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AN ANALYSIS OF THE WIND COMPONENTS AT THE 300 MB LEVEL ALONG THE GREAT CIRCLE TRACK BETWEEN SHANNON AND GANDER

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Abstract:

The mean wind components at the 300 mb. level along the Great Circle track between Shannon and Gander at 0300 and 1500 GMT. each day over the period May, 1950 to April, 1956, inclusive, were obtained from charts for this level. The mean value and standard deviation of the wind components are given for all months and years. The frequency distributions of the components and of the twelve-hour component changes are given for all months of the year. Correlation between the components at the 300 and 500 mb. levels is found to be high and linear regression equations computed for the different months give the 300 mb. components from the 500 mb. components to a high degree of accuracy.

Introduction:

It is expected that commercial aircraft will be flying over the North Atlantic at altitudes above the present operating ceilings of piston-engined aircraft in the near future. In view of this, a statistical investigation of the wind components at the 300 mb. level along the Great Circle track between Shannon and Gander was undertaken, and in this paper a summary is presented of the basic results for the period May, 1950, to April, 1956, inclusive, during which 300 mb. actual charts (as well as prognostic charts) were prepared at the Meteorological Office, Shannon Airport, for 0300 and 1500 GMT. each day. An account of a similar investigation of the components at the 700 mb. and 500 mb. levels had been published by Gillman and Rohan (1954). In order that the data for all three levels may be compared directly with one another, the lay-out of the present paper has been kept in conformity with that of Gillman and Rohan.

Definition and Method of Measurement of Components:

Throughout this analysis the term "component" is to be understood as being the mean value in knots of the wind velocity resolved along the Great Circle track at a fixed time, westerly winds being regarded as positive and easterly winds as negative. These components have been measured from the 300 mb. data for 0300 and 1500 GMT. each day throughout the period under review.

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 sum.

The use of such a template is open to criticism on the grounds that it ignores ageostrophic factors, and, also, that due to its width it measures an average component over a distance of 150 nautical miles on either side of the Great Circle rather than that along the Great Circle itself. In addition, being a mean value for the whole track for a fixed time, the component may differ appreciably from that experienced by an aircraft. The ageostrophic errors, which would appear from a survey reported by Murray (1954) to be of the order of 10 knots, are compensated to some extent by the practice in analysis over the North Atlantic, where the network of actual upper air ascents is not dense, of laying stress on actual wind reports in the drawing of contours. For the rest, the disadvantages are balanced by the speed and objectivity of the method, which, like the zonal index, provides a simple measure of the wind flow. Though little data are as yet available which would provide confirmation of the accuracy of this method of estimation of the component at the 300 mb. level, a routine check on the performance of west-bound flights from Shannon at the 700 and 500 mb. levels has proved the utility of this measure as a close first approximation to the in-flight components.

It is to be observed, however, that when a jet-stream impinges on the track the component measured by means of the template may differ appreciably from the actual value. Owing to the lack of concrete information on the structure of actual jet-streams, and to the paucity of wind reports along and near the track, it is not possible to make a reliable quantitative estimate of the error likely to arise from this source. Application of the template method to the measurement of the component in one zone affected by a theoretical jet-stream constructed along lines suggested by Crocker (1952), shows that when the jet-stream core lies along the Great Circle or within 150 nautical miles to north of it, the template underestimates the actual component, while if it lies within 150 miles to south of the Great Circle, the template measurement is an overestimate. As the number of occasions on which a jet-stream core lay to the south of the track considered is small compared with the number of occasions on which it lay to the north, the net result is probably an underestimate in the highest components measured. Examination shows, however, that the maximum error likely to arise from this source would increase the over-all average component by only about one-fifth of a knot.

Analysis of Actual Values:

The mean and the standard deviation of the wind component for all months and years are given in Tables I and II.

