DEPARTMENT OF INDUSTRY AND COMMERCE
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AN ANALYSIS OF WIND COMPONENTS AT THE 700 AND 500 MB. LEVELS ALONG THE GREAT CIRCLE TRACK BETWEEN SHANNON AIRPORT, IRELAND AND GANDER AIRPORT, NEWFOUNDLAND

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INTRODUCTION

Wind components along the Great Circle track between Shannon and Gander have been computed at the 700 mb. and 500 mb. levels twice daily at Shannon Airport since May, 1947.

The times of the Upper Air charts from which the components were computed were 0400 and 1600 GMT daily in 1947 and 1948 and 0300 and 1500 GMT daily in subsequent years.

Due to a fire at the airport, the 500 mb. values for January, 1948 were lost.

This paper is a statistical summary of the basic material up to the end of 1953.

DEFINITION AND METHOD OF MEASUREMENT OF COMPONENTS

Throughout this analysis the term "wind component" is to be understood as being the mean value of the wind velocity in knots resolved along the Great Circle track at a fixed time, westerly winds being regarded as positive and easterly winds as negative.

Each component is calculated using a transparent template whose centre line is shaped to the track, and whose width represents 300 nautical miles on the chart. The average pressure gradient along the track is obtained by summing differences in the contour values across the top and bottom edges of the template at eight equidistant points. The component is computed by applying a conversion factor to this result.

Although there are cases where the component value so obtained differs appreciably from the true value (due to the width of the template and neglect of ageostrophic factors), and also may differ sensibly from the "effective wind component" experienced by an aircraft, this method has the advantage of being quick and objective, and, like the zonal circulation index, of being a simple measure of the wind flow. A routine check on the performance of westbound flights from Shannon has proved the utility of this measure as a close first approximation to the in-flight components.

ANALYSIS OF ACTUAL VALUES.

The mean and standard deviation of the wind component for every month at both levels and the long period values (using all the data for the same month in each year) are given in Tables I to IV.

TABLE I

Mean Wind Components in Knots at the 700 mb. Level

Month:	1947	1948	1949	1950	1951	1952	1953	All
January ..	—	24.7	32.5	26.4	35.1	35.8	23.8	29.7
February ..	—	21.1	30.5	22.8	27.4	12.0	22.4	22.7
March	—	22.4	20.9	13.3	9.9	1.1	18.7	14.4
April	—	23.7	22.5	21.2	14.5	18.8	9.4	18.4
May	13.6	11.2	19.3	4.7	8.8	3.0	6.7	9.6
June	11.7	17.2	13.0	16.5	4.4	17.9	21.9	14.6
July	20.4	16.2	15.5	16.7	21.1	17.3	22.7	18.6
August ..	18.3	16.9	21.0	22.8	25.2	17.2	23.4	20.7
September ..	25.9	23.2	13.8	30.8	17.6	14.1	20.9	20.9
October ..	19.3	21.8	20.3	29.1	22.5	18.6	27.3	22.7
November ..	10.7	12.5	33.4	19.1	25.5	12.1	30.1	20.5
December ..	15.6	16.9	33.3	22.5	33.2	16.9	26.6	23.3

TABLE II

Standard Deviation of Wind Components at the 700 mb. Level.

Month:	1947	1948	1949	1950	1951	1952	1953	All
January ..	—	15.2	10.7	8.1	10.8	11.1	10.4	12.2
February ..	—	18.8	13.5	11.2	12.2	12.4	14.1	15.1
March	—	16.2	16.0	16.9	14.3	14.6	8.3	16.4
April	—	12.2	14.8	14.2	6.9	11.1	9.4	13.1
May	12.8	9.1	7.9	11.3	10.2	9.3	13.3	11.9
June	12.2	11.0	10.1	10.2	10.3	7.9	6.9	11.2
July	9.8	7.6	10.7	5.5	7.3	6.2	7.0	8.3
August ..	7.0	6.1	7.5	7.5	8.8	8.6	6.6	8.1
September ..	6.4	5.1	13.3	11.4	11.6	9.4	11.0	11.8
October ..	9.7	12.6	14.5	9.5	12.2	12.9	11.1	12.5
November ..	11.1	14.2	8.1	20.0	14.4	15.3	11.1	16.3
December ..	9.9	13.7	13.7	9.0	9.4	18.6	9.9	14.8

TABLE III

Mean Wind Components in knots at the 500 mb. Level

Month:	1947	1948	1949	1950	1951	1952	1953	All
January ..	—	—	44.5	37.6	50.7	50.2	32.4	43.1
February ..	—	31.9	44.0	33.5	39.7	18.3	29.7	32.8
March	—	34.2	28.1	18.7	18.1	6.4	25.6	21.9
April	—	34.8	34.1	30.4	23.3	24.2	15.8	27.1
May	18.7	16.9	28.9	9.4	12.9	6.6	12.5	15.1
June	18.2	24.8	21.3	22.7	8.4	25.0	29.6	21.4
July	26.8	21.2	23.4	25.1	29.9	22.1	30.1	25.5
August ..	25.3	25.9	30.4	30.9	33.1	24.6	35.0	29.3
September ..	37.0	33.6	19.6	44.0	26.5	20.6	26.8	29.7
October ..	27.3	32.4	28.7	41.4	33.7	25.8	37.6	32.4
November ..	21.8	20.1	47.1	30.6	37.5	17.5	43.0	31.1
December ..	21.2	23.0	47.6	30.8	47.6	23.7	38.5	33.2

TABLE IV

Standard Deviation of Wind Components at the 500 mb. Level.

