicted, on February 6th and 8th WAMS overpredicted.

EKOFISK (see Fig. 26, 28, 30 and 32)

In general WAMS performed well at this position. The ECMWF model as well the WAMS wave model calculated too low winds and waves on December 31th. On December 5th, 7th, 8th, 9th, 13th, January 25th and on February 6th the ECMWF winds are too high, and also the calculated wave heights are too high. On February 11th WAMS calculated the peak too low. On February 21th - 23rd ECMWF overpredicted the wind speeds, WAMS performed well.

BRENT (see Fig. 34, 36, 38 and 40)

Wave heights of 6 metres or more were frequently reported on this position. In general WAMS performed well. On December 7th and 13th WAMS overpredicted the wave heights. Remarkable are too low calculated wave heights on January 4th, 9th, 10th and 13th due to the ECMWF model's underprediction of the wind speed. On January 25th WAMS overpredicted. In this verification period we find the most spectacular peaks on March 2nd (9.5 m) and 6th (7.0 m). WAMS calculated about 2 metres too high.

III.2 WAMS versus GONO (see Fig. 2 to 41)

LEG (see Fig. 2 to 9)

On December 18th, 19th and 29th GONO calculated too high and on December 22nd - 23rd GONO underpredicted the wave heights. In the period January 13th - 16th GONO underpredicted, while WAMS performed well. The peak on March 2nd is underpredicted by WAMS. GONO calculated the wave height well.

IJMUIDEN (see Fig. 10 to 17)

In the period January 12th - 16th GONO calculated the wave heights too low and on February 6th too high due to the overprediction of the GONO winds.

K-13 (see Fig. 18 to 25)

On December 27th WAMS calculated the wave heights too high due to overprediction of the wind speeds. On January 12th - 17th GONO winds as well GONO gave too low results.

EKOFISK (Fig. 26 to 33)

In the periods December 21st - 24th, January 5th - 17th and on January 26th, 28th, February 22nd, 23rd and March 8th and 9th GONO underpredicted the wave heights, WAMS performed well.

BRENT (see Fig. 34 to 41)

On January 4th WAMS underpredicted the wave height, while GONO performed well. On January 25th, 26th and 28th WAMS results were better than GONO. (GONO too low). In the period February 3rd - 5th WAMS overpredicted the wave heights, even more than GONO did. On March 2nd and 6th WAMS overpredicted (2 - 3 m) and GONO underpredicted (2 - 3.5 m) the wave heights. In the period March 7th - 9th WAMS gave too high wave heights while GONO performed better.

IV Statistics

The statistics are presented in tables and scatter diagrams. The statistics include the number of the observations (NUMBER), the average of the observations (AV.OBS), the bias (BIAS) and the standard deviation (SD). Also are given the scatter index (SI) defined as 100 * (SD / AV. OBS) in percentages (table 2).
The bias and the standard deviation in the wind speeds are given in dm/sec and the wave heights in cm. The statistics is only determined for wind speeds > 5 m/s.

IV.1 Summary table: WAMS (and ECMWF winds) versus GONO (and GONO winds)

The table given below is showing the statistical parameters of wind direction (degrees), wind speed (dm/sec) and wave height (cm).

LEG	NUMBER	AV.OBS	WAMS BIAS	GONO BIAS	WAMS SD	GONO SD	WAMS SI	GONO SI
DD	216	-	5	5	23	23	-	-
FF	216	91	13	10	23	30	26	33
H_S	214	171	7	- 1	56	76	33	44
IJMUIDEN								
DD	243	-	19	18	28	25	-	-
FF	243	99	5	- 3	22	26	23	26
H_S	233	178	- 7	-14	51	67	28	37
K-13								
DD	256		- 3	- 4	24	19	-	-
FF	256	97	15	- 4	21	24	21	25
H_S	241	203	3	-21	54	67	26	33
EKOFISK								
DD	242	-	-12	-15	22	21	-	-
FF	238	102	13	-10	30	29	29	29
H_S	222	272	- 1	-48	79	90	29	31
BRENT								
DD	249	-	14	11	30	25	-	-
FF	249	115	0	-26	31	30	26	26
H_S	245	302	24	-54	115	104	38	33

TABLE 2 Statistic summary of wind direction, wind speed and wave height

IV.2 Summary tables: ECMWF winds versus GONO winds.

Table 3 gives a summary of the statistical verification of the winds, by sectors of 60.

ECMWF winds and GONO winds (period 8612 - 8703)
(wind speed in dm/sec.)

	SECTOR	N	ECMWF BIAS	GONO BIAS	ECMWF SD	GONO SD	ECMWF SI	GONO SI
LEG	0 - 60	41	7	-11	21	20	24	22
IJMUIDEN	0 - 60	52	4	-16	18	20	18	21
K-13	0 - 60	34	19	-13	19	21	23	26
EKOFISK	0 - 60	26	17	-15	29	17	34	20
BRENT	0 - 60	23	-21	-40	28	25	31	27
LEG	60 - 120	25	29	16	18	32	26	46
IJMUIDEN	60 - 120	43	2	-14	19	20	22	24
K-13	60 - 120	58	12	-22	19	17	18	16
EKOFISK	60 - 120	45	- 3	-31	39	33	33	28
BRENT	60 - 120	17	- 6	-32	48	37	50	39
LEG	120 - 180	28	15	5	21	18	28	24
IJMUIDEN	120 - 180	25	19	17	22	23	27	29
K-13	120 - 180	20	17	3	17	18	21	22
EKOFISK	120 - 180	36	12	-17	27	30	22	25
BRENT	120 - 180	79	6	-31	26	29	19	21
LEG	180 - 240	50	13	18	26	29	27	31
IJMUIDEN	180 - 240	47	6	6	27	29	24	26
K-13	180 - 240	42	15	10	24	24	22	22
EKOFISK	180 - 240	48	14	0	24	25	24	25
BRENT	180 - 240	32	7	- 5	19	24	17	23
LEG	240 - 300	43	18	30	18	26	16	23
IJMUIDEN	240 - 300	57	- 1	2	22	24	19	21
K-13	240 - 300	60	20	4	20	24	18	22
EKOFISK	240 - 300	36	17	0	29	30	29	31
BRENT	240 - 300	57	- 1	-25	32	29	29	26
LEG	300 - 360	29	- 1	- 2	23	30	27	34
IJMUIDEN	300 - 360	19	6	-15	22	17	27	21
K-13	300 - 360	42	10	- 2	22	20	28	26
EKOFISK	300 - 360	47	25	0	20	19	22	21
BRENT	300 - 360	44	3	-26	28	26	27	26

TABLE 3 Statistical summary of wind speed

divided in 6 sectors of wind direction

IV.3 Summary tables: WAMS waves versus GONO waves.

Table 4 gives a summary of the statistical verification of the wave heights, by sectors of 60.

WAMS waves and GONO waves (period 8612 - 8703)
(wave height in cm)

	SECTOR	N	WAMS BIAS	GONO BIAS	WAMS SD	GONO SD	WAMS SI	GONO SI
LEG	0 - 60	41	- 6	- 71	36	43	20	24
IJMUIDEN	0 - 60	50	- 1	- 67	36	40	21	23
K-13	0 - 60	34	0	- 58	48	38	25	20
EKOFISK	0 - 60	26	- 30	- 94	72	64	25	22
BRENT	0 - 60	23	- 11	- 52	74	60	42	34
LEG	60 - 120	25	24	- 51	33	29	28	22
IJMUIDEN	60 - 120	43	- 8	- 62	40	38	31	29
K-13	60 - 120	58	- 7	- 80	46	38	20	16
EKOFISK	60 - 120	42	- 50	-106	85	54	25	15
BRENT	60 - 120	16	23	- 65	122	70	58	33
LEG	120 - 180	27	21	15	47	42	58	51
IJMUIDEN	120 - 180	24	- 16	18	39	45	29	34
K-13	120 - 180	17	- 20	4	47	51	36	39
EKOFISK	120 - 180	32	1	- 37	67	109	27	38
BRENT	120 - 180	77	63	- 53	115	121	33	34
LEG	180 - 240	49	28	57	67	76	43	49
IJMUIDEN	180 - 240	41	6	45	67	69	36	37
K-13	180 - 240	34	0	33	56	64	30	34
EKOFISK	180 - 240	41	31	14	67	93	31	43
BRENT	180 - 240	32	12	- 35	133	117	41	36
LEG	240 - 300	43	- 5	40	59	64	23	25
IJMUIDEN	240 - 300	56	- 18	22	59	46	25	19
K-13	240 - 300	57	27	21	57	56	24	24
EKOFISK	240 - 300	35	14	- 23	64	72	24	25
BRENT	240 - 300	53	33	- 36	120	97	43	33
LEG	300 - 360	29	- 20	- 28	59	60	30	31
IJMUIDEN	300 - 360	19	- 3	- 51	40	36	23	21
K-13	300 - 360	41	3	- 23	52	55	30	32
EKOFISK	300 - 360	46	14	- 54	77	73	27	26
BRENT	300 - 360	43	- 30	- 87	69	88	20	26

TABLE 4 Statistical summary of wave height divided in 6 sectors of wind direction

IV.4 Scatter diagrams: Models versus observations.

In this paragraph we try to understand with the aid of the scatter diagrams the comparison between the modeled parameters and the observations.

Scatter diagrams (see Fig. 42 to 46)

The squares on the X- and Y-axis of the scatter diagrams give the average of the observations and the model-results, respectively. The bias and the standard deviation of the wind direction are given in degrees, the wind speed in dm/sec and the wave heights are given in cm.

LEG. (see Fig. 42)

Both models overpredicted the wind direction and the wind speed. The bias in the wave heights of both models are small, but the SD and the SI of the WAMS model are smaller (SD 56 cm and SI 33%) than the GONO model (SD 76 cm and SI 44%).

IJMUIDEN. (see Fig. 43)

The wind direction veered in both models (bias ca. 20 degrees), the SD and the SI of the ECMWF model are smaller than the GONO winds. The SI and the SD in the wave heights of WAMS are smaller than GONO.

K-13. (see Fig. 44)

The wind direction performed well in both models. The ECMWF winds overpredicted the wind speed (bias 3 m/sec) and GONO underpredicted a little (bias 1 m/sec). The statistical parameters of the WAMS model are smaller than in the GONO model.

EKOFISK. (see Fig. 45)

The wind direction is backed in both models (12 - 15 degrees). The wind speed is overpredicted in the ECMWF model (bias 1.3 m/sec) and underpredicted in the GONO model (bias 1.0 m/sec). The WAMS model calculated a smaller bias (1 cm) than the GONO model (bias 48 cm).

BRENT. (see Fig. 46)

The wind direction veered in both models (bias 11 - 14 degrees). The bias (0 m/s) of the ECMWF model was less than GONO (bias -2.6 m/sec)
As a result of underprediction of the wind speed GONO calculated the wave heights too low (bias -54 cm), while WAMS wave heights were too high (bias 24 cm).

IV.5 Summary tables: relation between FF error and H_S error.

Table 5 gives a relation between the error in the wind speed ΔFF (FFMODEL - FFOBS) and the error in the wave height ΔH_S (H_SMODEL - H_SOBS). We have separated the wind speed in 10 classes. We only used wind speeds > 10 m/sec.

ΔFF (dm/sec) (in 10 classes)	K-13 (WAMS) NUMBER	K-13 (WAMS) $< \Delta H_S >$ (cm)	K-13 (GONO) NUMBER	K-13 (GONO) $< \Delta H_S >$ (cm)
<-40	2	- 80	8	-102
-40 - -30	2	4	9	- 87
-30 - -20	5	- 65	13	- 53
-20 - -10	8	- 49	11	- 42
-10 - 0	6	- 64	8	- 23
0 - 10	9	- 4	18	- 2
10 - 20	21	16	8	51
20 - 30	25	36	5	61
30 - 40	9	22	7	77
> 40	11	79	11	126

ΔFF (dm/sec) (in 10 classes)	EKOFISK (WAMS) NUMBER	EKOFISK (WAMS) $< \Delta H_S >$ (cm)	EKOFISK (GONO) NUMBER	EKOFISK (GONO) $< \Delta H_S >$ (cm)
<-40	9	-176	19	-146
-40 - -30	2	-123	9	- 94
-30 - -20	5	- 21	19	- 85
-20 - 10	8	- 52	19	-105
-10 - 0	9	- 29	13	14
0 - 10	15	- 15	9	- 27
10 - 20	18	32	9	73
20 - 30	17	50	7	59
30 - 40	13	58	5	115
> 40	8	111	4	206

TABLE 5 $< \Delta H_S >$ (= $< H_S$MODEL - H_SOBS $>$) for different classes of wind speed error for K-13 and EKOFISK, where < > denotes an average over a particular class.

Table 6 gives us an impression of the sensitivity for differences between the wind observations and the modeled wind speeds.

Correlation coefficient

NAME	WAMS	GONO
LEG	0.81	0.86
IJMUIDEN	0.63	0.78
K-13	0.64	0.82
EKOFISK	0.82	0.81
BRENT	0.62	0.59

TABLE 6 Correlation between ΔFF and ΔH_S. Given are the correlation coefficients for 5 locations.

V. Conclusions

1. By comparing the time series of the WAMS model with the GONO model we noticed that in general WAMS performed better than GONO. It is conspicuous that GONO showed many fluctuations in the wave heights that we did not see in the WAMS graphs. Those fluctuations are often due to fluctuations in the wind speed, a phenomenon which is described in Van Moerkerken (1989).

2. In general, scatter index and bias of the WAMS model are smaller than of the GONO model. (see table 2)

3. Near the coast (IJMUIDEN and K-13) the sensitivity of the wave field to errors in the wind field is smaller in the WAMS model.

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KNMI Wetenschappelijk Rapport, WR 89-03.

Figures Captions.

Fig. 1 Locations of the reporting stations in the North Sea.

Fig 2 - 41 Time series with wind direction, wind speed and wave height.

Fig. 42 - 46 Scatter diagrams with wind direction, wind speed and wave height of the observations against the results of the models.

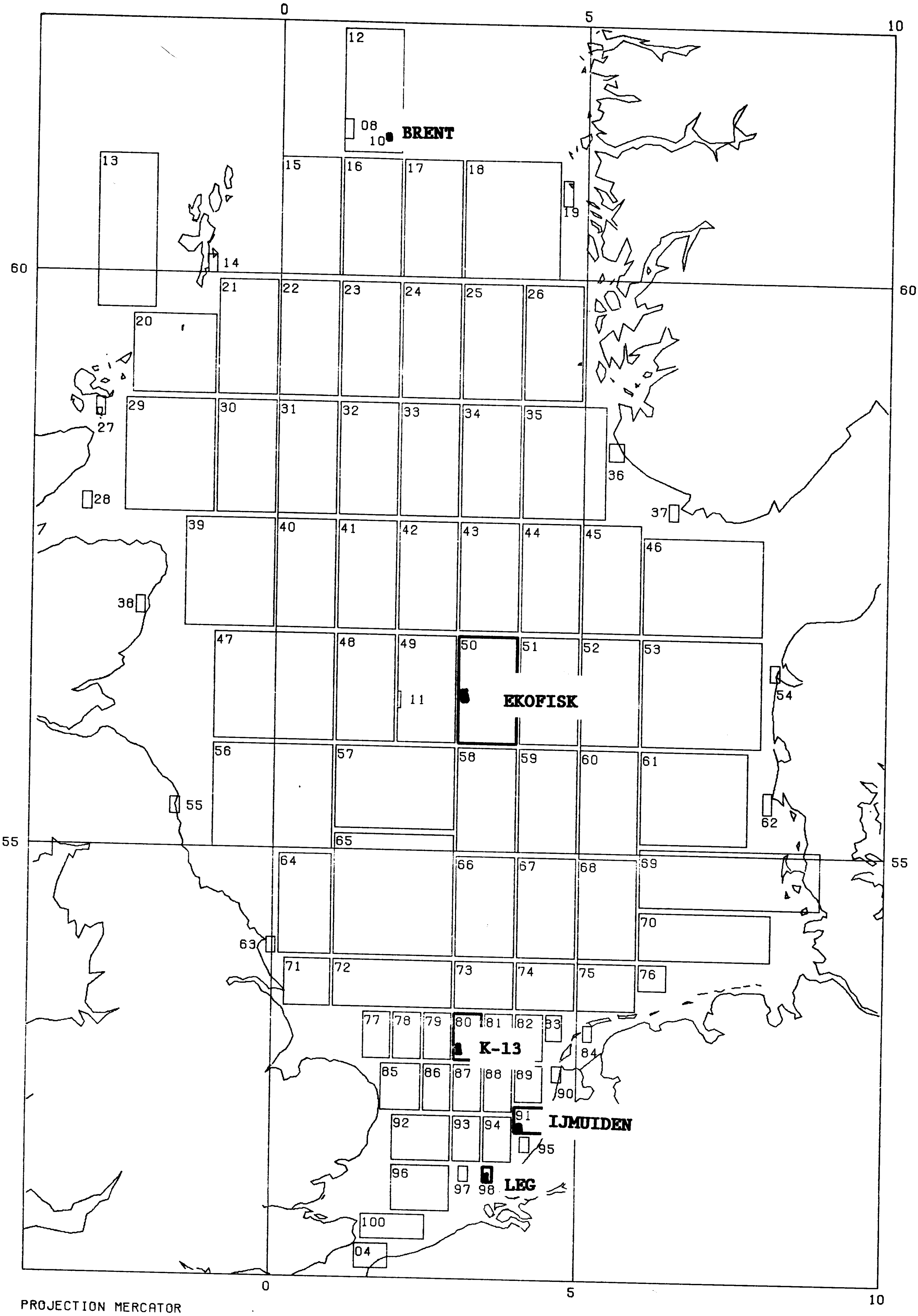

FIG. 1

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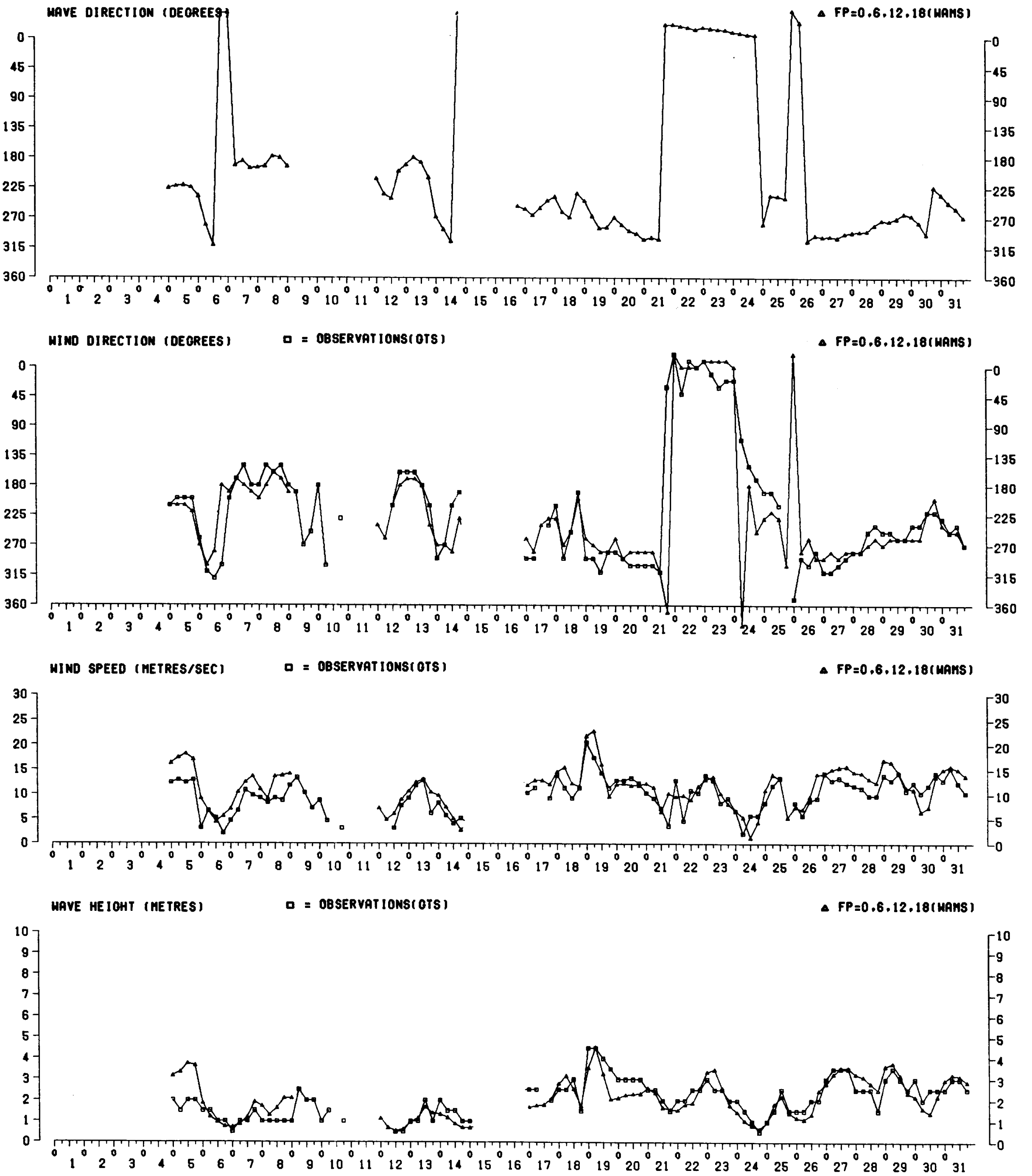

FIG. 2

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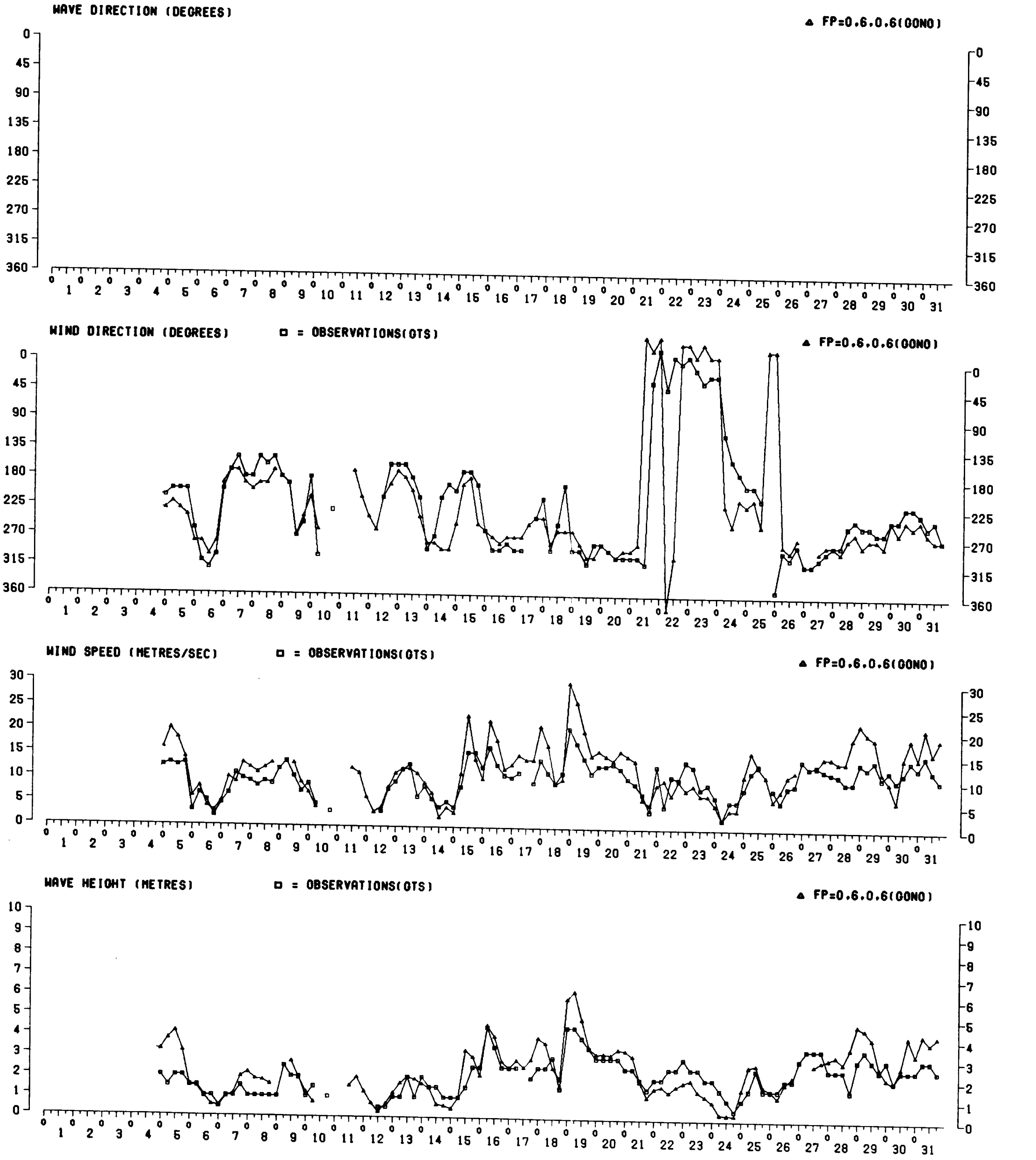
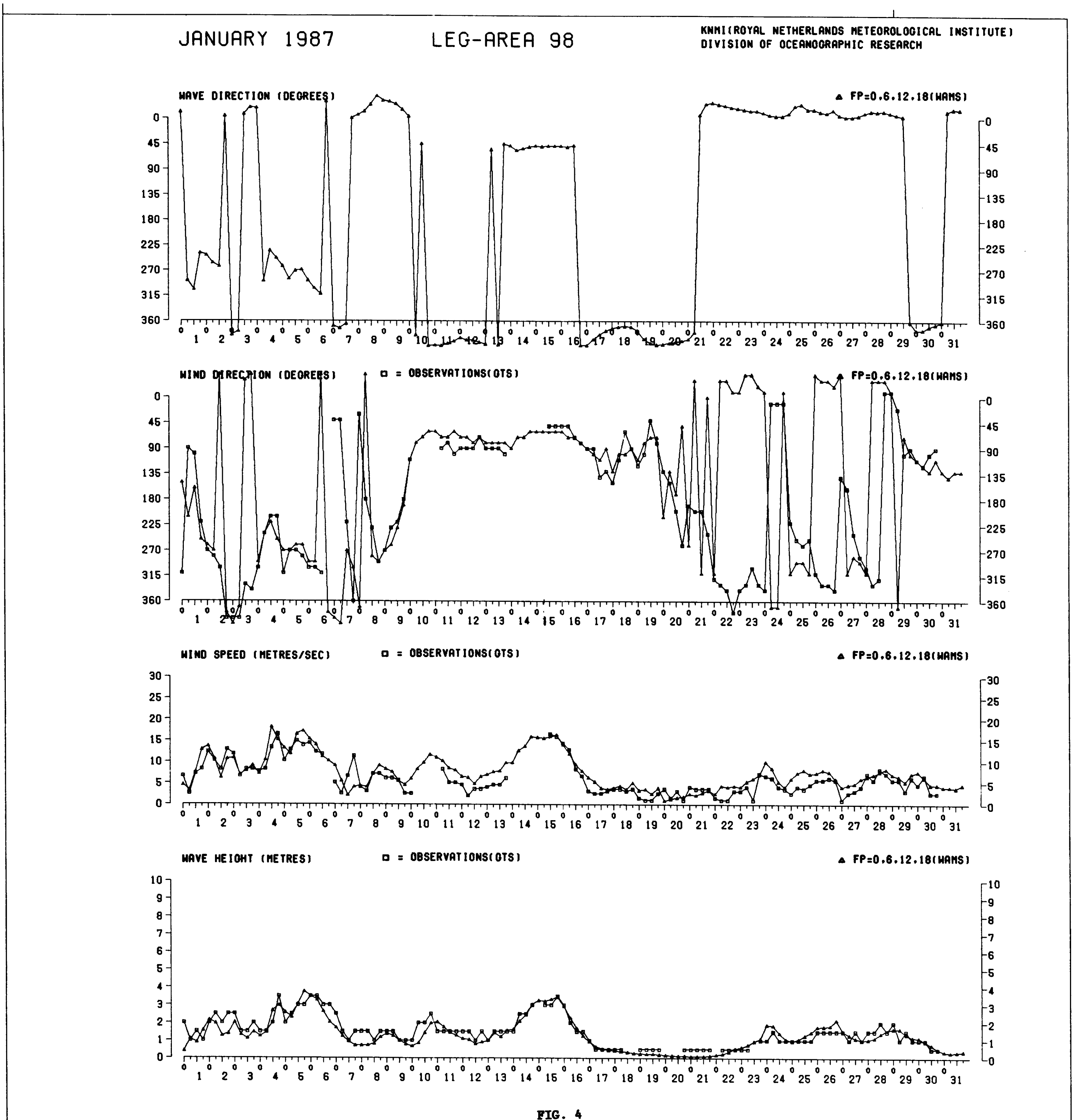


