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AN ANALYSIS OF CLOUD DISTRIBUTION AT ABERDEEN, DURING THE YEARS 1916-1918,

BY

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AN ANALYSIS OF CLOUD DISTRIBUTION AT ABERDEEN DURING THE YEARS 1916–18.

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It was with a view to obtaining some information that might prove useful in aerial navigation, as to the types and distribution of clouds likely to be experienced during the course of a year, that this short analysis was undertaken.

It is part of the daily observational routine at the Aberdeen Observatory of the Meteorological Office to note the cloud-type and its direction and quantity six times daily, namely, at 7h., 9h., 13h., 15h., 18h., 21h., but in addition to this, during the three years 1916 to 1918 a note has been kept of what might be termed the "cloud characteristic" of each day,* and the observations herein analysed were made on the following lines:—

(1) The classification used for cloud-types is the International Classification, and the heights assumed for the various types are the heights as specified in the International Cloud Atlas.

(2) It was assumed that when the cloud appeared, to an observer on the ground, to cover four-tenths of the sky, its obstruction of an airman's view, together with the reflected glare from the upper surface of the cloud, would be a source of trouble to pilots approaching or leaving aerodromes at large centres, if there were many machines in the air, and therefore, when the average, taken over the whole day, of the amount of sky covered by cloud was less than four-tenths, the day was considered as "clear." If four-tenths or more of the sky were covered, then a "characteristic" was assigned according to the type of cloud most persistently present, or present in greatest quantity. In cases where two layers were simultaneouly visible, the characteristic was given according to whether the lower layer was less than four-tenths or not. For example, in cases where a complete layer of Strato-cumulus had below it four-tenths or more of Cumulus, the characteristic of "Cumulus" was given, while if less than four-tenths of Cumulus were present, the characteristic given was "Strato-cumulus." On occasions when part of the day was cloudless and part dull, as in the case of a rainy morning clearing later

* The day referred to extends from 7h.–22h., no account can be given of the hours between 23h. and 6h.

to fine for the rest of the day, the characteristic of "clear" or cloud-type was given according as the major part of the day had proved cloudless or dull.

In actual practice the above rather rough arrangements worked fairly satisfactorily. There were a good many occasions when the cloud-types were either so mixed, or changed so frequently as to render any definite determination of characteristic impossible, and these occasions have been grouped under the heading of "various." In this group also were placed days of persistent fog.

The three years' records embrace about 1,100 observations altogether, and, though a longer series would have been preferable, yet it was deemed advisable, in the present position of aerial navigation, to set forth the results even though merely as a preliminary investigation, in order to draw attention to the possible advisability of a less localised adoption of some such method of recording the predominant forms of cloud experienced daily throughout the year. For this purpose the new cloud reports from stations making observations of the upper air conditions, which are published in the British Section of the Daily Weather Report, should prove of the greatest value. The present series of observations has had the disadvantage of a succession of unusually dry springs and rather wet summers, and the normal distribution of at least the Nimbus cloud has doubtless been affected thereby.

TABLE I.—MONTHLY DISTRIBUTION OF DAYS OF EACH CLOUD CHARACTERISTIC DURING THE 3 YEARS 1916–1918.

Cloud-Characteristic (Type).	Month.												Total.
	January	February	March	April	May	June	July	August	September	October	November	December	
Clear	12	7	2	5	7	5	9	3	4	5	10	8	77
Cirrus	2	4	1	0	3	2	3	4	2	0	1	1	23
Cirro-stratus	0	4	3	3	6	0	1	1	2	4	2	0	26
Cirro-cumulus	5	3	0	0	1	1	1	0	7	4	1	3	26
False-cirrus ...	3	4	0	0	0	0	0	0	0	3	2	3	15
Alto-cumulus	0	0	1	0	8	6	2	6	3	1	5	2	34
Alto-stratus ...	8	8	0	2	8	3	1	2	3	10	7	11	63
Strato-cumulus	13	16	16	11	10	10	17	16	21	13	22	21	186
Cumulus ...	2	2	8	19	12	17	13	14	16	3	4	2	112
Cumulo-nimbus	12	9	21	21	3	18	9	7	9	11	7	13	140
Nimbus ...	15	11	18	12	14	16	19	18	10	19	9	11	172
Stratus ...	13	12	8	15	12	6	12	18	6	9	14	12	137
"Various" ...	8	5	15	2	9	6	6	4	7	11	6	6	85

