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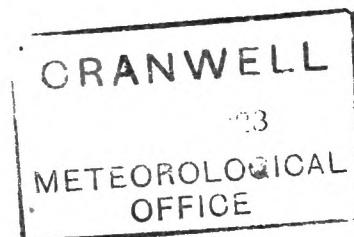
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Hourly Character Figures of Magnetic Disturbance at Kew Observatory, Richmond 1913-23

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HOURLY CHARACTER FIGURES OF MAGNETIC DISTURBANCE AT KEW OBSERVATORY, RICHMOND, 1913-1923

ABSTRACT

Magnetic character figures (0, 1 and 2) have been assigned to each hour of the 11 years 1913—1923 on the basis of the independent consideration of the *D* and *H* curves at Kew Observatory followed by the combination of the two judgments for the final figure. To standardize the entire system of figures, each hour of the two months March and August throughout the eleven years was examined afresh. New characters were assigned according to the original plan but entirely independently of the previous judgment of the hours in question. The ratio of the new assignment (March + August) to the original assignment (March + August) for each year was used as a factor of reduction to bring the eleven years on to a common standard.

The figures are tabulated to show the daily distribution of "total" and component characters separately in years, months and seasons, the "total" character being that derived from treating the 2's as numerical quantities. A well marked diurnal variation of each character becomes evident and the differences in the behaviour of these variations introduced by change of season are examined. Notable differences between the distributions of hours of moderate and great disturbances are disclosed. The chief features of similarity and disparity are summarized thus :—

Feature	Small or moderate disturbance (Hours of character 1)	Large disturbance. (character 2)
Incidence of maximum of diurnal variation.	Invariably at 1h.	Invariably in the late afternoon and evening. Advancing from 22h. in winter to 18h. in summer.
Incidence of minimum of daily variation.	Advances fully two hours from the winter to summer solstice.	Persistently one hour before mid-day.
Afternoon secondary maximum	Apparent in all seasons with develop- ment towards summer.	Develops markedly from winter to summer, so that in the latter season it not infre- quently supplies the principal maximum to the daily variation.

Sunspot influence on the diurnal variation is analyzed and differences in respect of shift of minimum, range of variation, development of secondary maximum and change in mean figure in passing from years of few to years of many sunspots are made evident. In some cases, especially in the apparent fixity of the daily minimum, the behaviour of large-disturbance hours is very conspicuously different from that of hours of character 1. The change in the mean seasonal variations with sunspot epoch is also investigated.

Mean monthly characters are derived from the hourly assignments and the annual variation of total and constituent figures so formed are examined. The changes introduced into this annual variation by sunspot influence are investigated, and some further differences in the behaviour of the component figures disclosed. While total (or component) figures show a change in the incidence of seasonal maxima in the direction of separation with increase of sunspottedness—the April maximum advances to March and that for September is retarded to October—the hours of more pronounced disturbance maintain persistent maxima in March and October.

The mean annual character figures deduced from those of the monthly figures are compared with those derived from the whole-day characters for the Kew and Eskdalemuir Observatories, as well as those published by the authorities at de Bilt as being internationally representative. The similarity between these last and the annual means of the Kew hourly characters is very pronounced. The fluctuations of disturbance on the whole solar cycle 1913—1923 are discussed in the light of these figures—special attention being given to the anomalous position of 1922 in the descending phase of the cycle.

PART I—THE DIURNAL VARIATION OF MAGNETIC DISTURBANCE

§ 1. INTRODUCTION.

Largely owing to the lack of a representative measure of disturbance which could be applied with facility to periods of time shorter than the day, little recent advance has been made in the study of the 27-day interval in recurrences of magnetic disturbance and calm. The hourly range derived from either a single element or as a mean of three rectangular components of magnetic force is too decidedly influenced by the ordinary solar diurnal variation to be of much assistance in such an investigation, and from this point of view alone, the squares of the hourly ranges can offer little additional advantage. Since, further, the examination of such a question as the variations in the length of the recurrence interval in the course of a sunspot cycle demands at least 11 years' data, other obvious considerations enter to make their adoption prohibitive.

On the other hand, the "character" figures assigned to each day's magnetograph traces at most observatories have been shown to be of great value in such studies. For, in addition to being easily manipulated, they can be considered to be more entirely representative of really disturbed and calm periods than corresponding range figures. They are naturally, however, purely empirical and therefore open to the easy criticism of liability to change of standard. But for some purposes such changes are of minor importance and for others, methods can be introduced with a view to maintaining a relative constancy, especially if the variations in standard can be assumed to have crept in at definite stages. Character figures were accordingly adopted in this investigation.

At a certain stage the results began to give evidence of a well defined daily distribution of disturbance which at times became so marked as to mask entirely the effects of the 27-day recurrence sought for. This suggested a separate inquiry into the nature of the daily distribution of these disturbance figures, and the present paper is a summary of the results obtained.

§ 2. DETAILS OF CHARACTERIZATION.

(a) *The characters and their significance.*—The three figures 0, 1 and 2, in use in the international (de Bilt) system of characterizing entire days, were adopted with a similar significance attached to each. With the smaller time unit, however, a somewhat more precise scale could be used in deciding the classification of a particular hour. The requirement of an (almost) perfect magnetic calm over such a small period as an hour could be insisted on with greater rigidity and consistency than in the case of an interval 24 times as long. The lower limit, at least, of disturbance necessary to allow an hour to qualify for a "2" could be mentally fixed with almost equal definiteness. To merit the assignment of this figure the criterion of large range and decided oscillatoriness could be enforced more rigorously with the 60-minute intervals treated than with a time interval of a day. For, when a single hour worth a "2" occurred among 23 of a less disturbed nature, the general process in such a scheme as that adopted for the determination of the international quiet and disturbed days would be to dilute its intensity down to a mean level of say a "1." The more general "1" allocated to mild or moderate disturbance necessarily varied more widely in its significance. The hour used throughout was that ending at the exact hour G.M.T. Thus in the tables and graphs below, "hour 1" denotes the 60-minute interval 0h. om. to 1h. om. and "hour 24," 23h. om. to 24h. om.