Table I - Mean Wind Component in Knots at the 300 mb. Level

	1950	1951	1952	1953	1954	1955	1956	All Years
Jan.	-	63.4	66.3	41.0	45.3	21.4	34.0	45.2
Feb.	-	52.6	24.1	36.9	49.9	25.8	26.8	35.9
Mar.	-	27.9	10.8	31.2	32.9	15.5	34.1	25.4
Apr.	-	33.0	35.4	22.8	38.9	28.1	20.1	29.7
May	11.8	15.1	12.8	18.6	21.5	29.2	-	18.2
June	28.4	14.9	32.3	39.4	26.3	30.9	-	28.7
July	41.1	41.6	28.2	44.5	52.0	40.0	-	41.2
Aug.	42.8	46.5	35.5	55.0	43.6	40.6	-	44.0
Sept.	64.7	41.2	30.0	35.1	56.1	50.8	-	46.3
Oct.	53.8	47.3	40.0	50.6	50.4	33.8	-	46.0
Nov.	39.4	49.8	22.2	57.1	66.1	16.7	-	41.9
Dec.	40.4	63.7	33.0	52.3	57.5	39.9	-	47.8
Mean of all 4,384 components:- 37.5 knots								

Table II - Standard Deviation of Wind Components at the 300 mb. Level

	1950	1951	1952	1953	1954	1955	1956	All Years
Jan.	-	19.5	24.2	17.4	25.4	17.8	17.7	26.0
Feb.	-	24.0	25.6	24.6	22.5	28.0	26.8	28.0
Mar.	-	26.0	24.6	16.8	23.8	23.6	29.7	25.7
Apr.	-	15.8	23.3	19.0	30.6	23.3	16.4	23.0
May	20.3	18.0	14.8	18.4	13.8	17.9	-	18.3
June	21.1	18.6	17.8	12.2	14.1	24.9	-	20.0
July	12.1	14.0	12.3	19.3	13.1	10.3	-	15.5
Aug.	14.3	14.3	15.7	12.1	14.3	13.1	-	15.4
Sept.	12.9	16.6	22.1	23.8	15.8	13.5	-	21.7
Oct.	20.2	19.2	20.3	20.8	28.6	30.0	-	24.5
Nov.	38.2	28.9	22.7	24.2	23.6	16.8	-	31.7
Dec.	17.0	17.9	29.8	17.6	19.7	30.2	-	25.1
Standard Deviation of all 4,384 components:- 24.8 kts								

The distribution of component values is shown in histogram form in Figs. I and II, and that for the whole period in Fig. III. While this last shows a distribution very close to Gaussian to which reference will be made later, many of the histograms for the individual months suggest a compound distribution, and this is supported by an analysis using arithmetical probability paper. Investigation of the frequency tables from which the diagrams were prepared shows that some features were reproduced year after year, which leads to the conclusion that these features are not due to any marked abnormality in any individual year.

The most marked bi-modal distributions occur in February, April and June. This was also observed at the 700 and 500 mb. levels by Gillman and Rohan, who explain that for February as follows :- "..... the bi-modal 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 Willet (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 bi-modal structure of the histograms for February is not anomalous."

Gillman and Rohan also noticed an effect in the January histograms of the 700 and 500 mb. component frequencies produced by the onset of this blocking action towards the end of January. This effect does not appear in the 300 mb. component histogram, for the low component regime at 300 mb. did not set in before the beginning of February in any of the years 1951 to 1956. The slight bi-modal trend seen in the January diagram is to be attributed to a regime of very strong winds which occurred throughout a considerable portion of that month in the years 1951 and 1952, and the influence of this is also noticable in the shift towards higher components of the February minor mode, which is due to an extension beyond the end of January of this very strong regime.

While the 300 mb. distribution for May does not show as marked a bimodal appearance as those of the corresponding 700 and 500 mb. components, the persistence of blocking highs over the eastern North Atlantic and Western Europe during this month, pointed out by Sanders (1953), is reflected in the low average values of the component for May. The bimodal structure of the histograms for April and June, is to be attributed to the fact that the distribution for these months is affected by the date of commencement and cessation of this blocking action.

While the histogram for March shows one mode, an analysis of the data for this month on probability paper suggests there are two arising from two different distributions. Examination of the basic data shows a period of low components in each year, but only in 1952 does this follow directly on the February low component spell. It may be remarked that in 1952 the component exceeded 30 knots on only nine days between February 7 and April 3, and that the mean component for March 1952 was the lowest for any month during the period dealt with in this investigation.

The histogram showing the least tendency towards regularity is that for November. Examination of the data on which the diagram was based shows that while there was, in each month of November, a period of low components, as is illustrated by the appearance of a mode well towards the "negative" end of the scale, the frequency of individual positive components of from 25 to 80 knots is remarkably uniform, and the frequency of components greater than 90 knots was higher than in any other month.

The distribution in September shows a minor mode towards the low-component end of the scale, attributable almost entirely to a spell of low components in September, 1953. That for December shows a minor mode towards very high components, reflecting short periods of strong winds which occurred in that month in each year.