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Table I gives for every month the number of days during the period of three years upon which each cloud-type was predominant. It will be noticed at once that the skies most frequently met with are those of the combined Cumulus and Cumulo-nimbus types—clouds associated with rising air and much consequent turbulence—and that these types embrace 23 per cent. of the total number of observations. The other low clouds, Strato-cumulus, Stratus, and Nimbus are also very numerous. Among the higher forms of cloud perhaps the most noteworthy point is that the Alto-stratus sky is almost twice as frequent as is the Alto-cumulus one, while the Cirro-stratus and Cirro-cumulus types are equally numerous. Perhaps this anomaly may be accounted for by the fact that very often Alto-stratus skies are subsequent developments both of Cirro-stratus and of Cirro-cumulus, for on numerous occasions it has been observed at Aberdeen that layers of heavy Cirro-cumulus eventually fused into a perfectly uniform sheet of Alto-stratus. On the other hand, though Alto-cumulus may also develop from Cirro-cumulus, it certainly never owes its origin to true Cirro-stratus.

If the average heights of the various cloud-types be taken into consideration, some idea can then be formed of the probabilities of the air being cloud-free up to these heights. For this purpose the clouds have been placed in four separate groups. Group I includes the "clear" days and also the various types of Cirrus, as these clouds are practically confined to heights at which it is extremely unlikely that aeroplanes will generally work, namely, 15,000 to 30,000 feet. In Group II there are placed Alto-cumulus, Alto-stratus, and "False" cirrus, the last-named being placed in this group because it generally develops before long into either Alto-cumulus or Alto-stratus. The heights for this group are between 7,000 and 14,000 feet. Group III is composed of the Strato-cumulus, Cumulus, and Cumulo-nimbus types, with heights from 3,000 to 6,000 feet; while Group IV includes Nimbus and Stratus, with heights generally below 3,000 feet. The treatment of Cumulo-nimbus and Nimbus may call for some comment, because in the International Classification Nimbus is given an average height of about 6,000 feet, while the apices of Cumulo-nimbus may reach sometimes almost to the Cirro-cumulus level. But it must be remembered that, since the cloud is to be regarded from the airman's point of view, it is the low-lying base of the Cumulo-nimbus that must be taken into account; while in the case of Nimbus, the effect of the screen of falling rain, extending as it does right down to the ground and thereby greatly limiting visibility, places Nimbus on practically the same footing as Stratus. Besides, Nimbus usually consists of a compound arrangement of clouds at more than one level, with a good deal of low-lying "scud" cloud floating beneath.

TABLE II.—SHOWING PERCENTAGE OF OCCASIONS WHEN AIR WAS CLOUD-FREE BELOW CERTAIN HEIGHTS.

Group Number and Heights.	Cloud-Type.	Number of Occasions.		% of Total.
I. (15,000 to 30,000 feet)	Clear	77	152	15
	Cirrus	23		
	Cirro-stratus	26		
	Cirro-cumulus	26		
II. (7,000 to 14,000 feet)	False cirrus	15	112	11
	Alto-cumulus	34		
	Alto-stratus	63		
III. (3,000 to 6,000 feet)	Strato-cumulus	186	438	43
	Cumulus...	112		
	Cumulo-nimbus... ...	140		
IV. (Below 3,000 feet)	Nimbus	172	309	31
	Stratus	137		

In Table II the above arrangement has been carried out with the following results. If the number of observations under the heading "various" (which form 8 per cent. of the total number) is neglected as probably capable of proportionate distribution over the other observations, the number of occasions upon which flying would have been handicapped on account of the lowness of the cloud is 31 per cent. of the total; while of the remaining 69 per cent. of occasions when heights from 3,000 feet upwards would have been navigable, rather more than one-third show no cloud below 7,000 feet.

TABLE III.—SHOWING MAXIMUM PERCENTAGE DEPARTURE (D) OF ANY INDIVIDUAL YEAR FROM THE AVERAGE OF THE THREE YEARS.

Group Number.	Year.			Average.	D (%).
	1916.	1917.	1918.		
I.	50	52	50	51	2
II.	33	35	44	37	19
III.	144	163	131	146	12
IV.	116	87	106	103	16

Table III indicates, for the several groups, to what degree each individual year agrees with the average over the whole period. Only in the case of Group II—that with the smallest number of observations—does the divergence of any year from the mean value reach as high as 20 per cent.