Throughout the entire process figures were first assigned on the basis of declination alone using the notation 0, $\bar{0}$ (greater than 0 but less than 1), $\bar{1}$ (greater than 1 but less than 2), etc., the "barred" figures indicating a position which might by judgment from another element be thrown either one way or another. Then each hour of the horizontal force traces was examined on its own merits and from the two independent judgments a final figure 0, 1, or 2 was awarded to each hour. The artificially produced oscillations on the traces from the vertical force magnetograph, especially during the years subsequent to 1916, made the incorporation of a force from this element contribution to the final estimate impracticable.

In all the estimates the ranges introduced by the ordinary "quiet" diurnal variation were, as far as possible, disregarded in the characterization, although such facts as the increase of diurnal inequality amplitude on disturbed days were kept constantly in mind. In effect, it was the divergence from the mean quiet day curve for the season of the year concerned that was characterized rather than the actual curve as it stood.

(b) *The origin of a probable variation of standard and reduction to a common basis.*—Originally the investigation of the years 1921-23 alone was undertaken. This was later extended to the seven years 1917-23 (in the two stages, 1917 alone and subsequently 1918-20) and the data worked up for this period, annual and seasonal mean daily distributions being computed from the original figures. Later the question of how the sequence of the monthly and annual total character figures compared with variations in sunspot activity as indicated by Wolfer's numbers suggested the extension of the characterization to the entire sunspot cycle 1913-1923, which when ultimately effected, included some 100,000 available hours the characterization of which necessitated thrice that number of judgments.

Monthly totals for each Greenwich mean hour were obtained, giving :—

- (1) A total character figure, i.e., the 2's were treated simply as numerical quantities by giving them, in comparison with the 1's, double weight. Thus, if in any given hour throughout the month n_1 = No. of "1" hours, and n_2 = No. of "2" hours, the total used in deriving the mean character for that hour was $2n_2 + n_1$.
- (2) Frequency of 2's alone (i.e., n_2).
- (3) Frequency of 1's alone (i.e., n_1).

At a certain stage when monthly, and more especially annual, mean hourly character figures were computed the run of the figures seemed to suggest that a variation in standard in the different periods considered had crept in. Though from the point of view of the determination of the mean distribution frequency of 1's and 2's throughout the days of the season and the year this was immaterial, and though the standard for a "2" (and therefore, presumably a "1") was consciously changed from years of low to years of high general magnetic activity, yet, a fair approximation to a progressive rise and fall of standard with general magnetic storminess was to be desired rather than a disjointed set of four standards which must unavoidably have arisen from such a procedure as that outlined above. To decide how far this ideal had been departed from, each hour of the 11 Marches and 11 Augusts in the cycle was characterized afresh in precisely the same way as before—first *D* throughout both months, followed by *H*, and then a final combination. Monthly totals of the figures for each hour for entire character ($n_1 + 2n_2$), 2's alone (n_2) and 1's alone (n_1) were formed to allow comparison with the original, disjointedly obtained estimates.

The resultant mean daily variation of character for both months on the two bases as well as the sequence of the mean monthly values throughout the 11 years for the combined and separate estimates were tabulated and graphed for comparison purposes.* Allowance being made for the nature of the process of judgment and the conditions under which the estimates were obtained the two sets showed remarkable agreement. Indeed, the similarity in the sequences of the mean diurnal distributions obtained for the two months (especially that for August) is not a little surprising; while the runs of the individual monthly totals on the new and original evaluations show a good parallelism.

(c) *The standardizing factor.*—In order to put the 11 years on the common basis supplied by the mean of these two months a ratio

$$\frac{\text{Revised total (March + August) character figure}}{\text{Original total (March + August) character figure}}$$

* The tables and graphs are not reproduced here, they are retained in MS. at the Meteorological Office and may be consulted on application to the Director.

was obtained for each year and this ratio employed as a factor to bring each month of the year on to the same standard. The first table shows the original mean hourly

TABLE I.—ORIGINAL AND REVISED MEAN HOURLY CHARACTER FIGURES
WITH STANDARDIZING FACTORS.

Year	Original Mean Character figure	Standardizing Factor	Revised Character figure
1913	0.42	0.934	0.39
1914	0.54	0.861	0.46
1915	0.66	0.785	0.52
1916	0.63	0.857	0.54
1917	0.55	0.935	0.51
1918	0.64	0.888	0.56
1919	0.55	0.960	0.52
1920	0.36	1.084	0.39
1921	0.45	0.874	0.40
1922	0.64	0.737	0.47
1923	0.28	1.157	0.32

character figure over each year on the original and standardized basis along with the reducing factor used.

§ 3. SEASONAL CHANGE IN THE DAILY DISTRIBUTION OF TOTAL CHARACTER FIGURES.

Total character figures for each hour of the day were obtained for the three seasons—winter, equinox and summer—as well as for the year as a whole in the following manner. A mean figure for each hour of the day was obtained from the hourly figures for the four winter months January, February November and December; these means were then standardized by applying the appropriate factor for the year, and the averages over the eleven years were taken. The process was repeated for the equinoctial months March, April, September and October, and for the summer months. The final figures obtained are set out in Table II and graphed on Plate I, Fig. 1.

TABLE II.—DIURNAL VARIATION OF MEAN HOURLY CHARACTER FIGURES
IN YEAR AND SEASONS.

Hour ..	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Mean
Year ..	.70	.63	.54	.49	.44	.38	.34	.30	.29	.30	(.26)	.34	.38	.43	.44	.46	.47	.49	.50	.51	.55	.59	.62	.66	.46
Winter..	.67	.59	.48	.42	.40	.37	.33	.29	.27	.28	(.23)	.29	.31	.35	.34	.36	.39	.43	.46	.48	.53	.58	.60	.62	.42
Equinox..	.76	.68	.59	.54	.50	.43	.40	.34	.33	.32	(.30)	.39	.44	.47	.46	.47	.50	.52	.54	.56	.62	.67	.70	.72	.51
Summer	.67	.64	.55	.52	.41	.35	.29	.26	.26	.29	(.26)	.35	.40	.48	.50	.56	.53	.53	.50	.48	.50	.52	.56	.62	.45

* For the meaning of the brackets see below.