Month	1947	1948	1949	1950	1951	1952	1953	All
January ..	—	—	14.3	11.6	15.4	15.9	13.8	15.9
February ..	—	26.6	20.0	17.3	18.0	16.0	20.5	21.4
March	—	21.5	20.8	22.0	20.6	19.3	10.7	21.5
April	—	14.3	15.9	24.4	9.8	17.5	13.0	17.8
May	16.0	12.1	9.6	13.7	14.4	11.5	15.8	15.1
June	16.0	14.5	14.9	13.3	12.2	10.6	9.0	14.6
July	11.4	9.7	13.8	6.9	9.4	7.6	10.1	10.6
August ..	7.6	8.9	9.2	8.9	11.0	11.6	7.5	10.1
September ..	10.6	9.6	16.9	8.2	11.8	12.3	13.8	14.7
October ..	13.0	15.3	16.6	14.9	14.1	16.0	13.8	15.6
November ..	11.7	17.8	12.3	27.6	19.1	18.5	19.1	21.6
December ..	16.7	19.4	21.0	12.6	11.6	24.4	13.0	20.5

The distribution of component values is shown in histogram form for each month of the year for the 700 mb. level in FIGS. I and II and for the 500 mb. level in FIGS. III and IV. These diagrams are arranged to facilitate comparison of months in the winter and summer regimes, the end months being repeated in each diagram. The appearance of the histograms suggests that the distribution is compound for most months, and this is supported by by an examination using probability paper. A close examination of the frequency tables from which FIGS. I to IV were prepared suggests that the main features are not due to any marked abnormality in an individual year, and that these diagrams may be considered as a fair representation of the usual distribution for each month.

In particular the bimodal distribution for February, which reflects the occurrence of a pronounced low component regime at that time of year, is of interest. The occurrence of this "index cycle" in February has been described by Namias (1950) using data for a different period (1944-1948), and is supported by results based on a study by Willett (1947) in respect of the years 1932 to 1939. A list of cases of blocking action for 1933-1940 and 1945-1950 given by Rex (1950) shows that blocking action occurs in the North Atlantic almost every year in February and supports the view that the bimodal structure of the histograms for February is not anomalous. The histograms for January and March are also clearly affected due to variation in the date of commencement of the index cycle centred around February.

Sanders (1953) has shown that in the period 1899-1938 more blocking highs were located over the eastern North Atlantic and Western Europe in the month of May than in any other month, and the appearance of the histograms for May suggests another strongly bimodal distribution.

The appearance of the November histograms suggests the occurrence of a low component regime in this month and an examination of the original data shows that this has occurred in five of the seven years under review.

The quarterly and annual distributions are, however, very close to the normal, and this result agrees with that found by Gregg and van Zandt (1924) for another east-west air route (New York - Chicago), at a lower altitude.

An analysis of the cumulative frequency curves for both 700 mb. and 500 mb. is presented in FIGS V and VI, where the component values correspond-ing to selected percentiles may be readily determined. Values within the ranges 1% to 25% and 75% to 99% may be obtained by linear interpolation on arithmetical probability paper.

RELATIONSHIP BETWEEN 700 MB. AND 500 MB. COMPONENTS

The coefficient of correlation between the components has been computed for every month and also for each month using all the data, and for the total period. General linear regression equations have also been derived for each month and for the total period, showing both the 700 mb. and the 500 mb. component as the independent variable. These values for each month of the year are given in Table V.

TABLE V

Correlation Coefficient and Linear Regression Equations between 700 mb. and 500 mb. components for each month of the year.

Month	Correlation Coefficient	Regression Equations: x = 700 mb. Compt. — y in terms of x.	Regression Equations: y = 500 mb. Compt. — x in terms of y.
January	.904	1.28x + 4.2	0.64y + 3.2
February	.939	1.34x + 2.5	0.66y - 0.3
March	.955	1.25x + 3.9	0.73y - 1.5
April	.936	1.26x + 3.9	0.69y - 0.2
May	.948	1.20x + 3.6	0.75y - 1.7
June	.948	1.23x + 3.4	0.73y - 1.0
July	.906	1.15x + 4.2	0.71y + 0.4
August	.856	1.06x + 7.3	0.69y - 0.5
September	.928	1.16x + 5.5	0.74y - 1.1
October	.933	1.17x + 5.9	0.74y - 0.4
November	.951	1.26x + 5.3	0.72y - 1.9
December	.946	1.31x + 2.8	0.69y - 0.5
All data:	.946	1.26x + 3.7	0.71y - 0.6

For an individual month the departure of the correlation coefficient from the value for all months of the same name is not, in general, more than may be expected from such comparatively small samples. The most striking departure occurs in August, 1953, where the correlation coefficient is 0.56. This is due to a number of lows which moved slowly close to the track, giving, on some occasions, simultaneously rather low values at the 700 mb. level and high values at the 500 mb. level. This substantially affected the correlation coefficient and the regression equations for August as a whole, and is noticeable even in the results for the entire period.

ANALYSIS OF 12 AND 24 HOUR CHANGES AT THE 700 MB. LEVEL

As it has been felt that the presentation of the standard deviation alone as a measure of monthly variation may be misleading for certain comparison purposes, owing to the coherence or persistence of component values, the 12 hour and 24 hour changes at the 700 mb. level were analysed. An analysis of the cumulative frequency distribution of these changes is given in FIGS. VII and VIII. One interesting feature shown by these diagrams is, that, in general, more extreme changes occur with decreasing rather than increasing westerlies. The root mean squares for each month of the period are given in Tables VI and VII.

TABLE VI.

Root Mean Square Twelve-hour Change of the 700 mb. Component.

Month	1947	1948	1949	1950	1951	1952	1953	All
January	--	6.8	7.1	6.0	7.2	6.4	6.6	6.69
February	--	8.7	7.4	4.9	7.1	5.9	6.7	6.89
March	--	7.9	6.1	6.9	5.0	6.0	6.4	6.44
April	--	5.4	6.6	6.2	5.4	5.7	5.9	5.88
May	5.9	5.1	5.7	4.6	5.5	5.4	6.9	5.61
June	7.4	5.2	5.5	4.7	3.9	4.4	4.9	5.20
July	5.2	5.0	4.1	4.3	4.2	4.1	4.3	4.50
August	5.4	4.6	4.4	4.0	5.2	4.7	6.7	5.05
September	4.5	4.2	5.5	4.9	5.6	4.3	5.2	4.91
October	7.0	5.3	5.4	6.6	6.0	6.7	6.0	6.04
November	6.7	7.6	5.6	7.3	7.4	6.0	6.5	6.79
December	8.4	7.9	6.0	5.1	8.5	7.1	5.9	7.10
Annual value based on last column								5.98

TABLE VII

Root Mean Square Twentyfour-hour Change of the 700 mb. Component.