On examining the seasonal distribution of the cloud-types some interesting points are brought to light. But before proceeding

to do this I should like to mention that in the Annual Supplement to the Geophysical Journal for 1916 there is printed an "Analysis of Clouds observed at Aberdeen Observatory during the five years 1912-1916."* To this analysis reference will be made both in support of and in comparison with the present analysis. The two analyses have been made on different lines, since, in the case of 1912-1916 analysis the observations were made at a particular hour, and had no reference to actual predominance of the cloud-type; they were really observations giving the frequencies rather than the quantities of the different clouds. [It may be well to draw attention to the fact that the Geophysical Journal analysis covers the five years 1912-1916, whereas the present one deals with the three years 1916-1918. There is thus a seven-year period from which some conclusions may be drawn, as only one year of overlap occurs.]

Referring then to the lowest clouds—those in Group IV—it will be seen that both Nimbus and Stratus are rather irregularly distributed throughout the year, the summer maximum for Nimbus being no doubt accounted for by the succession of wet summers that have occurred in these three years. On account of the impossibility of making observations of Nimbus and Stratus clouds with the nephoscope, owing to their uniformity and lack of detail, no comparable results can be obtained from the five-year analysis.

The third group includes the great cloud-heaps of the Cumulus and Cumulo-nimbus types, and also the cloud-sheet called Stratocumulus. First of all, the distribution of the Cumulus and Cumulo-nimbus may be examined. Both these cloud-types—for the Cumulo-nimbus is really only a much more vigorous Cumulus—owe their origin to the rising upward of currents of warm moist air, and are associated with much vertical air movement; they may therefore be dealt with together. If the number of days upon which these types have been predominant in each month during the years 1916-1918 be plotted as a graph, we obtain the curve shown at (A) in Fig. I. Beside it at (B) is a similar graph obtained from the frequencies shown in the analysis