Note on the 11h. phenomenon.—As a preliminary to any discussion of the results it is necessary to mention some obviously artificial effects which have crept into the work. Of these the most immediately noticeable (indeed the only serious one) is the persistent irregularity at 11h. G.M.T., forming a minimum of invariable position there, while the trend of the curve before and after suggests a more natural run. This arises immediately from the fact that the change over from one day's trace to the next was almost invariably effected between 10 and 11 o'clock in the forenoon. Thus the magnetogram covering the eleventh hour of each day is almost without exception in two portions. The difficulty of ensuring a smooth run of character figures over such a broken hour can be appreciated only by investigators in this or similar fields.

After the seven years 1917-23 had been characterized and the discontinuity made evident, efforts were made to eliminate the effect in the assignment of figures to the other years necessary for the completion of the cycle. But the final figures showed that in these it was as marked, if not more so, than in the later years; and certainly

the double cross-section of Marches and Augusts carried out with the experience of 132 months characterization showed no decrease in the tendency to introduce the discontinuity at that time each day. Except in one or two cases, however, this unnatural effect does not mark the true sequence of affairs about that time, and in many cases, where no doubt can exist, the discontinuity on the graphs has been bridged by a dotted line and its existence in the tables intimated by bracketing the corresponding figures.

§ 4.—THE EVIDENCE OF A DIURNAL VARIATION OF CHARACTER FIGURES.

The mean character figures in Table II showing the annual and seasonal variation of daily distribution of total characters reduced to the common standardized basis exhibit some noteworthy features. Of these the chief are:—

- (1) A well defined and comparatively smooth variation throughout the 24 hours.
- (2) A principal maximum of this diurnal variation persistent throughout the year between midnight and 1h. G.M.T.
- (3) A noticeable advancement of the time of incidence of minimum with earlier sunrise; being about—
 - (a) 10h. in winter.
 - (b) 9h. 30m. in the equinoctial months.
 - (c) 8h. to 8h. 30m. in summer,
 the mean for the year falling near 9h.
- (4) The appearance and seasonal development of a secondary afternoon maximum which extends as well as intensifies in amplitude from winter to summer.
- (5) The suggestion of a retardation of the time of maximum development of this afternoon crest with increase of length of day, falling about 14h. G.M.T. and 16h. or 17h. at the winter and summer solstices respectively.
- (6) The range of the diurnal variation, using a smoothed minimum in the hours preceding mid-day, is a maximum in the equinoctial months and a minimum in winter. The mean summer range is only slightly in excess of that for the winter months.

These features can be examined in greater detail from Table III in which are presented the mean hourly character figures derived from each of the eleven months of the same denomination in the eleven years. The total figure is still (as in the above discussion) the basis of the work; that is, the hours of character "2" have been doubly weighted and added to the frequency of "1" hours to produce the final

TABLE III.—CHANGE IN THE MONTHLY MEAN DIURNAL VARIATION OF CHARACTERS THROUGHOUT THE YEAR.

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Mean	Days used
											*															
Jan.	.77	.67	.56	.52	.49	.46	.41	.37	.32	.34	(.27)	.34	.37	.44	.39	.42	.45	.50	.53	.53	.60	.69	.67	.74	.50	341
Feb.	.76	.69	.57	.50	.48	.41	.42	.35	.35	.36	(.31)	.40	.38	.45	.42	.40	.45	.48	.53	.57	.66	.67	.60	.73	.50	368
Mar.	.87	.75	.64	.60	.56	.49	.48	.42	.41	.40	(.36)	.50	.53	.61	.56	.54	.58	.60	.65	.66	.72	.81	.83	.76	.60	338
Apr.	.85	.74	.69	.65	.59	.51	.42	.34	.34	.34	(.34)	.43	.49	.56	.57	.58	.59	.62	.61	.62	.68	.73	.70	.81	.58	336
May	.83	.76	.62	.62	.53	.44	.39	.33	.34	.40	(.35)	.48	.55	.61	.62	.71	.68	.69	.63	.61	.61	.64	.69	.76	.58	337
June	.65	.64	.58	.51	.38	.35	.29	.26	.26	.26	(.26)	.33	.39	.49	.55	.58	.53	.55	.50	.49	.49	.50	.55	.60	.46	330
July	.72	.69	.64	.57	.47	.40	.31	.28	.27	.30	(.26)	.34	.39	.55	.54	.61	.57	.56	.53	.49	.54	.54	.61	.66	.49	341
Aug.	.81	.75	.63	.64	.53	.42	.36	.34	.33	.34	(.30)	.42	.49	.53	.54	.61	.60	.58	.60	.58	.57	.64	.60	.76	.55	337
Sept.	.85	.77	.68	.61	.51	.45	.44	.38	.39	.39	(.34)	.43	.50	.53	.52	.54	.56	.58	.56	.56	.64	.68	.70	.78	.50	328
Oct.	.80	.73	.63	.55	.55	.48	.45	.38	.36	.33	(.33)	.41	.45	.48	.47	.47	.53	.56	.58	.67	.71	.73	.75	.79	.55	336
Nov.	.72	.65	.50	.41	.42	.40	.35	.29	.29	.27	(.25)	.30	.33	.39	.39	.40	.44	.50	.53	.53	.56	.59	.67	.63	.49	330
Dec.	.71	.62	.50	.44	.40	.37	.33	.30	.26	.26	(.21)	.27	.30	.30	.32	.40	.39	.43	.45	.48	.55	.63	.63	.66	.13	330

* For explanation of brackets see § 3.

PLATE I

To face p. 8.