FIG. 3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▲ FP=0,6,12,18(WAMS)
WIND DIRECTION (DEGREES)
□ = OBSERVATIONS(OTS)
▲ FP=0,6,12,18(WAMS)
WIND SPEED (METRES/SEC)
□ = OBSERVATIONS(OTS)
▲ FP=0,6,12,18(WAMS)
WAVE HEIGHT (METRES)
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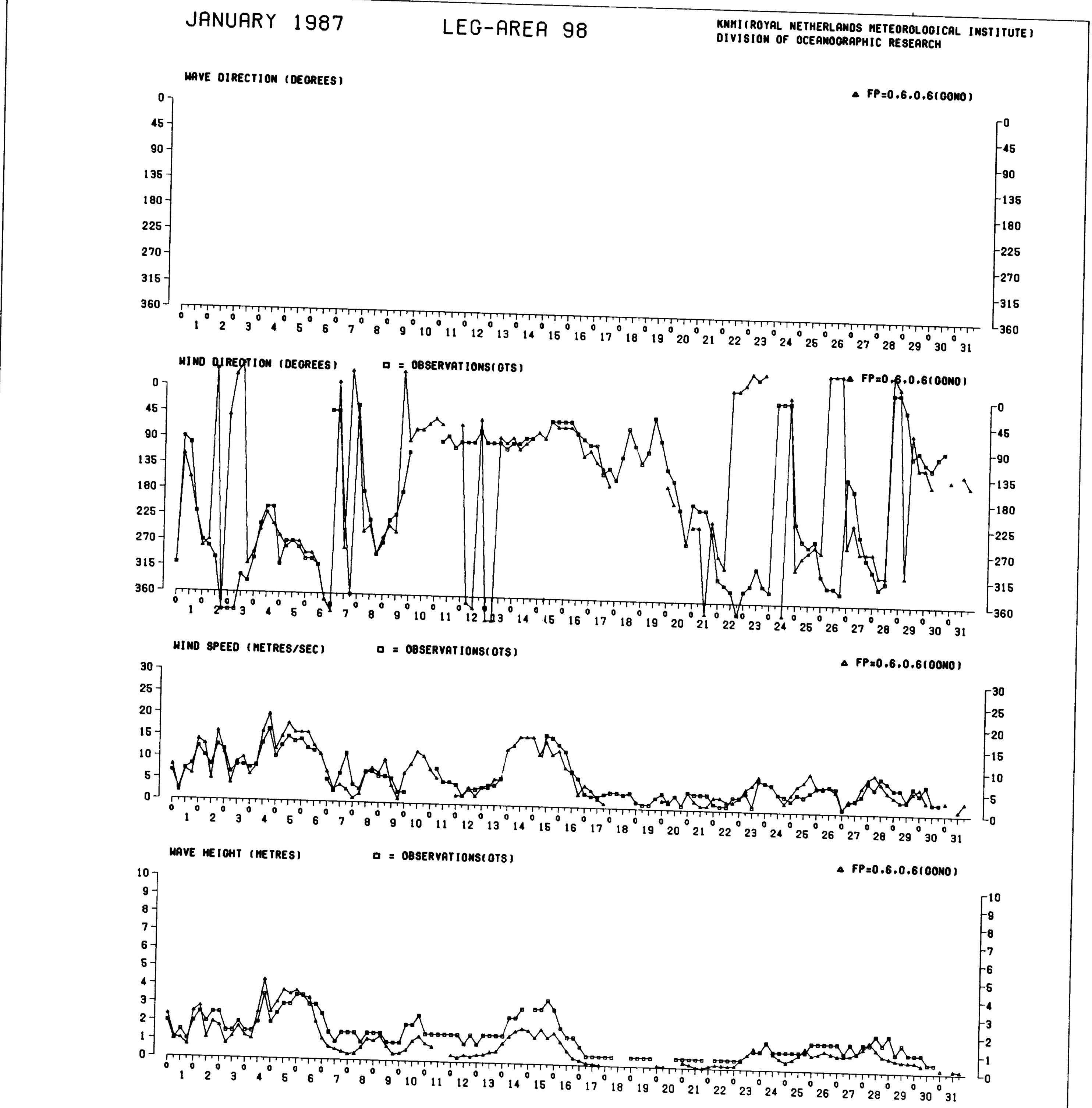
FIG. 4



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WIND SPEED (METRES/SEC)
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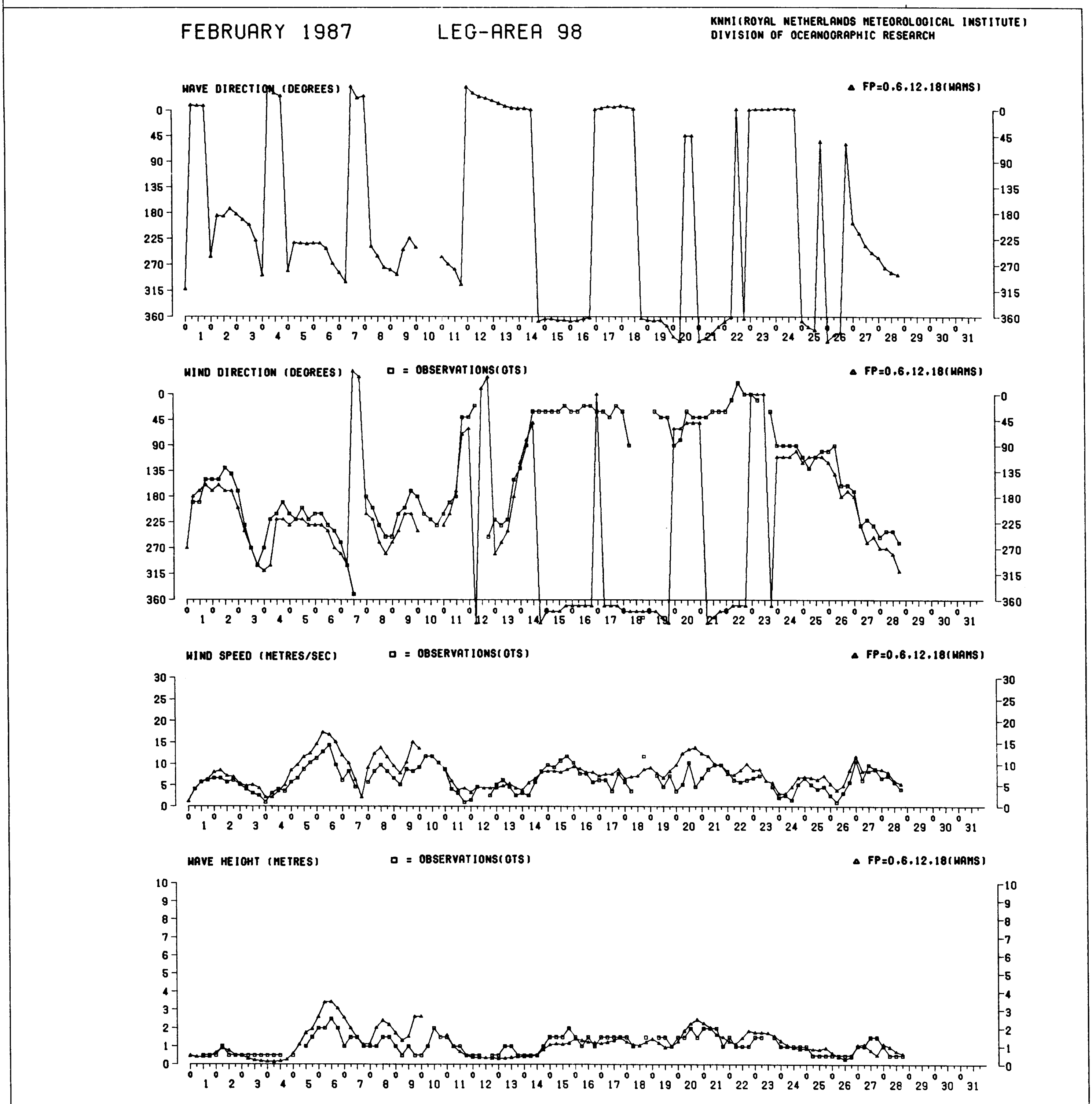
FIG. 5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WIND SPEED (METRES/SEC)
□ = OBSERVATIONS(OTS)
▲ FP=0,6,12,18(WAMS)
0 5 10 15 20 25 30
WAVE HEIGHT (METRES)
□ = OBSERVATIONS(OTS)
▲ FP=0,6,12,18(WAMS)
0 1 2 3 4 5 6 7 8 9 10

FIG. 6

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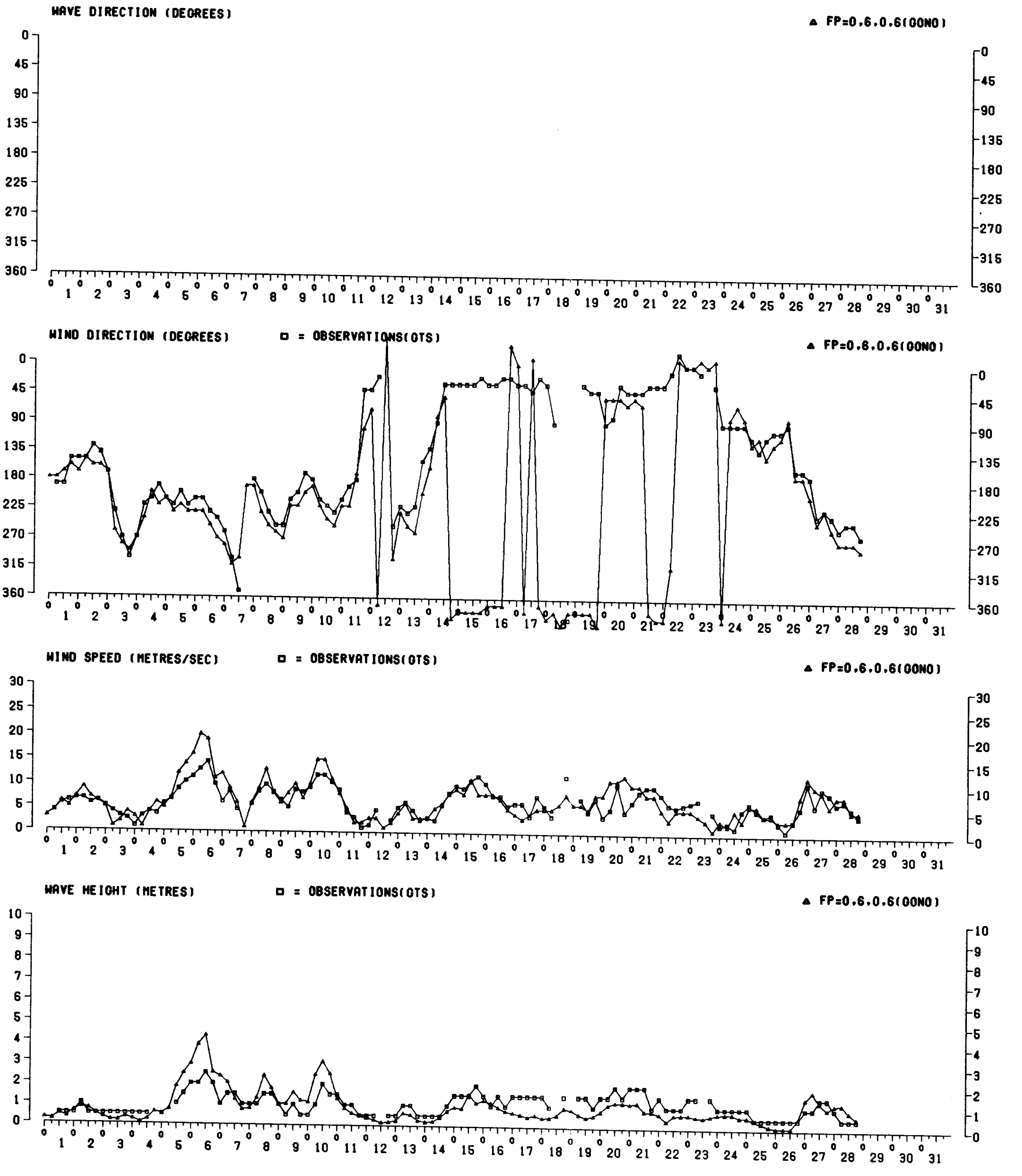
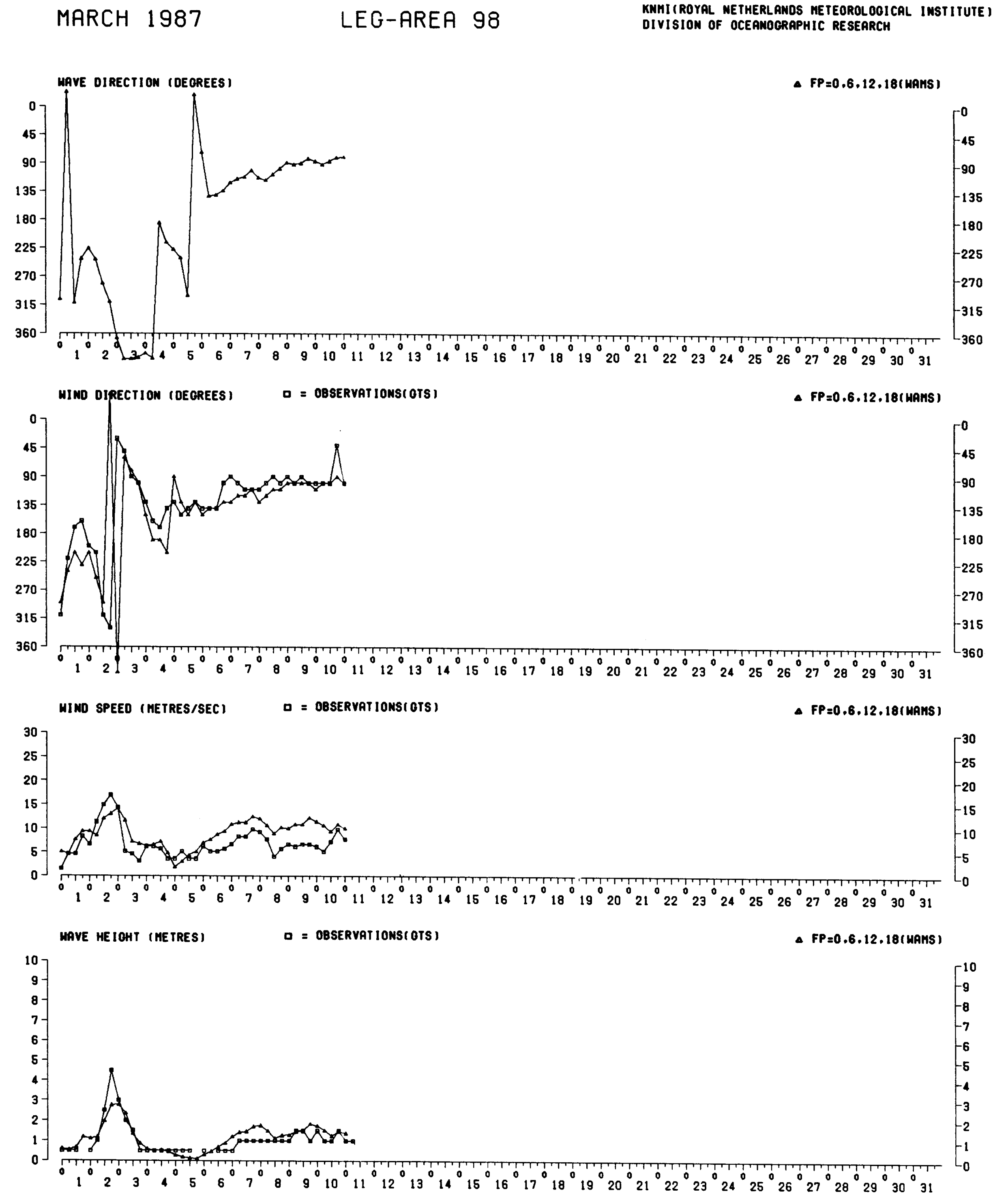


FIG. 7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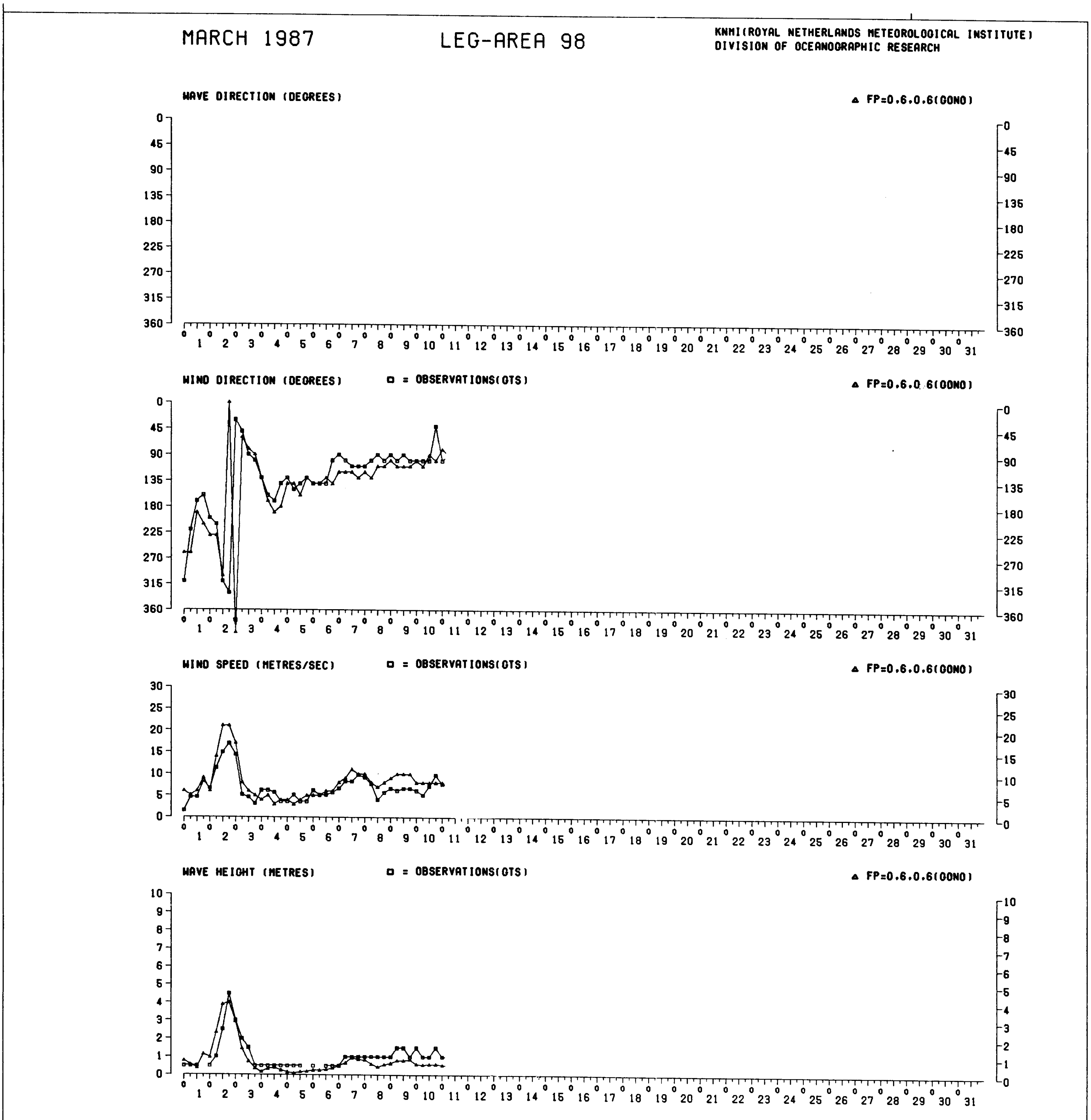
WAVE HEIGHT (METRES)
□ = OBSERVATIONS(OTS)
▲ FP=0,6,12,18(WAMS)

FIG. 8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▲ FP=0.6,0.6(GONO)
WIND DIRECTION (DEGREES)
□ = OBSERVATIONS(OTS)
▲ FP=0.6,0.6(GONO)
WIND SPEED (METRES/SEC)
□ = OBSERVATIONS(OTS)
▲ FP=0.6,0.6(GONO)
WAVE HEIGHT (METRES)
□ = OBSERVATIONS(OTS)
▲ FP=0.6,0.6(GONO)

