August, 1969.

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London Weather Centre Memorandum No. 13

Analysis of Errors in Wind Forecasting to North Sea Oil Rigs

by

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I. Introduction:-

Oil rigs depend on accurate weather reports for their safety; it was thus decided that some estimate of the error involved in forecasting should be obtained. The heights of the waves to which oil rigs are subjected are of particular importance due to the instability of rigs when in rough water (ref. 1). Since wave height depends on fetch and wind speed, this analysis is concerned solely with wind forecasting, the rig under consideration being in such a position that a change in wind direction does not alter fetch to any significant extent and hence wave height is affected by wind speed alone (ref. 2). However, as this is not the case with other rigs, the vector error, including direction as well as speed, might be valuable as an indication of the general accuracy of wind forecasting. This latter part of the analysis was not completed because of shortage of time, but the relevant data is available.

II. Data:-

The data used was a set of observations, as reported by 'Staflo', a semi-submersible oil rig operating in the North Sea (blocks 21.26 and 21.11, 57° - 58°N, 0° - 1°E), and the corresponding forecasts issued to 'Staflo' by the London Weather Centre. A change in position from block 21.26 (June) to block 21.11 (July) was ignored as having a negligible effect on the data. The most complete set of observations was obtained for the period from January, 1968, to September, 1968, and this consisted of, in the main, two observations per day recorded at 0600 hours and 1800 hours.(occasionally 0001, 1200 or 2000 hours) and the relevant forecasts.

Four forecasts were considered: 12 hour, 24 hour, 48 hour and 72 hour forecasts, the number of hours referring to the approximate difference between time of issue and time at the end of the period to which the forecast applied. The forecasts were:

1. 12 hour forecast, covering the 12 hours from 1600 hours, day 1, to 0400, day 2, compared with the 0600 hours, day 2, observation;
2. 24 hour forecast, covering the 12 hours from 0400 hours, day 2, to 1600 hours, day 2, and ending 24 hours from time of issue, i.e. just before 1600 hours, day 1.
3. 48 hour forecast covering the 24 hours from 1600 hours, day 2, to 1600 hours, day 3, and ending 48 hours from time of issue.
4. 72 hour forecast covering the 24 hours from 1600 hours, day 3, to 1600 hours, day 4, and ending 72 hours from time of issue.

The last three forecasts were compared, where possible, with the 1800 hours observation on the appropriate day, but all the forecasts were compared with the observation closest in time to the end of the forecast period. The time difference between forecast and observation was usually 2 hours but occasionally 8 or more hours, in which case the forecast was omitted from the analysis.

Since the forecasts were not always precise as to the wind direction and speed or to the exact time period to which they referred, the following conventions were adhered to:

1. Where the words 'becoming' or 'backing' were used, the final speed and direction were taken, e.g. 'SW 20 becoming NW30' was taken as NW 30 (since the time given to a forecast was the time at the end of the forecast period).
2. Where the word 'to' or a dash was used, as in 'N to NW, 10-20', the average wind speed and direction were taken i.e. NNW 15 in this case.

3. Equivalent speeds of 5, 10, 13, 16 and 19 were used for wind speed descriptions 'light', 'light to moderate', 'moderate', 'moderate to fresh' and 'fresh' respectively. 'Less than 10' was taken as 5.

4. When forecast speed was greater than actual speed, the error was said to be positive, when less than the actual speed, negative.

III Calculations:-

Initially, in order to obtain some idea of the average error, the absolute values of the errors were plotted as a histogram and their mean calculated. However, although the mean for each month and forecast has been calculated, and can be seen in Table I, the distribution of errors, positive and negative, was judged to give a more useful indication of the order of the errors involved. It was thus decided to group the data, prior to calculating the means and standard deviations of the distributions of errors.

The data, which consisted of approximately 270 errors for each time period, was grouped in 14 classes of length 5 knots, from -41 kts: -36 kts. to +30.5 kts: +35.5 kts, and the mean and standard deviation were calculated using these classes. The average absolute error was calculated using ungrouped data.

Also calculated using grouped data were:

1. Mean and standard deviation of winter forecast errors and summer forecast errors separately. January - April was regarded as winter, May - September as summer, since these seasons correspond with periods of greater and lesser wind speed respectively (in this block) (ref. 3).

2. Mean and standard deviation of errors associated with strong winds (speeds greater than or equal to 22 knots). Originally errors for speeds greater than 35 knots, the wind speed warning level for 'Staflo', were investigated but these winds were too infrequent for a proper analysis to be carried out.

All the calculations were carried out to four decimal places, but are quoted in histograms and tables to two decimal places.

IV Results:-

The frequencies of grouped errors are summarized in Tables II - IV and histograms 1 (a-d), 2 (a-d) and 3 (a-d).

(1) All Wind Speeds During All Months:-

(Table II, histograms 1 (a-d))

The means and standard deviations for each forecast are tabulated below:

Forecast	12 hour	24 hour	48 hour	72 hour
Mean	2.12	1.25	1.09	0.74
S.d.	9.10	8.87	9.54	10.32
No. of obs.	270	269	268	267

D. G. Hunter, in August 1967, using data from 'Transocean Two', block 49.26, noted a tendency towards overestimation of wind speed, a tendency confirmed in this analysis by the positive means. This bias, however, became less as forecasts were made for further ahead when negative errors, i.e. underestimations of actual speed, tended to balance positive errors.

In all forecast periods over 60% of all forecasts lay within 8 knots of the true value and over 90% (72 hour forecasts) or over 95% (12, 24 and 48 hour forecasts) lay within 19 knots of the true value (Table II).

A comparison was made between the differences of standard deviations and the standard errors of differences of standard deviations of samples of the same population. The results are shown below, the 24 hour, 48 hour and 72 hour forecast standard deviations being compared with the 12 hour forecast standard deviation in each case.

Forecasts compared	24 hr. - 12 hr.	48 hr. - 12 hr.	72 hr. - 12 hr.
Difference of s.d.s.	0.23	0.44	1.23
Standard error of diffs. of s.d.s	0.55	0.57	0.59

We see from the above table that there is no significant difference between the 12 hour standard deviation and the 24 hour standard deviation or between the 12 hour standard deviation and the 48 hour standard deviation. The difference between the 12 hour standard deviation and the 72 hour standard deviation is double the standard error of a distribution of such differences and may indicate a real difference between the 12 hour and 72 hour forecast, in so far as the frequency of extreme errors is concerned. These facts imply that only the 72 hour forecast was appreciably inferior to the 12 hour forecast.

(2) Winter and Summer Forecasts:-

(Table III, histograms 2 (a-d))

The means and standard deviations for each forecast are tabulated below:-

Forecast	12 hour	24 hour	48 hour	72 hour
Mean	2.04	0.77	0.66	0.15
S.d.	7.92	7.80	8.11	9.03
No. of obs.	151	150	150	150

(Summer)

Forecast	12 hour	24 hour	48 hour	72 hour
Mean	2.22	1.85	1.63	1.50
S.d.	10.41	10.06	11.10	11.77
No. of obs.	119	119	118	117

(Winter)

As can be seen from the tables above, the winter mean is consistently higher than the summer mean, an indication that overestimation was more common in winter than in summer.

A significance test on the winter and summer standard deviations was carried out on similar lines to the one described in section(2.). and the results are shown below.