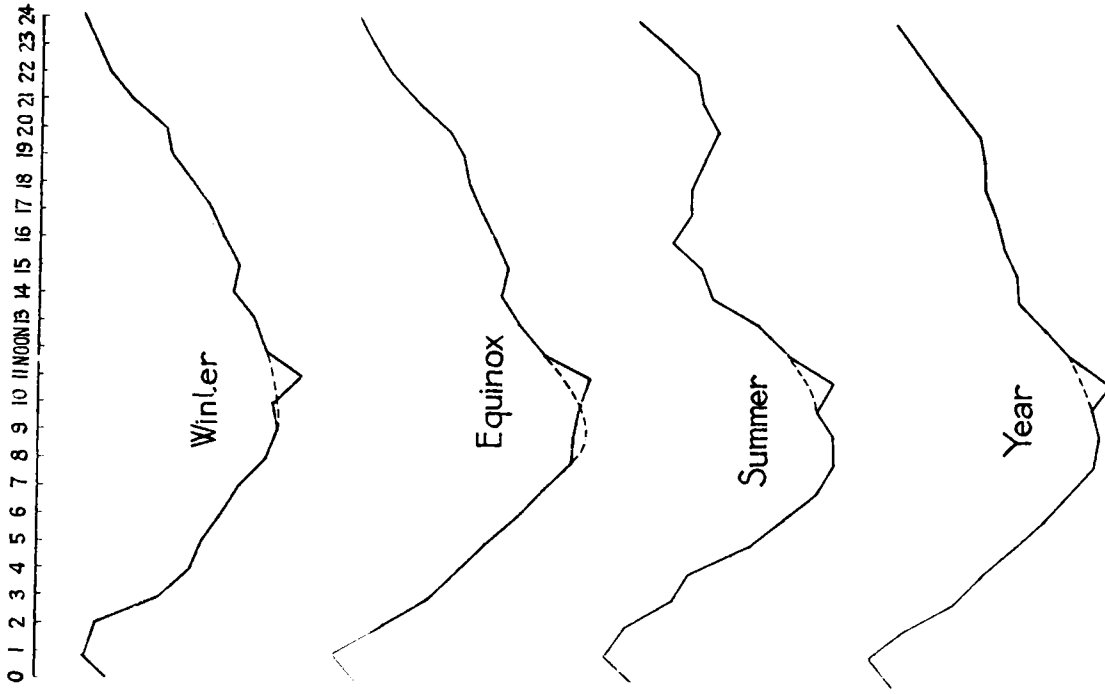


Fig 1.- Mean Diurnal Variation of Total Character:

Derived from Hourly Characters assigned throughout the 11 years, 1913-23.

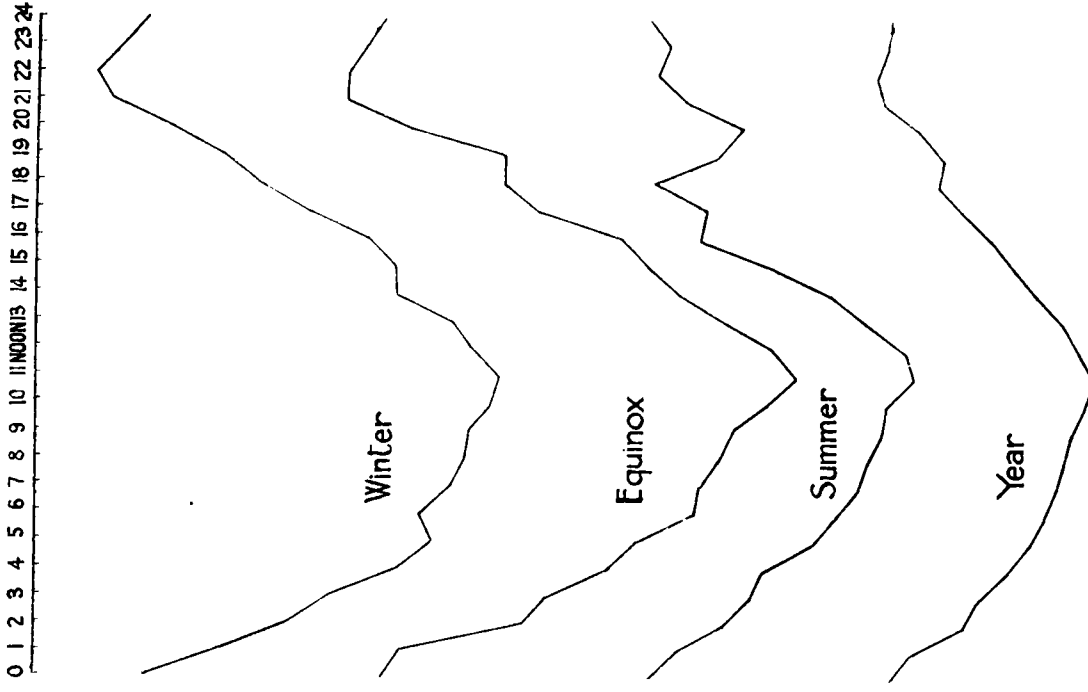


Fig 2.- Mean Diurnal Variation of Character 2.

PLATE II

To face p. 9.