FIG. 9

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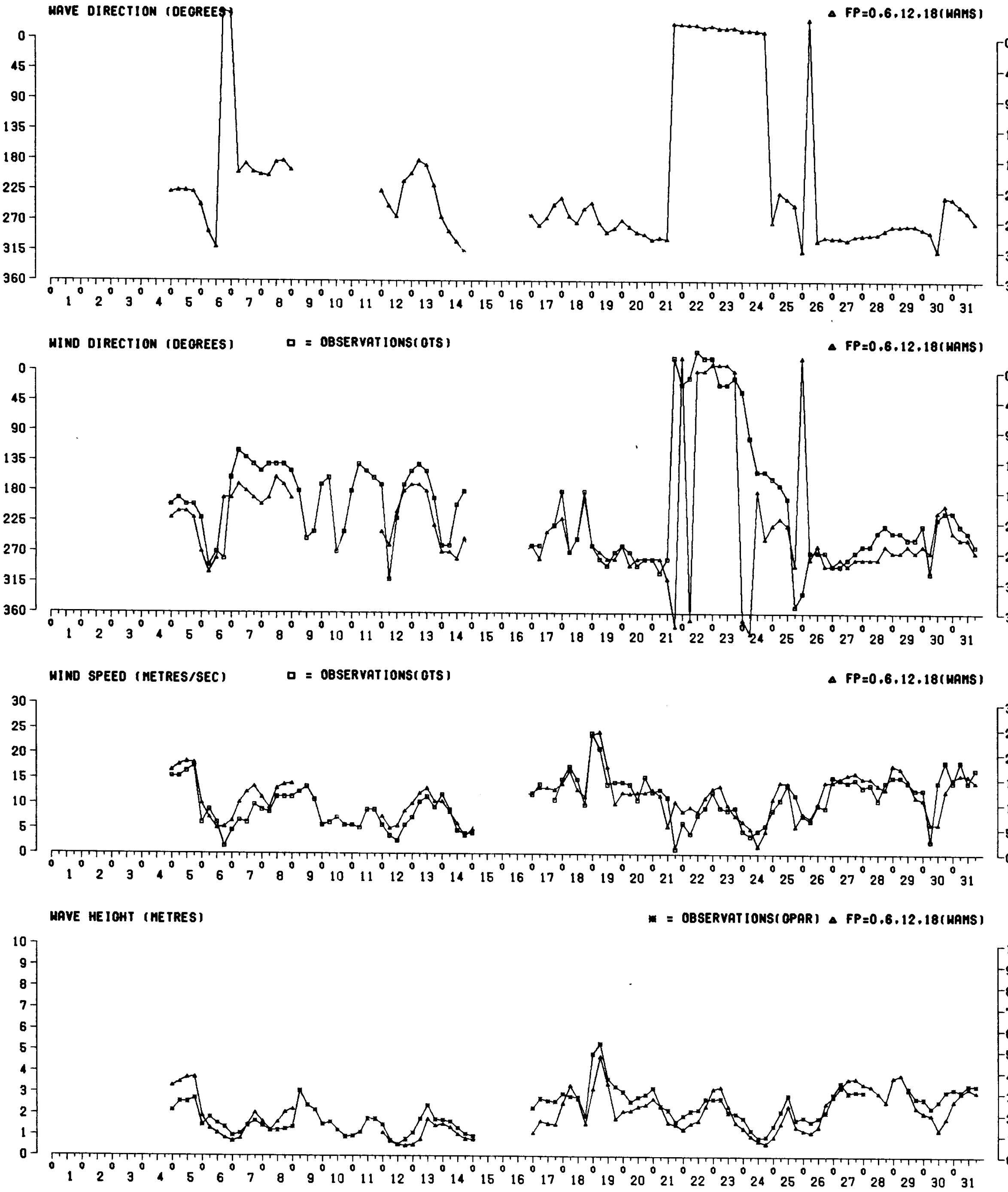

FIG. 10

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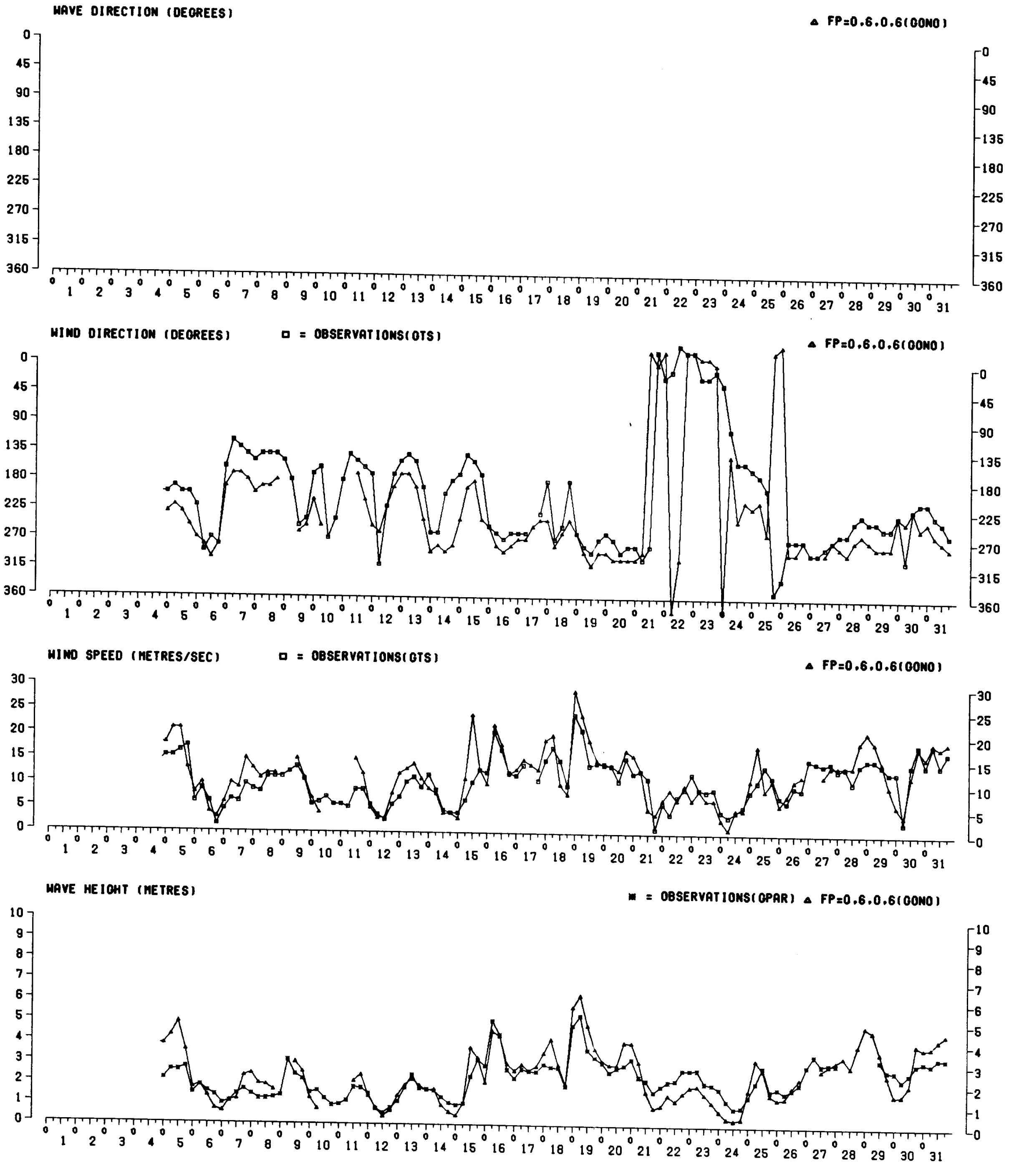
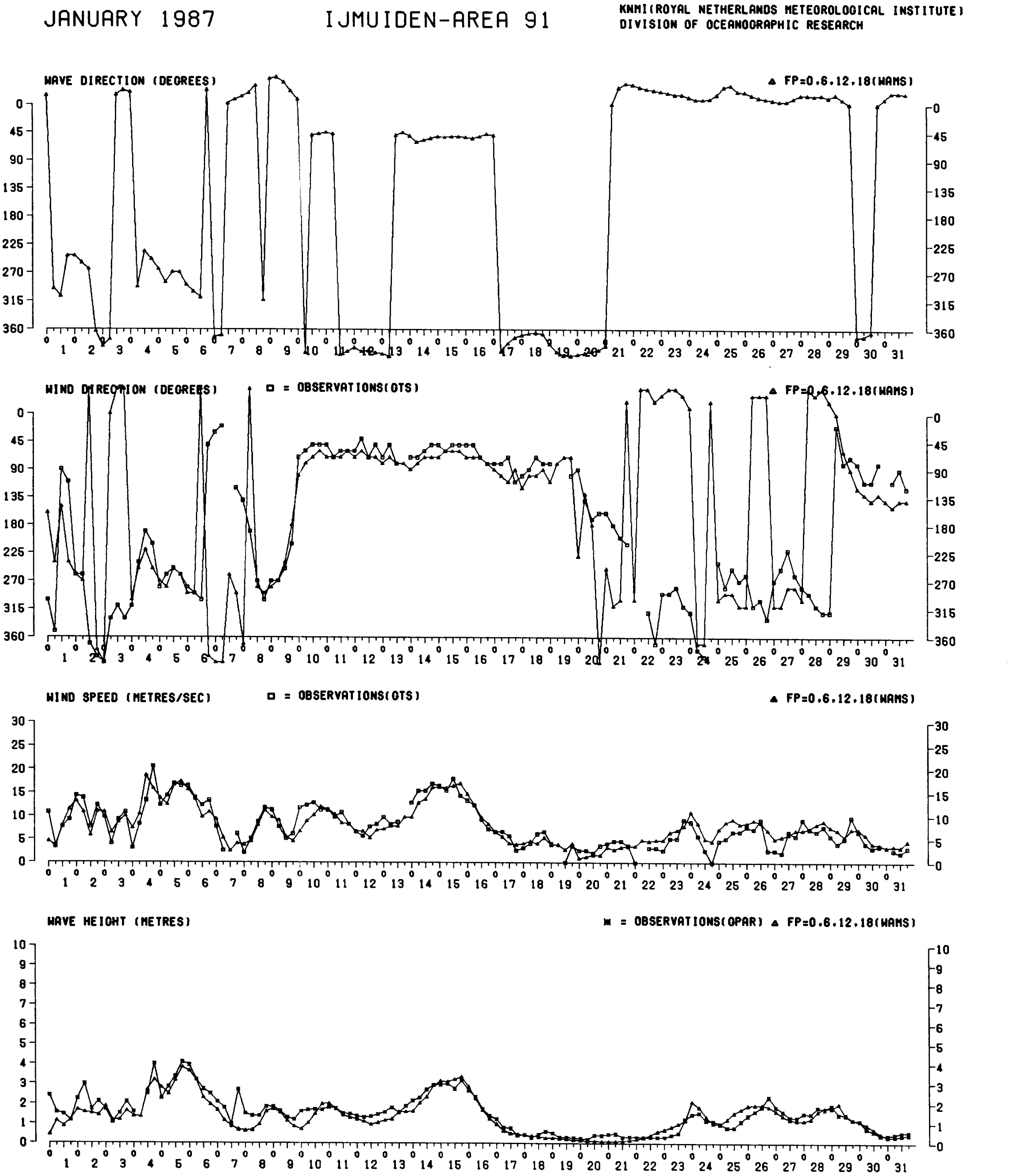


FIG. 11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DIVISION OF OCEANOGRAPHIC RESEARCH
WAVE DIRECTION (DEGREES)
▲ FP=0.6.12.18(WAMS)
WIND DIRECTION (DEGREES)
□ = OBSERVATIONS(OTS)
▲ FP=0.6.12.18(WAMS)
WIND SPEED (METRES/SEC)
□ = OBSERVATIONS(OTS)
▲ FP=0.6.12.18(WAMS)
WAVE HEIGHT (METRES)
✱ = OBSERVATIONS(OPAR) ▲ FP=0.6.12.18(WAMS)

FIG. 12

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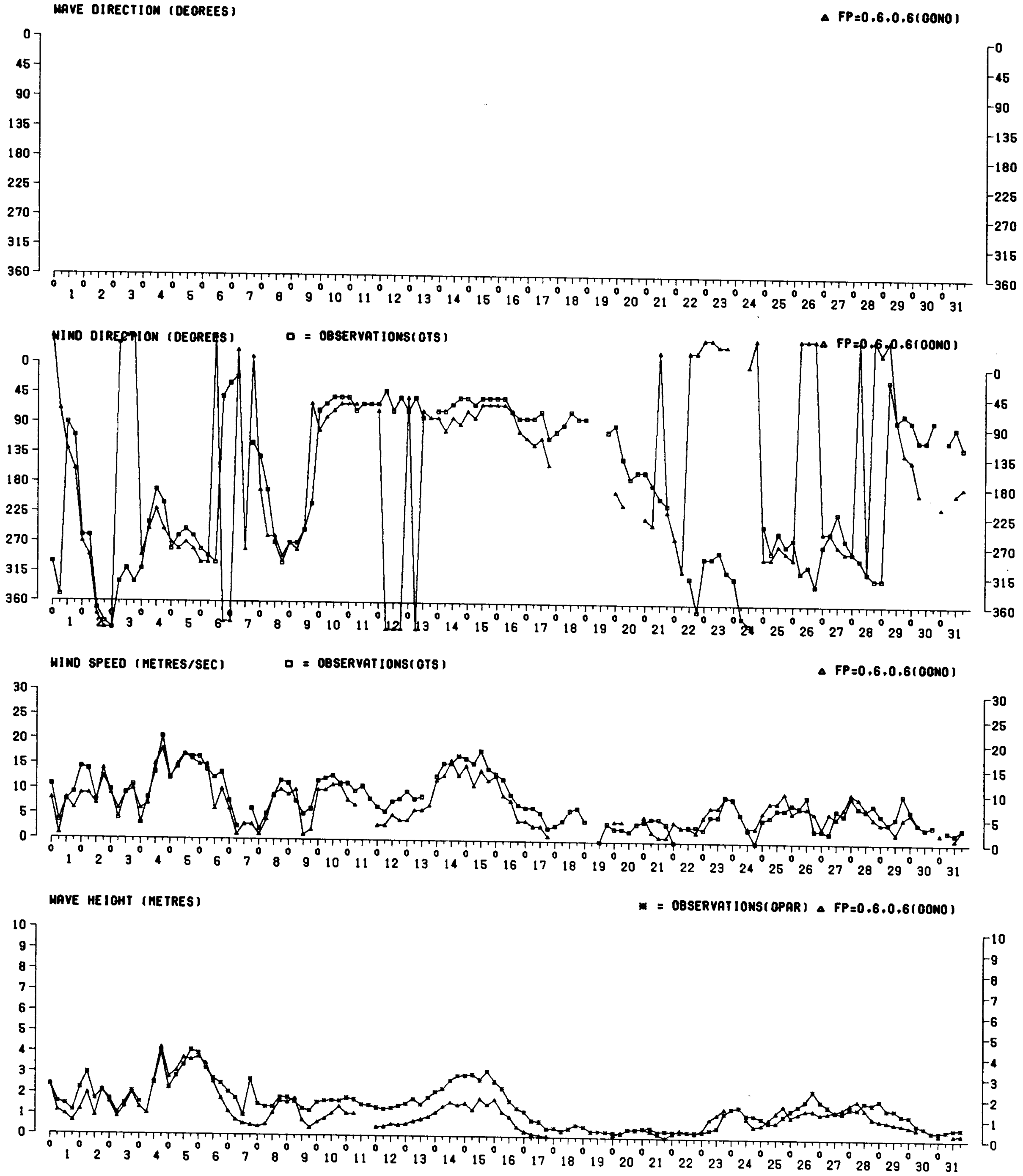
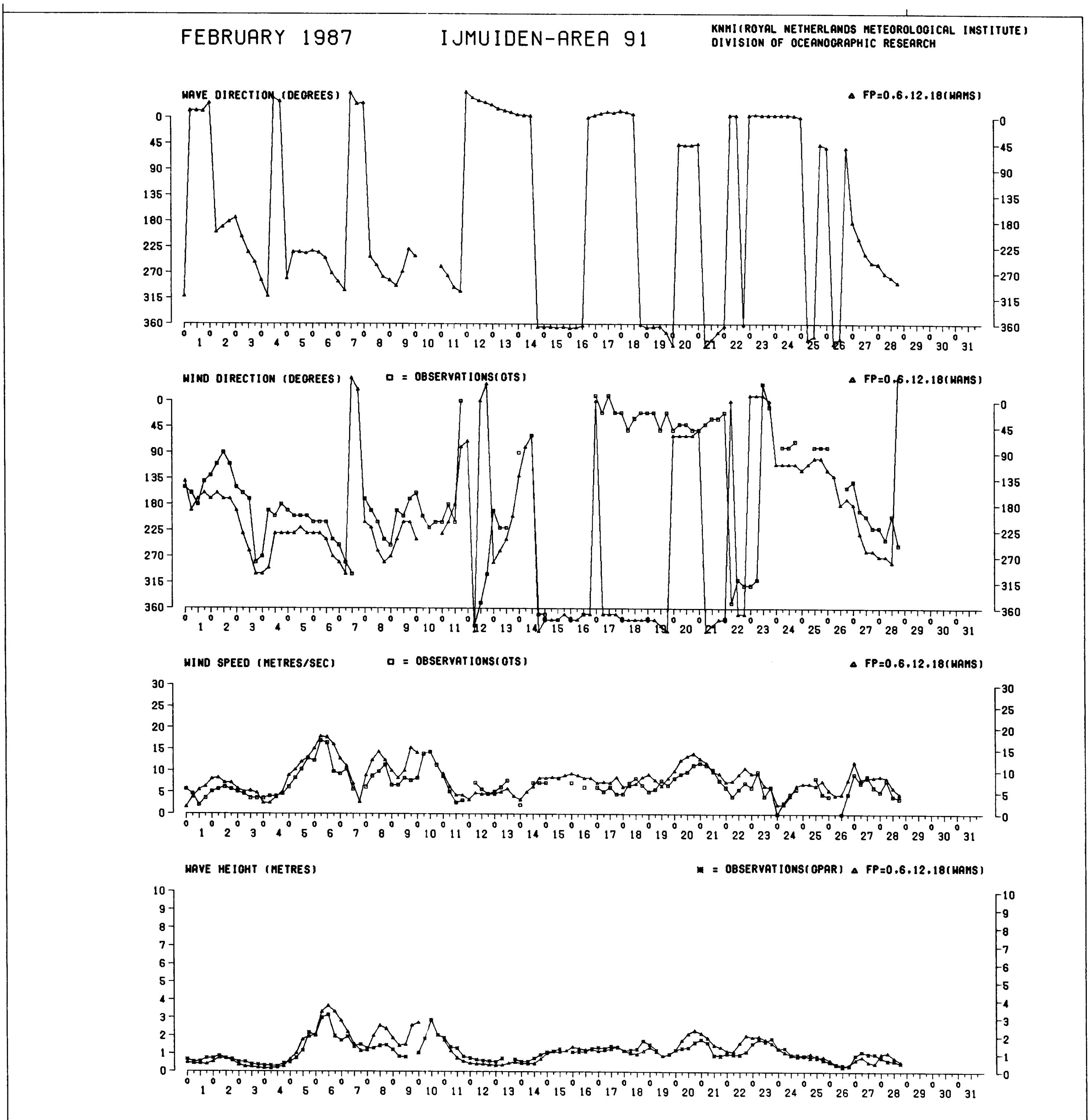


FIG. 13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WAVE DIRECTION (DEGREES)
▲ FP=0.6.12.18(WAMS)
WIND DIRECTION (DEGREES)
□ = OBSERVATIONS(OTS)
▲ FP=0.6.12.18(WAMS)
WIND SPEED (METRES/SEC)
□ = OBSERVATIONS(OTS)
▲ FP=0.6.12.18(WAMS)
WAVE HEIGHT (METRES)
✱ = OBSERVATIONS(OPAR)
▲ FP=0.6.12.18(WAMS)

FIG. 14

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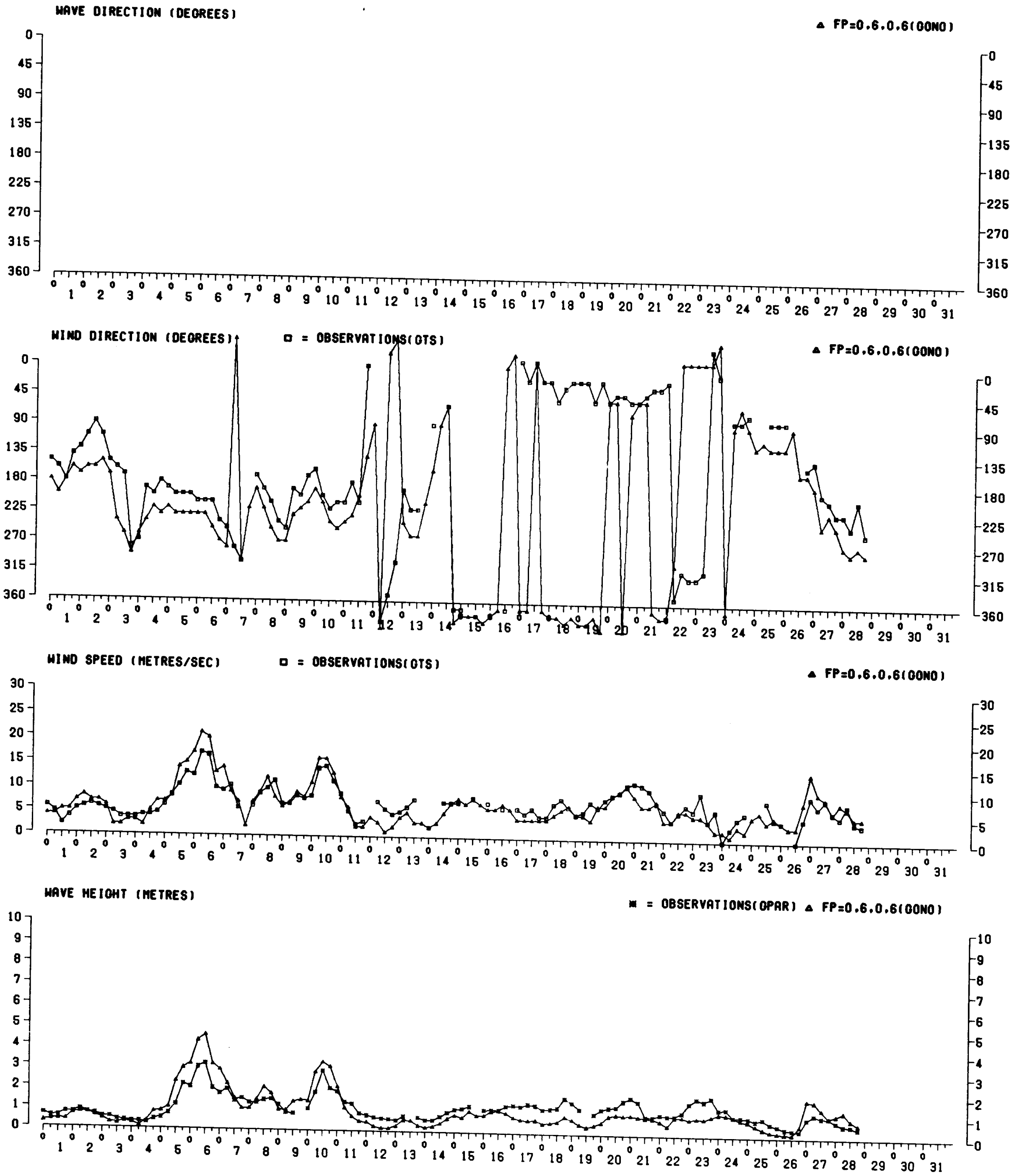