Month	1947	1948	1949	1950	1951	1952	1953	All
January	—	8.6	9.6	9.2	11.0	9.1	10.1	9.63
February	—	11.6	10.3	7.2	10.2	8.5	10.8	9.90
March	—	12.0	8.9	10.9	9.0	8.3	8.4	9.70
April	—	6.8	9.2	9.5	8.2	8.7	9.0	8.60
May	7.9	7.1	7.5	7.0	8.5	8.5	9.6	8.05
June	10.3	8.1	6.6	7.6	5.2	6.6	6.2	7.38
July	7.0	7.2	5.4	5.7	5.7	5.8	5.4	6.09
August	7.1	5.9	7.3	5.7	7.9	6.3	8.0	6.93
September	6.0	5.6	7.8	6.7	8.3	5.5	6.5	6.69
October	8.3	8.7	8.4	9.8	9.6	9.8	8.4	9.01
November	9.2	11.0	8.1	12.1	11.6	9.6	10.5	10.36
December	9.5	11.4	9.8	7.4	10.1	13.9	8.9	10.31
Annual value based on last column								8.67

The use of a statistic derived from successive differences as a measure of dispersion in cases where a shift may occur in the mean (due to long term trend) but where there is no shift in the short term mean has been suggested by 'Student' (1927) and Pearson (1935). More recently von Neumann, Kent, Bellinson and Hart (1941) reconsidered the problem, and suggested that the mean square successive difference be used as a measure of variation which minimises the effect of trend. This is particularly applicable to the present problem, not only as a 'good' estimator of variability (and as such a measure of difficulty in forecasting), but also as a parameter to be used in an examination of the data considered as a time series.

ACKNOWLEDGEMENTS:

We wish to express our thanks to the various members of the staff of the Meteorological Office, Shannon Airport, and particularly to Mr. F. Ó hAonghusa, for assistance in the computational work.

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HISTOGRAMS OF 700 MB WIND COMPONENT ON G.C. SHANNON TO GANDER

BASED ON DATA FOR MAY 1947 TO DEC. 1953 INCLUSIVE. FREQUENCIES EXPRESSED AS PERCENTAGES. THE INTERVAL OF WIND COMPONENT IS 3 KNOTS. THE MEAN VALUE FOR EACH MONTH IS MARKED BY A VERTICAL LINE. EACH 5 PERCENT IS INDICATED BY A SHORT DASHED LINE.

OCTOBER — APRIL

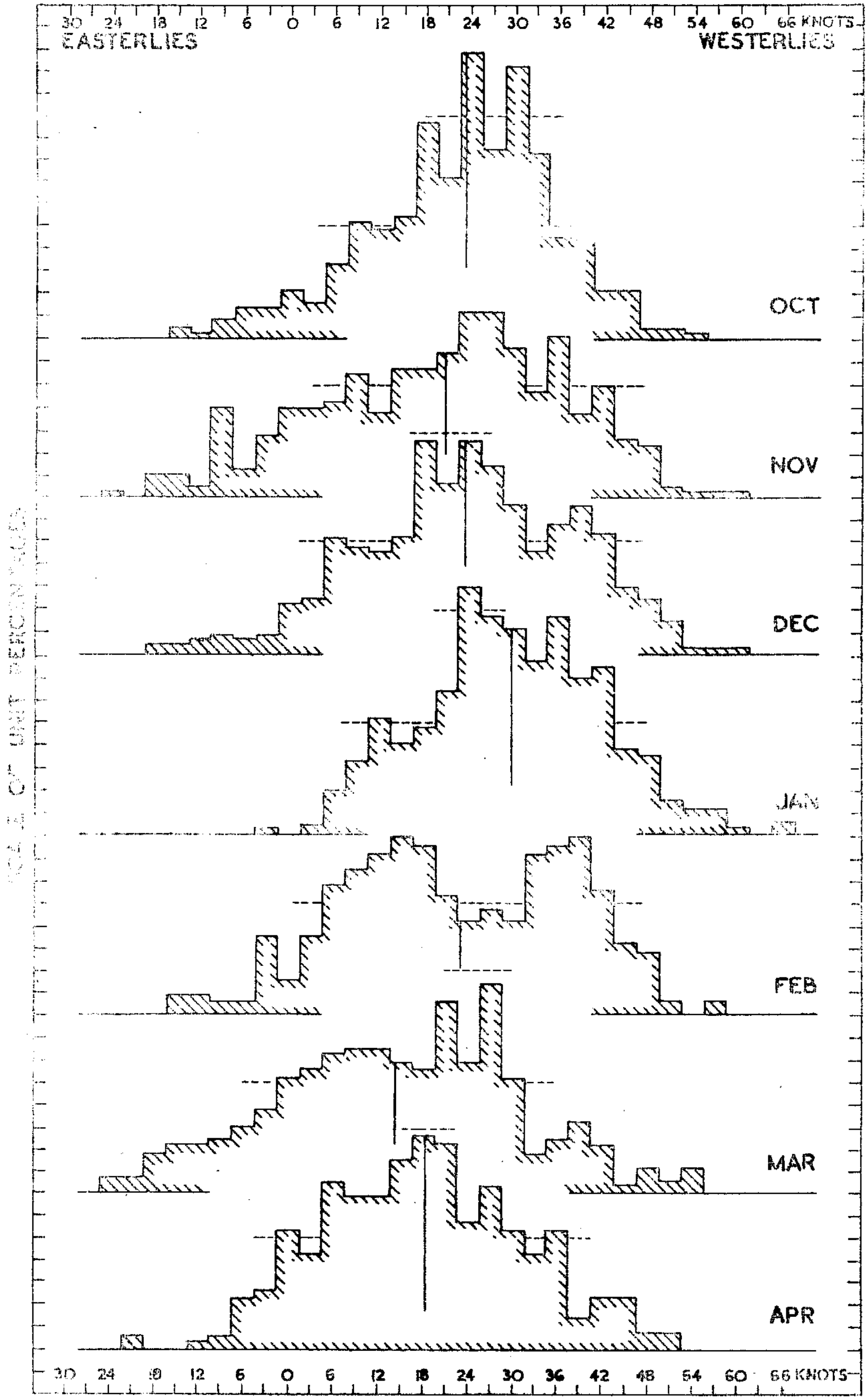

FIG. I.