In each of the remaining months, July, August and October, the distribution shows only one significant mode. A feature of interest is the complete absence of any instances of net easterly components in either July or August.

Figure III shows the histogram of the frequency distribution of the components throughout the whole period. The appearance of the anomalous distribution of the components above 96 knots supports the remarks made above about the unreliability of the template measurements of very high components.

The frequency distributions for the monthly and "whole-period" data were examined for kurtosis and skewness by a method due to Geary and Pearson (1938). The distribution of the "whole-period" data shows a very close approximation to normality, as is apparent from Fig. III, where the curve fitted to the histogram is the normal curve

$$y = 70.52 \exp(-x^2/1230)$$

Relationship between 300 mb. and 500 mb. Components:

The co-efficients of correlation between the components at 300 mb. and 500 mb. levels

(1) for each month, using the data for that month in all years, and

(2) for the whole period,

are shown in Table III, together with general linear regression equations showing both the 300 mb. and the 500 mb. component as independent variable.

TABLE III

Correlation Co-efficients and Linear Regression Equations between 500 and 300 mb. Components

Month	Corr Coeff.	Regression Equations x = 300 mb. Component y = 500 mb. Component	
		x in terms of y	y in terms of x
Jan.	0.914	1.14y + 6.8	0.73x + 0.6
Feb.	0.910	1.18y + 3.6	0.71x + 1.8
Mar.	0.915	1.16y + 4.5	0.71x + 0.2
Apr.	0.910	1.25y + 3.3	0.67x + 1.3
May	0.823	1.10y + 5.5	0.60x + 0.6
June	0.848	1.16y + 4.7	0.62x + 2.9
July	0.828	1.30y + 3.5	0.51x + 8.2
Aug.	0.751	1.15y + 10.0	0.49x + 8.0
Sept.	0.859	1.34y + 2.9	0.56x + 6.8
Oct.	0.893	1.18y + 7.5	0.68x + 1.5
Nov.	0.936	1.28y + 1.4	0.68x + 2.9
Dec.	0.904	1.21y + 4.7	0.75x - 0.1
All data	0.897	1.19y + 5.4	0.68x + 1.6

In addition the value of the correlation co-efficient for each of the seventy-two months was calculated. Almost all the values so obtained show a high degree of correlation between the wind components at the 300 and 500 mb. levels, even for individual months. The month showing the smallest value of the correlation co-efficient is August, as was found by Gillman and Rohan for the correlation between the 500 and 700 mb. wind components. This comparatively poor correlation was found to be, as with Gillman and Rohan, largely due to a number of lows which, in August 1953 (for which month the correlation co-efficient was only 0.552) moved slowly close to the track, and, on occasions gave zonal components of opposite sign at the 300 and 500 mb. levels. In general, however, the co-efficients for the individual months show only small departures from those of the monthly values taken over the whole six years.

The values of the 300 mb. components calculated from the appropriate regression equations agree very closely with observed values. Correlation co-efficients as high as 0.98 were found. This suggests that where a "solid" flow covers most of the track considered, a suitable regression equation would give one component in terms of the other to a high degree of accuracy.

Cumulative Frequencies of 300 mb. Components:

An analysis of the cumulative frequency curves is presented in Fig. IV, where the component values corresponding to selected percentiles are shown. Values within the ranges 1% to 25% and 75% to 99% may be obtained by linear interpolation on arithmetical probability paper.

A comparison with the corresponding curves for the 700 and 500 mb. levels (Gillman and Rohan) shows the following points of interest:-

(1) The comparative 1% to 99% range for March and September at 300 mbs. is less than at the lower levels.

(2) The greatest range is found in March at the 700 mb. level, in December at the 500 mb. level and in November at the 300 mb. level.

(3) The smallest range is found at all levels in August.

While, as was remarked above, a considerable error in the values of the high components, as measured by the template method, would lead to only an insignificant increase in the average component, it could have a marked influence on the position of the 99% percentile level in the cumulative frequency diagrams. Components of 100 knots and above were found only in the winter half year October to March, inclusive. During these months, therefore, a shift to the right of the 99% percentile level might be expected, though this could be significant only for November and January, which account for twenty out of the thirty-one components of this magnitude which were encountered.

Analysis of 12-hour Changes in the Wind Component at the 300 mb. Level:

Figure V shows the percentiles of changes in the components between the times of successive charts. The diagram is provided in order to supplement the information given by the standard deviation, which, alone, does not provide a satisfactory measure of variation for all purposes of comparison.