FIG. 15

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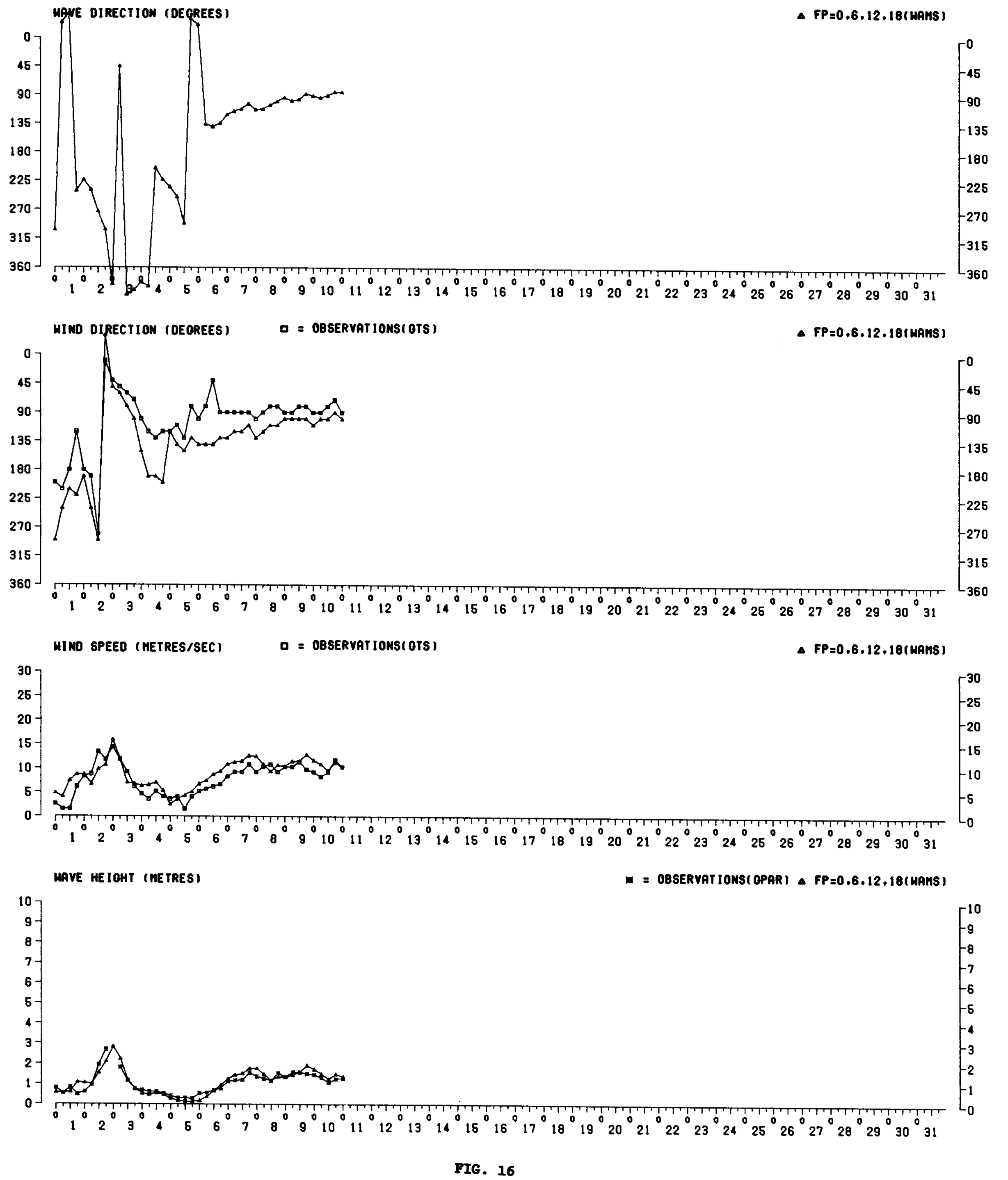
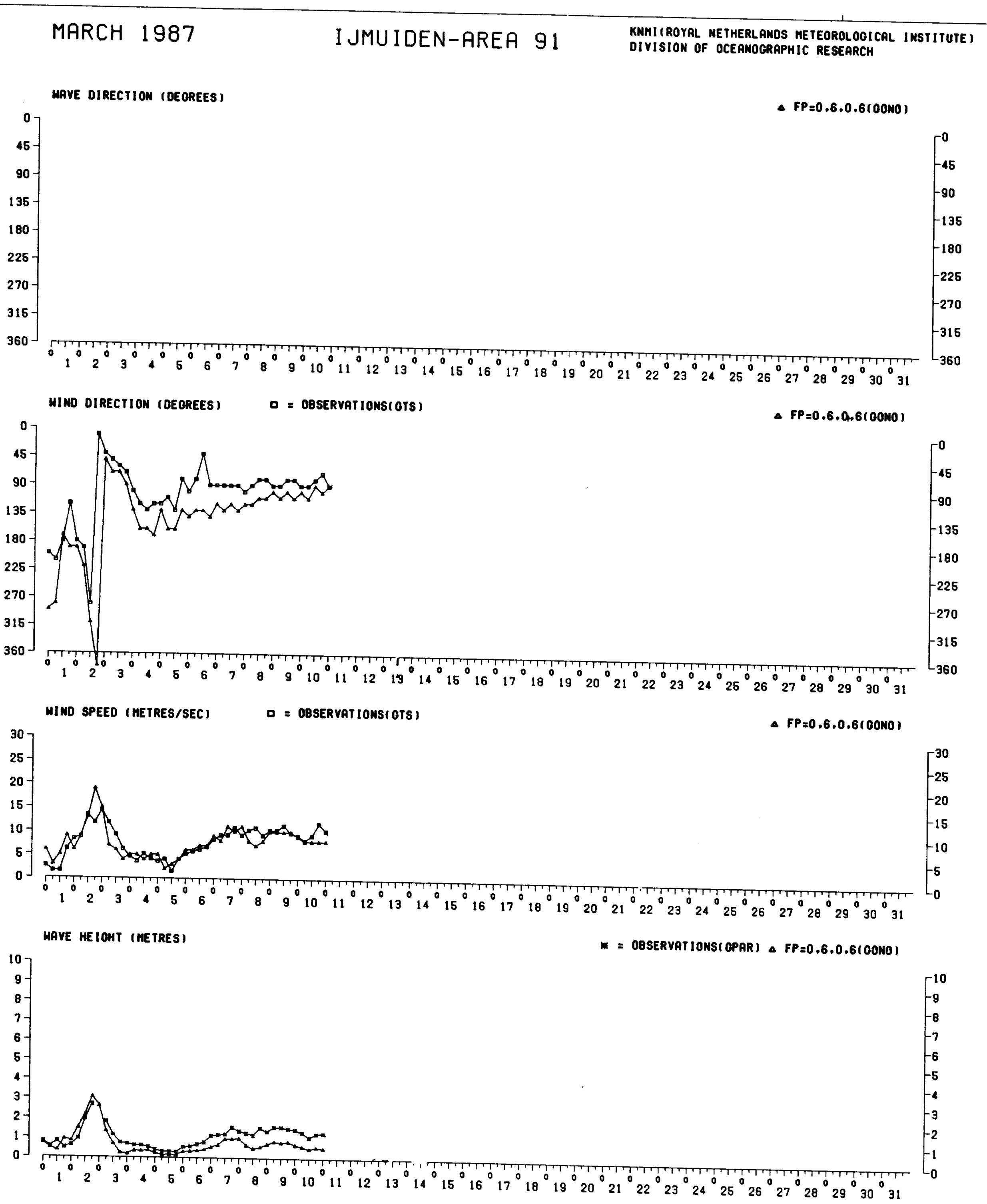


FIG. 16


MARCH 1987
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KNMI(ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE)
DIVISION OF OCEANOGRAPHIC RESEARCH
WAVE DIRECTION (DEGREES)
▲ FP=0.6.0.6(OONO)
WIND DIRECTION (DEGREES)
□ = OBSERVATIONS(OTS)
▲ FP=0.6.0.6(OONO)
WIND SPEED (METRES/SEC)
□ = OBSERVATIONS(OTS)
▲ FP=0.6.0.6(OONO)
WAVE HEIGHT (METRES)
✱ = OBSERVATIONS(OPAR) ▲ FP=0.6.0.6(OONO)

FIG. 17

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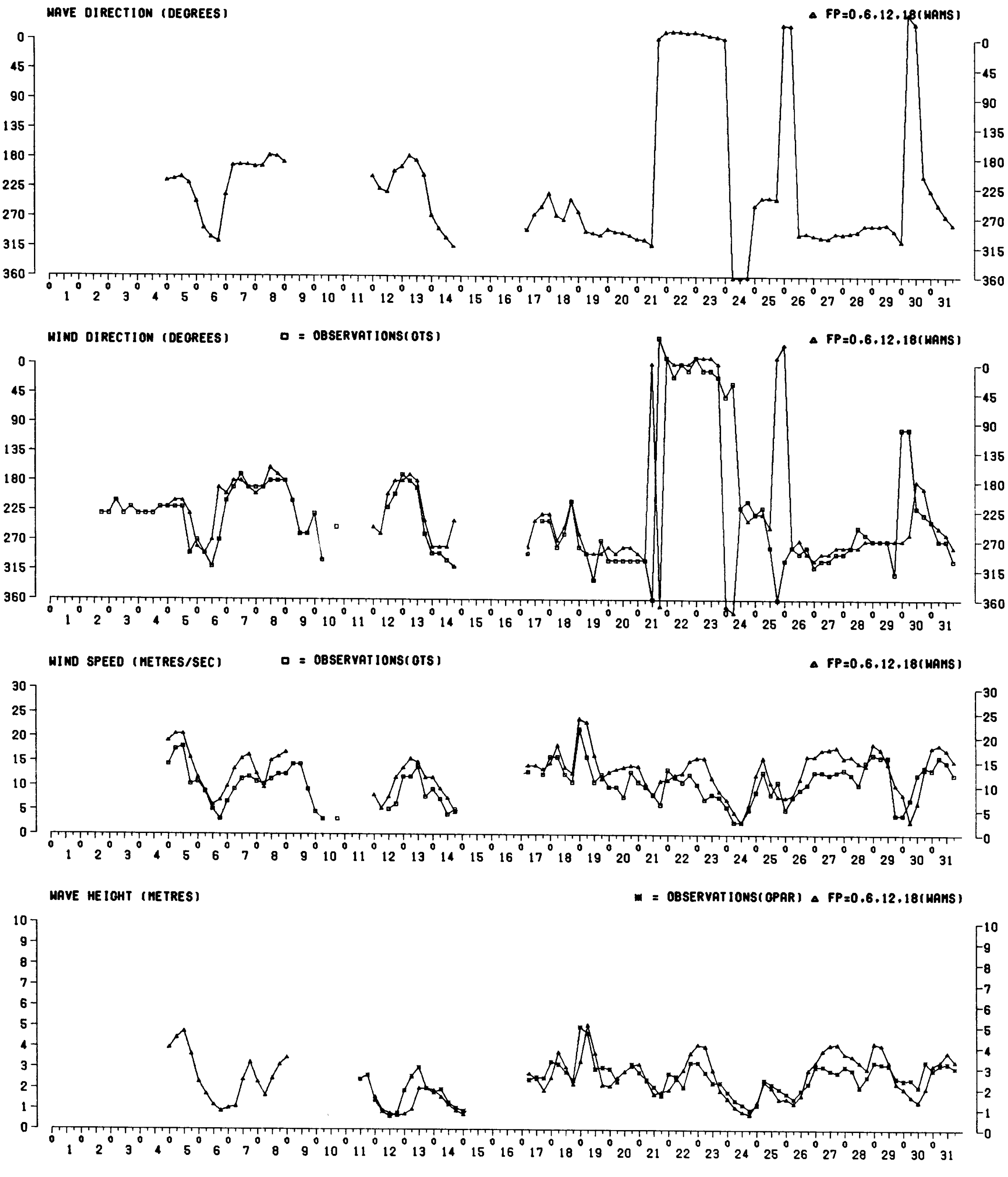
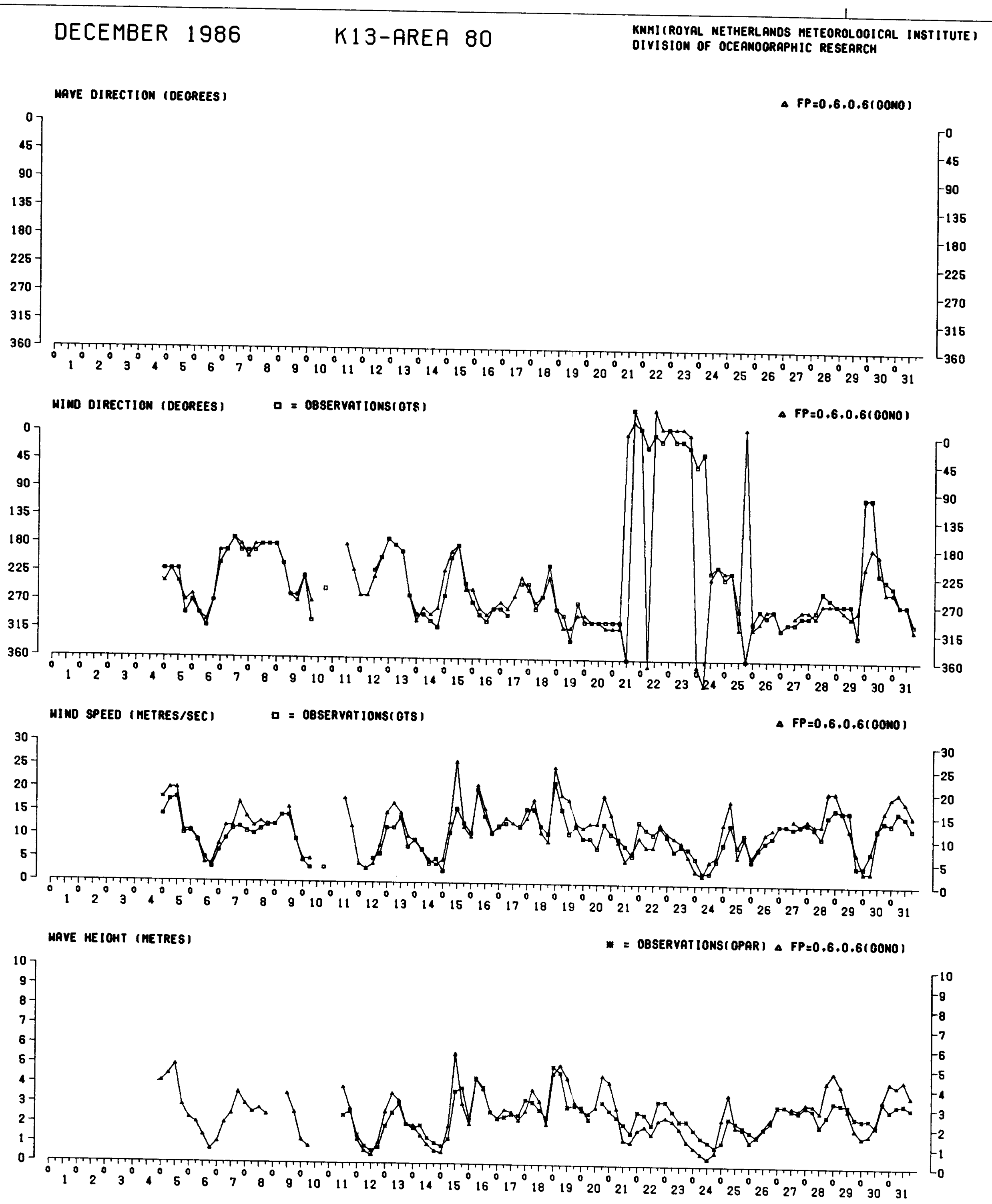


FIG. 18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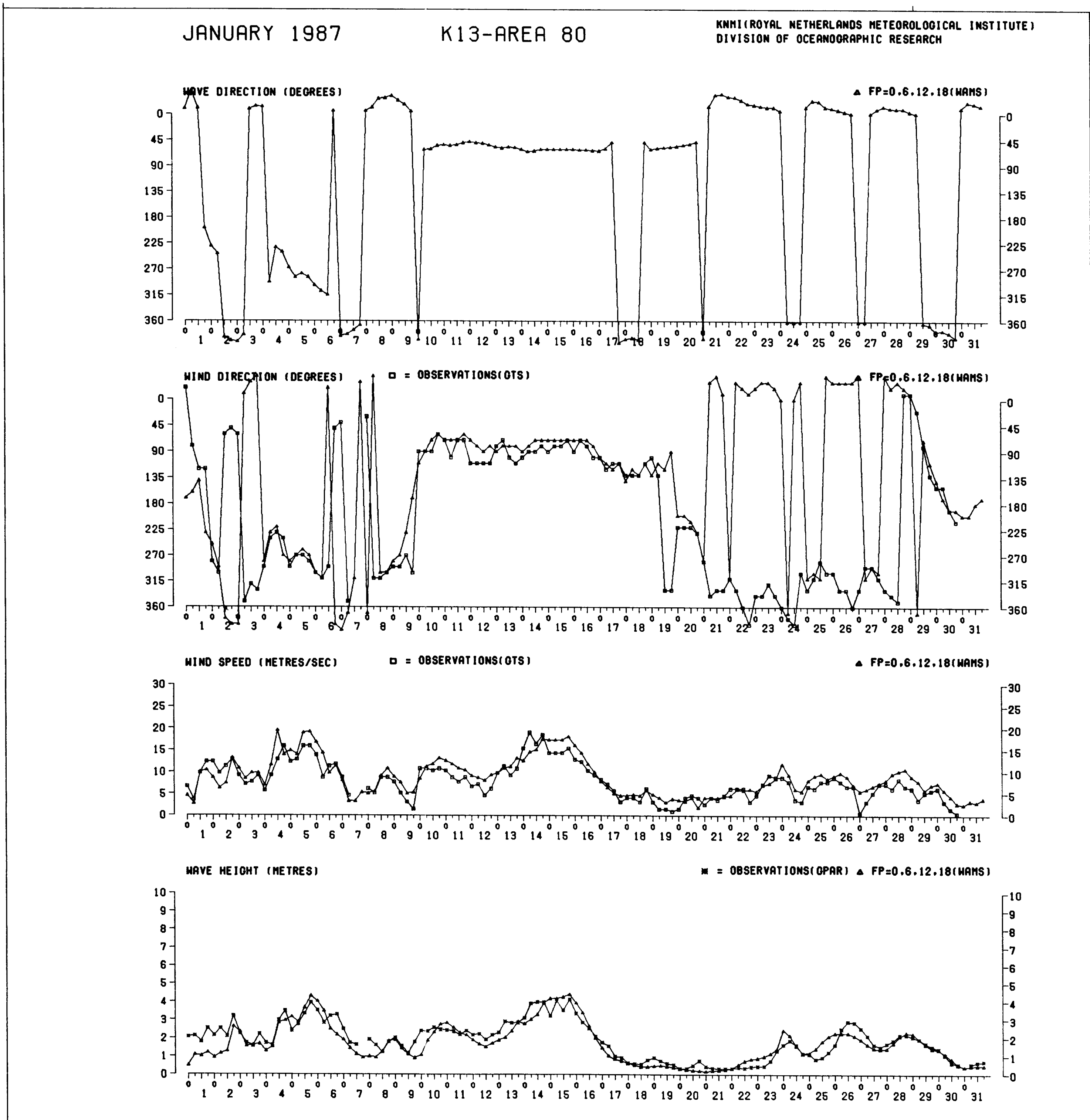
KNMI(ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE)
DIVISION OF OCEANOGRAPHIC RESEARCH
WAVE DIRECTION (DEGREES)
▲ FP=0.6,0.6(OONO)
WIND DIRECTION (DEGREES)
□ = OBSERVATIONS(OTS)
▲ FP=0.6,0.6(OONO)
WIND SPEED (METRES/SEC)
□ = OBSERVATIONS(OTS)
▲ FP=0.6,0.6(OONO)
WAVE HEIGHT (METRES)
* = OBSERVATIONS(GPAR) ▲ FP=0.6,0.6(OONO)

FIG. 19



JANUARY 1987
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DIVISION OF OCEANOGRAPHIC RESEARCH
WAVE DIRECTION (DEGREES)
▲ FP=0,6,12,18(WAMS)
WIND DIRECTION (DEGREES)
□ = OBSERVATIONS(OTS)
▲ FP=0,6,12,18(WAMS)
WIND SPEED (METRES/SEC)
□ = OBSERVATIONS(OTS)
▲ FP=0,6,12,18(WAMS)
WAVE HEIGHT (METRES)
✱ = OBSERVATIONS(OPAR) ▲ FP=0,6,12,18(WAMS)

FIG. 20

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DIVISION OF OCEANOGRAPHIC RESEARCH

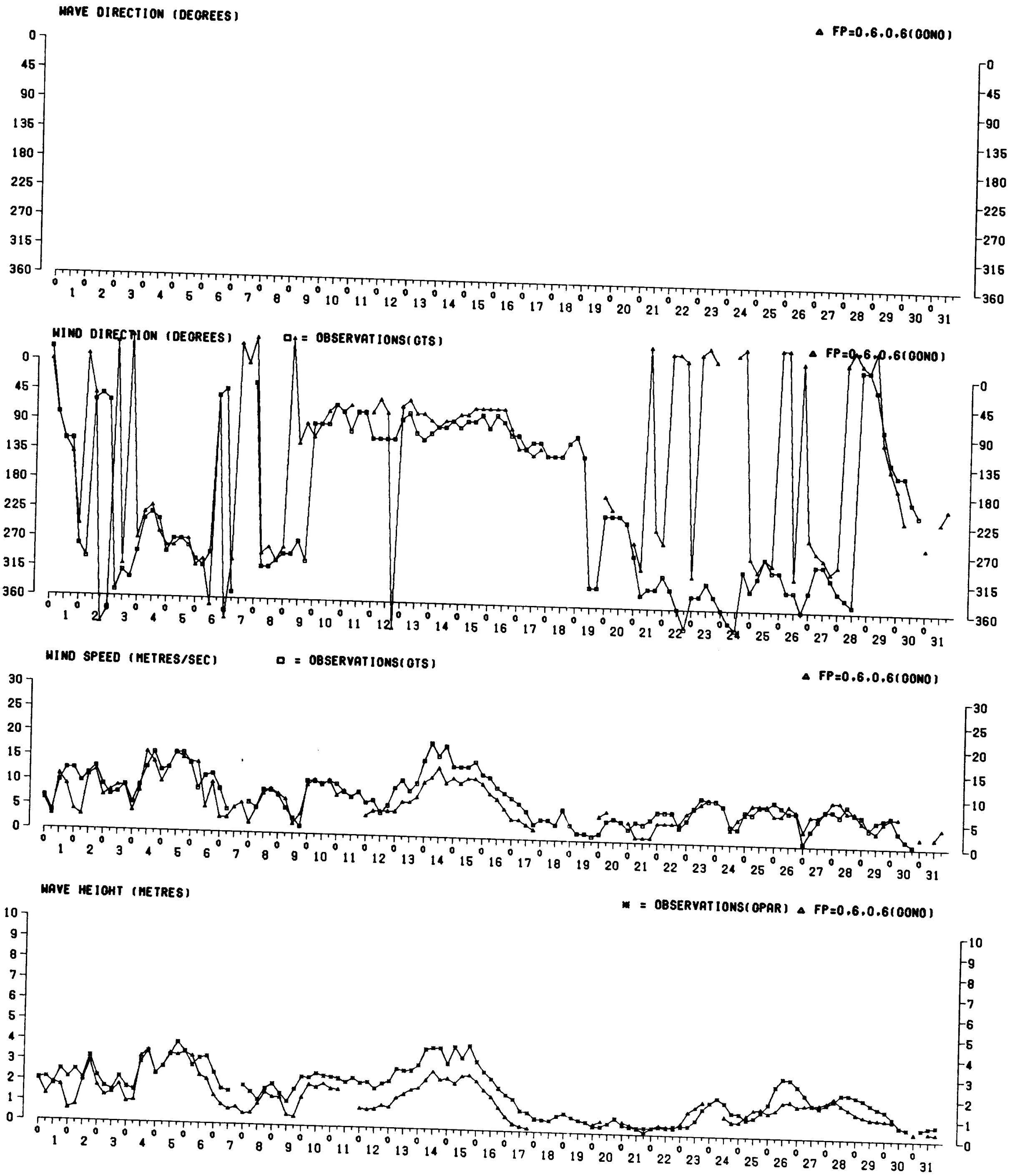
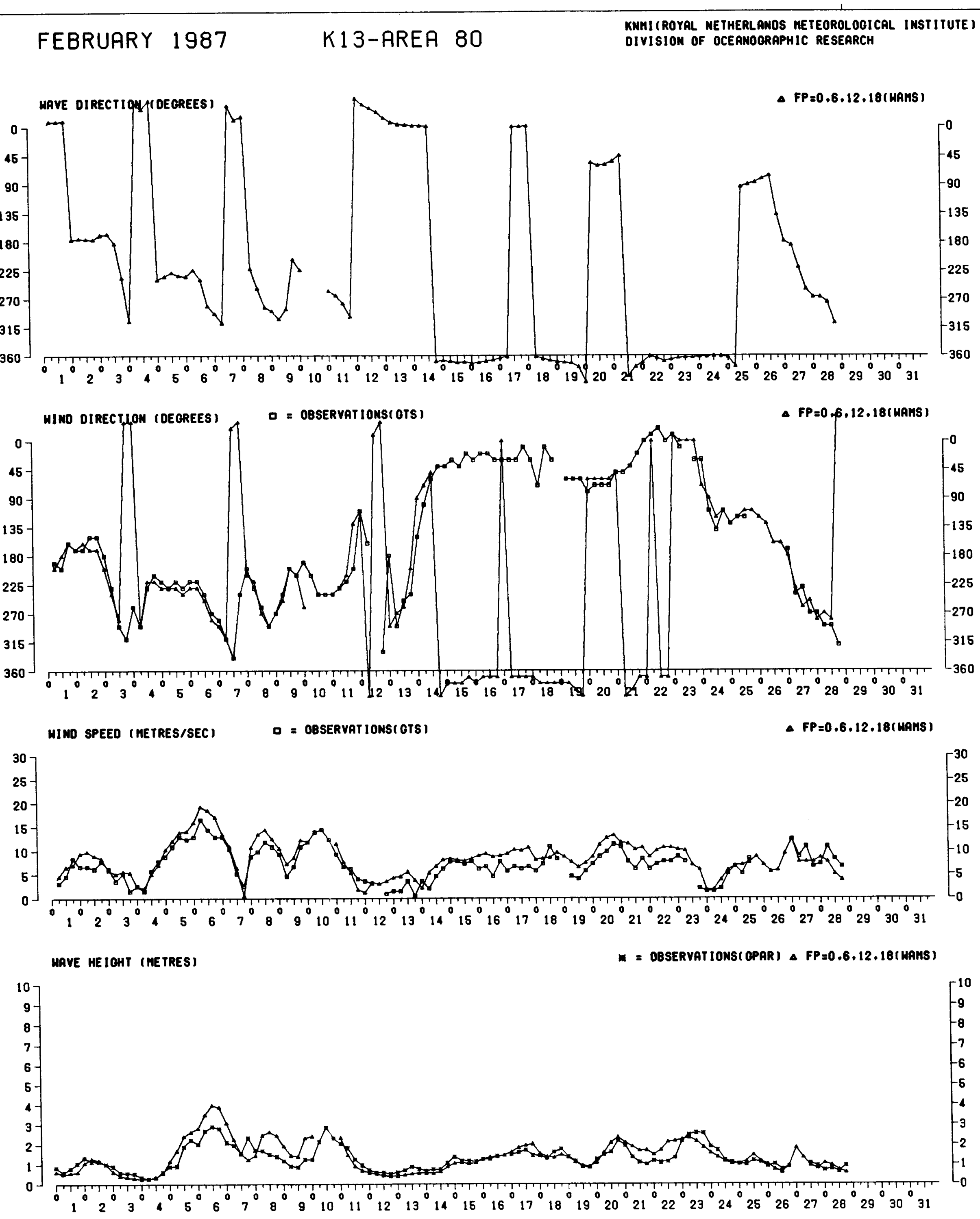