HISTOGRAMS OF 700 MB WIND COMPONENT ON G.C. SHANNON TO GANDER

BASED ON DATA FOR MAY 1947 TO DEC. 1953 INCLUSIVE. FREQUENCIES EXPRESSED AS PERCENTAGES. THE INTERVAL OF WIND COMPONENT IS 3 KNOTS. THE MEAN VALUE FOR EACH MONTH IS MARKED BY A VERTICAL LINE. EACH 5 PERCENT IS INDICATED BY A SHORT DASHED LINE.

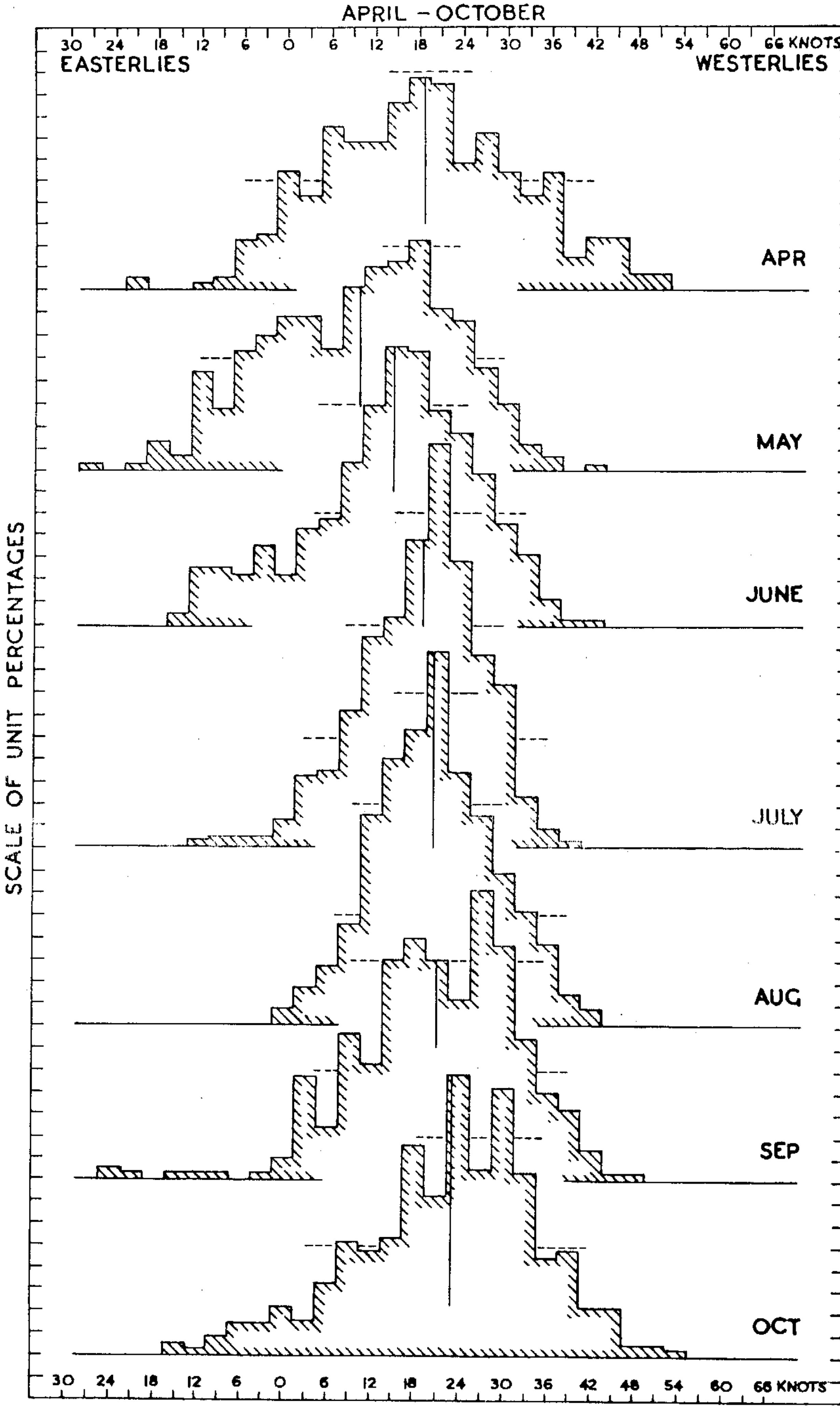

FIG. II.

HISTOGRAMS OF 500 MB WIND COMPONENT ON G.C. SHANNON TO GANDER

BASED ON DATA FOR MAY 1947 TO DEC. 1953 INCLUSIVE. FREQUENCIES EXPRESSED AS PERCENTAGES. THE INTERVAL OF WIND COMPONENT IS 4 KNOTS. THE MEAN VALUE FOR EACH MONTH IS MARKED BY A VERTICAL LINE. EACH 5 PERCENT IS INDICATED BY A SHORT DASHED LINE.