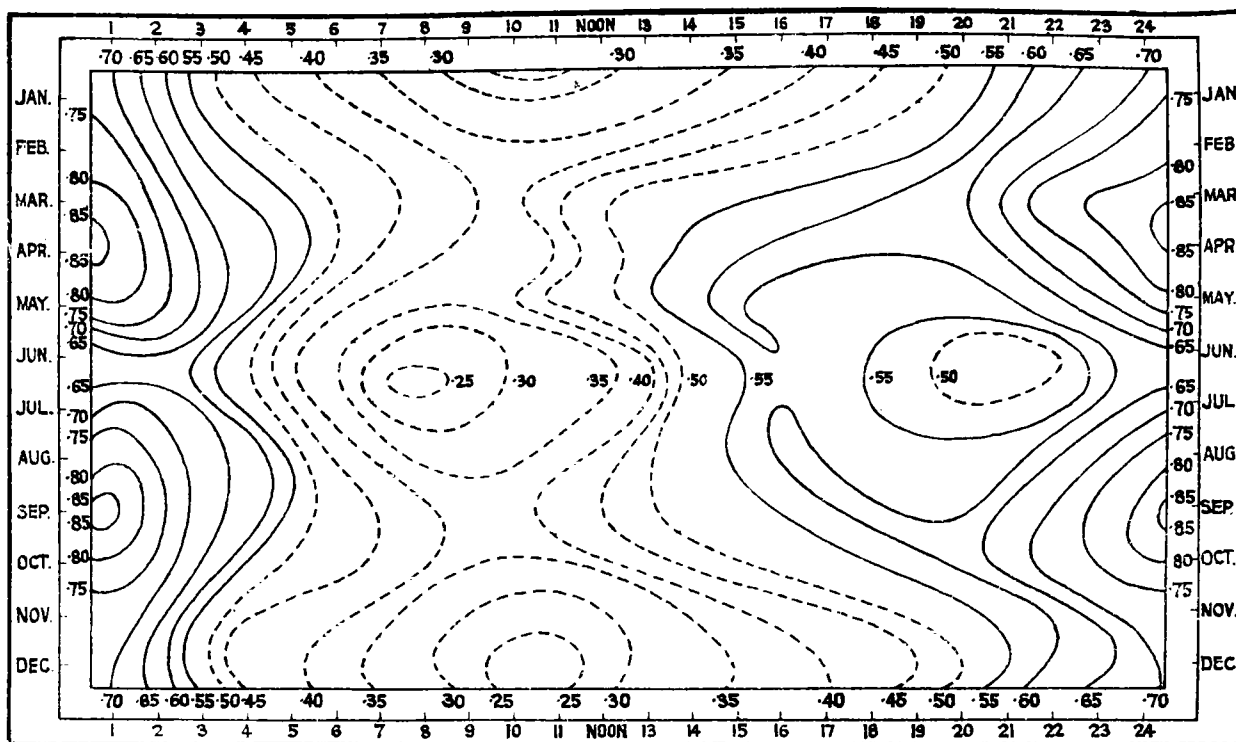


Fig.3.- Isopleths of "Total" Hourly Character Figures
at Kew Observatory, (1913-23)

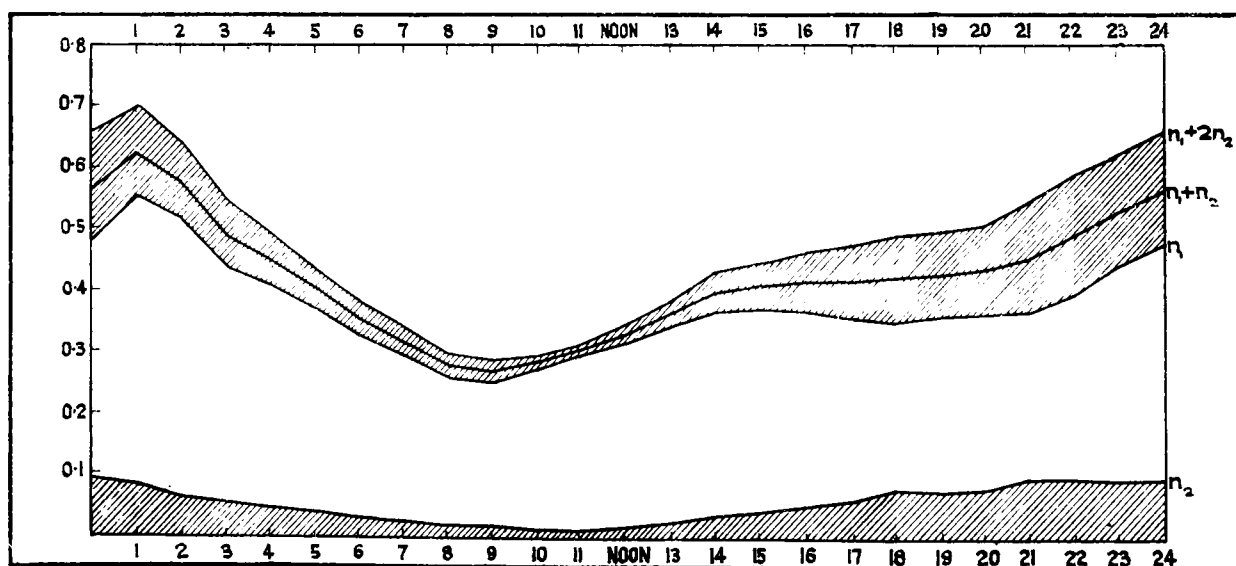


Fig.4.- Contribution of Component Figures to the Total Character
Variation for a Mean Day, (1913-23)
(n_1 represents the number of 1s, n_2 the number of 2s for each hour.)

total to be meant. In these statistics the progressive change from month to month becomes more evident but the accidental and artificially introduced effects naturally show up more conspicuously. Only one or two additional features make their appearance :—

- (1) The incidence of a preliminary maximum before midnight in two months of the year, March and November, and the suggestion of a similar tendency in the other months grouped around the winter solstice.
- (2) In opposition to this, the rise after the late afternoon secondary maximum to the midnight and 1h. maximum is exceptionally quick and regular in the summer months.
- (3) A trace of an excrescence occurring about 4h. (or 5h.) in the generally smooth declension from 1h. to 8h. (or 9h.) is more likely to be attributable to accidental effects than to purely physical phenomena.

The month to month changes in a diurnal variation can be appropriately summarized in an isopleth diagram. Such a diagram, Plate II, Fig. 3, has been constructed for the total character variations over the entire 11-year period after smoothing the most outstanding irregularities in the statistics.

§ 5. THE DIURNAL VARIATION IN THE FREQUENCY OF CHARACTER "2."

In order to examine the part played by the more violently disturbed hours in the daily distribution shown by the "total" character figures, the monthly totals of 2's alone were extracted. Sums were obtained for each of the groups of eleven months of the same name and from these the seasonal and annual mean sequences shown in Table IV were computed. They are represented diagrammatically in Plate I,

TABLE IV.—FREQUENCY DISTRIBUTION OF HOURLY TOTALS OF 2'S
THROUGHOUT THE YEAR AND SEASONS.

Hour	..	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total.
Winter	..	108	82	66	41	30	35	24	19	18	10	7	18	24	44	45	54	75	93	108	126	147	153	144	134	1604
Equinox	..	158	113	106	83	73	52	50	43	38	26	15	24	40	58	69	78	109	121	120	155	178	174	171	165	2219
Summer	..	98	81	72	67	48	40	33	30	25	23	13	16	30	43	64	91	88	109	85	76	96	107	102	110	1548
Year	..	364	276	244	191	151	127	107	92	81	59	35	58	94	145	178	223	272	323	313	357	421	434	417	409	5371

Fig. 2. Some interesting sidelights are thus thrown on the deductions made from the total characters :—

- (1) While the maximum for the total character figure occurs without exception in the first hour of the day, that for the 2's alone is invariably in the late afternoon and evening. The decided advancement of the time of incidence from a mean position of 22h. in the winter half of the year to 18h. in the summer half is too well marked to pass unnoticed. (See Table V, the symmetry of which is striking.)
- (2) Though the criterion for a 2 was too well defined to allow allocation of 2's to be alone responsible for the previously mentioned anomaly† at 11h. in each set of means, yet the persistence of the minimum of 2's at that hour attracts immediate attention in view of the variation in the total character figure. The general smoothness of the curves in the region of 11h. is too definite to question the reality of the incidence there and the constancy of its position is made especially apparent when the seasonal graphs for 2's are compared with the corresponding runs for total figures.
- (3) The development of the afternoon maximum is even more conspicuous in the distribution of 2's than in the combined characters. In the four winter months scarcely any break in the regularity of the run of the hourly

TABLE V.—TIME OF INCIDENCE OF "2" MAXIMUM.