FIG. 21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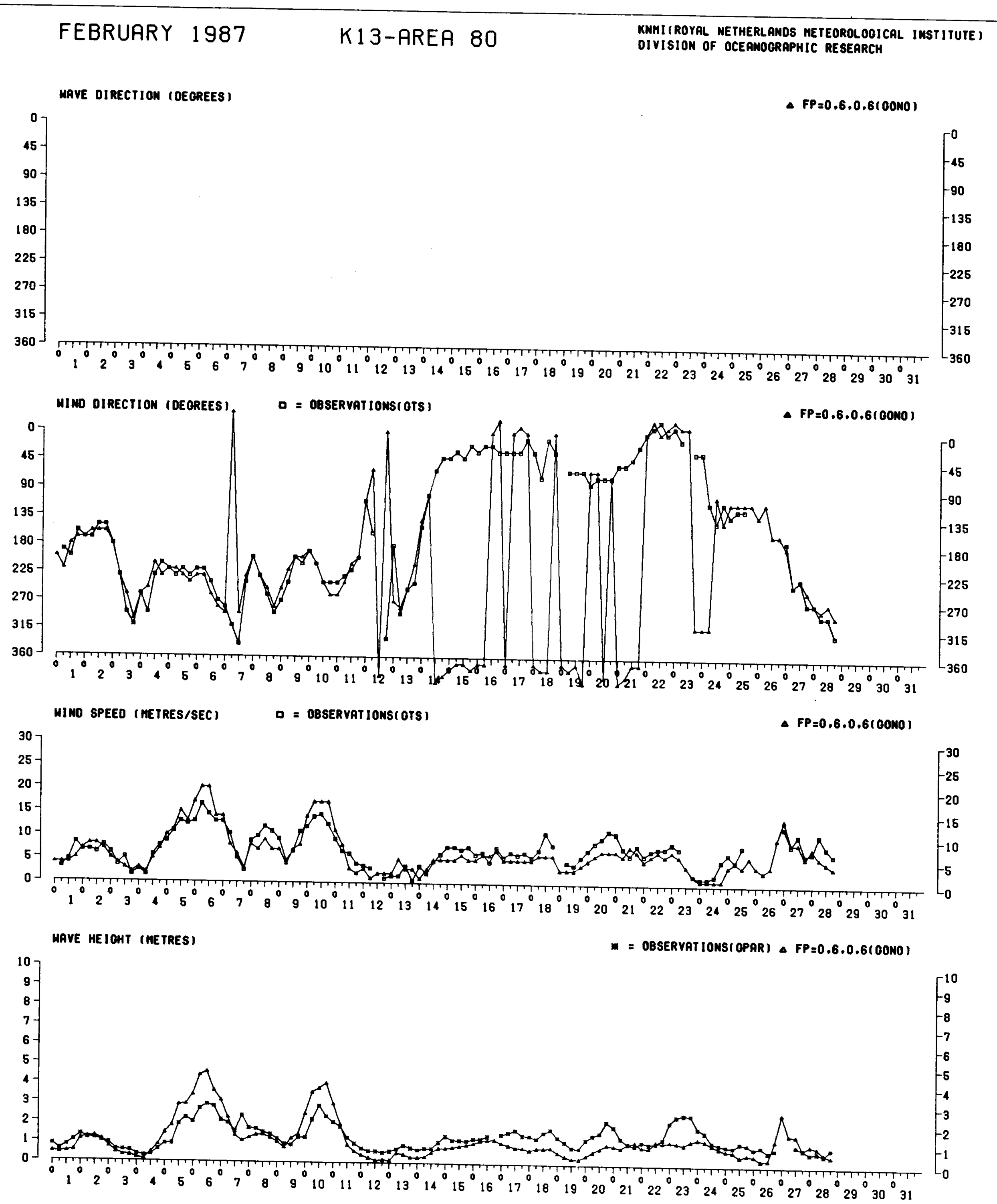
DIVISION OF OCEANOGRAPHIC RESEARCH
WAVE DIRECTION (DEGREES)
▲ FP=0.6.12.18(WAMS)
WIND DIRECTION (DEGREES)
□ = OBSERVATIONS(OTS)
▲ FP=0.6.12.18(WAMS)
WIND SPEED (METRES/SEC)
□ = OBSERVATIONS(OTS)
▲ FP=0.6.12.18(WAMS)
WAVE HEIGHT (METRES)
✱ = OBSERVATIONS(OPAR) ▲ FP=0.6.12.18(WAMS)

FIG. 22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KNMI(ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE)
DIVISION OF OCEANOGRAPHIC RESEARCH
WAVE DIRECTION (DEGREES)
▲ FP=0.6.0.6(OONO)
WIND DIRECTION (DEGREES)
□ = OBSERVATIONS(OTS)
▲ FP=0.6.0.6(OONO)
WIND SPEED (METRES/SEC)
□ = OBSERVATIONS(OTS)
▲ FP=0.6.0.6(OONO)
WAVE HEIGHT (METRES)
✱ = OBSERVATIONS(OPAR) ▲ FP=0.6.0.6(OONO)

FIG. 23

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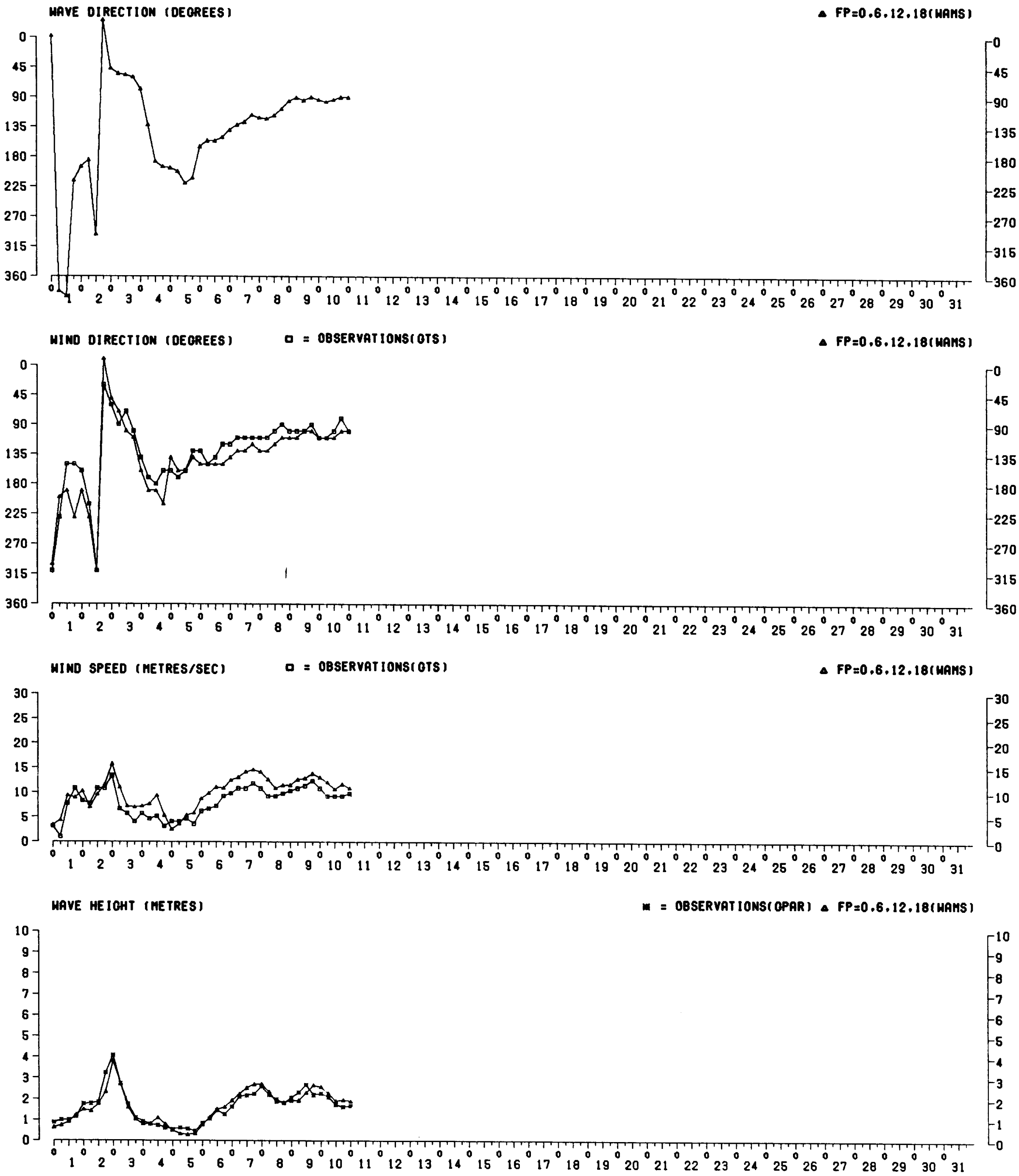

FIG. 24

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DIVISION OF OCEANOGRAPHIC RESEARCH

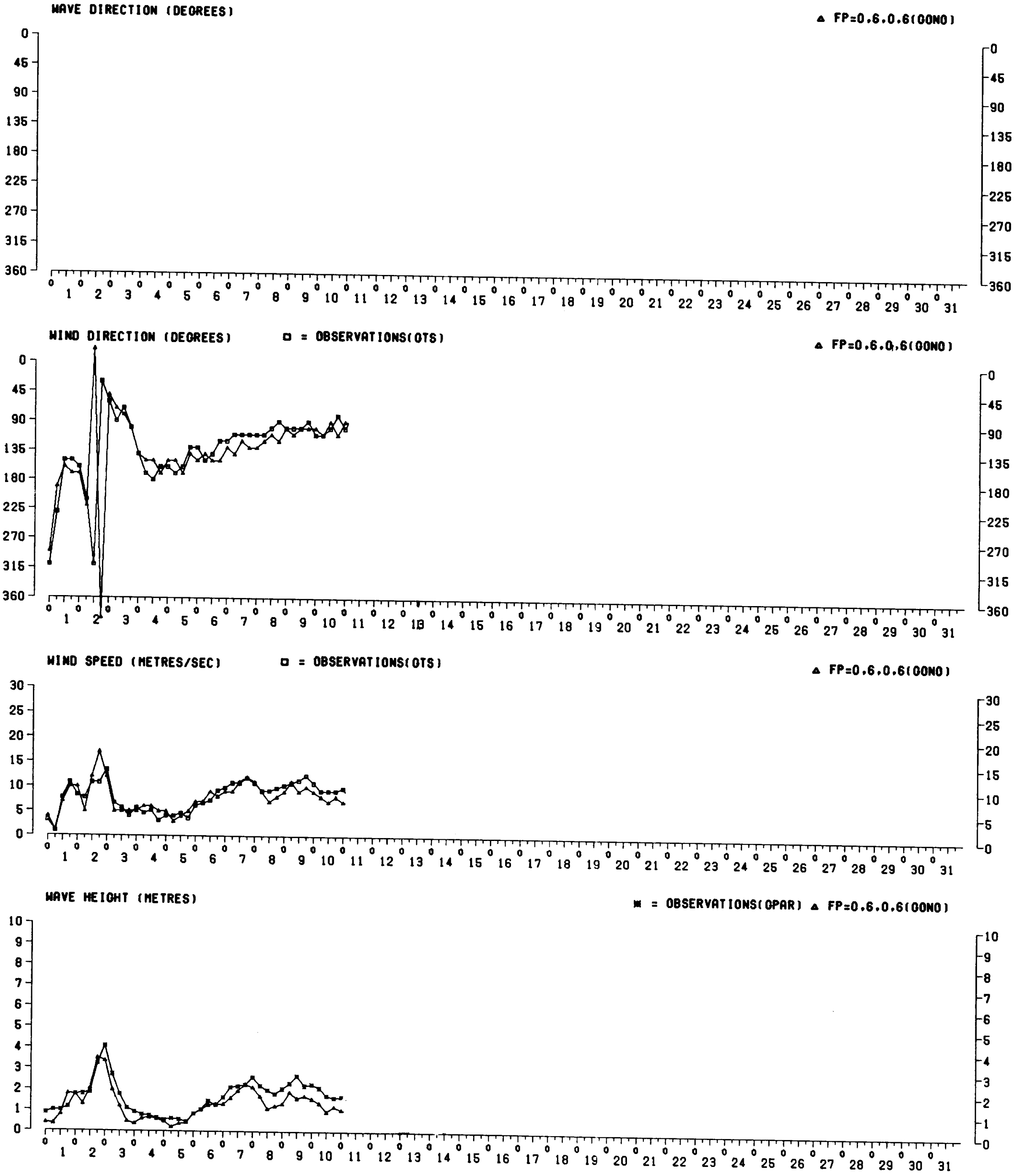
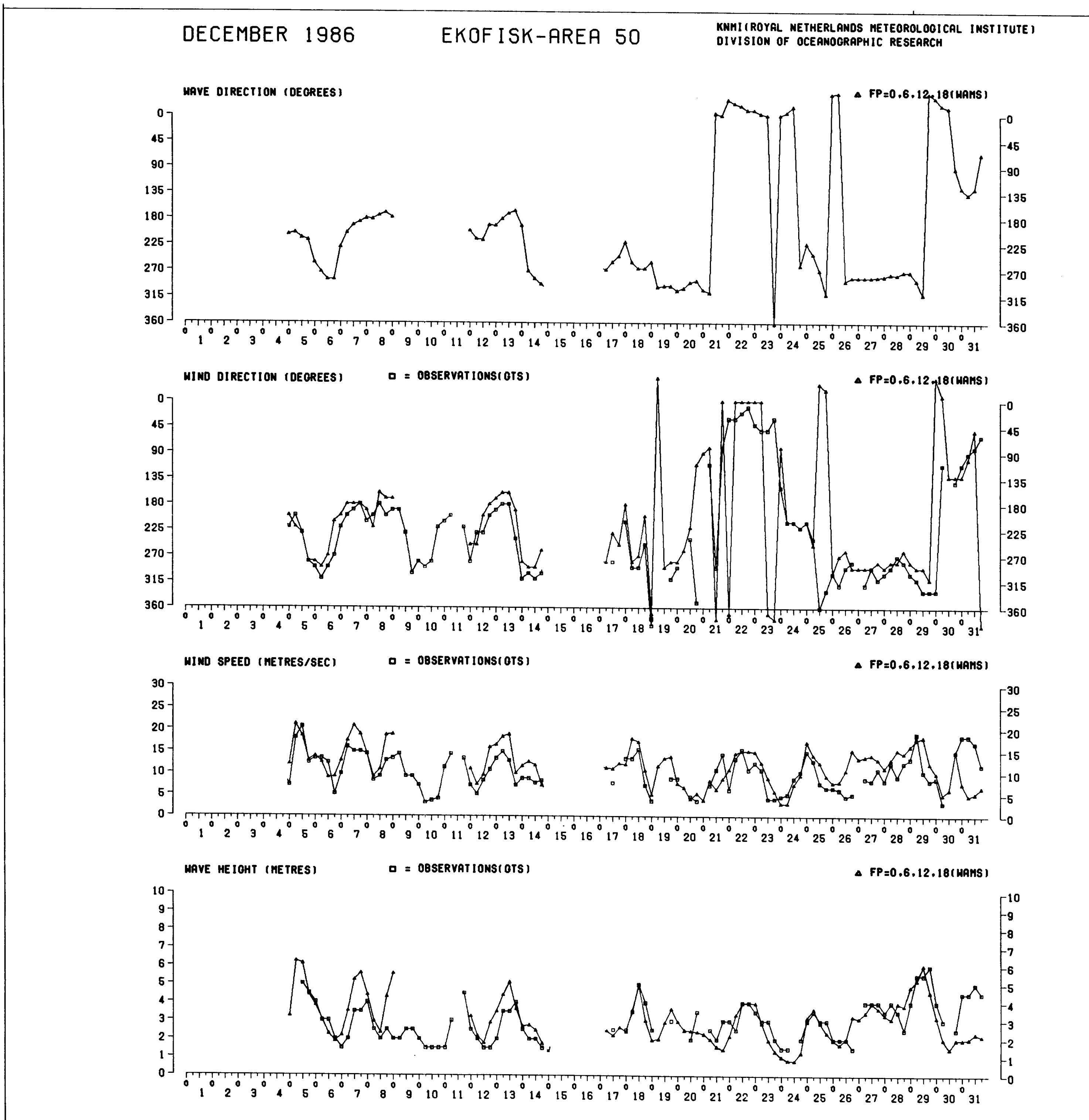


FIG. 25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KNMI(ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE)
DIVISION OF OCEANOGRAPHIC RESEARCH
WAVE DIRECTION (DEGREES)
▲ FP=0.6.12.18(WAMS)
WIND DIRECTION (DEGREES)
□ = OBSERVATIONS(OTS)
▲ FP=0.6.12.18(WAMS)
WIND SPEED (METRES/SEC)
□ = OBSERVATIONS(OTS)
▲ FP=0.6.12.18(WAMS)
WAVE HEIGHT (METRES)
□ = OBSERVATIONS(OTS)
▲ FP=0.6.12.18(WAMS)

FIG. 26

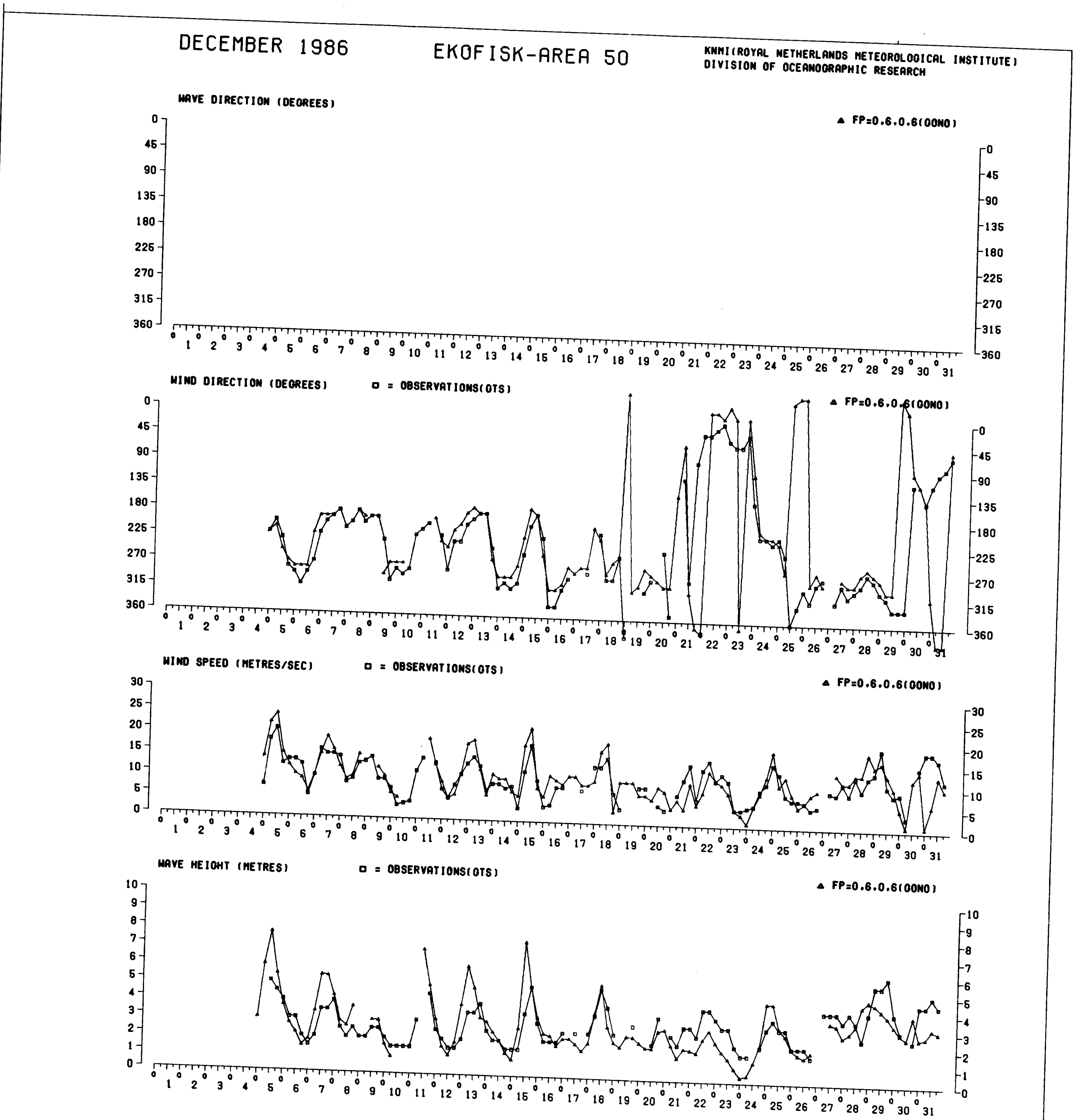
DECEMBER 1986
EKOFISK-AREA 50
KNMI(ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE)
DIVISION OF OCEANOGRAPHIC RESEARCH
WAVE DIRECTION (DEGREES)
▲ FP=0.6.0.6(GONO)
WIND DIRECTION (DEGREES)
□ = OBSERVATIONS(OTS)
WIND SPEED (METRES/SEC)
WAVE HEIGHT (METRES)

FIG. 27

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DIVISION OF OCEANOGRAPHIC RESEARCH

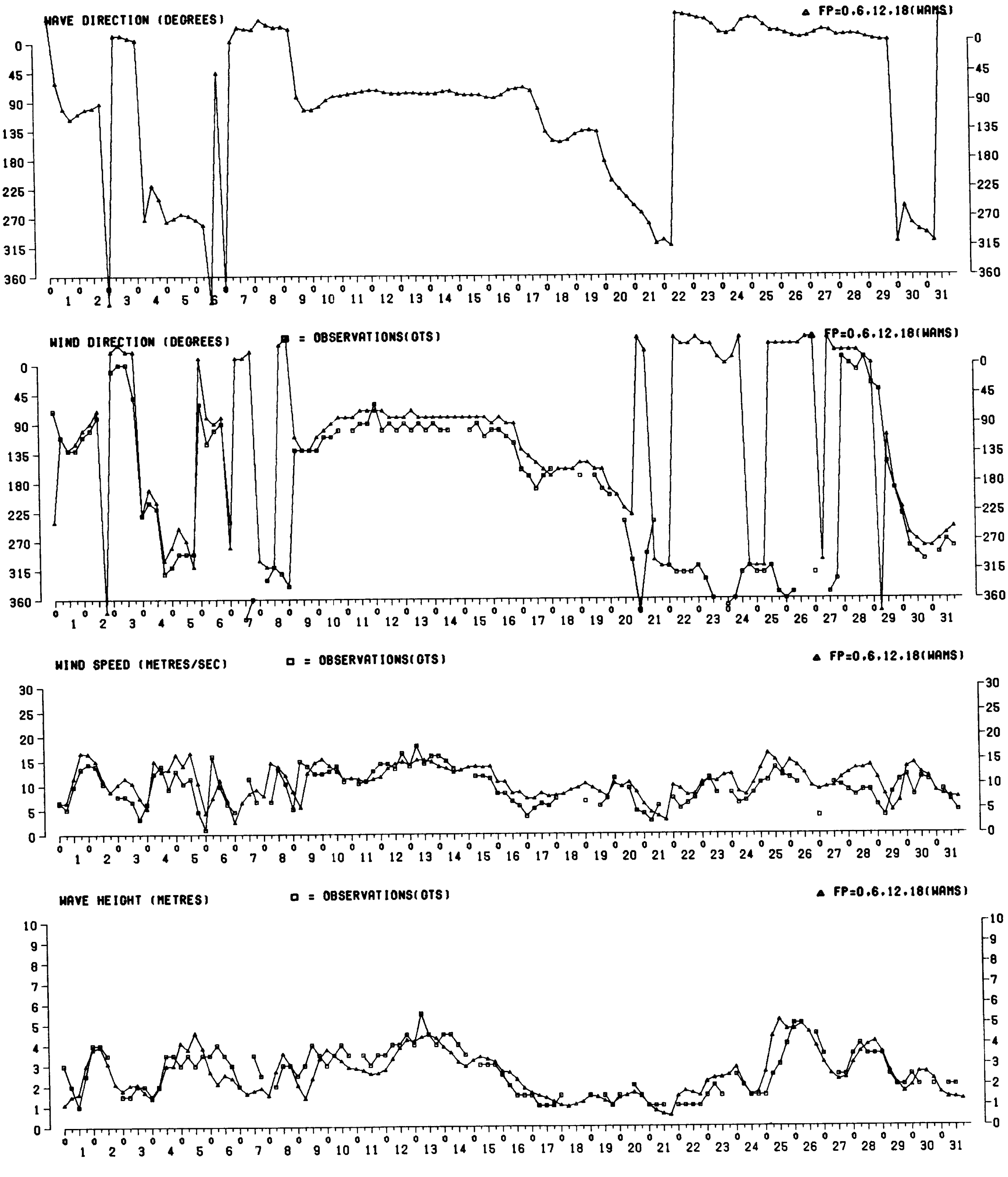

FIG. 28

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KNMI (ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE)
DIVISION OF OCEANOGRAPHIC RESEARCH