Acknowledgements:

We wish to express our appreciation of the help given to us in the preparation of this paper by various members of the Meteorological Service, and in particular to Messrs. Rohan and Gillman, not least for the benefit of their experience in suggesting the most convenient method of compiling and tabulating the data, which made our task a much less lengthy one than it might otherwise have been.

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HISTOGRAMS OF 300 MB WIND COMPONENT ON G.C. SHANNON TO GANDER

BASED ON DATA FOR MAY 1950 TO APRIL 1956 INCLUSIVE. THE INTERVAL OF WIND COMPONENT IS 5 KNOTS. FREQUENCIES ARE EXPRESSED ABSOLUTELY. MEAN VALUE FOR EACH MONTH IS MARKED BY A VERTICAL LINE.

OCTOBER — MARCH

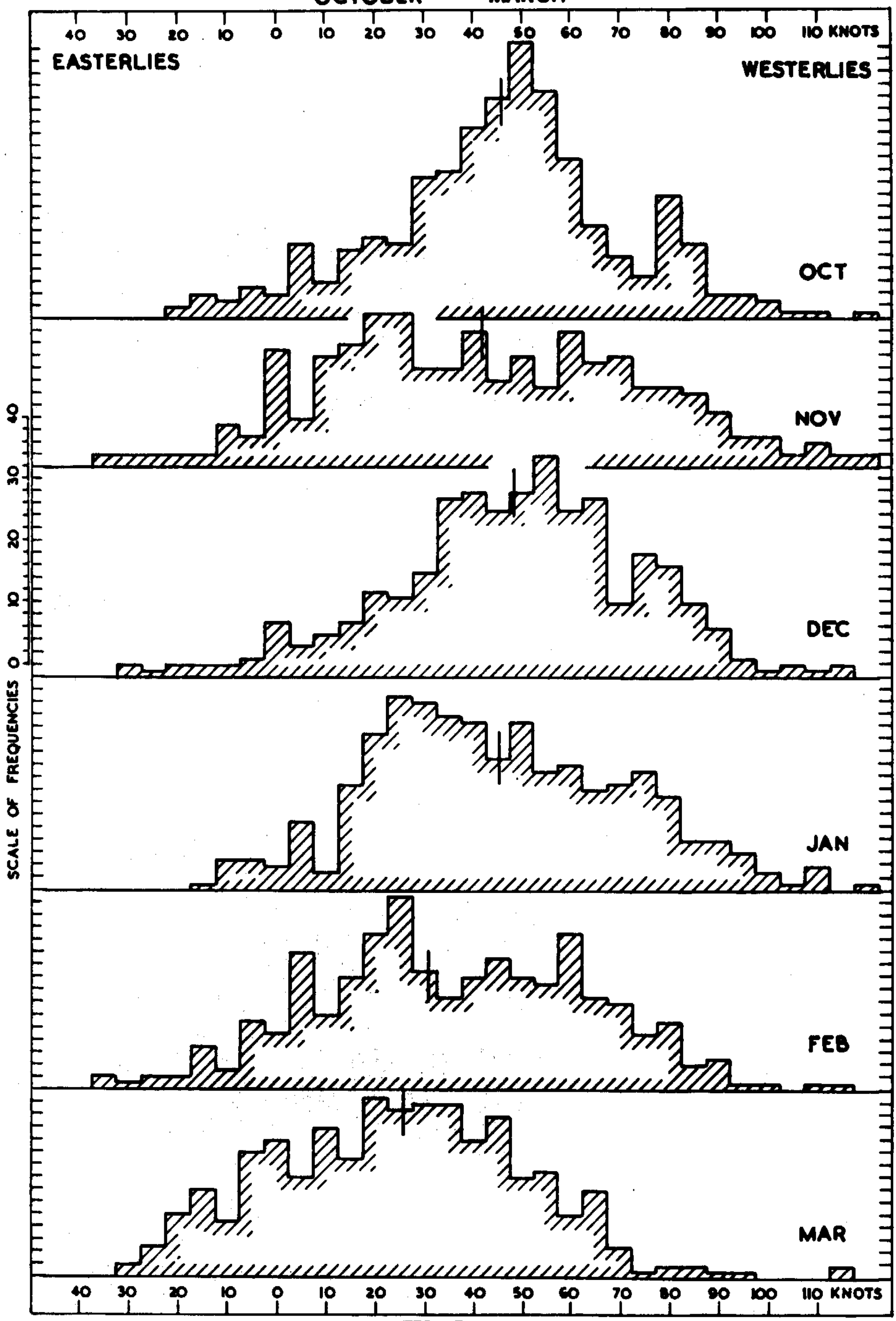

FIG. I.