Forecast	12 hour	24 hour	48 hour	72 hour
Diff. of winter and summer s.d.s	2.49	2.25	2.99	2.74
Standard error of diffs. of s.d.s	0.79	0.77	0.83	0.90

Comparing standard deviations in this way, a significant difference between winter and summer standard deviations is observed in all forecast periods - extreme errors were more often made in winter.

(3) Strong Wind Forecasts:-

(Table IV, histograms 3 (a-d))

The means and standard deviations for errors associated with actual wind speeds which are greater than or equal to 22 knots are tabulated below:

Forecast	12 hour	24 hour	48 hour	72 hour
Mean	-5.72	-5.01	-6.06	-7.50
S.d.	8.58	9.62	9.24	10.13
No. of obs.	77	77	78	77

Although the standard deviations of errors associated with strong winds are roughly comparable with the standard deviations of those associated with all wind speeds, the mean error is negative, demonstrating a bias towards underestimation of the actual wind speed, in contrast with the usual overestimation. This was particularly marked in the 72 hour forecast where the low mean and high standard deviation led to a relatively large number of extreme underestimates.

(4) Extreme Errors ($\geq$ 25 knots):-

Only one extreme error occurred during summer (May - September), and was an overestimate of 27.5 knots in the 12 hour forecast. There were no extreme errors after May.

The rest were made in January - April, the greatest frequency (4) occurring as underestimates in the 72 hour forecast. The total number of extreme errors was 14, the worst errors being underestimates of 37.5 knots in January and February. The worst month was March which had 6 extreme errors (including all forecast periods). The numbers of these errors were too small for analysis.

The above four sections can be summarized as follows:

Although the majority of forecasts were reasonably accurate there was a tendency to overestimation, when all wind speeds in both seasons were considered. The 12 hour forecast was not significantly better than the 24 hour or 48 hour forecasts and not much better than the 72 hour forecast with regard to the spread of errors involved.

Winter forecasts were not as accurate as summer forecasts, owing to a greater frequency of extreme errors in January - April, the season corresponding to the period of greater wind variability (ref. 3).

Forecasts for strong winds had a marked tendency to underestimation.

Extreme errors occurred during the winter particularly as underestimates in the 72 hour forecast.

Further analyses of wind forecasting errors, one which investigates the vector error and one in which a persistence method of forecasting is compared to the present method, are suggested by this analysis.

References:

1. Brazell, J. H., 'Forecasting for North Sea Oil Drilling' (Lecture notes).

2. Darbyshire, M. and Draper, L., 'Forecasting Wind Generated Sea Waves'.

3. Dutton, M. J., 'Analysis of Wave Heights in the North Sea 1965 - 68'.
(London Weather Centre Memorandum No. 10).

TABLE I

Average Absolute Error in Wind Forecasting - (months) - for 'Staflo' Blocks 21.26 & 21.11, Jan - Sept, 1968

	Error (knots)			
Month	12 hours	24 hour	48 hours	72 hours
January	10.3	8.8	10.6	8.8
February	8.5	7.9	7.4	9.1
March	9.2	8.1	10.3	10.5
April	7.2	6.0	8.8	8.5
May	7.2	7.2	6.5	7.3
June	7.6	5.4	5.9	6.4
July	5.4	6.7	7.4	7.8
August	4.7	6.5	6.8	7.1
September	7.2	6.8	5.8	8.1

TABLE II

Frequencies of Errors in Wind Forecasting
for 'Staflo' Blocks 21.26 & 21.11, Jan - Sept, 1968

Class (knots)	Mid-Mark	Frequency			
		12 hours	24 hours	48 hours	72 hours
-41 : -36	-38.5	0	1	1	0
-35.5 : -30.5	-33.0	1	0	0	2
-30 : -25	-27.5	0	1	1	2
-24.5 : -19.5	-22.0	4	2	3	5
-19 : -14	-16.5	7	10	8	11
-13.5 : -8.5	-11	17	19	31	21
-8 : -3	-5.5	39	42	43	45
-2.5 : +2.5	0	77	77	63	61
3 : 8	5.5	65	65	57	61
8.5 : 13.5	11.0	35	32	41	36
14 : 19	16.5	18	18	14	14
19.5 : 14.5	22.0	4	2	5	8
25 : 30	27.5	3	0	1	1
	Total	270	269	268	267

TABLE III

Frequencies of Errors in Wind Forecasting - (Winter and Summer) - for 'Staflo' Blocks 21.26 & 21.11, Jan-April, 1968 and May-Sept, 1968

Class (knots)	Mid-Mark	Frequency							
		12 hours		24 hours		48 hours		72 hours	
		Jan-Apr	May-Sept	Jan-Apr	May-Sept	Jan-Apr	May-Sept	Jan-Apr	May-Sept
-41: -36	-38.5	0	0	1	0	1	0	0	0
-35.5:-30.5	-33.0	1	0	0	0	0	0	2	0
-30: -25	-27.5	0	0	1	0	1	0	2	0
-24.5:-19.5	-22.0	2	2	2	0	2	1	3	2
-19: -14	-16.5	5	2	4	6	6	2	6	5
-13.5: -8.5	-11.0	8	9	6	13	12	19	6	15
-8: -3	-5.5	18	21	14	28	15	28	13	32
-2.5: +2.5	0	28	49	36	41	21	42	30	31
3: 8	5.5	25	40	27	38	26	31	24	37
8.5: 13.5	11.0	16	19	15	17	21	20	15	21
14: 19	16.5	12	6	11	7	9	5	10	4
19.5: 24.5	22.0	2	2	2	0	3	2	5	3
25: 30	27.5	2	1	0	0	1	0	1	0
	Total	119	151	119	150	118	150	117	150