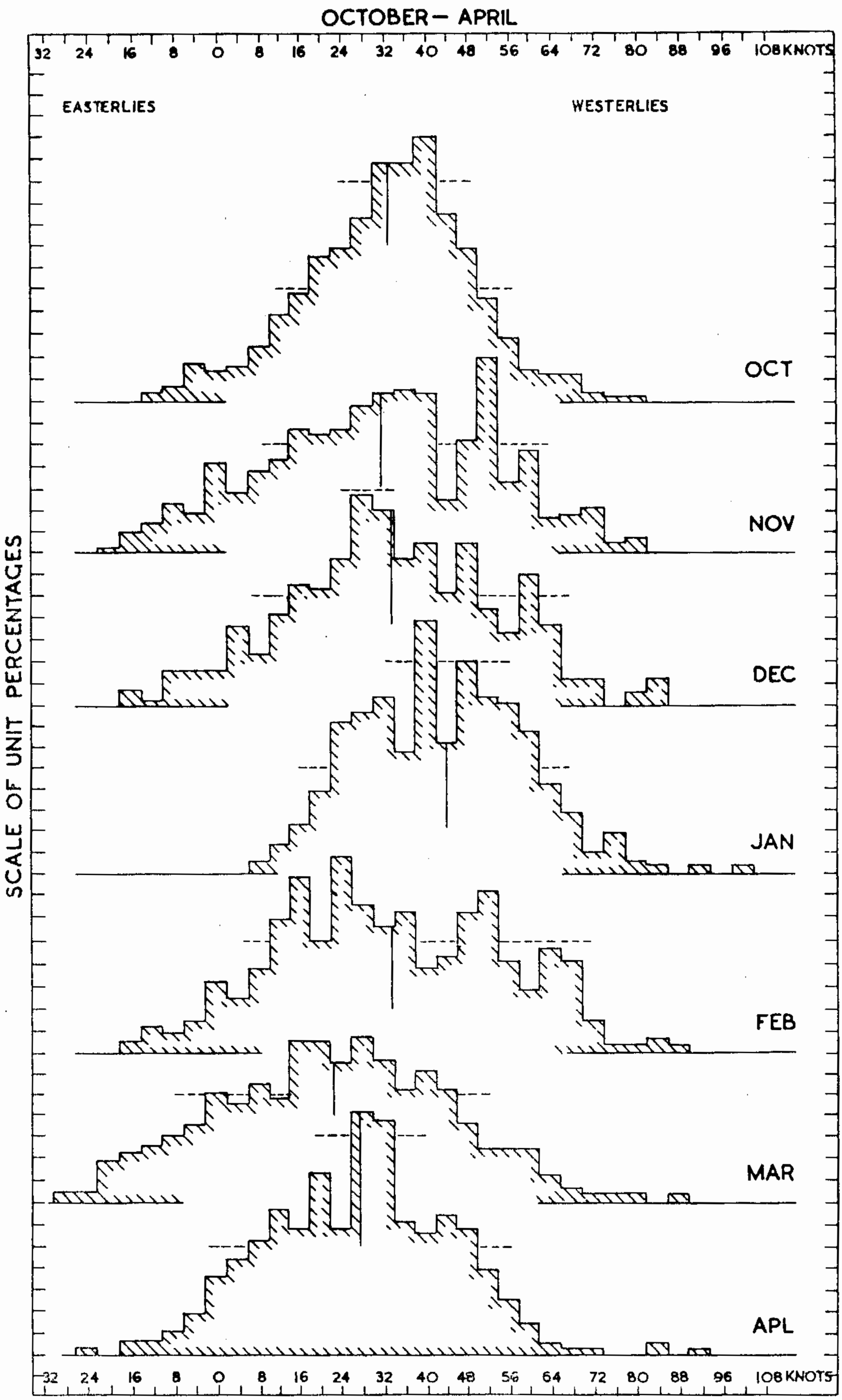

FIG. III.

HISTOGRAMS OF 500 MB WIND COMPONENT ON G.C. SHANNON TO GANDER

BASED ON DATA FOR MAY 1947 TO DEC. 1953 INCLUSIVE. FREQUENCIES EXPRESSED AS PERCENTAGES. THE INTERVAL OF WIND COMPONENT IS 4 KNOTS. THE MEAN VALUE FOR EACH MONTH IS MARKED BY A VERTICAL LINE. EACH 5 PERCENT IS INDICATED BY A SHORT DASHED LINE.