HISTOGRAMS OF 300 MB WIND COMPONENT ON G.C. SHANNON TO GANDER

BASED ON DATA FOR MAY 1950 TO APRIL 1956 INCLUSIVE. THE INTERVAL OF WIND COMPONENT IS KNOTS FREQUENCIES ARE EXPRESSED ABSOLUTELY. MEAN VALUE FOR EACH MONTH IS MARKED BY A VERTICAL LINE.

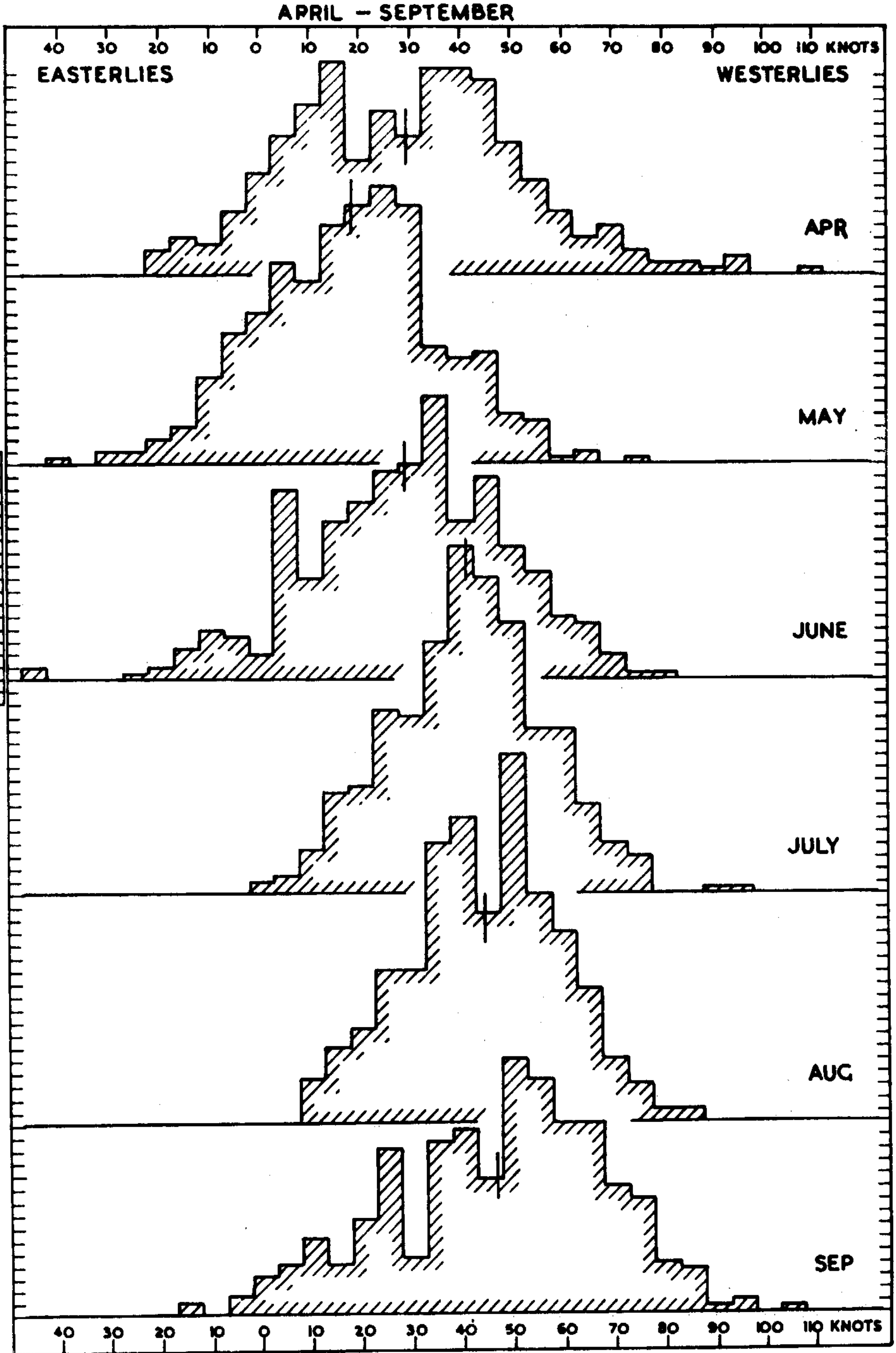

FIG. II.