TABLE IV

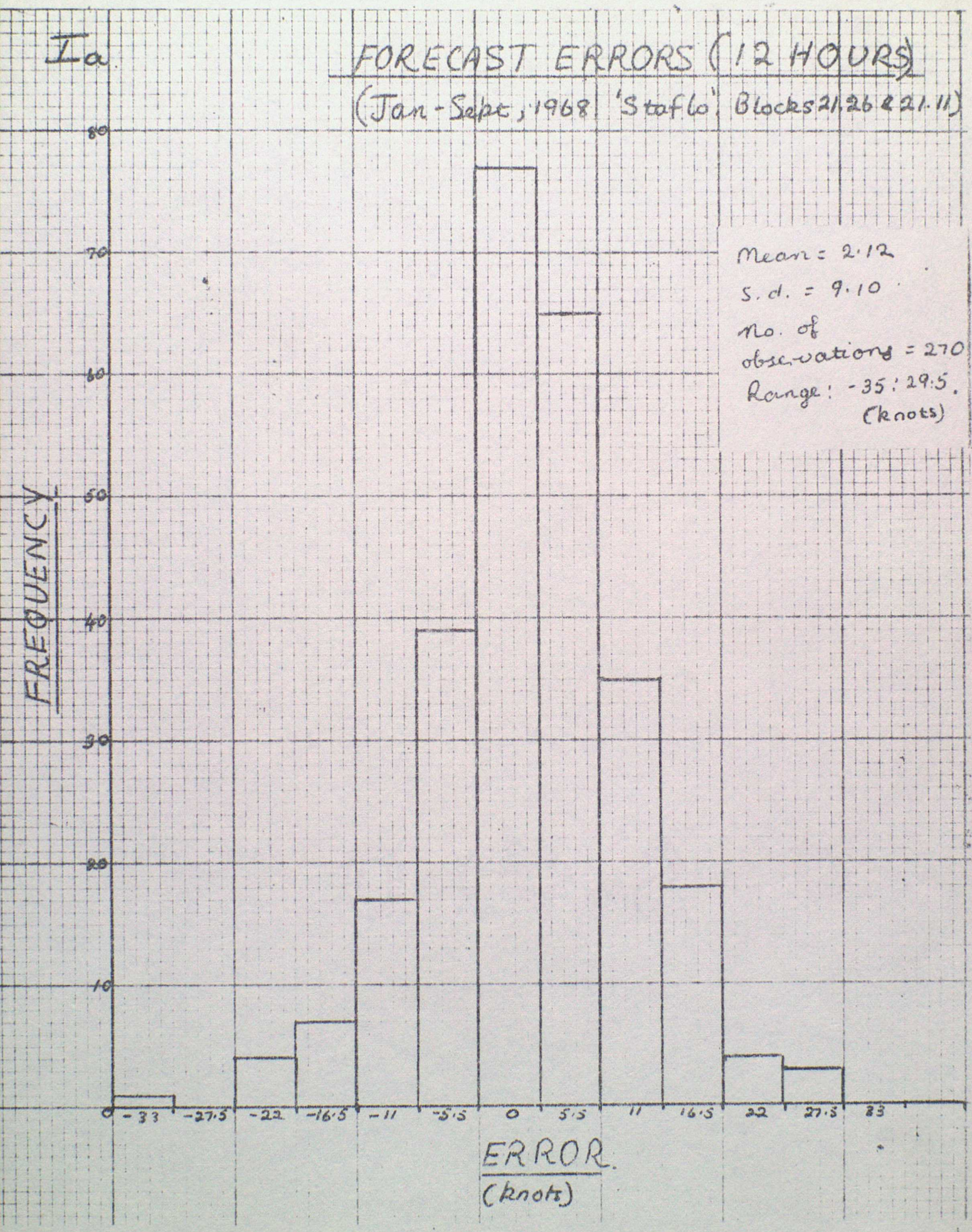
Frequencies of Errors in Wind Forecasting -
(Wind speeds greater than or equal to 22 kts)
- for 'Staflo' Blocks 21.26 & 21.11, Jan - Sept, 1968.

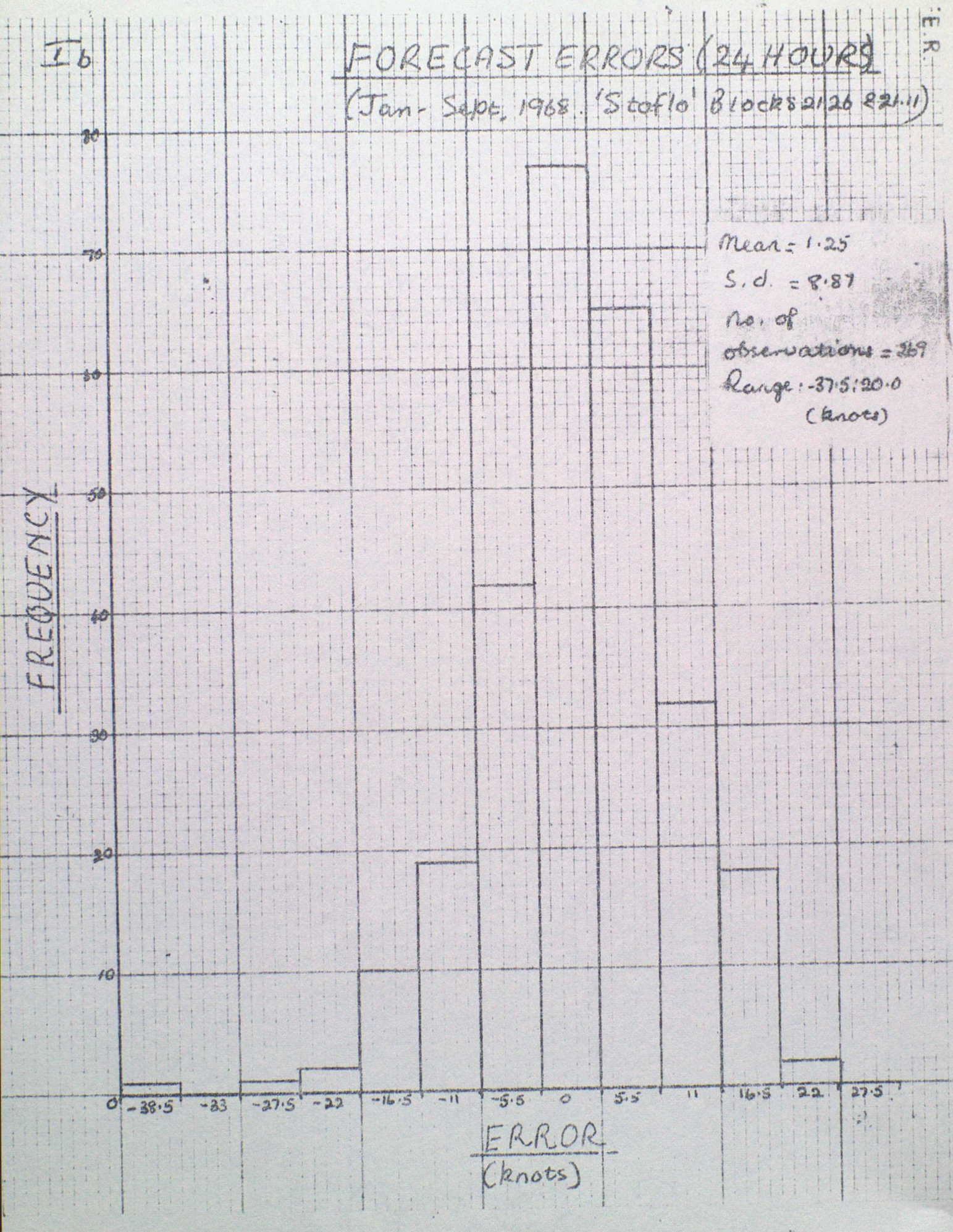
Class (knots)	Mid-Mark	Frequency			
		12 hours	24 hours	48 hours	72 hours
-41 : -36	-38.5	0	1	0	0
-35.5 : -30.5	-33.0	1	0	0	2
-30 : -25	-27.5	0	1	2	2
-24.5 : -19.5	-22.0	5	2	2	4
-19 : -14	-16.5	6	9	7	12
-13.5 : -8.5	-11.0	12	16	27	15
-8 : -3	-5.5	24	15	14	18
-2.5 : +2.5	0	18	19	13	12
3 : 8	5.5	9	12	8	8
8.5 : 13.5	11.0	1	2	3	3
14 : 19	16.5	1	2	1	1
19.5 : 24.5	22.0	0	0	1	0
25 : 30	27.5	0	0	0	0
	Total	77	79	78	77