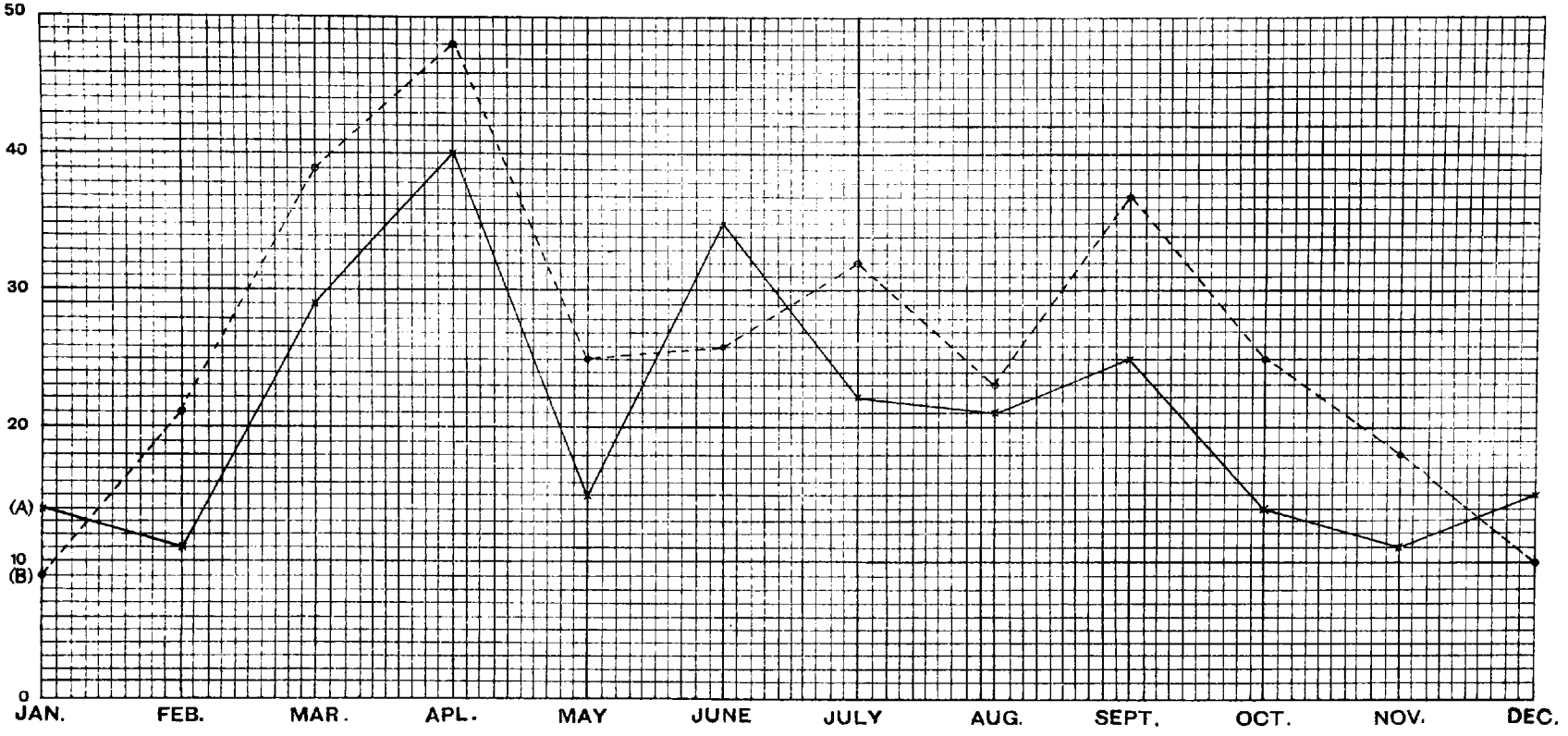
* During the years 1912–1916 (the period of the "Analysis" given in the G.J.), the nephoscopic observations of clouds were made daily, whenever possible, at 13h. The nephoscope used was the Fineman pattern, and the observations made were of (1) the direction of the cloud, (2) its velocity-height ratio. The observations were made originally at the request of De Bilt Observatory (Prof. Van Everdingen) and used to be included in the 13h. telegram to London daily, except on Sunday. The observations were made within half an hour of 13h. usually, though on a very few occasions they were made at 12h. (mostly in cases where a trace of cloud only was seen on an otherwise clear day). Only on a few occasions (relatively to the whole number) were high and low clouds simultaneously measured, but every endeavour was made to obtain measurements of the high clouds, whenever they were to be seen, so that I think it would be quite true to say that "both types were observed and recorded whenever possible. Nimbus and Stratus, being clouds with practically no visible detail, do not give an image in the mirror sufficiently definite to enable observations to be made of them, unless in exceptional cases. They do not, therefore, appear in the Nephoscope Analysis of 1912–16. Alto-stratus labours under the same disadvantage to a lesser extent, and so also does Cirro-stratus.

Figure I.

To face page **146.**

Characteristic for 1916-1918. (A).

Frequency for 1912-1916. (B).



FREQUENCY OF CUMULUS AND CUMULO-NIMBUS (COMBINED).