Hour	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
16	—	—	—	—	$\frac{1}{2}$	—	—	—	—	—	—	—
17	—	—	—	—	$\frac{1}{2}$	—	—	—	—	—	—	—
18	—	—	—	—	$\frac{1}{2}$	1	1	—	—	—	—	—
19	—	—	—	—	—	—	—	—	—	—	—	—
20	—	—	—	—	—	—	—	—	—	—	—	—
21	—	$\frac{1}{2}$	—	—	—	—	—	—	—	1	—	—
22	1	$\frac{1}{2}$	1	—	—	—	—	—	1	—	—	1
23	—	$\frac{1}{2}$	—	—	—	—	—	—	—	—	1	—
24	—	—	—	1	—	—	—	1	—	—	—	—

totals of 2's from mid-day to the 22h. maximum is caused by the afternoon secondary, but in the summer sequence, the afternoon maximum is the predominating aspect of the daily distribution—supplying, as it does, the principal maximum of the day at 18h.

- (4) Finally, the slightly perceptible excrescence about 4 or 5h. in some months in the total character figures re-appears in the winter totals of 2's in the neighbourhood of 6h. and in some individual months (especially later autumn and winter) somewhat noticeably so. Its genuineness, however, seems still questionable.

§ 6. CONTRIBUTION TO THE TOTAL DAILY VARIATION MADE BY COMPONENT FIGURE 1.

Up to this point there have been examined (1) the variations in the general magnetic disturbance throughout the day, and (2) the variations in the incidence of the specially disturbed hours symbolized by the character "2."

There remains to be analyzed the behaviour of the mild or moderate disturbance. For this purpose totals of 1's alone were extracted from the monthly sheets. Since the contribution of these disturbances formed, throughout the whole period, a considerable fraction of the total hourly figure, the computation of hourly characters from 1's alone results in means which are of decidedly more significance than those from the corresponding totals of 2's and are accordingly used in the subsequent investigation. Hence, while seasonal totals were given for the 2's, mean hourly character figures are derived for the discussion of the distribution of 1's. The final figures reduced to annual and seasonal mean diurnal variations are reproduced below (Table VI).

TABLE VI.—SEASONAL CHANGE IN DIURNAL VARIATION OF DISTURBANCE DEDUCED FROM "1's" ALONE.

Hour ..	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Mean.
Winter..	57	53	43	41	40	36	34	30	28	30	(25)	30	31	33	31	32	32	34	35	34	37	41	45	48	37
Equinox	61	58	50	48	44	41	37	32	32	33	(32)	41	43	46	43	41	40	41	42	40	42	48	52	54	43
Summer	61	59	51	49	41	34	29	26	26	29	(27)	37	41	48	47	49	46	43	44	43	41	42	48	53	42
Year ..	60	57	48	46	42	37	33	29	29	31	(28)	31	38	42	40	41	40	39	40	39	40	44	49	52	41

As is to be expected, an examination of average diurnal variations in this moderate disturbance figure explains the more obvious divergences between the total characters and the distribution of the more stormy hours. Thus seasonal variation of the time of incidence of the minimum of total character figure in the morning is seen to be

† Vide § 3.

compatible with the persistence of that of the 2's when the very decided shift in the time of moderate disturbance is noted. Examination of the mean daily distributions for the three separate seasons suggests an advancement of fully two hours in the minimum from shortest to longest "day," being just after 10h. at the winter and not far from 8h. at the summer solstice. The time of equinoctial incidence is practically mid-way between these, thus giving a mean time for the year about 9h.

Although the afternoon crest is quite conspicuous the summer development is not so marked as in the case of the disturbed hours, never approaching the stage of supplying the main maximum of the day as happens in that case. The increase in separation of the minimum of the 24-hour variation and the secondary crest with increasing length of daylight at Kew is as noticeable as with the 2's, though the time of maximum development of the crest of the latter seems about 2 hours later than that for the more moderately disturbed hours.

It may also be worthy of note that, whereas in the case of the 2's the three seasonal mean diurnal variations conspire together to give an annual sequence which presents little remaining evidence of such a marked afternoon maximum as existed in summer, the corresponding mean diurnal variation of 1's retains a decided (though flattened) trace of the same effect in moderate disturbance.

A diagrammatic representation of the total character variation and that of the constituent figures is given in Fig. 4, Plate II. The values from which the graphs are derived are all on the standardized basis and the 11h. irregularity has been bridged over in the case of the 1's, 1 + 2's and "total" sequences. The main features of similarity and disparity are thus brought out simultaneously.

§ 7. THE RANGE OF THE DIURNAL VARIATION AND MEAN CHARACTER IN SEASON AND YEAR.

Some further points of interest in the mutual contribution of the two intensities of disturbance to the total daily run of magnetic character and the variations of this contribution throughout the year are brought out in the subjoined Table VII.

TABLE VII.—SEASONAL DIFFERENCES IN RANGE OF VARIATION AND PERCENTAGE CONTRIBUTION OF COMPONENTS TO TOTAL FIGURE.

				Range of Diurnal Variation from Smoothed Minimum.				Percentage of Year's Mean Figure.		
				Winter.	Equinox.	Summer.	Year.	Winter.	Equinox.	Summer.
Total character	..	..	..	0.40	0.45	0.42	0.41	90	110	97
2's alone	..	..	..	1.46	1.63	0.97	1.33	89	124	86
1's alone	..	..	..	0.30	0.31	0.35	0.31	90	106	104

The first half of the table concerns the range (maximum value *minus* minimum value) derived from each of the mean seasonal and annual daily variations by smoothing the hourly values in the neighbourhood of 11h. where necessary. In the case of the total character and 1's alone the entries are mean hourly character figures; for the 2's the direct hourly totals of the number of occurrences of 2 are employed as in the previous discussion. The second portion of the table gives the mean seasonal figures (or totals) in terms of the mean (or total) for the whole year.