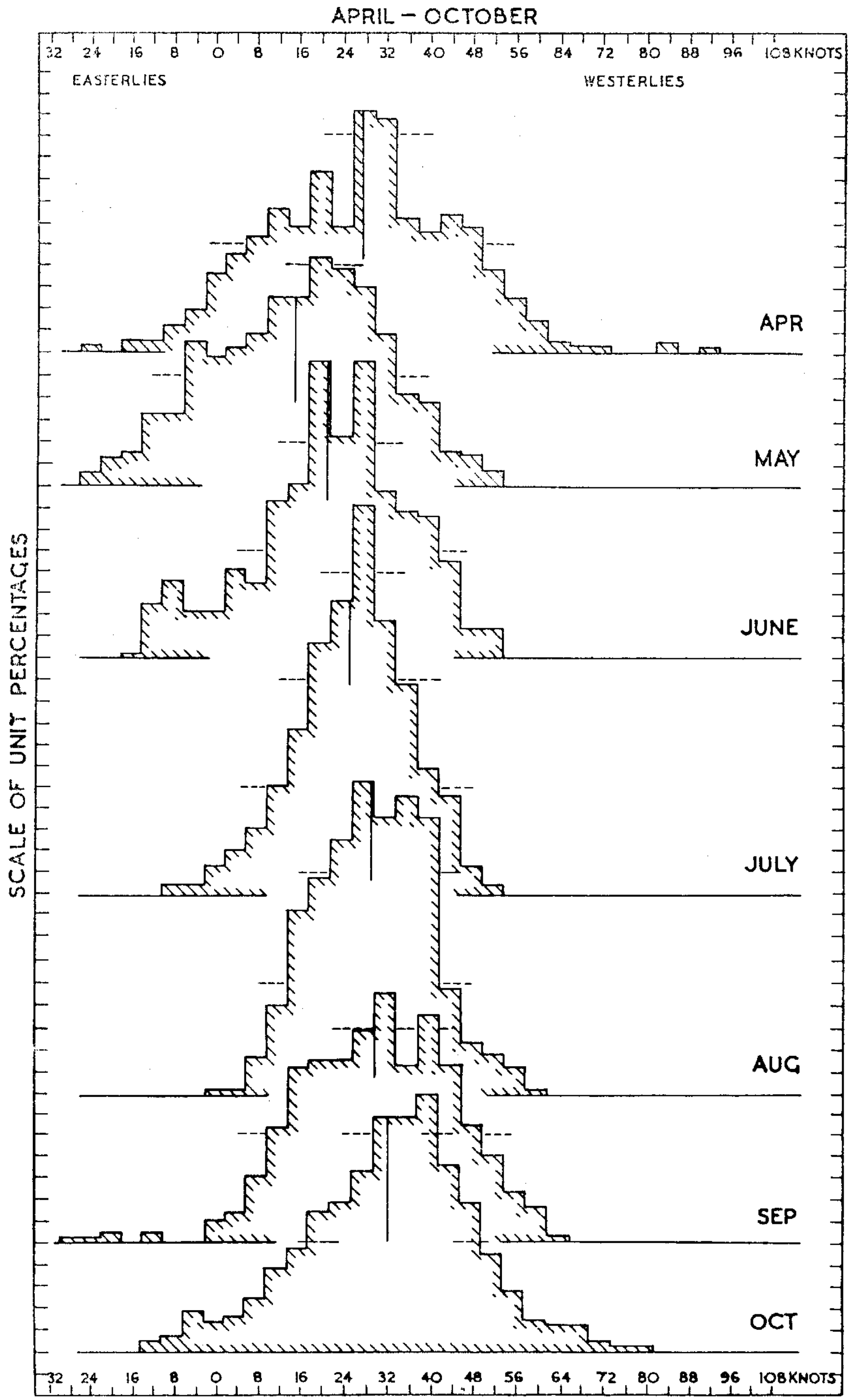

FIG. IV

DIAGRAM SHOWING PERCENTILES OF 700 MB WIND COMPONENT ON G.C. TRACK SHANNON – GANDER

BASED ON DATA FOR PERIOD MAY 1947 – DEC 1953 INCLUSIVE

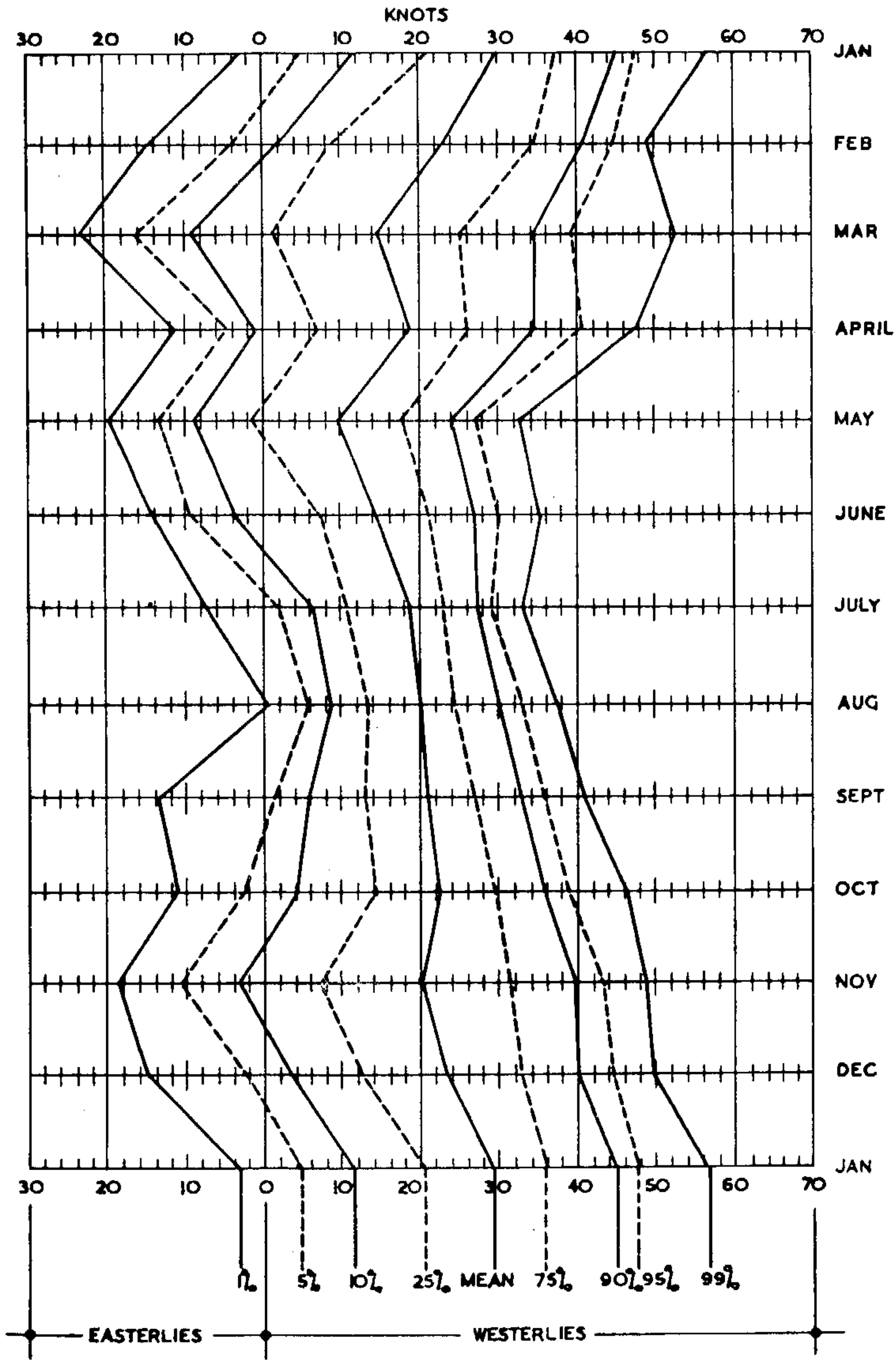

FIG. V

DIAGRAM SHOWING PERCENTILES OF 500 MB WIND COMPONENT ON G.C. TRACK SHANNON – GANDER

BASED ON DATA FOR PERIOD MAY – DEC 1947 AND FEB 1948 – DEC 1953 ALL MONTHS INCLUSIVE