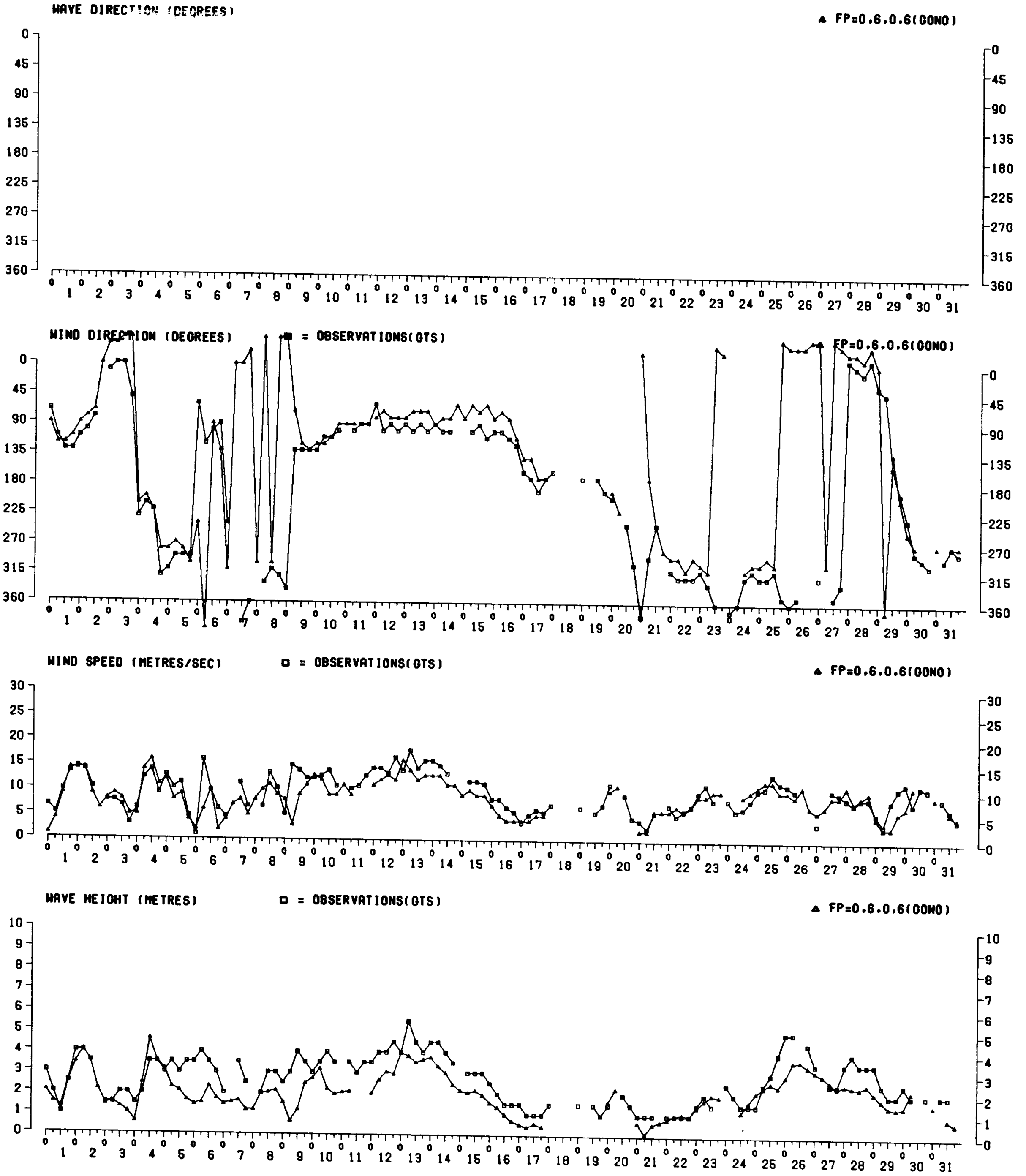

FIG. 29

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KNMI(ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE)
DIVISION OF OCEANOGRAPHIC RESEARCH

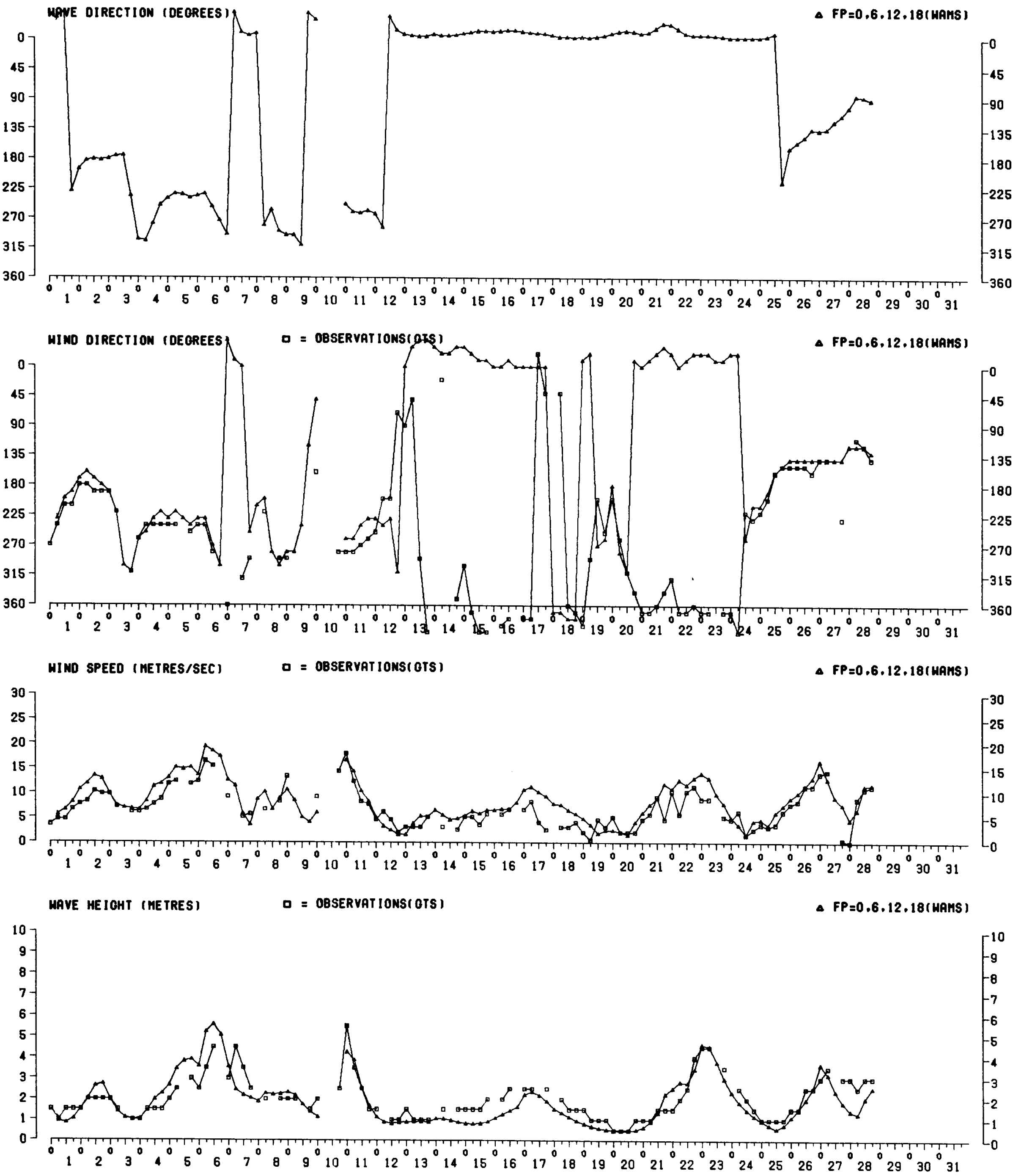

FIG. 30

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KNMI(ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE)
DIVISION OF OCEANOGRAPHIC RESEARCH

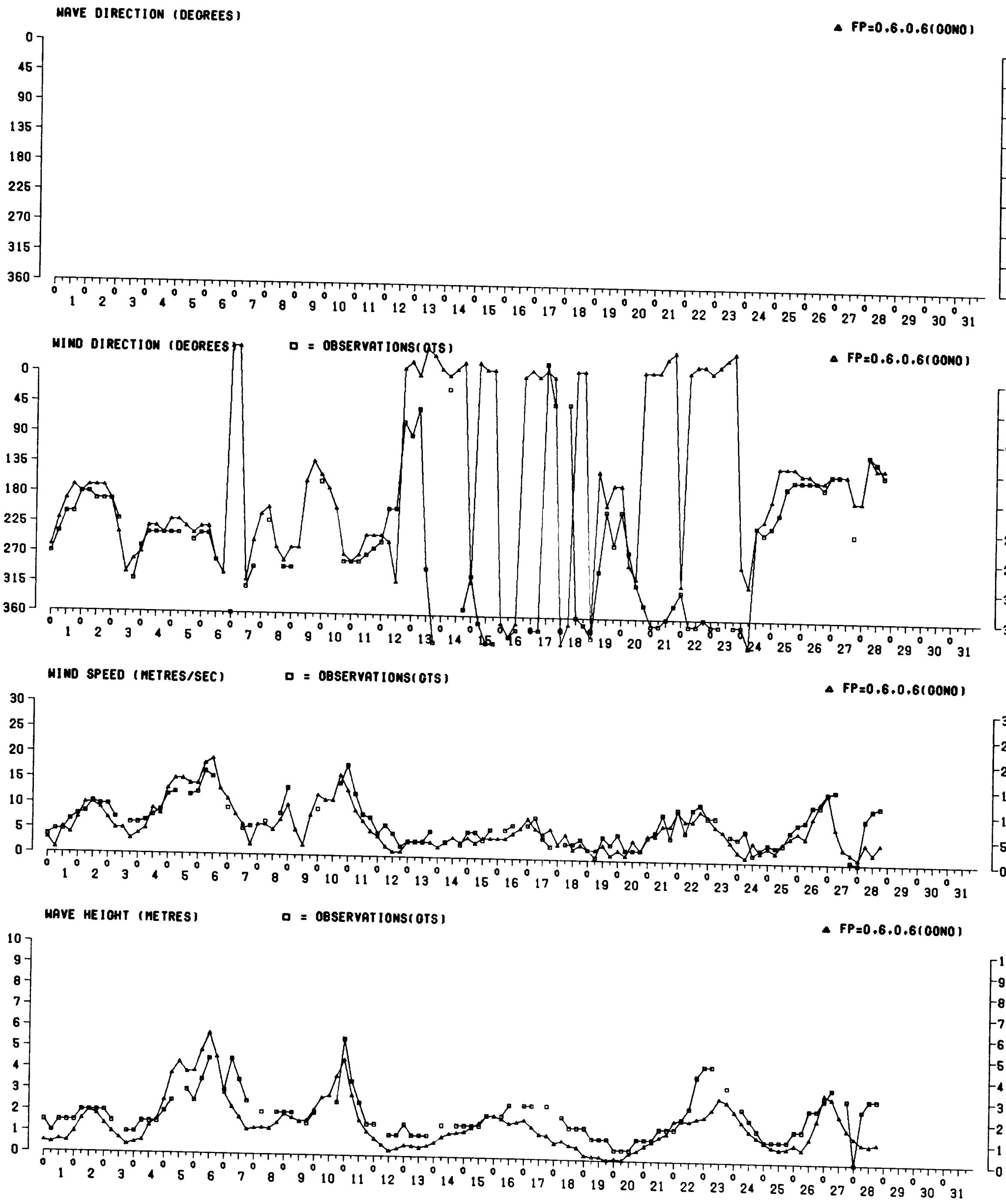

FIG. 31

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DIVISION OF OCEANOGRAPHIC RESEARCH

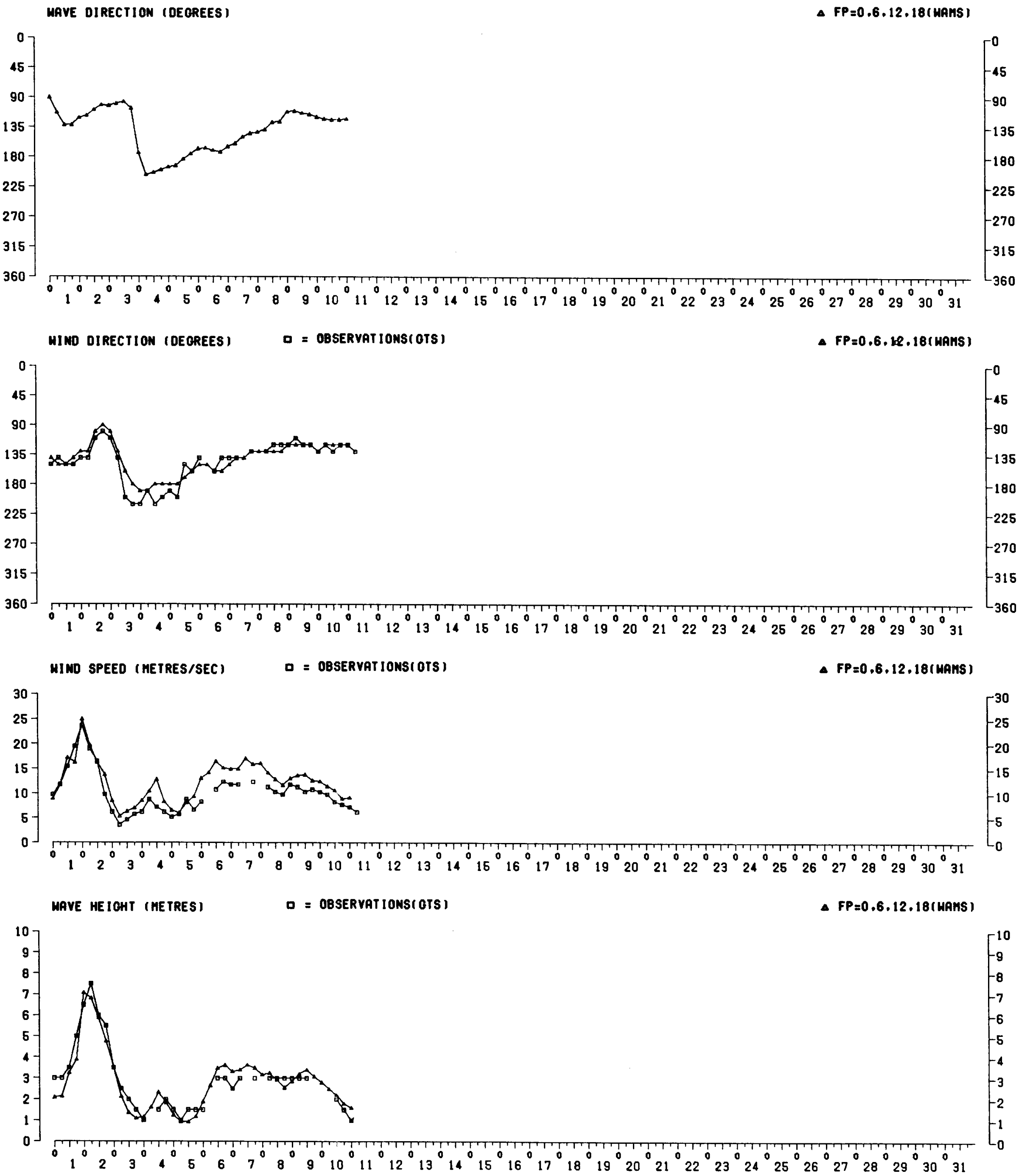
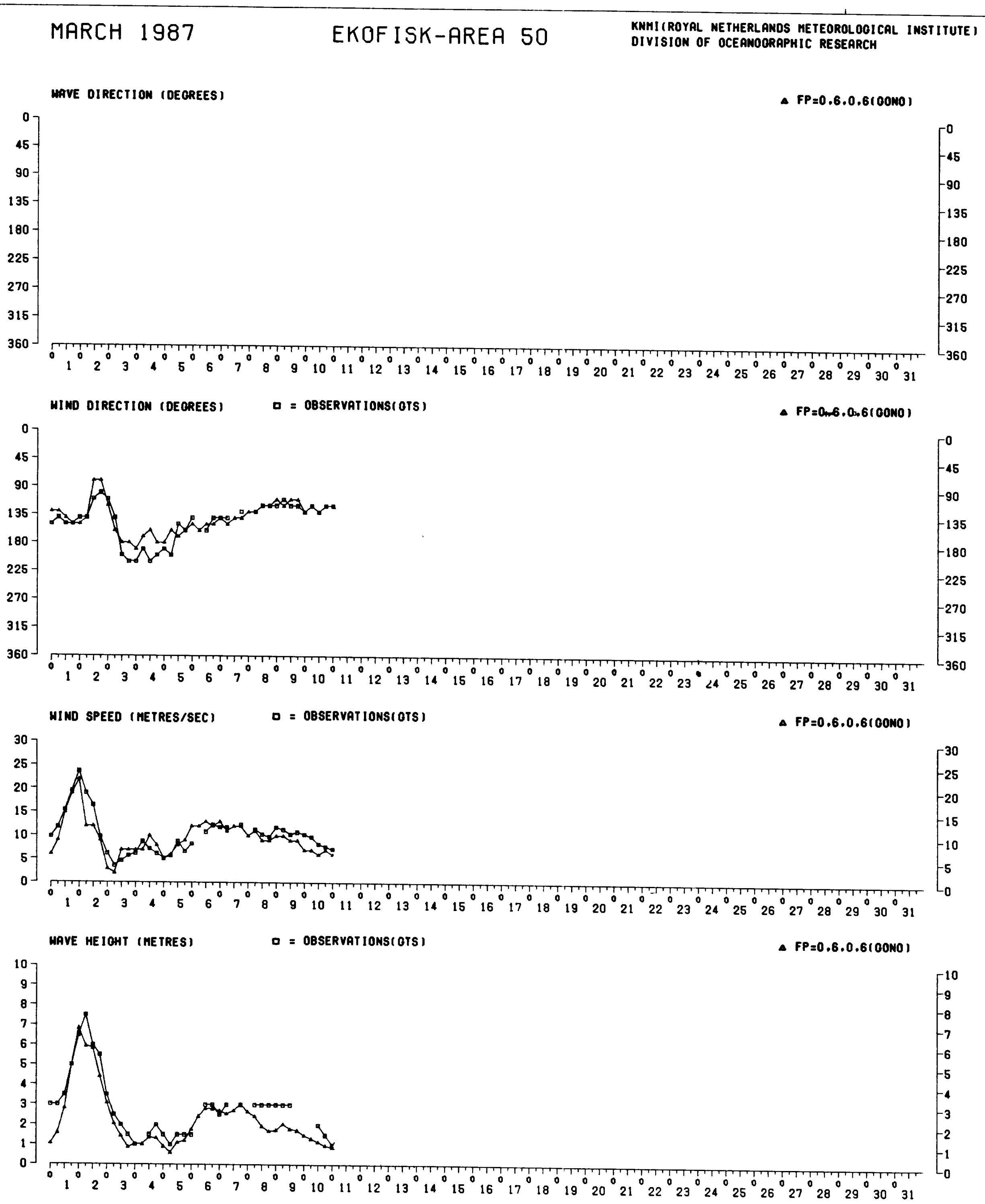


FIG. 32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EKOFISK-AREA 50
KNMI(ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE)
DIVISION OF OCEANOGRAPHIC RESEARCH
WAVE DIRECTION (DEGREES)
▲ FP=0.6,0.6(OONO)
WIND DIRECTION (DEGREES)
□ = OBSERVATIONS(OTS)
WIND SPEED (METRES/SEC)
WAVE HEIGHT (METRES)

FIG. 33

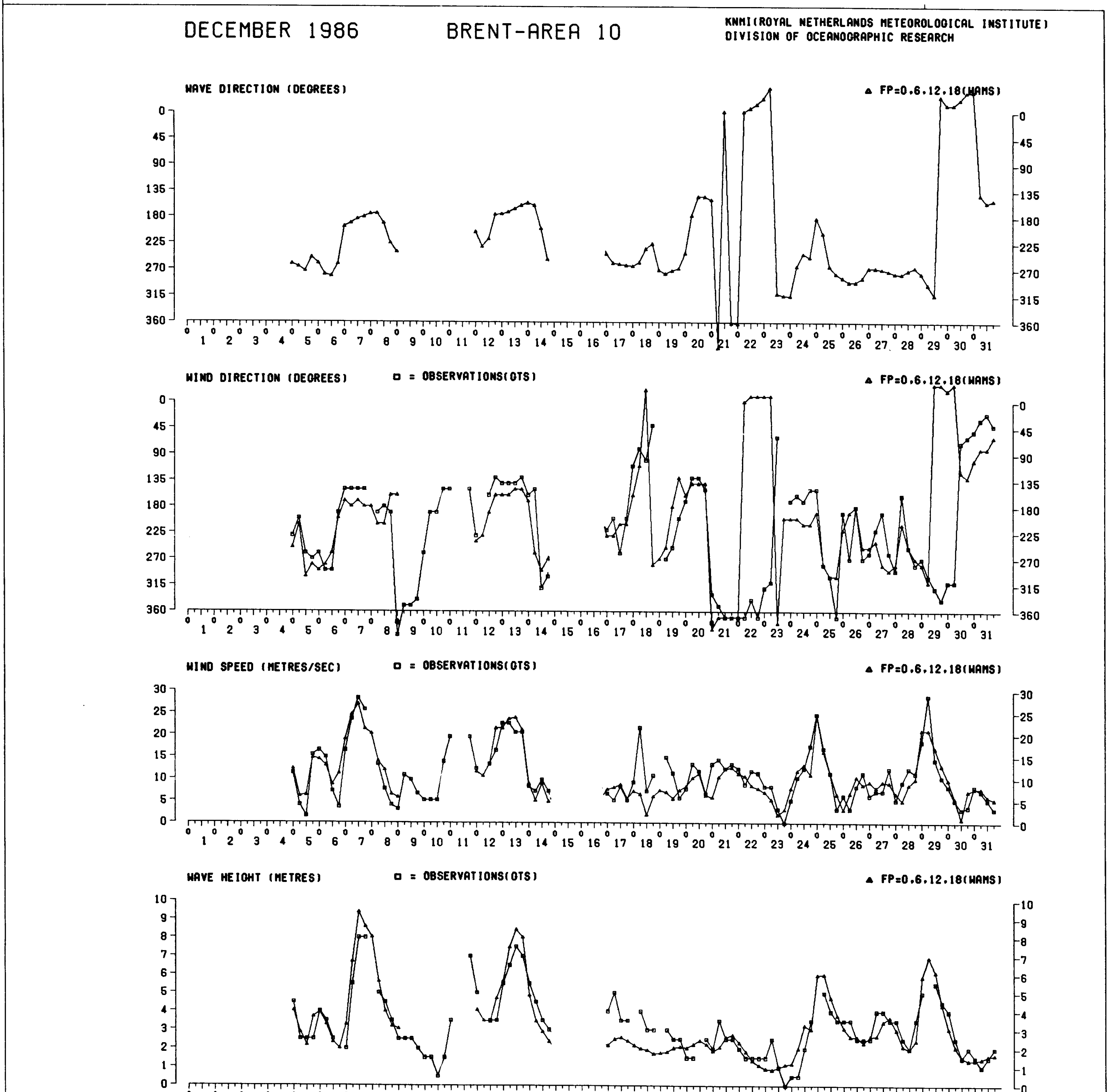
DECEMBER 1986
BRENT-AREA 10
KNMI(ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE)
DIVISION OF OCEANOGRAPHIC RESEARCH
WAVE DIRECTION (DEGREES)
▲ FP=0,6,12,18(WAMS)
WIND DIRECTION (DEGREES)
□ = OBSERVATIONS(OTS)
▲ FP=0,6,12,18(WAMS)
WIND SPEED (METRES/SEC)
□ = OBSERVATIONS(OTS)
▲ FP=0,6,12,18(WAMS)
WAVE HEIGHT (METRES)
□ = OBSERVATIONS(OTS)
▲ FP=0,6,12,18(WAMS)

FIG. 34

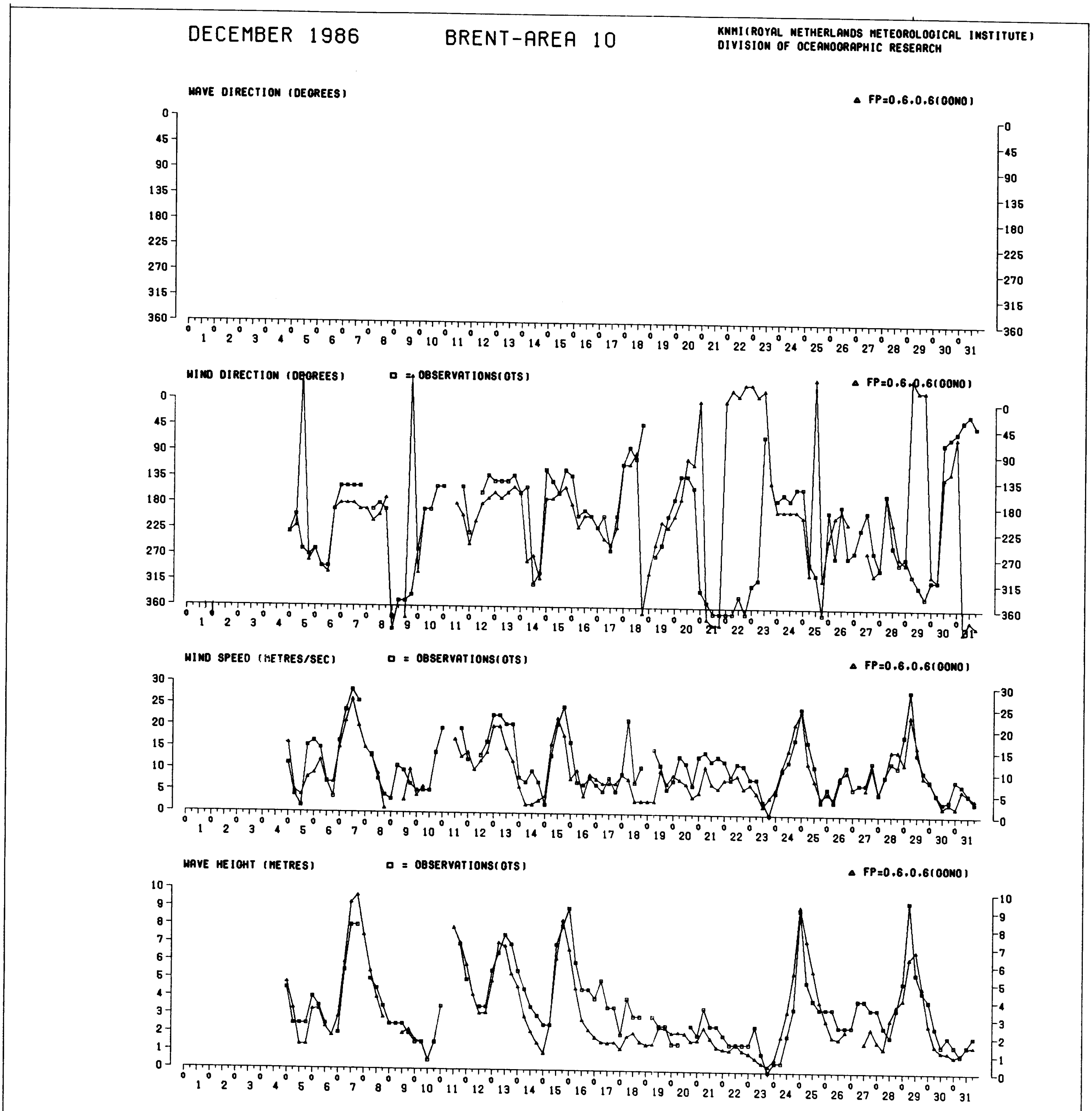
DECEMBER 1986
BRENT-AREA 10
KNMI(ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE)
DIVISION OF OCEANOGRAPHIC RESEARCH
WAVE DIRECTION (DEGREES)
▲ FP=0.6,0.6(OONO)
WIND DIRECTION (DEGREES)
□ = OBSERVATIONS(OTS)
▲ FP=0.6,0.6(OONO)
WIND SPEED (METRES/SEC)
□ = OBSERVATIONS(OTS)
▲ FP=0.6,0.6(OONO)
WAVE HEIGHT (METRES)
□ = OBSERVATIONS(OTS)
▲ FP=0.6,0.6(OONO)