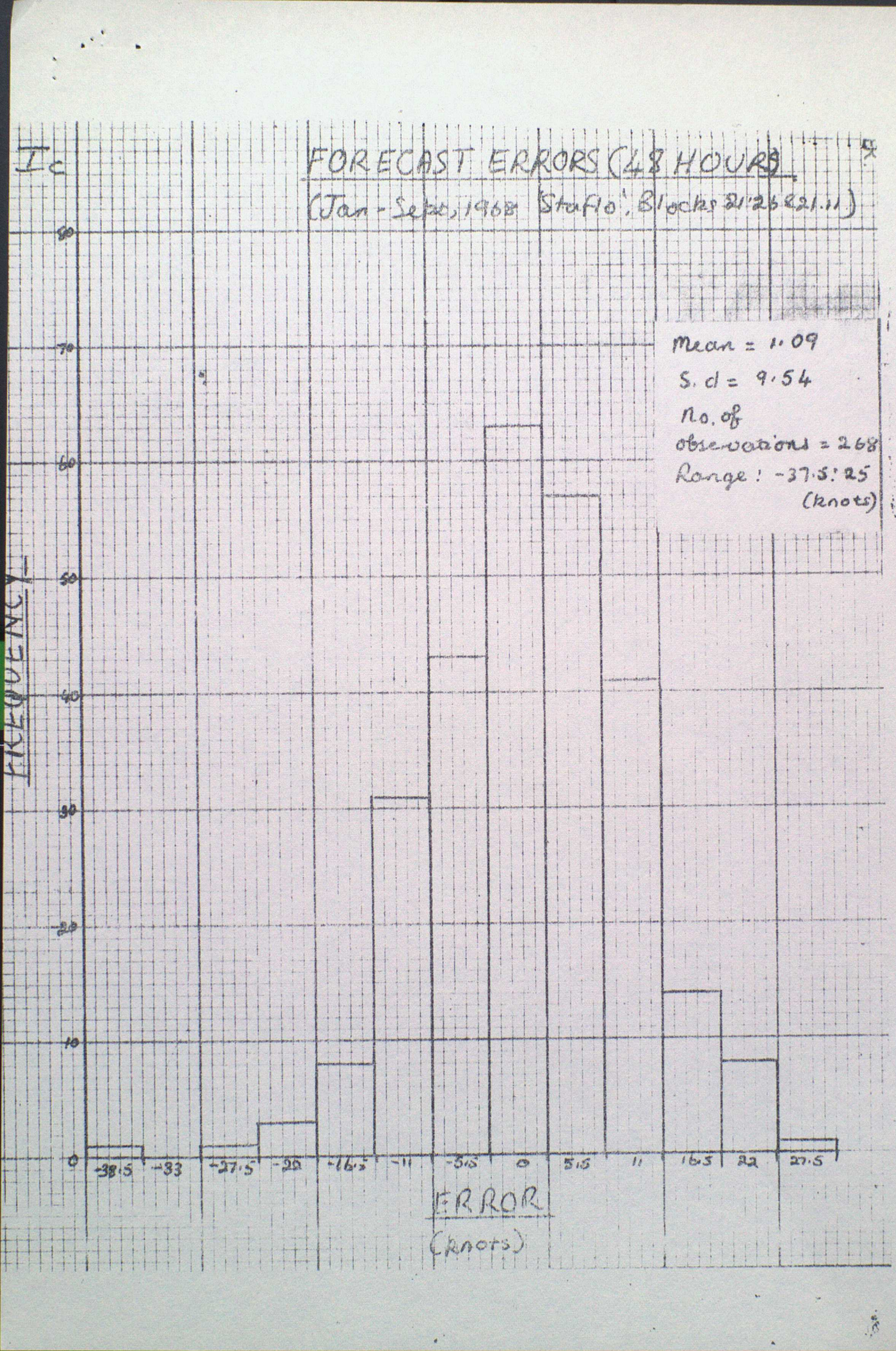
Ia

FORECAST ERRORS (12 HOURS)

(Jan - Sept, 1968 'Staflo' Blocks 21, 26 & 21, 11)

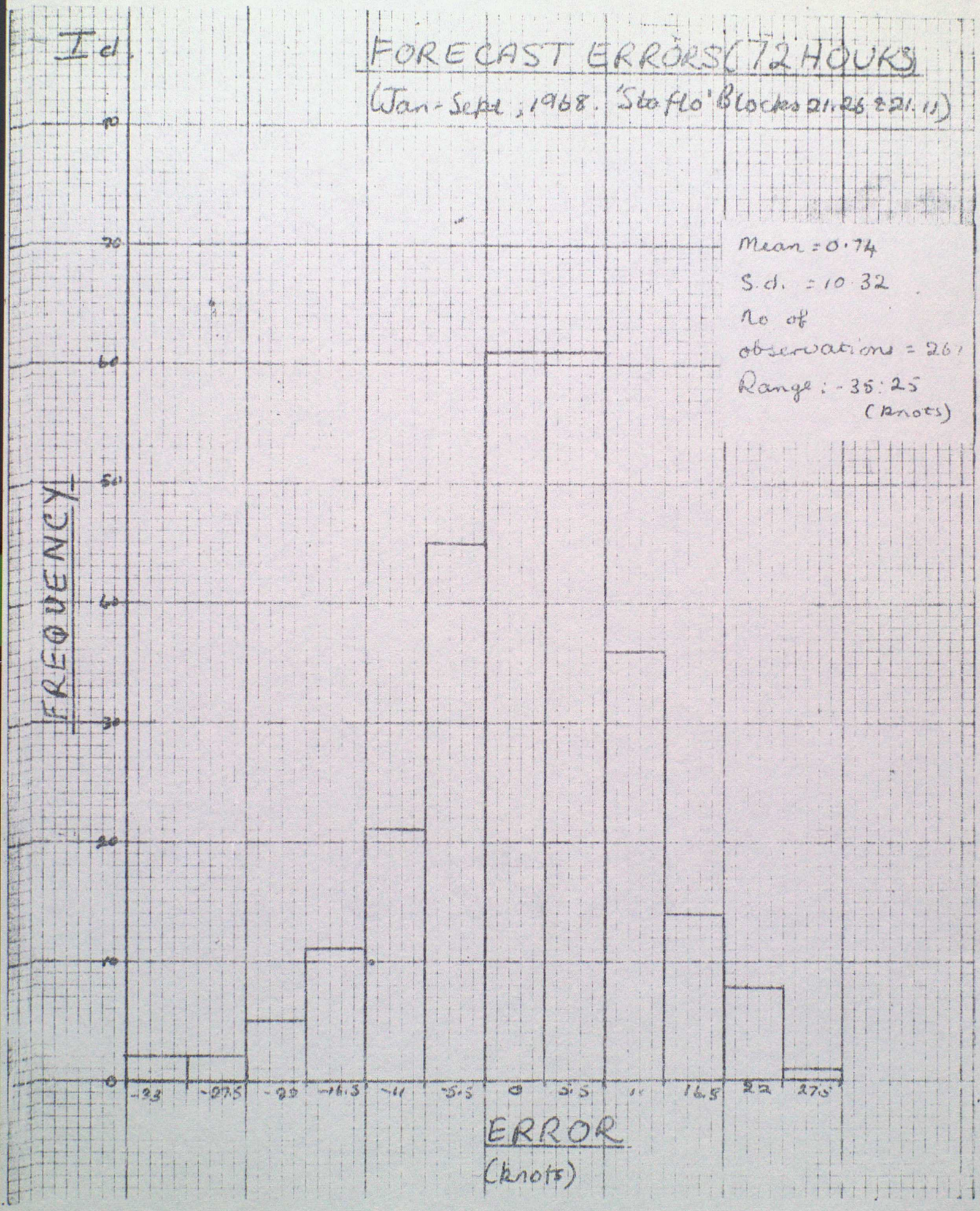



FORECAST ERRORS (24 HOURS)
(Jan - Sept. 1968. 'Stoflo' Blocks 21, 26 & 21.11)
E.R.
Mean = 1.25
S.d. = 8.87
No. of observations = 269
Range: -37.5 : 20.0 (knots)
FREQUENCY
0
10
20
30
40
50
60
70
80
-38.5
-33
-27.5
-22
-16.5
-11
-5.5
0
5.5
11
16.5
22
27.5
ERROR (knots)