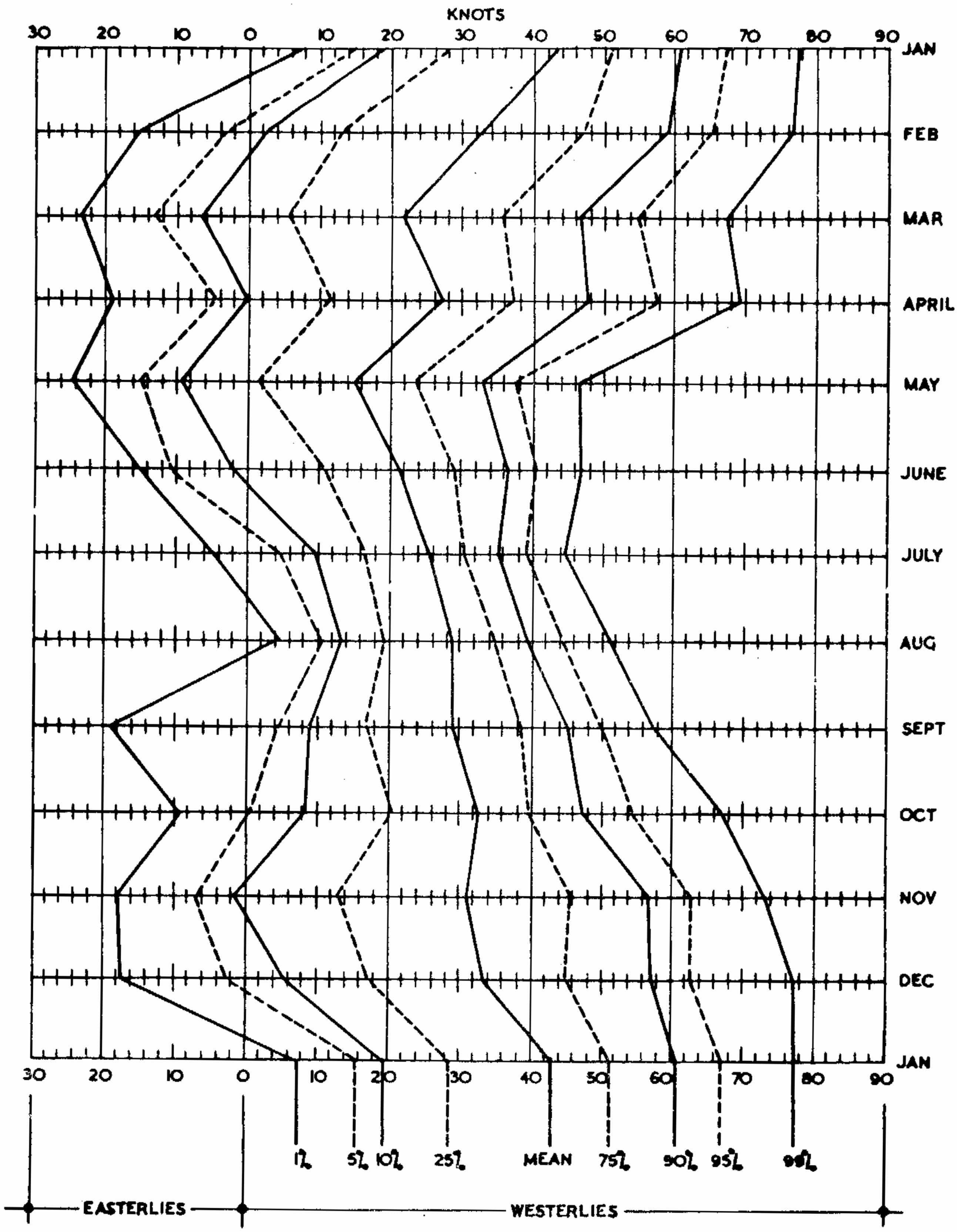

FIG. VI

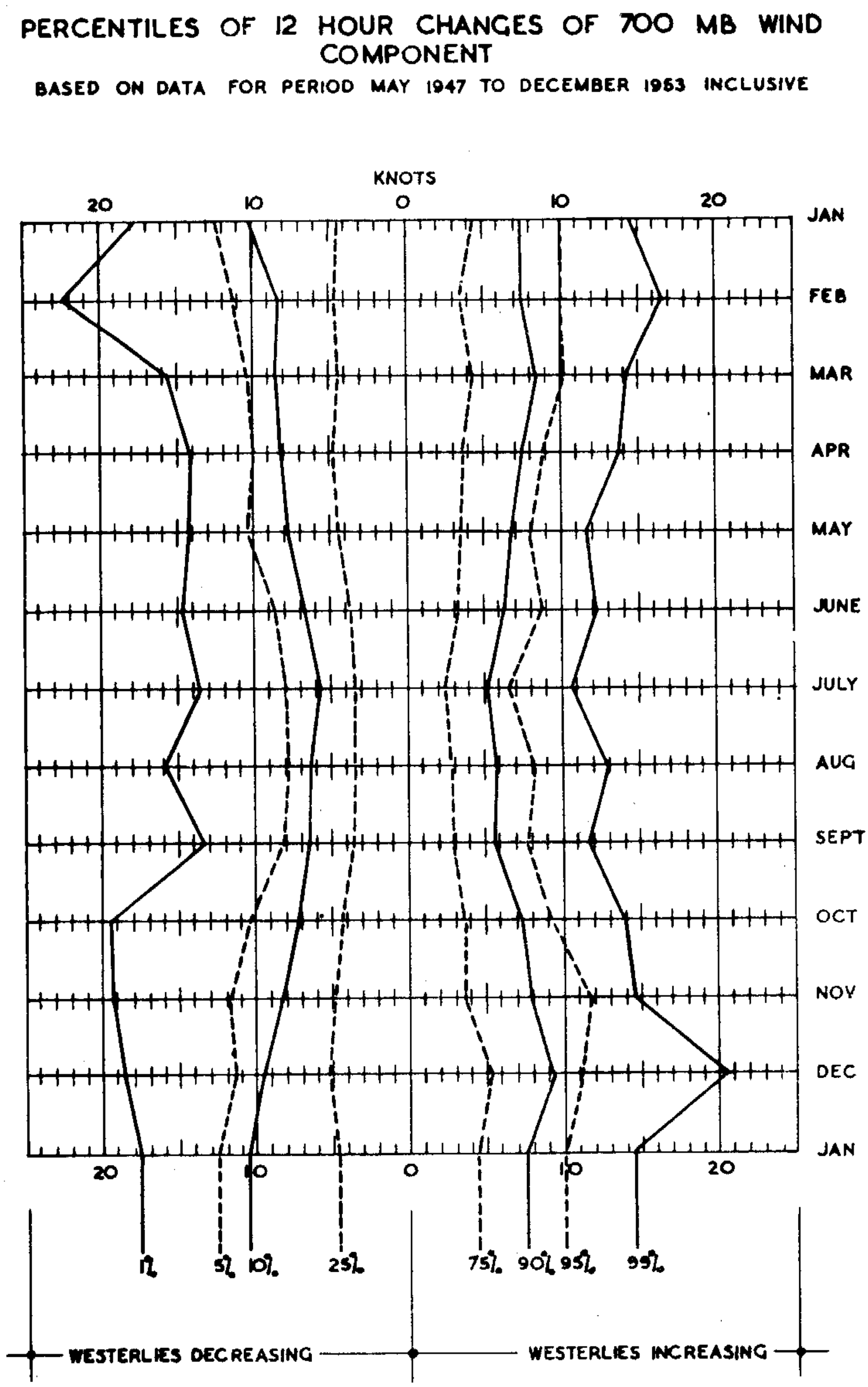
PERCENTILES OF 12 HOUR CHANGES OF 700 MB WIND COMPONENT
BASED ON DATA FOR PERIOD MAY 1947 TO DECEMBER 1953 INCLUSIVE
KNOTS
20
10
0
10
20
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
JAN
1%
5%
10%
25%
75%
90%
95%
99%
WESTERLIES DECREASING
WESTERLIES INCREASING