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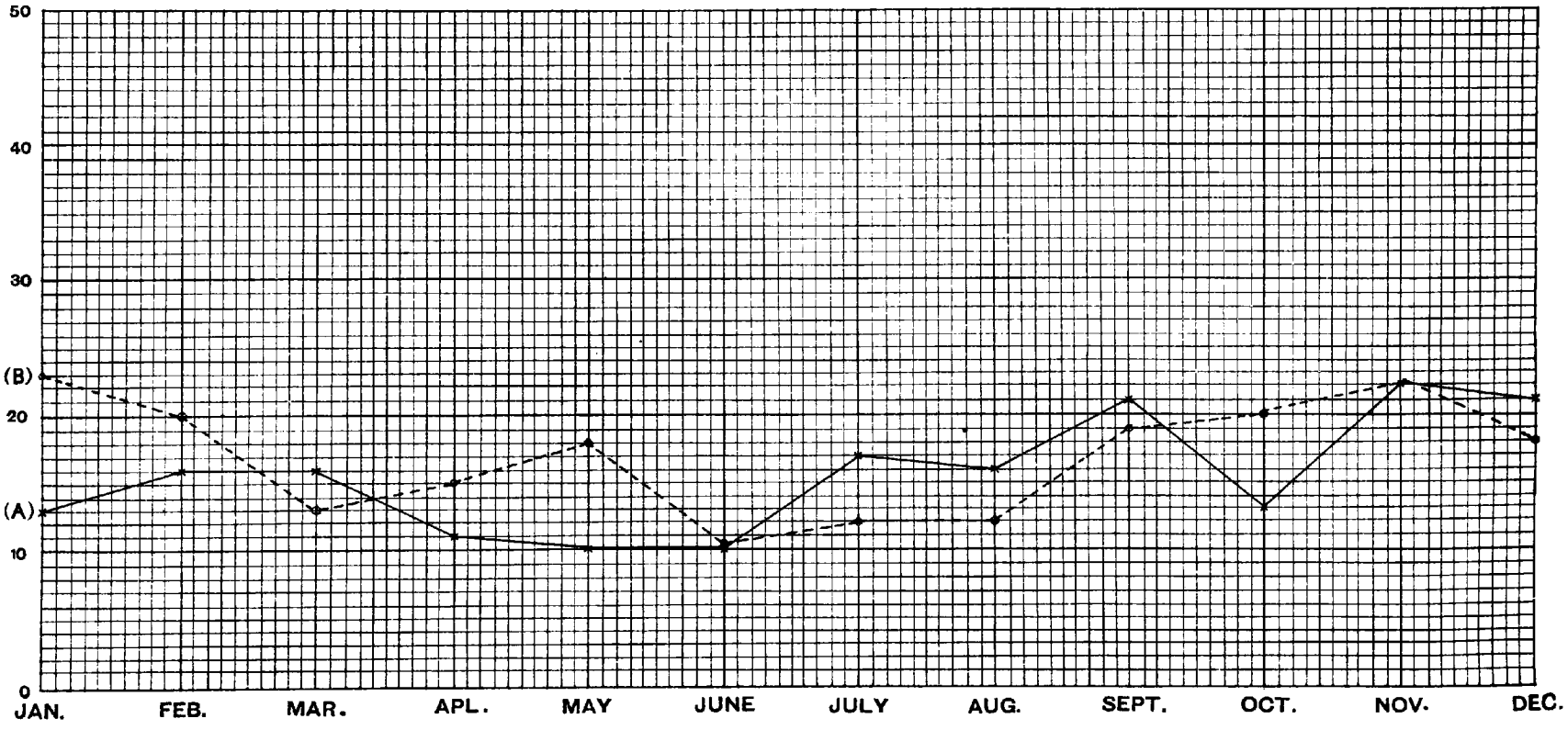
Figure II.

To face page 147.

Characteristic for 1916-1918. (A).

Frequency for 1912-1916. (B).



FREQUENCY OF STRATO-CUMULUS.

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Figure III.

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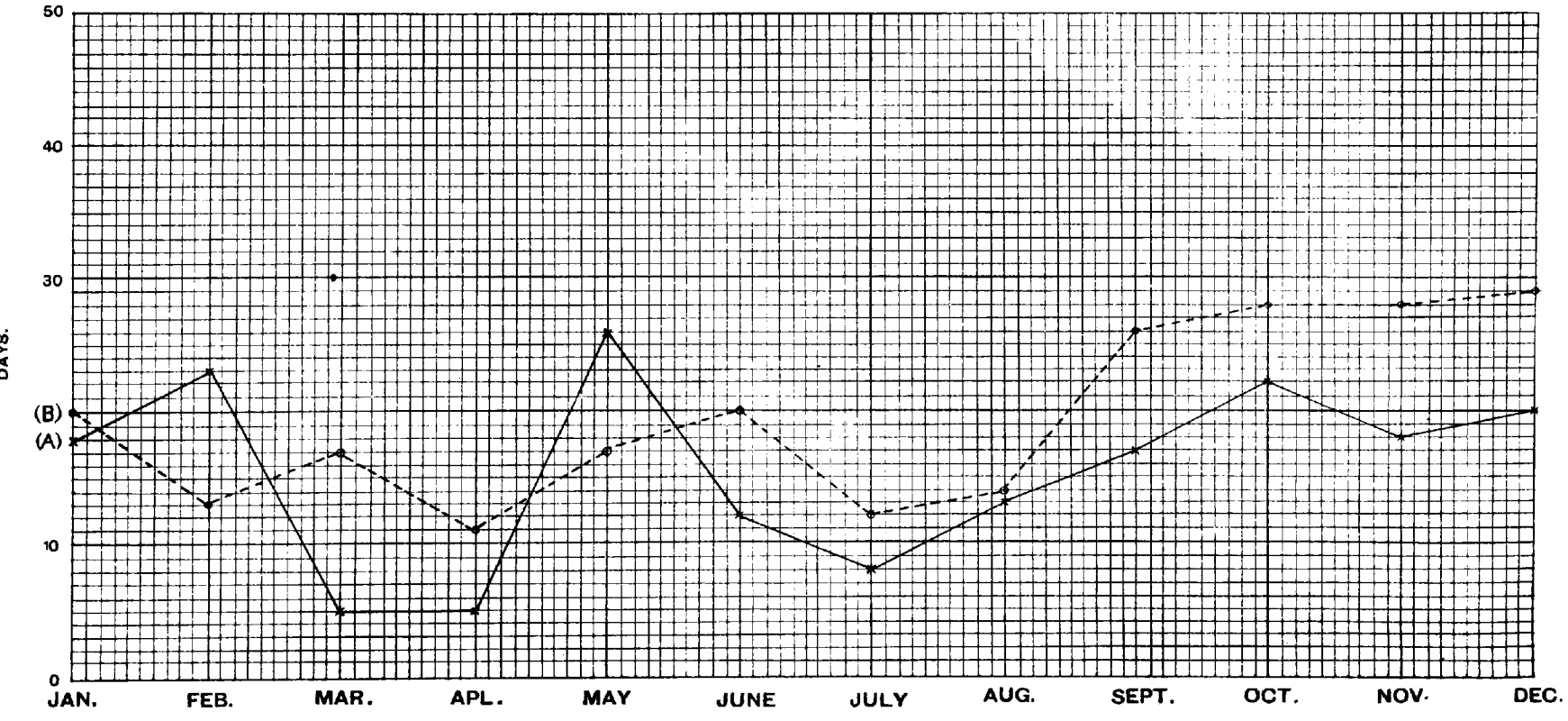