FIG. 35

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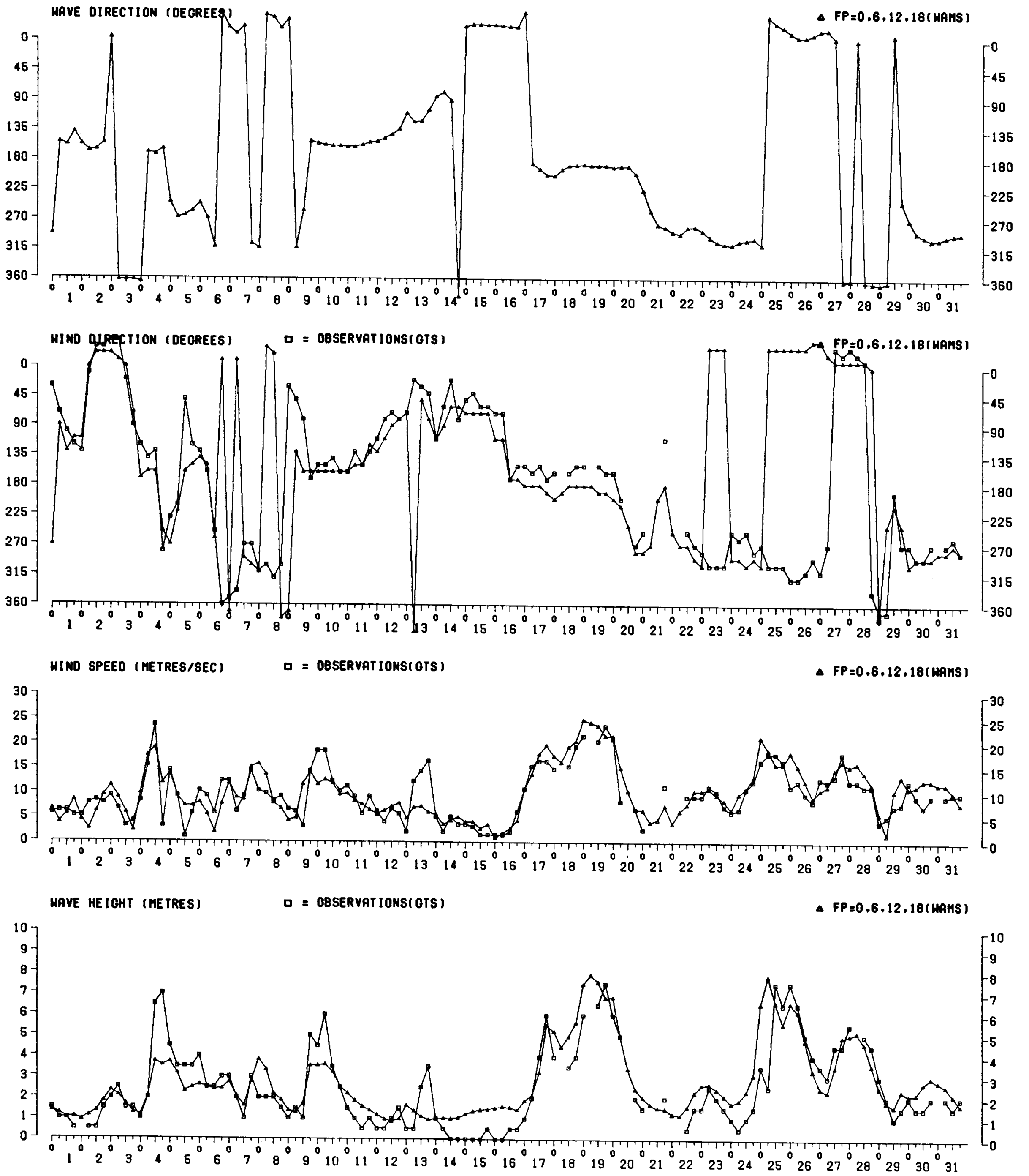

FIG. 36

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KNMI(ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE)
DIVISION OF OCEANOGRAPHIC RESEARCH

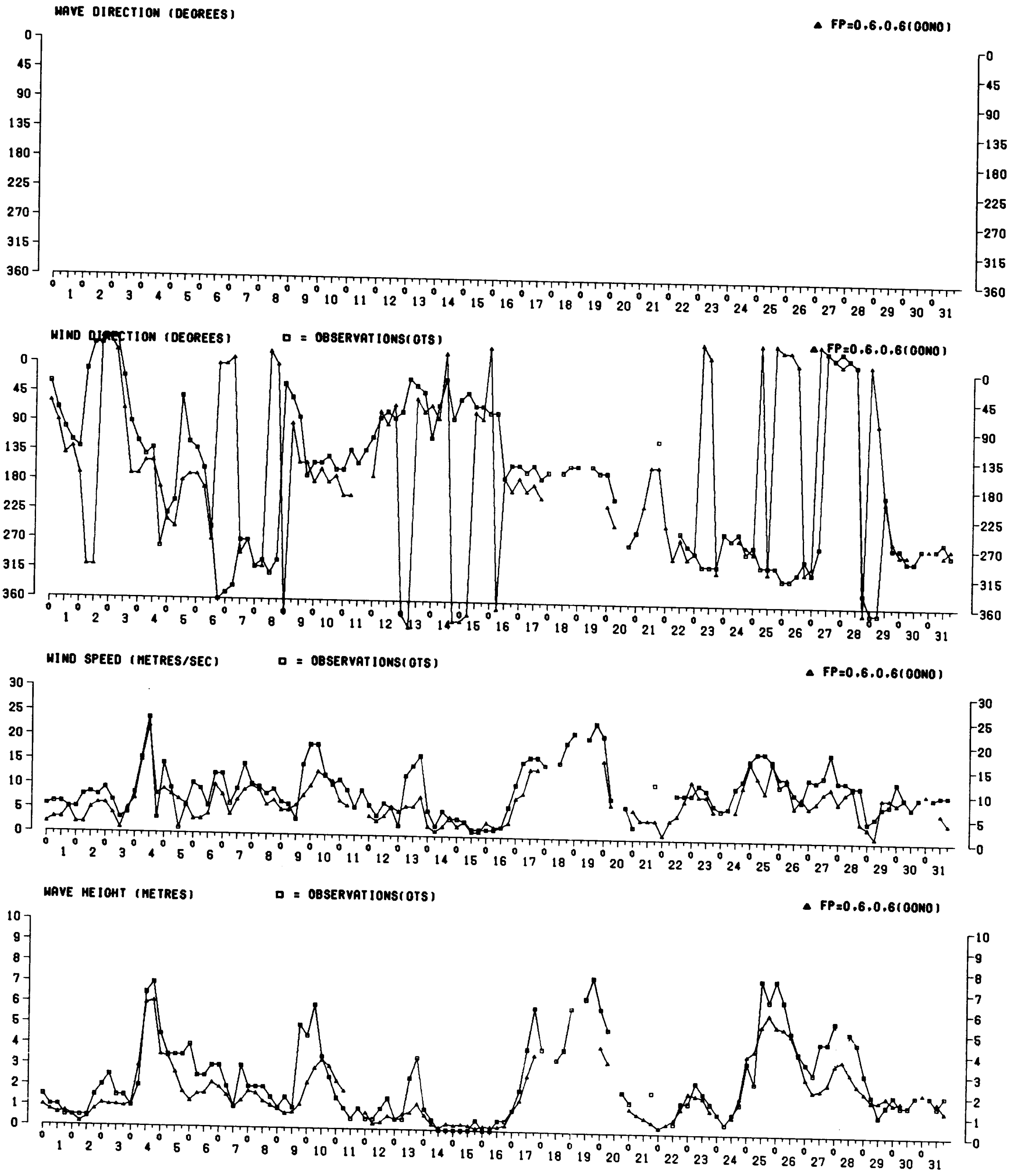

FIG. 37

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KNMI(ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE)
DIVISION OF OCEANOGRAPHIC RESEARCH

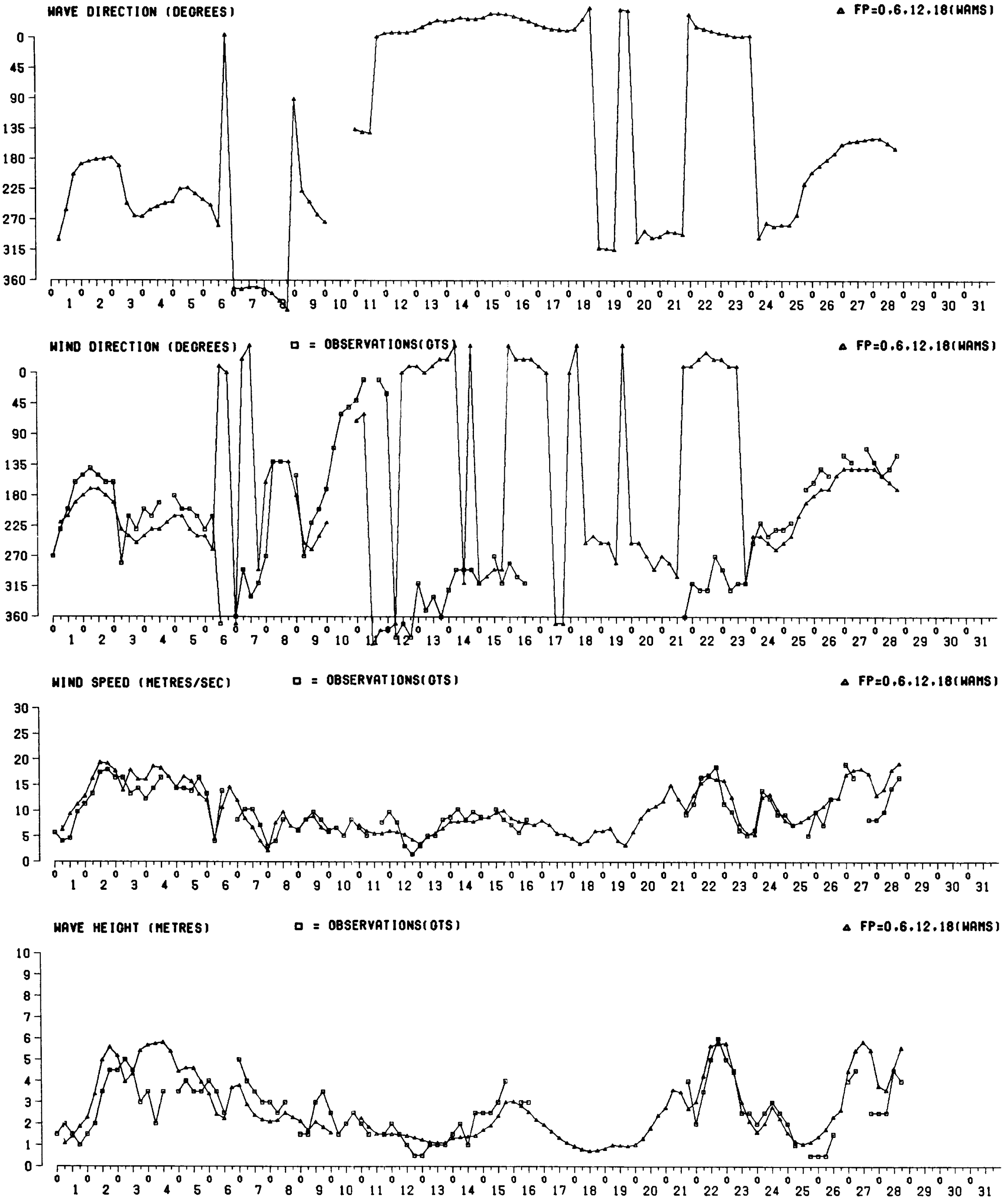

FIG. 38

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KNMI (ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE)
DIVISION OF OCEANOGRAPHIC RESEARCH

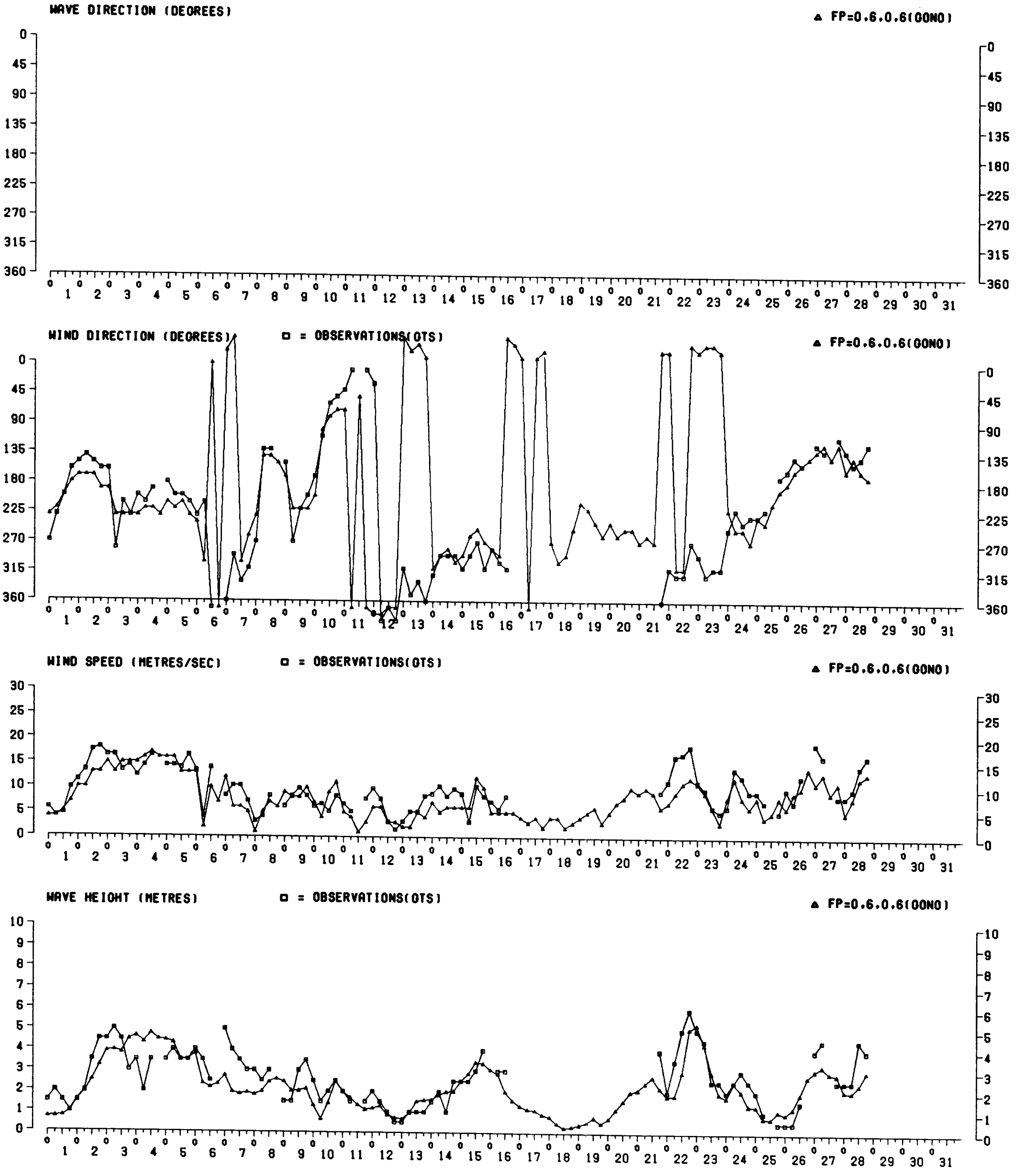

FIG. 39

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KNMI (ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE)
DIVISION OF OCEANOGRAPHIC RESEARCH

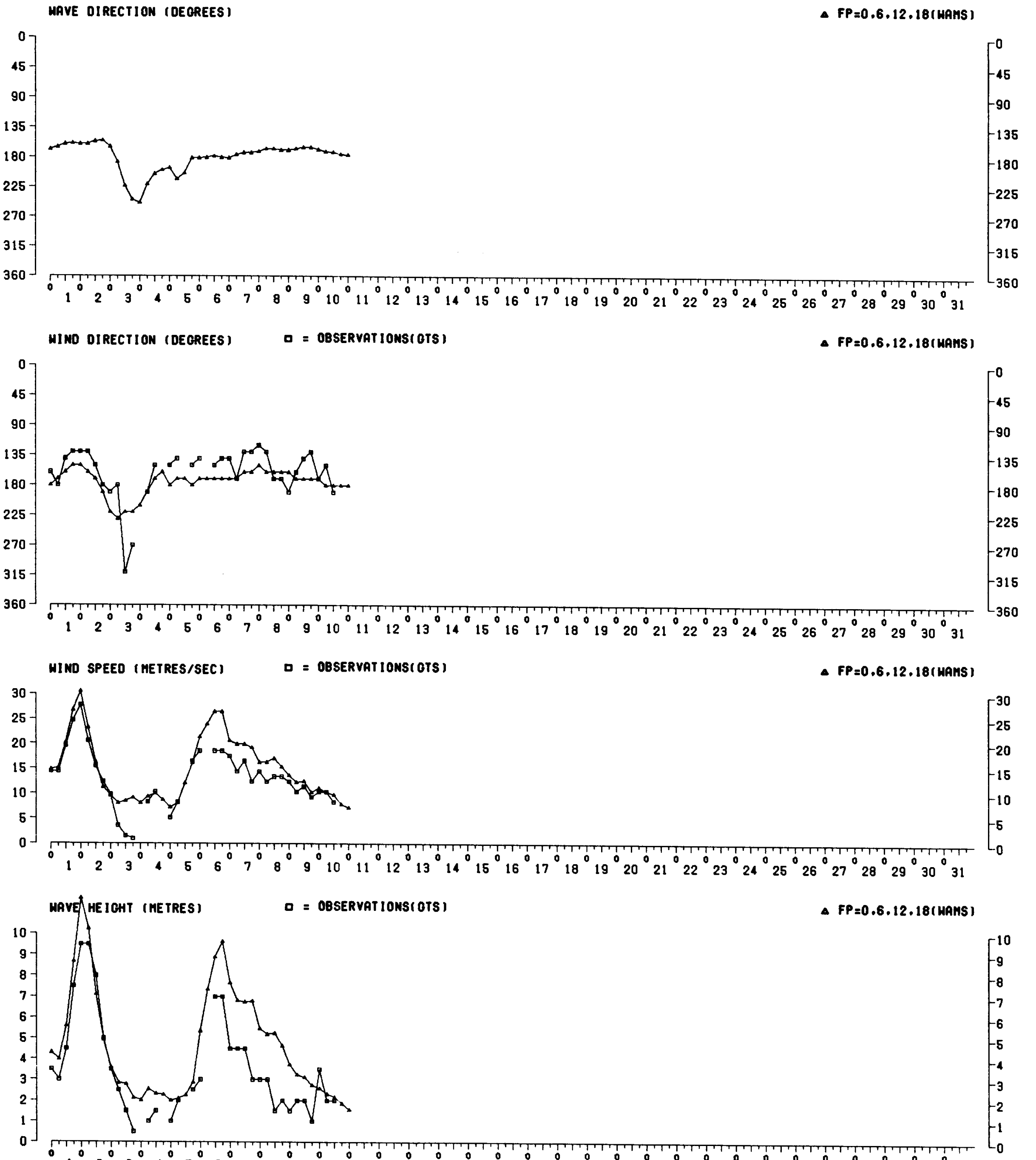

FIG. 40

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KNMI (ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE)
DIVISION OF OCEANOGRAPHIC RESEARCH