FORECAST ERRORS (48 HOURS)
(Jan - Sept, 1968 Stafio', Blocks 21.26 & 21.11)
Mean = 1.09
S.d = 9.54
No. of observations = 268
Range: -37.5 : 25 (knots)
FREQUENCY
80
70
60
50
40
30
20
10
0
-38.5
-33
-27.5
-22
-16.5
-11
-5.5
0
5.5
11
16.5
22
27.5
ERROR
(knots)

FORECAST ERRORS (72 HOURS)

(Jan - Sept ; 1968. 'Stoflo' Blocks 21.26 & 21.11)



Mean = 0.74

S.d. = 10.32

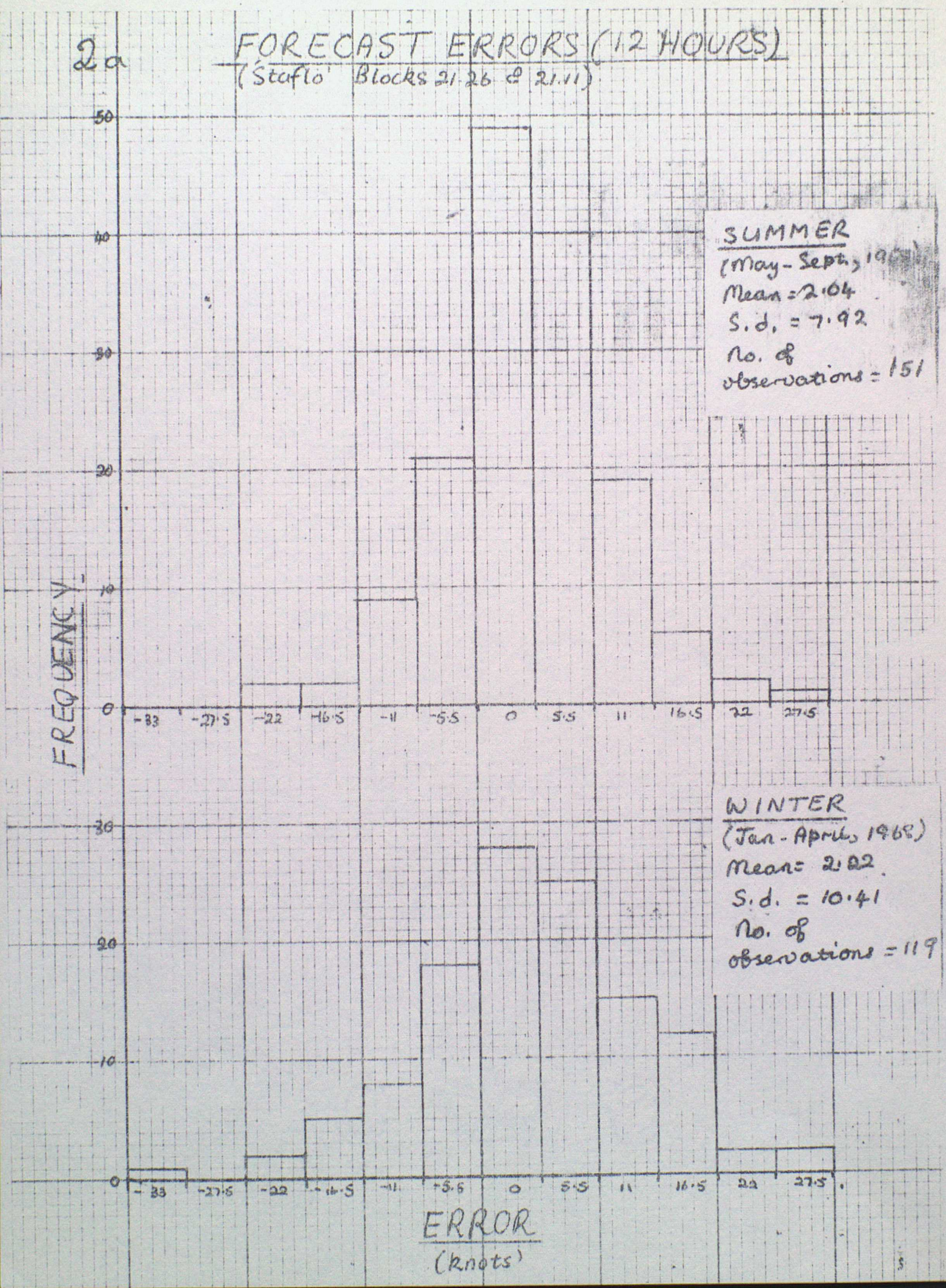
No of observations = 261

Range : -35 : 25 (knots)

2a

FORECAST ERRORS (12 HOURS)