FREQUENCY OF ALL INTERMEDIATE AND HIGHER CLOUDS.

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of 1912-1916. The two curves show the same general features, a very marked maximum in April and two lesser maxima in midsummer and in September. It is rather significant that these cloud-types appear with greatest frequency and in greatest quantity about the time of the equinoxes, just when the heating power of the sun is changing at its greatest rate, as well as in midsummer when the sun's heating power is at its maximum; and therefore, on account of the energetic vertical currents which accompany these clouds pilots should find air conditions most "bumpy" at these periods. At Aberdeen, in midsummer, the Cumulo-nimbus clouds are largely of the "thundercloud" variety, very extensive and massive clouds with powerful ascending and descending air currents, and are usually accompanied by light variable winds, while frequently the upper and lower portions of the cloud may even be moving from different directions. In spring and autumn the Cumulo-nimbus clouds are usually of a smaller type associated with rather squally moderate to fresh breezes and hail and rain showers.

Fig. II gives at (A) and (B) similar curves for the Strato-cumulus type, and from them it may be seen that Strato-cumulus is a much more common sky in winter than in summer. At first sight this might lead to the supposition that, since the average height of the Strato-cumulus type is greater than that of the bases of Cumulus and Cumulo-nimbus, there exists more frequently a clear space below the cloud of greater depth in winter than in summer; but observations made at Potsdam, Toronto and Blue Hill tend to show that the average height of Strato-cumulus in winter is approximately the same as that of the bases of Cumulus and Cumulo-nimbus in summer, so that the advantage above referred to is more apparent than real. On the other hand, the fact that the latter clouds are clouds of the daytime, and that they gradually disperse and disappear as evening approaches, leaving the sky clear for night-flying, indicates that the advantage rests actually with the summer conditions. In addition, broken clouds are much less hindrance to navigation than a continuous sheet.

With regard to the intermediate and higher clouds in Groups I and II, the distribution of observations of these types is entirely dependent upon the presence or absence of the lower clouds, and that therefore no very definite conclusions can be drawn from these observations. But, taken as a whole, there seems to be a slight tendency towards the greater frequency of skies fairly well covered by the intermediate and higher cloud-types during the winter half of the year. This is corroborated by the nephoscopic observations for 1912-1916, and in this latter case it is all the more noteworthy because the greatest care was taken to obtain nephoscopic observations of the upper clouds. Fig. III gives the two graphs (A) and (B) as in the cases of the previous groups, when all clouds in Groups I and II are combined.

In this paper no note has been taken of two other conditions which most profoundly affect aerial navigation—the incidence of haze, mist, or fog, and also of gales but it was deemed advisable to treat the cloud conditions as a factor by itself.

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