In both sections of the combined character figure results the equinoctial figures conspicuously exceed those of the two other seasons and the summer range and mean are well above those of the winter. This last relation is more exaggerated in the case of moderate disturbances. Indeed, the summer range is here decidedly superior even to that of the equinox. For the 2's, however, the results are somewhat different. The equinoctial figures are more markedly in excess of the solstitial seasons and winter now shows both a wider diurnal range and a higher mean than summer, though the excess in the latter case is not great.

§ 8. BIDLINGMAIER'S DIAGRAMS.

Diagrammatic representation in a limited space of simultaneous variations of three or four quantities (as 0, 1, 2, and total characters) is somewhat cumbersome, and though graphs assist in giving pictures of isolated broad variations they fail to convey an adequate idea of the course of events as related to the sun which is presumably the source of all the changes. A method introduced by Prof. Bidlingmaier, late of Wilhelmshaven Magnetic Observatory, goes some way to meet these requirements. The 11-year mean diurnal variation of total characters given in Table II has been represented according to his scheme in Fig. 5, Plate III, together with the daily distribution of frequency of 2's (Fig. 6). The diagrams are self-explanatory.

§ 9. THE DISTRIBUTION OF DISTURBANCE DERIVED FROM OTHER SOURCES.

During the course of this investigation it has been found that hourly character data are available for other stations though over limited periods. Thus, in the volume discussing the magnetic results of the British Antarctic Expedition, 1910-13, Dr. C. Chree has given monthly mean daily distributions of what, in this paper, have been called "total" character figures, as well as frequencies of 0's and 2's for the Eskdalemuir curves over the 22 months February, 1910, to November, 1911. Corresponding sequences are also given for the Antarctic state of affairs throughout the same period. Since the figures are fully published in that volume (pp. 150-6) they are not reproduced but those relating to the Eskdalemuir data are partially represented according to Bidlingmaier's plan (Figs. 7 and 8, Plate III) in a manner similar to that for Kew above. The scales of the diagrams in the two cases are not the same, the day's mean value is, however, shown by a dotted line.

The fifth diagram after Bidlingmaier's style (Fig. 9) represents material derived from a somewhat different source. During the years 1918 to 1924 the Kew magnetic curves were examined weekly with a view to notifying the Institute of Mining Engineers of the occurrence of periods of large disturbance. For this purpose the day 0h. to 24h. was divided into 12 two-hourly periods. The records of these "stormy" intervals have been examined and totals found for the $6\frac{3}{4}$ years (April, 1918, to December, 1924) over which figures are available. These totals are shown in Table VIII below. The final distribution as shown in Fig. 9, Plate III is seen to agree in its main features with those for the Kew and Eskdalemuir single hourly distribution of 2's.

TABLE VIII.—DISTRIBUTION OF 2-HOURLY PERIODS OF LARGE DISTURBANCE (KEW).

Hour	Number of Occurrences of large Disturbance in each 2-hourly interval.												Total.
	0/2	2/4	4/6	6/8	8/10	10/12	12/14	14/16	16/18	18/20	20/22	22/24	
1918*	14	12	8	2	1	1	3	7	15	26	30	24	143
1919 ..	25	21	10	7	2	1	3	8	23	35	32	26	193
1920 ..	14	12	11	4	2	2	5	7	13	20	19	18	127
1921 ..	14	16	9	7	5	3	4	10	11	14	16	15	124
1922 ..	18	19	12	7	3	2	3	15	19	22	21	16	157
1923 ..	6	6	3	—	—	—	1	3	5	6	6	5	41
1924 ..	9	9	2	1	1	—	—	2	5	8	11	12	60
Totals ..	100	95	55	28	14	9	19	52	91	131	135	116	845

* Figures derived from 9 months.

PART II—SUNSPOT RELATIONS TO THE VARIATION OF DISTURBANCE

§ 10. CHANGE IN DIURNAL VARIATION WITH PROGRESSION THROUGH THE SUNSPOT CYCLE.

Up to the present point the eleven years have been treated merely as representative years for furnishing monthly and seasonal mean variations of character figures. The vicissitudes of solar activity in the whole cycle together with their

PLATE III

To face p. 12.

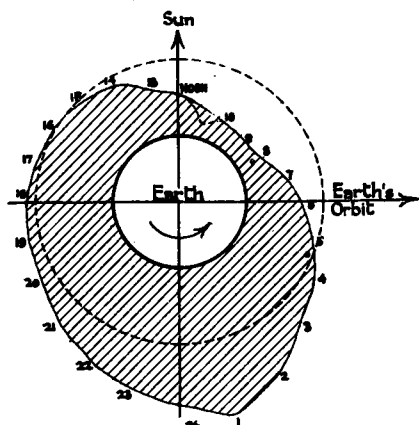


Fig. 5 - Diurnal Variation of Total Character Figures, Kew, 1913-23.

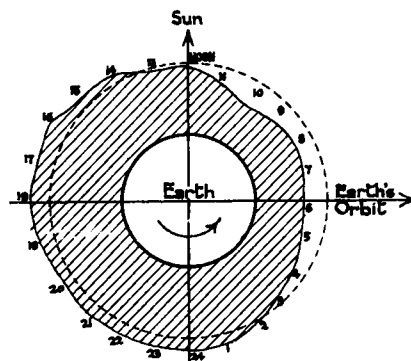


Fig. 7 - Diurnal Variation of Total Character. Eskdalemuir, 1910-13.

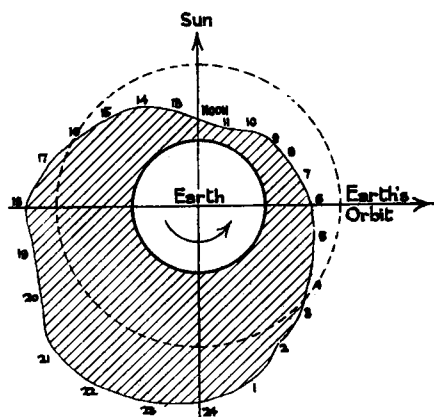


Fig. 6 - Diurnal Variation of Character Figure 2 (11 years' mean at Kew).