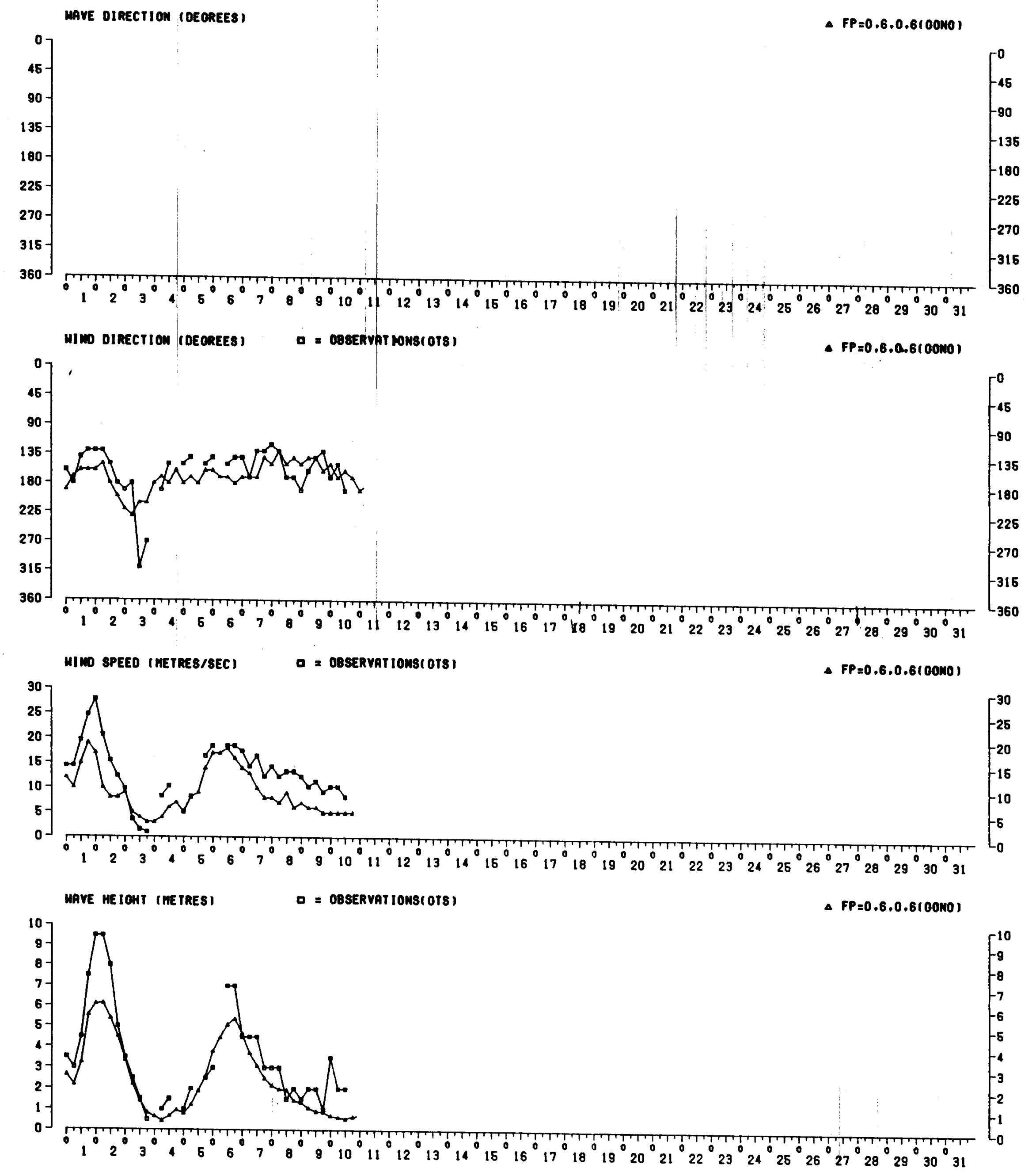


FIG. 41

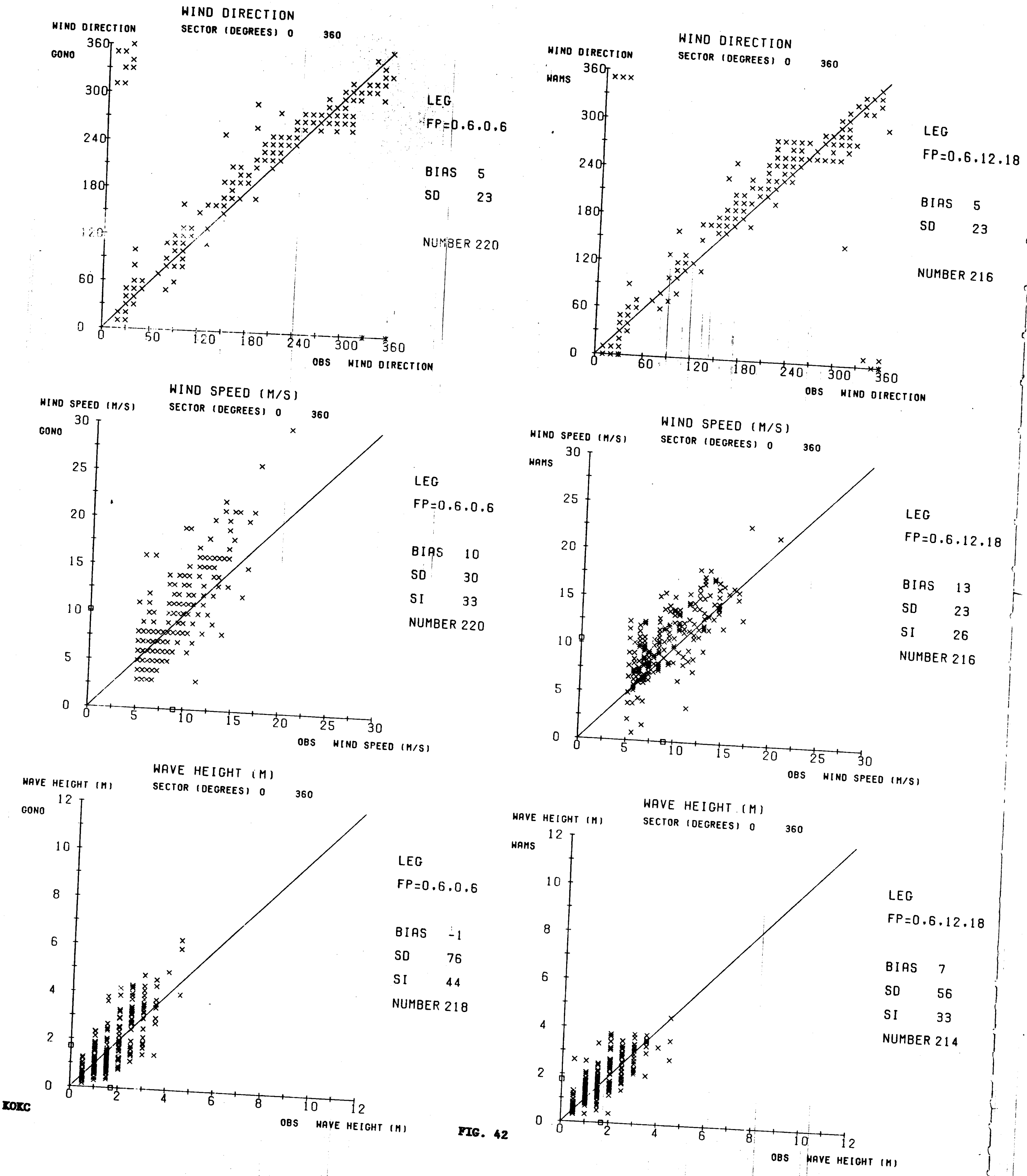
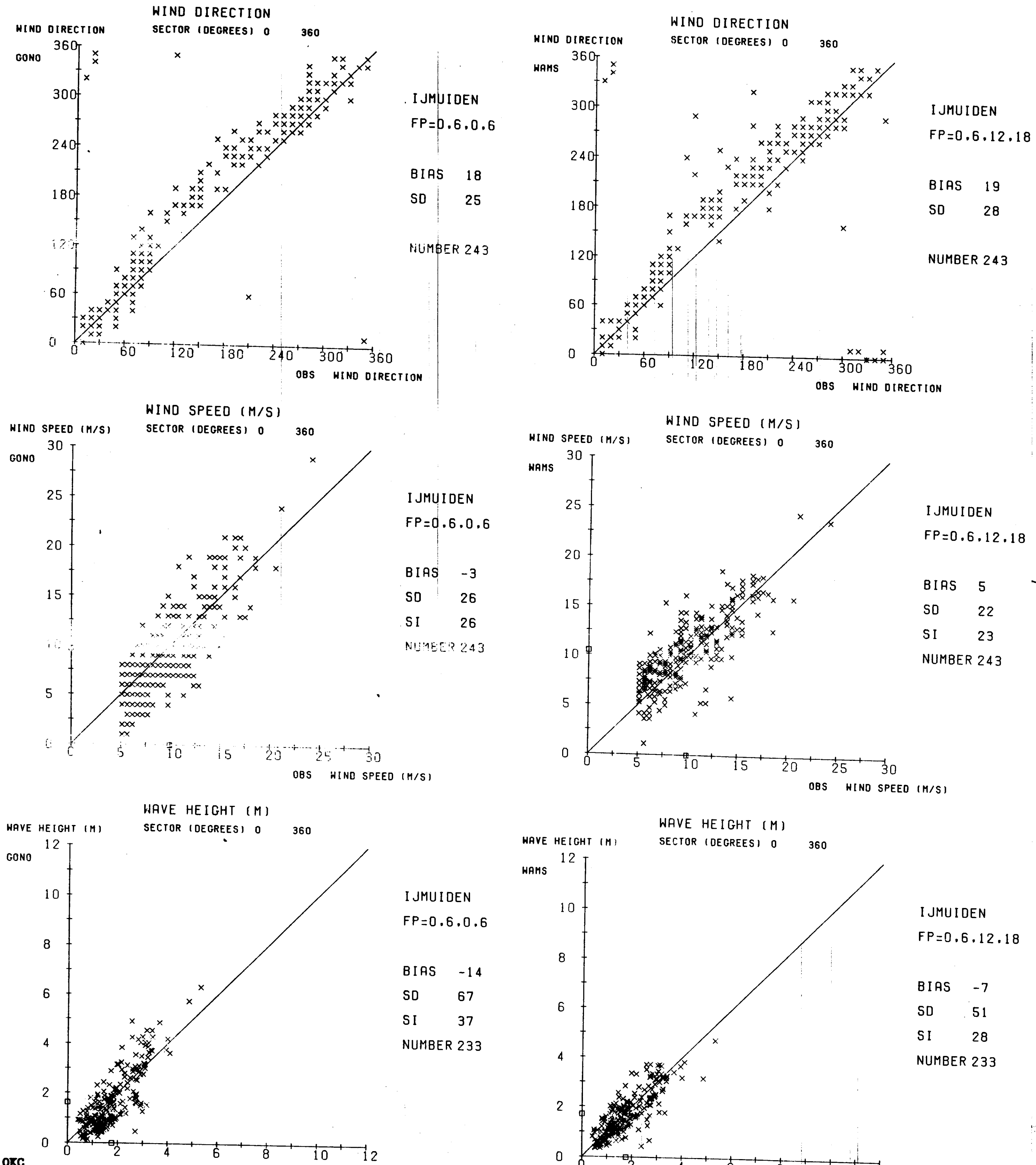
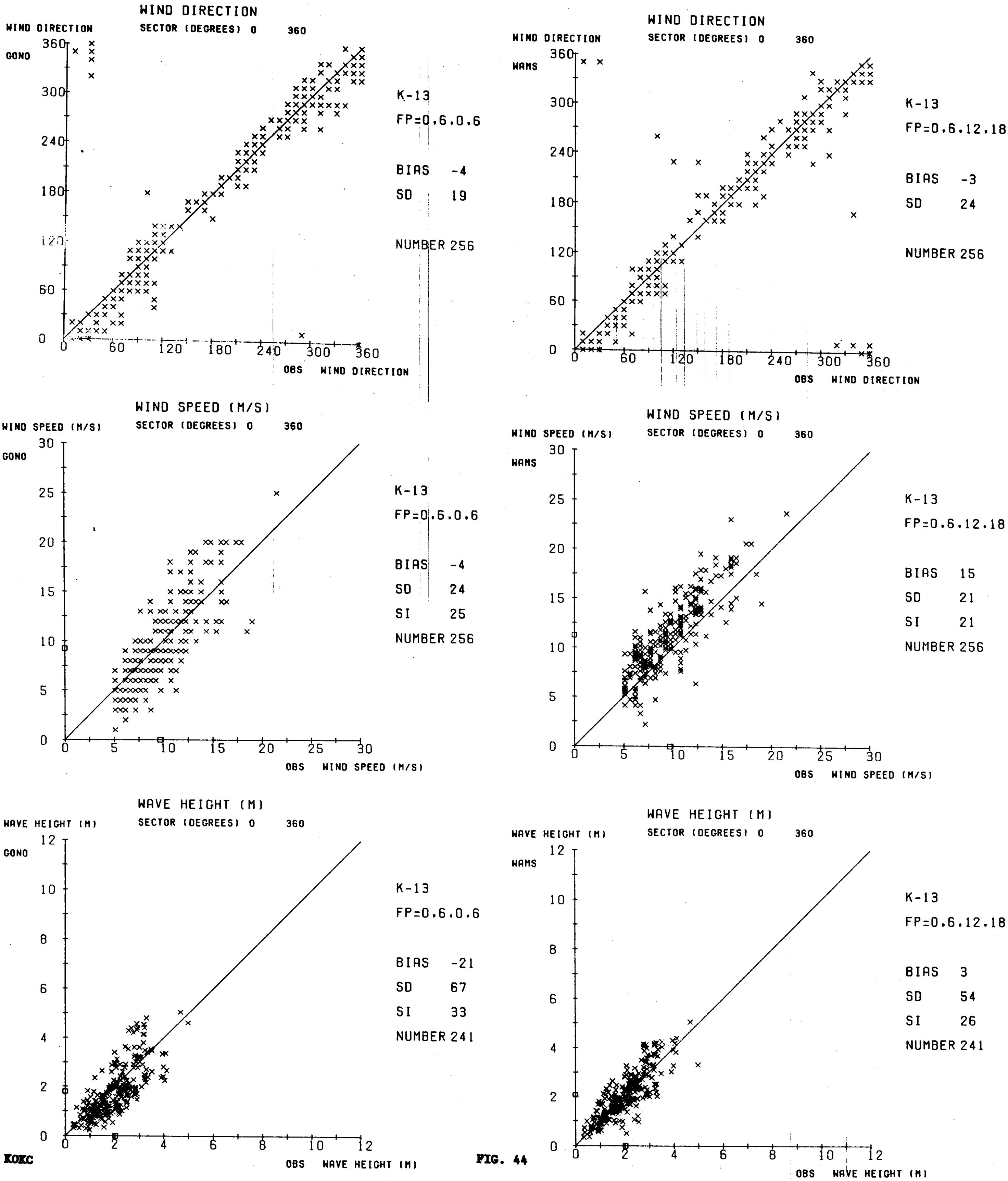

WIND DIRECTION
SECTOR (DEGREES) 0 360
WIND DIRECTION
GONO
LEG
FP=0.6.0.6
BIAS 5
SD 23
NUMBER 220
OBS WIND DIRECTION
WIND DIRECTION
SECTOR (DEGREES) 0 360
WIND DIRECTION
WAMS
LEG
FP=0.6.12.18
BIAS 5
SD 23
NUMBER 216
OBS WIND DIRECTION
WIND SPEED (M/S)
SECTOR (DEGREES) 0 360
WIND SPEED (M/S)
GONO
LEG
FP=0.6.0.6
BIAS 10
SD 30
SI 33
NUMBER 220
OBS WIND SPEED (M/S)
WIND SPEED (M/S)
SECTOR (DEGREES) 0 360
WIND SPEED (M/S)
WAMS
LEG
FP=0.6.12.18
BIAS 13
SD 23
SI 26
NUMBER 216
OBS WIND SPEED (M/S)
WAVE HEIGHT (M)
SECTOR (DEGREES) 0 360
WAVE HEIGHT (M)
GONO
LEG
FP=0.6.0.6
BIAS -1
SD 76
SI 44
NUMBER 218
OBS WAVE HEIGHT (M)
WAVE HEIGHT (M)
SECTOR (DEGREES) 0 360
WAVE HEIGHT (M)
WAMS
LEG
FP=0.6.12.18
BIAS 7
SD 56
SI 33
NUMBER 214
OBS WAVE HEIGHT (M)
KOKC

FIG. 42


WIND DIRECTION
SECTOR (DEGREES) 0 360
WIND DIRECTION GONO
OBS WIND DIRECTION
IJMUIDEN
FP=0.6.0.6
BIAS 18
SD 25
NUMBER 243
WIND DIRECTION
SECTOR (DEGREES) 0 360
WIND DIRECTION WAMS
OBS WIND DIRECTION
IJMUIDEN
FP=0.6.12.18
BIAS 19
SD 28
NUMBER 243
WIND SPEED (M/S)
SECTOR (DEGREES) 0 360
WIND SPEED (M/S) GONO
OBS WIND SPEED (M/S)
IJMUIDEN
FP=0.6.0.6
BIAS -3
SD 26
SI 26
NUMBER 243
WIND SPEED (M/S)
SECTOR (DEGREES) 0 360
WIND SPEED (M/S) WAMS
OBS WIND SPEED (M/S)
IJMUIDEN
FP=0.6.12.18
BIAS 5
SD 22
SI 23
NUMBER 243
WAVE HEIGHT (M)
SECTOR (DEGREES) 0 360
WAVE HEIGHT (M) GONO
OBS WAVE HEIGHT (M)
IJMUIDEN
FP=0.6.0.6
BIAS -14
SD 67
SI 37
NUMBER 233
WAVE HEIGHT (M)
SECTOR (DEGREES) 0 360
WAVE HEIGHT (M) WAMS
OBS WAVE HEIGHT (M)
IJMUIDEN
FP=0.6.12.18
BIAS -7
SD 51
SI 28
NUMBER 233

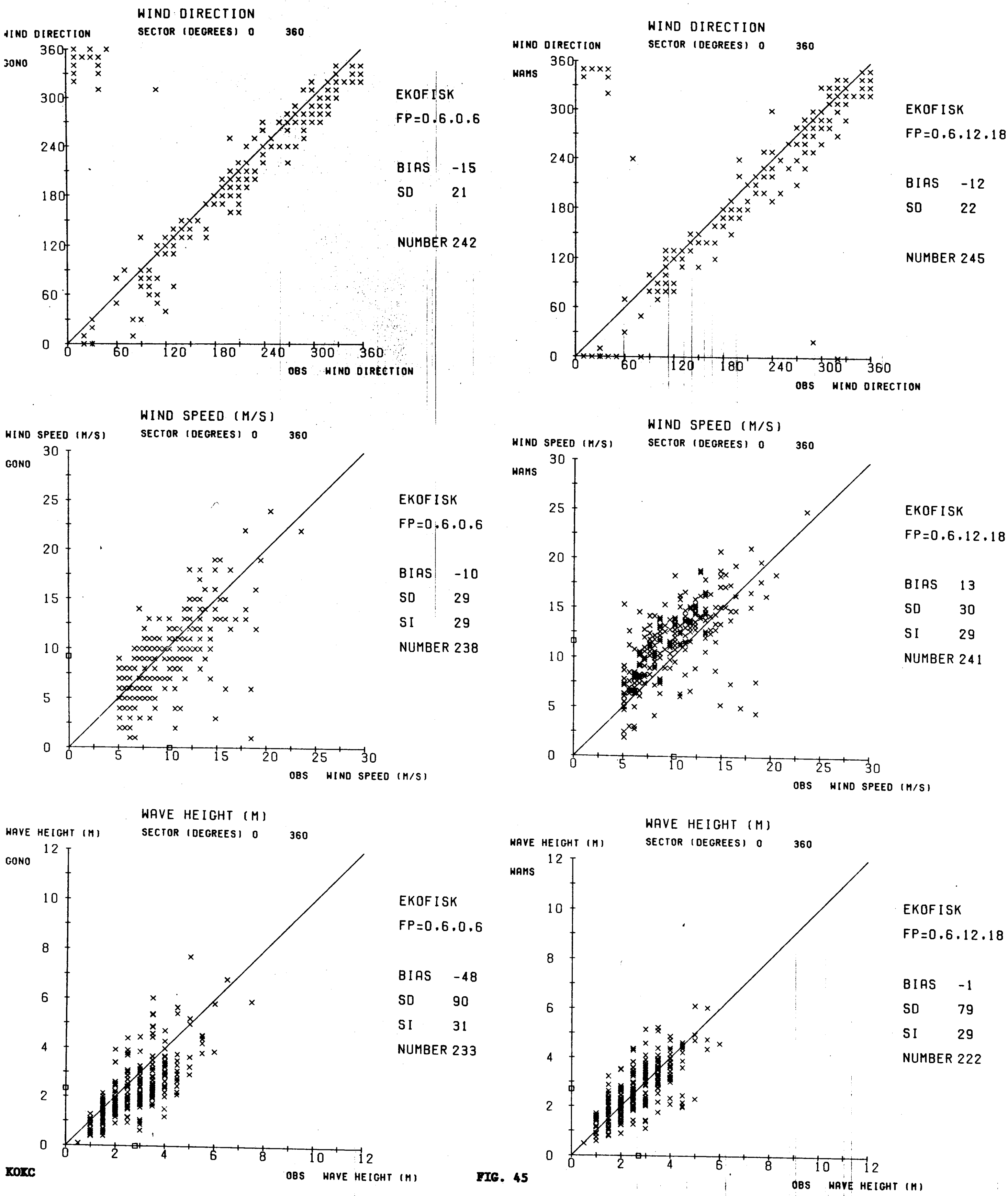
OKC

FIG. 43


WIND DIRECTION
WIND DIRECTION GONO
SECTOR (DEGREES) 0 360
OBS WIND DIRECTION
K-13
FP=0.6.0.6
BIAS -4
SD 19
NUMBER 256
WIND DIRECTION
WIND DIRECTION WAMS
SECTOR (DEGREES) 0 360
OBS WIND DIRECTION
K-13
FP=0.6.12.18
BIAS -3
SD 24
NUMBER 256
WIND SPEED (M/S)
WIND SPEED (M/S) GONO
SECTOR (DEGREES) 0 360
OBS WIND SPEED (M/S)
K-13
FP=0.6.0.6
BIAS -4
SD 24
SI 25
NUMBER 256
WIND SPEED (M/S)
WIND SPEED (M/S) WAMS
SECTOR (DEGREES) 0 360
OBS WIND SPEED (M/S)
K-13
FP=0.6.12.18
BIAS 15
SD 21
SI 21
NUMBER 256
WAVE HEIGHT (M)
WAVE HEIGHT (M) GONO
SECTOR (DEGREES) 0 360
OBS WAVE HEIGHT (M)
K-13
FP=0.6.0.6
BIAS -21
SD 67
SI 33
NUMBER 241
WAVE HEIGHT (M)
WAVE HEIGHT (M) WAMS
SECTOR (DEGREES) 0 360
OBS WAVE HEIGHT (M)
K-13
FP=0.6.12.18
BIAS 3
SD 54
SI 26
NUMBER 241

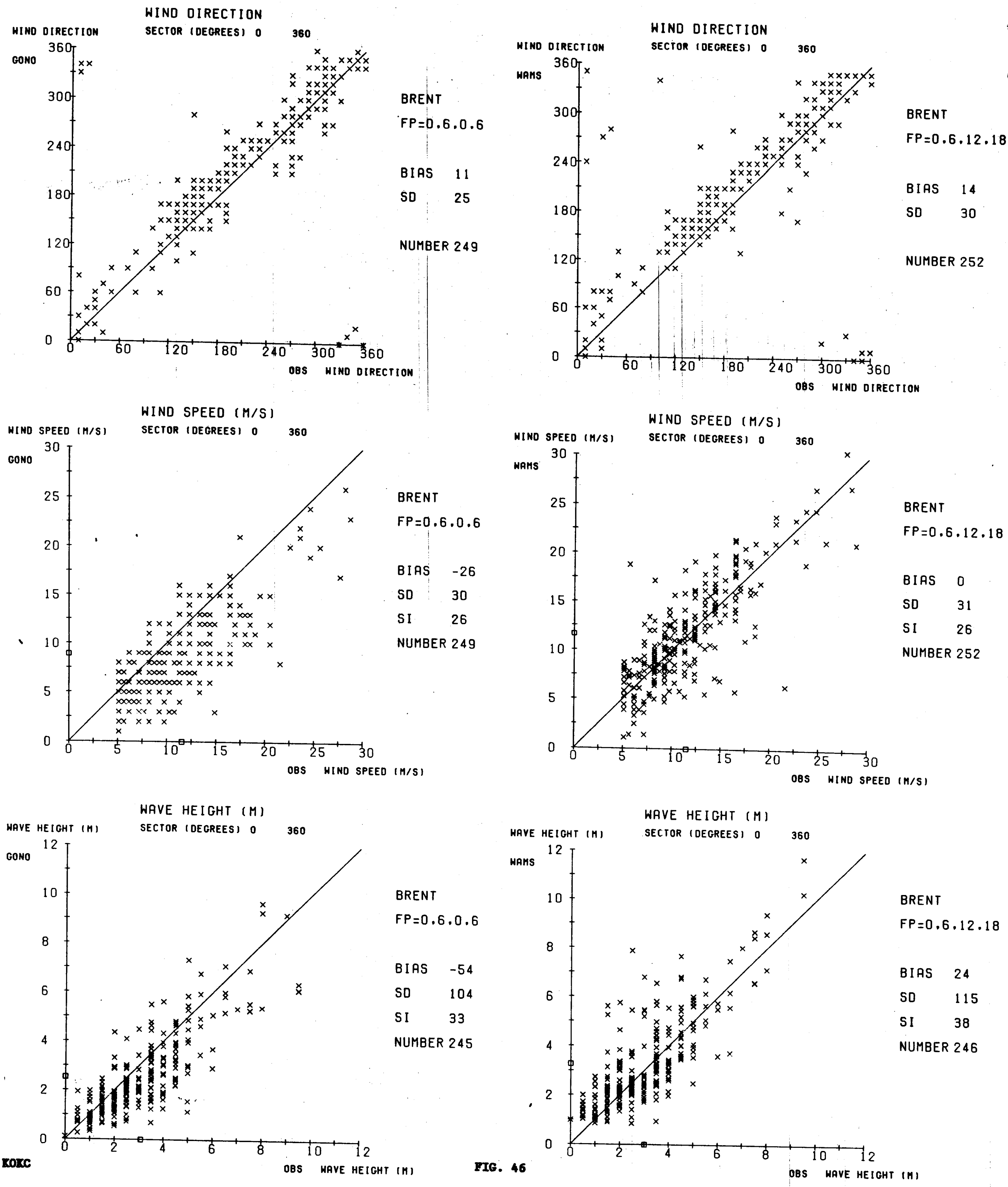
KOKC

FIG. 44


WIND DIRECTION
WIND DIRECTION
GONO
SECTOR (DEGREES) 0 360
OBS WIND DIRECTION
EKOFISK
FP=0.6.0.6
BIAS -15
SD 21
NUMBER 242
WIND DIRECTION
WIND DIRECTION
WAMS
SECTOR (DEGREES) 0 360
OBS WIND DIRECTION
EKOFISK
FP=0.6.12.18
BIAS -12
SD 22
NUMBER 245
WIND SPEED (M/S)
WIND SPEED (M/S)
GONO
SECTOR (DEGREES) 0 360
OBS WIND SPEED (M/S)
EKOFISK
FP=0.6.0.6
BIAS -10
SD 29
SI 29
NUMBER 238
WIND SPEED (M/S)
WIND SPEED (M/S)
WAMS
SECTOR (DEGREES) 0 360
OBS WIND SPEED (M/S)
EKOFISK
FP=0.6.12.18
BIAS 13
SD 30
SI 29
NUMBER 241
WAVE HEIGHT (M)
WAVE HEIGHT (M)
GONO
SECTOR (DEGREES) 0 360
OBS WAVE HEIGHT (M)
EKOFISK
FP=0.6.0.6
BIAS -48
SD 90
SI 31
NUMBER 233
WAVE HEIGHT (M)
WAVE HEIGHT (M)
WAMS
SECTOR (DEGREES) 0 360
OBS WAVE HEIGHT (M)
EKOFISK
FP=0.6.12.18
BIAS -1
SD 79
SI 29
NUMBER 222

KOKC

FIG. 45


WIND DIRECTION
WIND DIRECTION
SECTOR (DEGREES) 0 360
GONO
OBS WIND DIRECTION
BRENT
FP=0.6.0.6
BIAS 11
SD 25
NUMBER 249
WIND DIRECTION
WIND DIRECTION
SECTOR (DEGREES) 0 360
WAMS
OBS WIND DIRECTION
BRENT
FP=0.6.12.18
BIAS 14
SD 30
NUMBER 252
WIND SPEED (M/S)
WIND SPEED (M/S)
SECTOR (DEGREES) 0 360
GONO
OBS WIND SPEED (M/S)
BRENT
FP=0.6.0.6
BIAS -26
SD 30
SI 26
NUMBER 249
WIND SPEED (M/S)
WIND SPEED (M/S)
SECTOR (DEGREES) 0 360
WAMS
OBS WIND SPEED (M/S)
BRENT
FP=0.6.12.18
BIAS 0
SD 31
SI 26
NUMBER 252
WAVE HEIGHT (M)
WAVE HEIGHT (M)
SECTOR (DEGREES) 0 360
GONO
OBS WAVE HEIGHT (M)
BRENT
FP=0.6.0.6
BIAS -54
SD 104
SI 33
NUMBER 245
WAVE HEIGHT (M)
WAVE HEIGHT (M)
SECTOR (DEGREES) 0 360
WAMS
OBS WAVE HEIGHT (M)
BRENT
FP=0.6.12.18
BIAS 24
SD 115
SI 38
NUMBER 246

KOKC

FIG. 46