FREQUENCY DIAGRAMS OF 300 MB COMPONENT ON G.C. SHANNON TO GANDER

BASED ON MEASUREMENTS FOR PERIOD MAY 1950 TO APRIL 1956, INCLUSIVE.
THE INTERVAL OF WIND COMPONENT IN THE HISTOGRAM IS 6 KNOTS.
THE SMOOTH CURVE IS THE NORMAL CURVE $Y = 70{\cdot}52 \, EXP\left(-\frac{X^2}{1230}\right)$.
THE CENTRAL VERTICAL LINE CORRESPONDS TO THE MEAN COMPONENT, – 37·5 KTS.

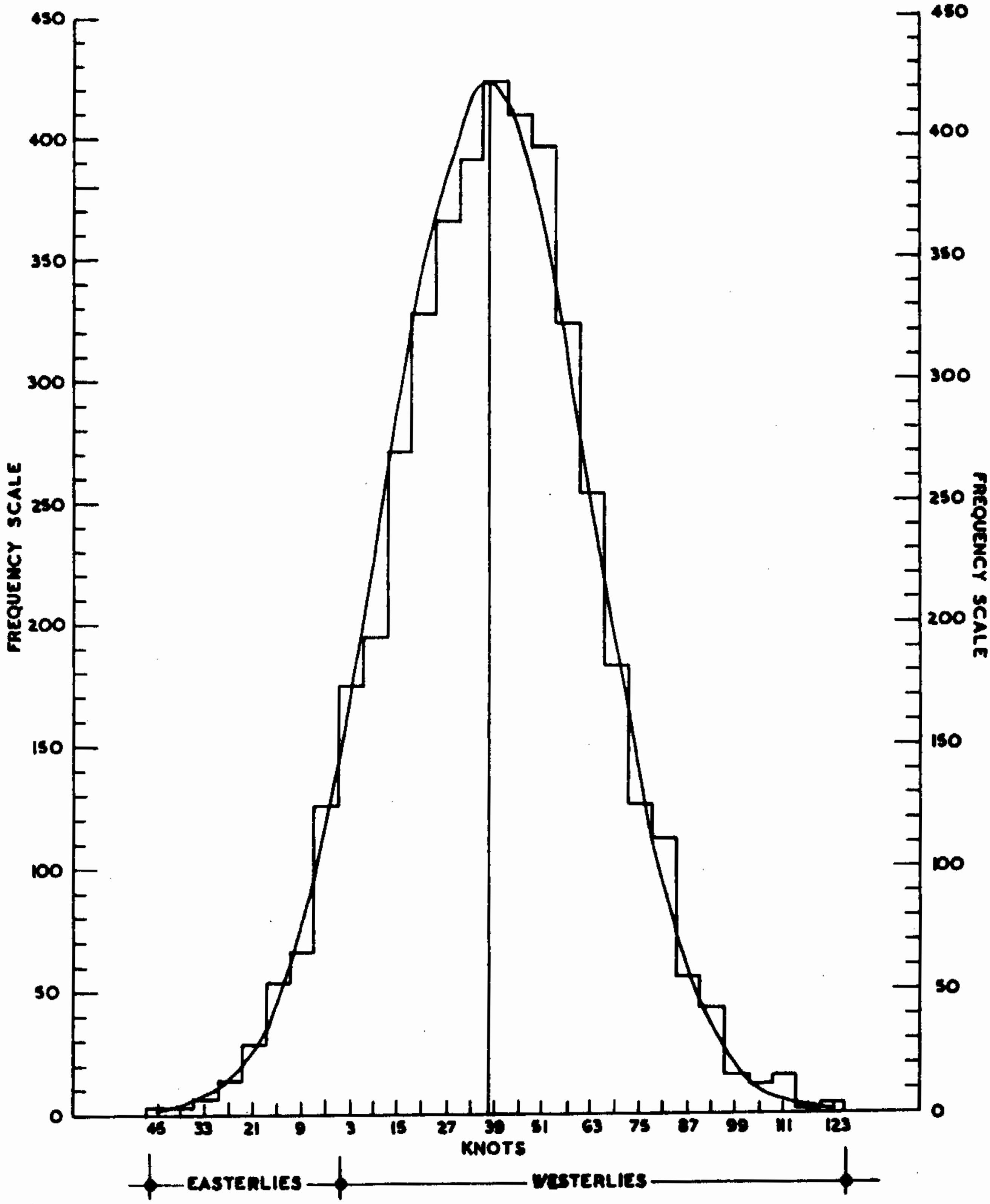

FIG. III.