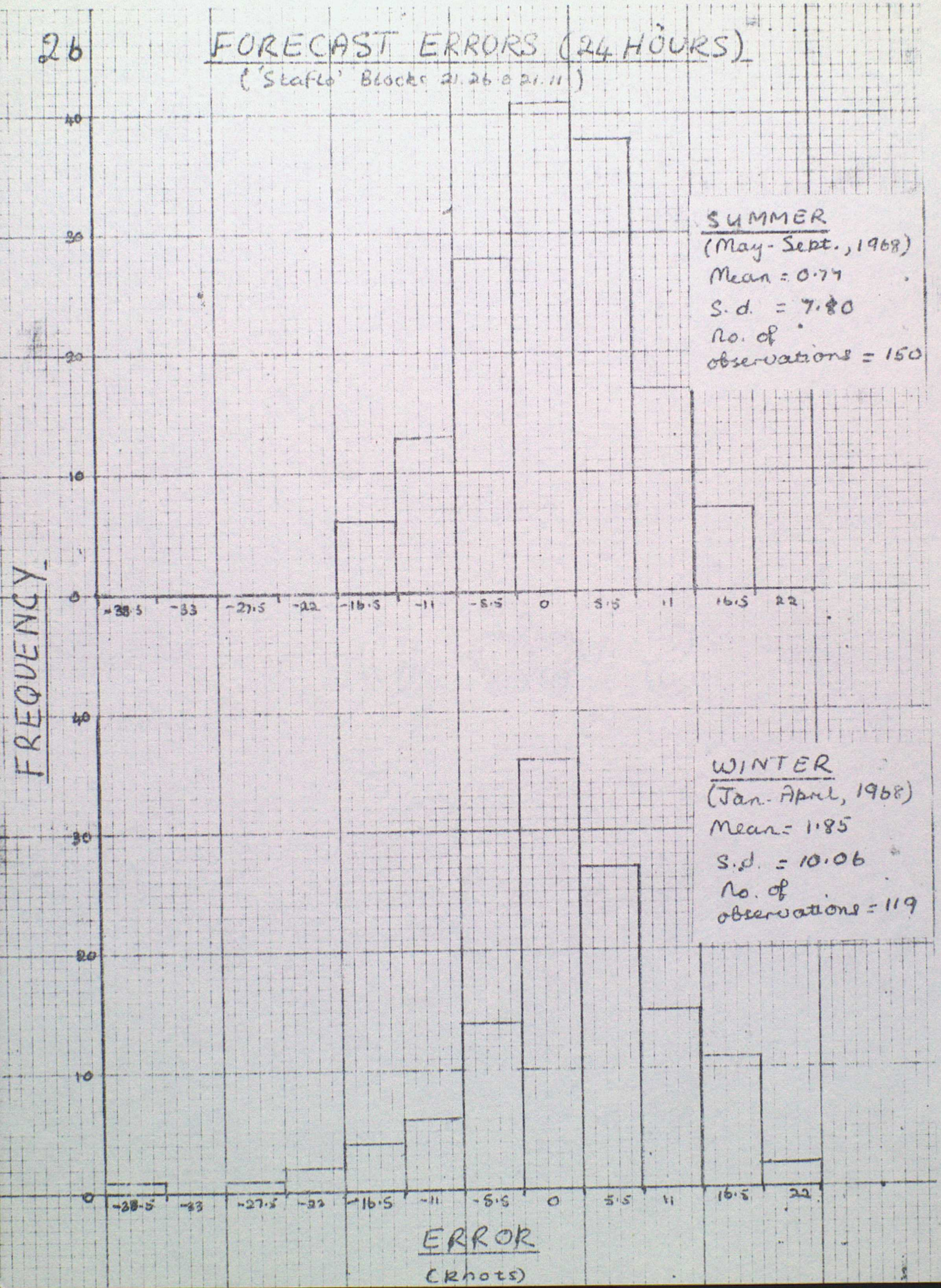
('Staflo' Blocks 21.26 & 21.11)



26

FORECAST ERRORS (24 HOURS)

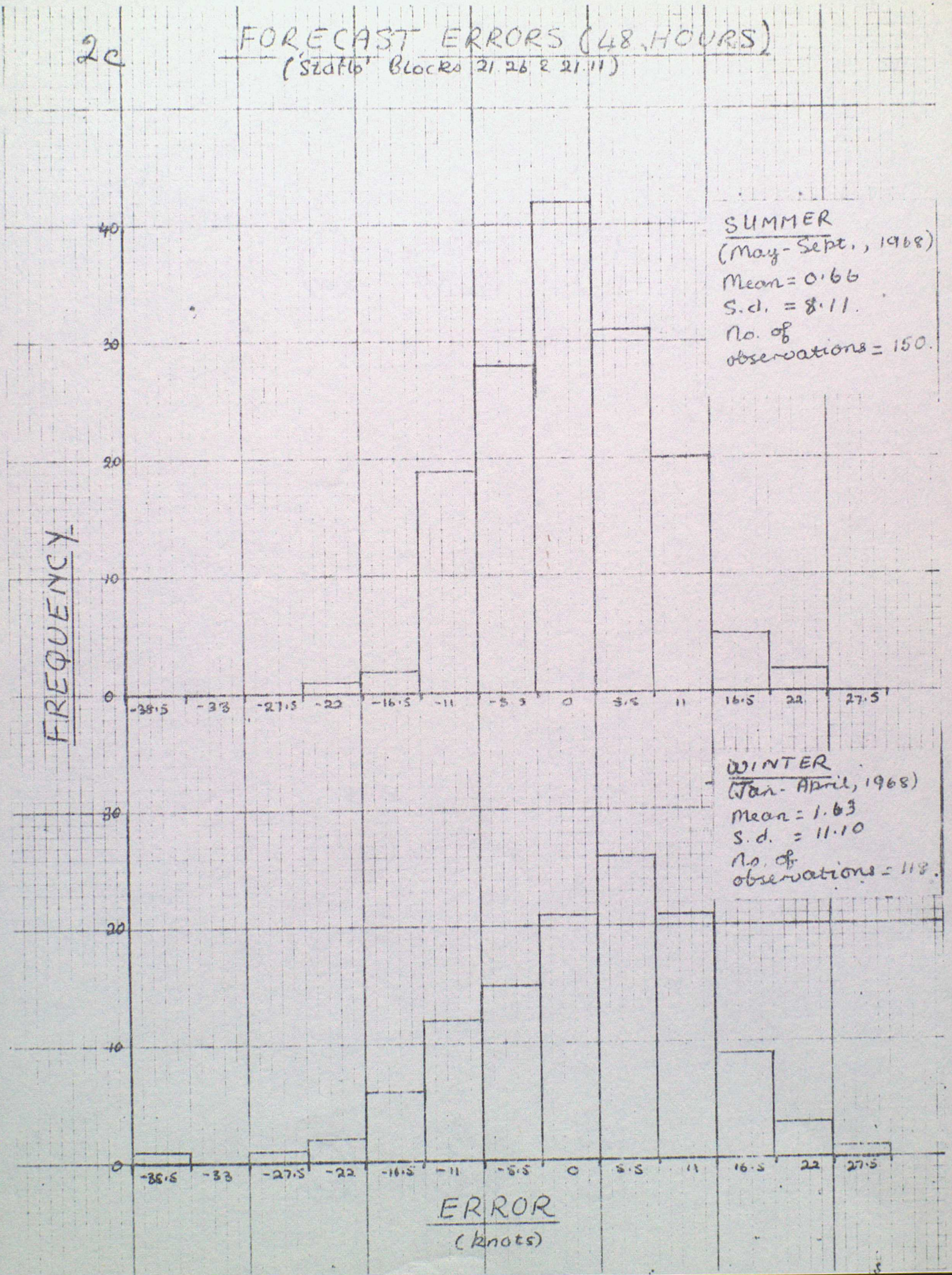
('Stafio' Blocks 21.26 & 21.11)



2c

FORECAST ERRORS (48 HOURS)