FIG. VII

PERCENTILES OF 24 HOUR CHANGES OF 700 MB WIND COMPONENT

BASED ON DATA FOR PERIOD MAY 1947 TO DECEMBER 1953 INCLUSIVE

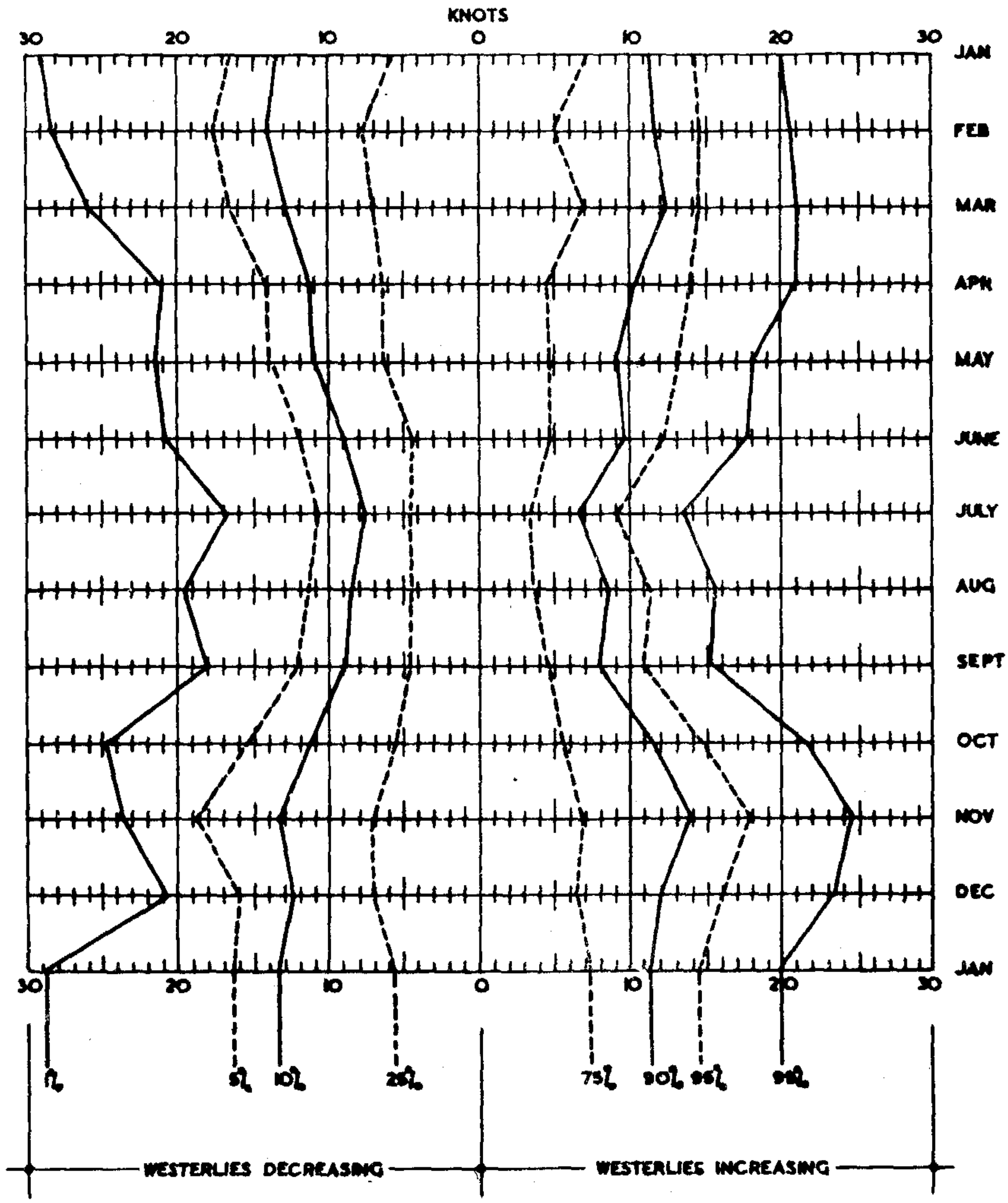

FIG. VIII