DIAGRAM SHOWING PERCENTILES OF 300 MB COMPONENT ON G.C. TRACK BETWEEN SHANNON AND GANDER

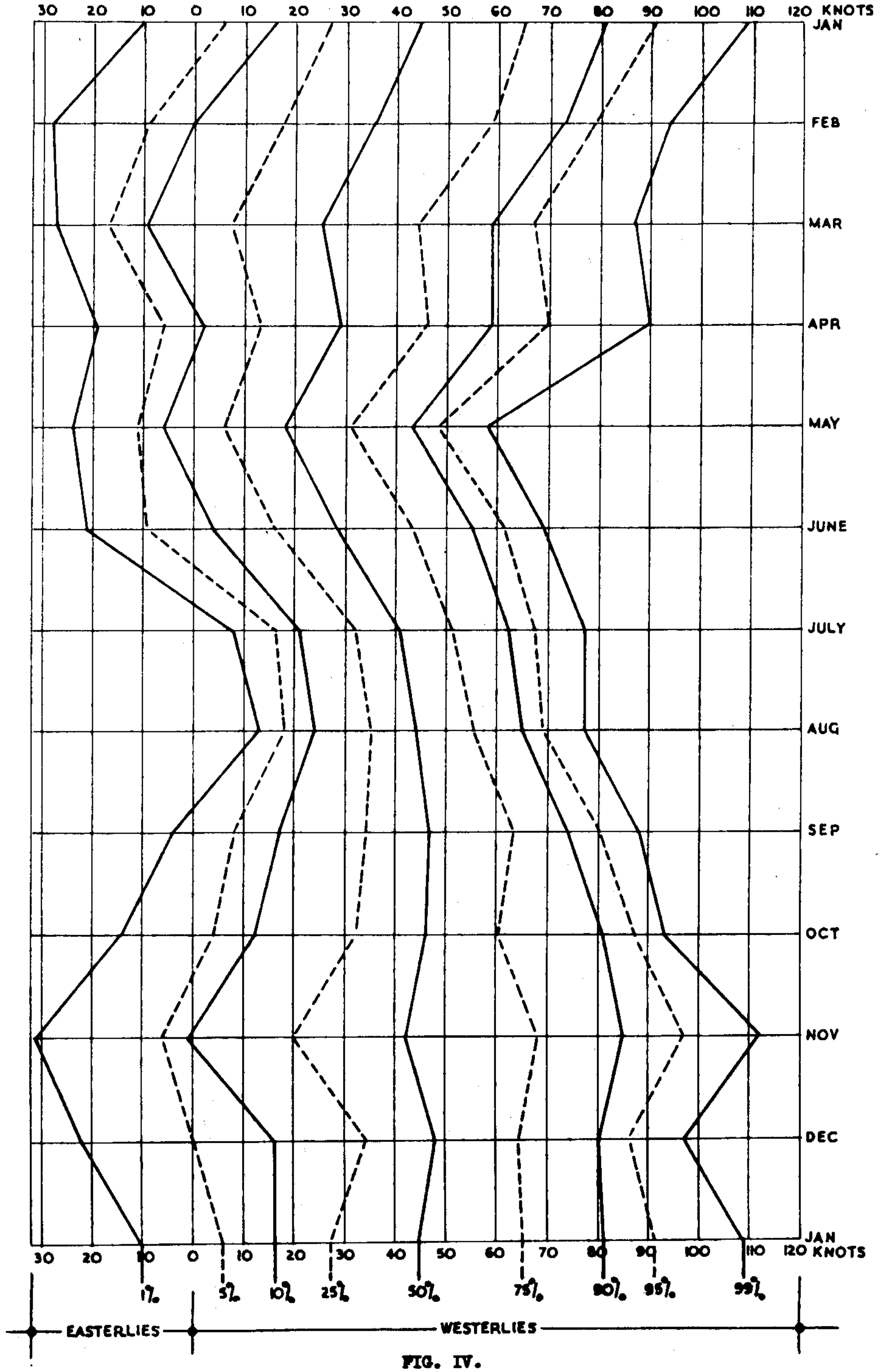

FIG. IV.