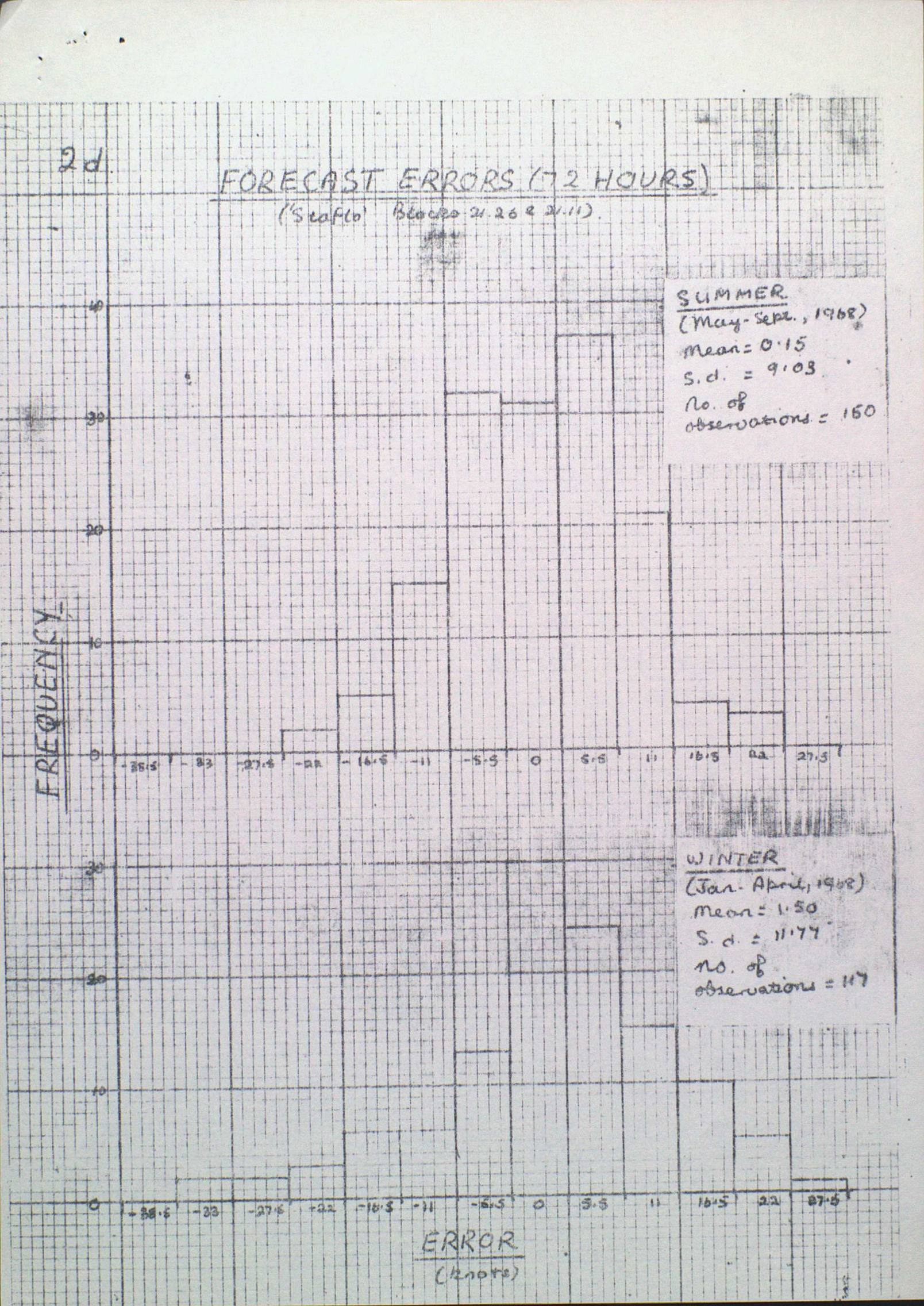
('Stafio' Blocks 21.26 & 21.11)



2d.

FORECAST ERRORS (+12 HOURS)

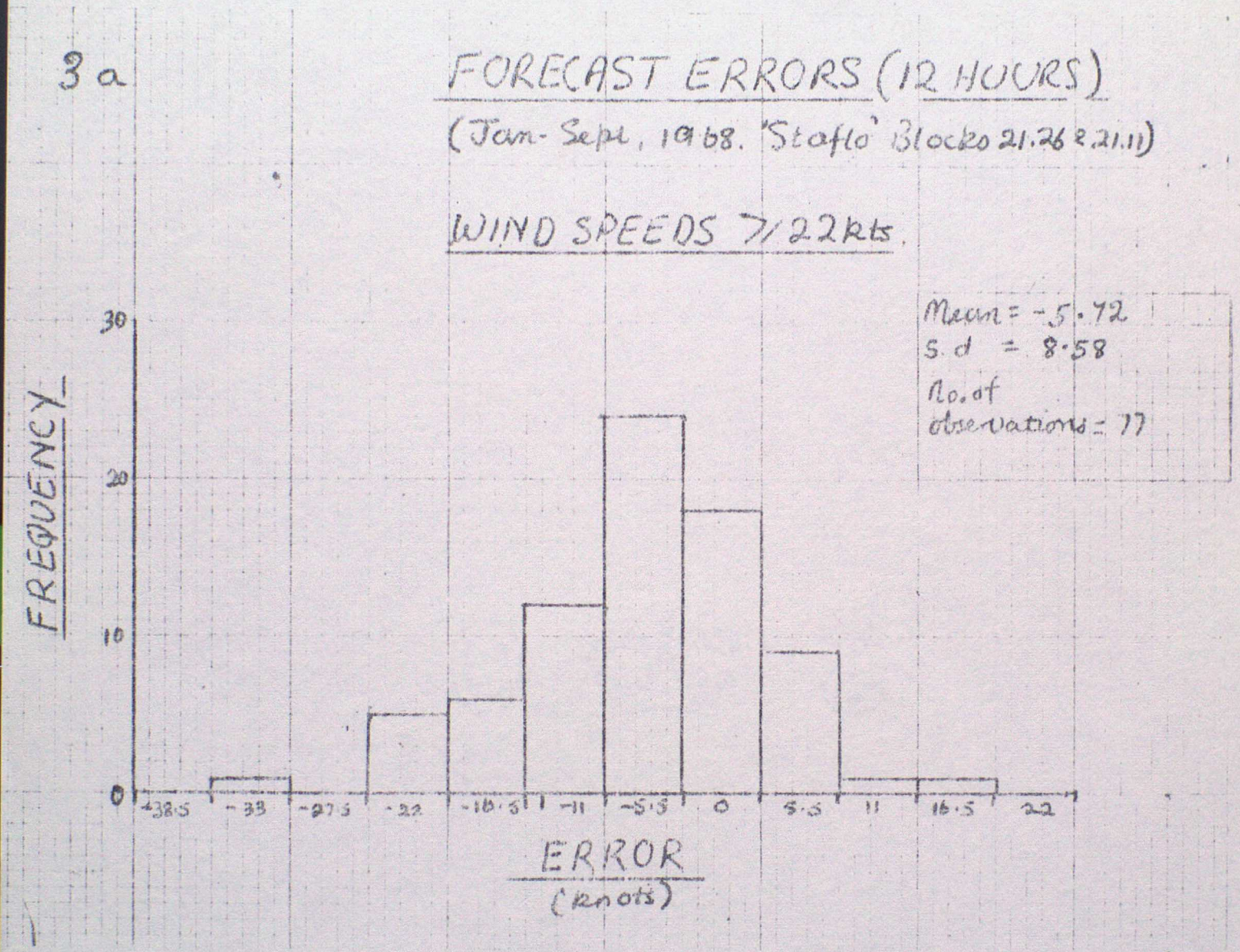
('Scaflo' Blocks 21.26 & 21.11).



FORECAST ERRORS (12 HOURS)

(Jan-Sept. 1968. 'Staflo' Blocks 21.26 & 21.11)

WIND SPEEDS 7/22 kts.