PERCENTILES OF 12 HOUR CHANGES OF 300 MB WIND COMPONENT.

BASED ON DATA FOR PERIOD MAY 1950 TO APRIL 1956, INCLUSIVE.

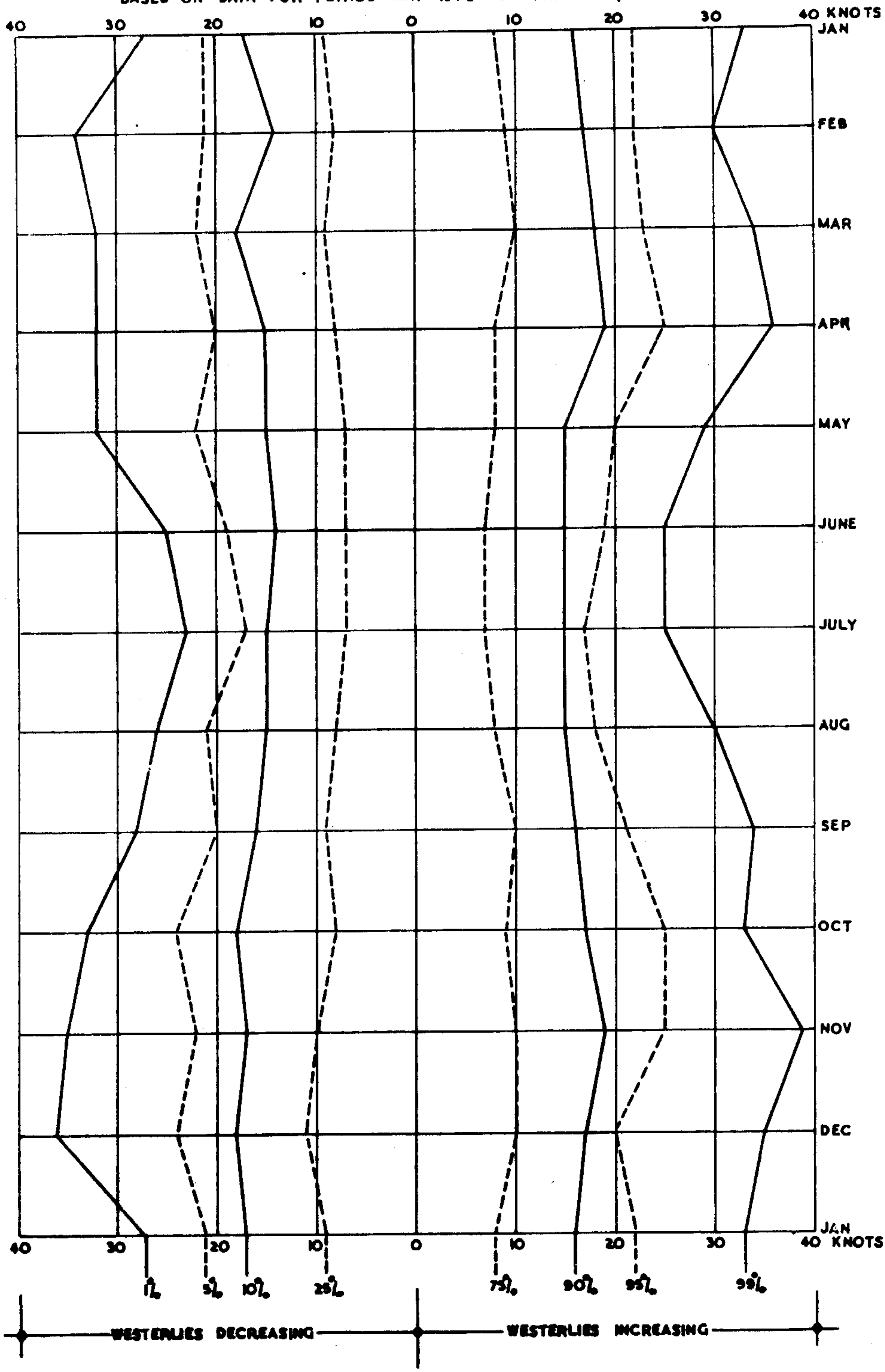

FIG. V.