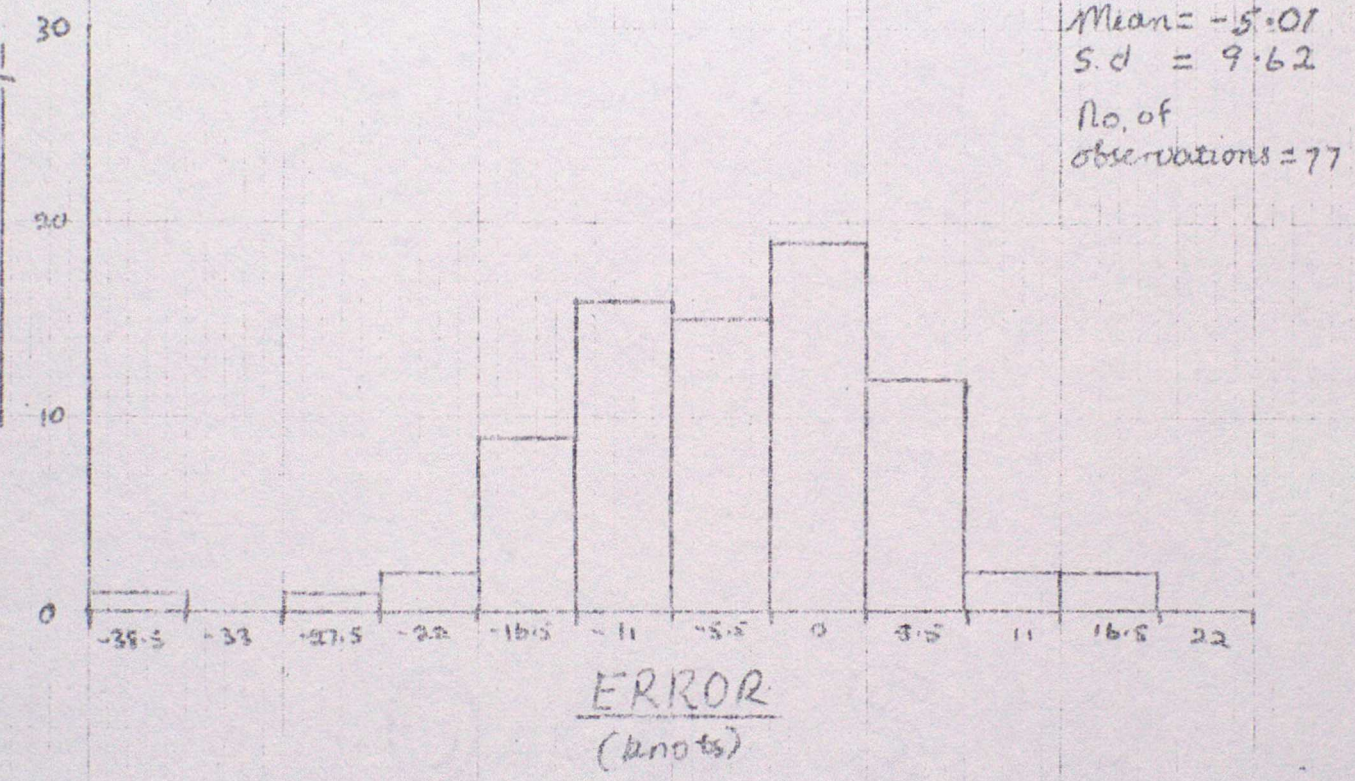


36

FORECAST ERRORS (24 HOURS)

(Jan - Sept. 1968 'Stafio' Blocks 21.26-21.11)

WIND SPEEDS ≥ 22 kts

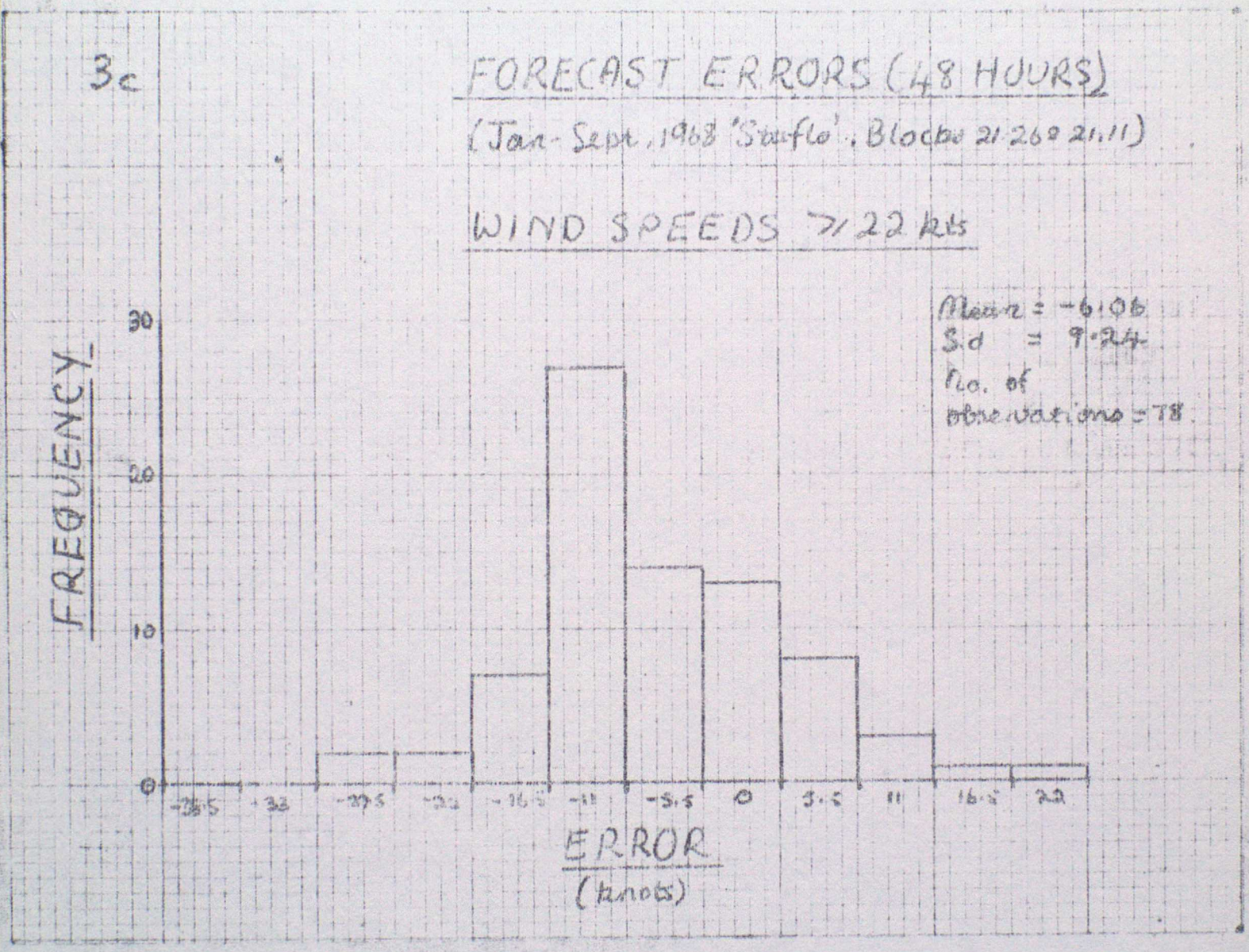


3c

FORECAST ERRORS (48 HOURS)

(Jan-Sept. 1968 'Starflo', Blocks 21.26 & 21.11)

WIND SPEEDS ≥ 22 kts



3d

FORECAST ERRORS (72 HOURS)

(Jan-Sept, 1968. 'Staflo' Blocks 21.26 & 21.11)

WIND SPEEDS ≥ 22 kts.