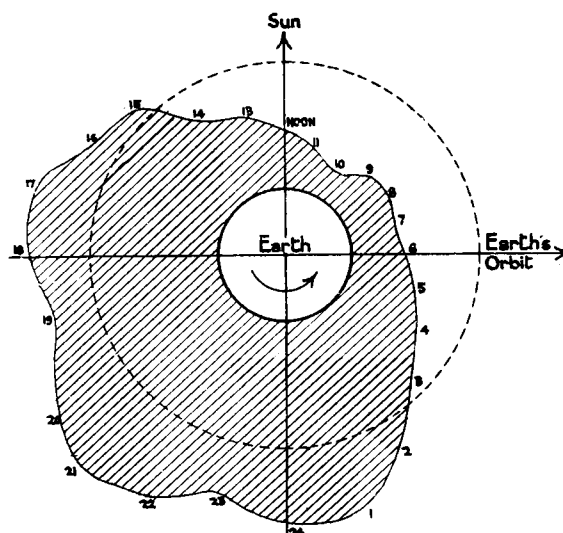


Fig. 8 - Frequency of 2's as percentage of Days Mean, Eskdalemuir, 1910-13.

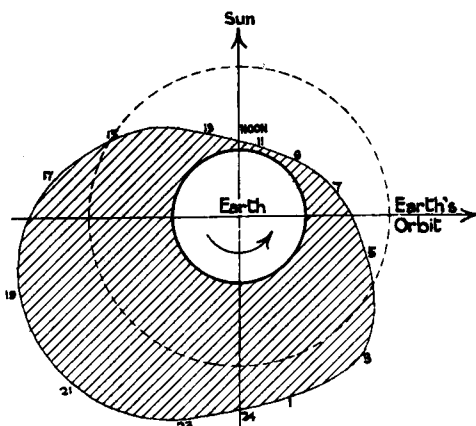


Fig. 9 - 2-Hourly Intervals of Disturbance, Kew, 1918-24.

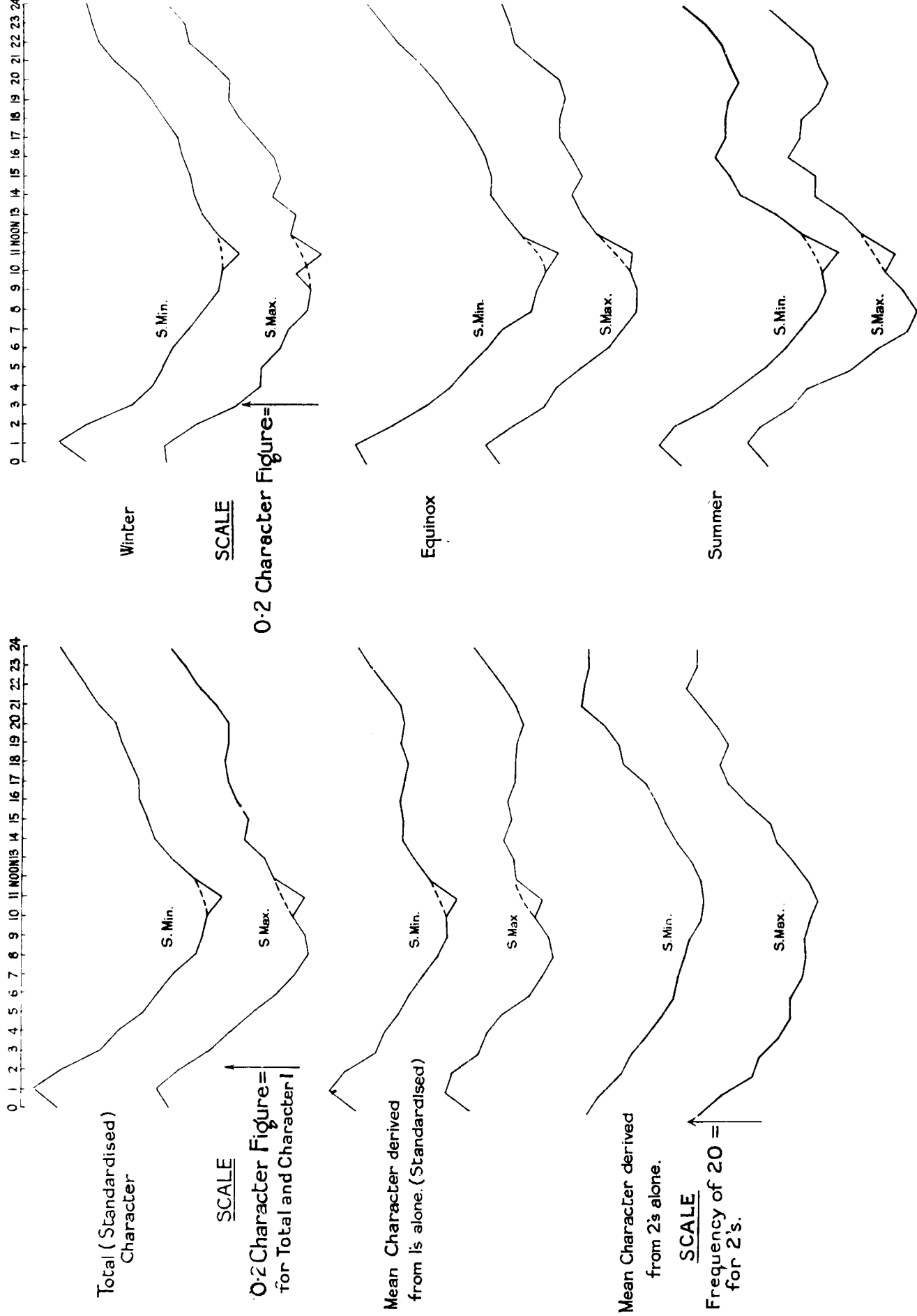


Fig. 10 - Change in Diurnal Variation from Years of Many to Years of Few Sunspots.

Fig. 11 - Change in Diurnal Variation of Total Character Figures with Sunspottedness (for 3 seasons).

probable influence on magnetic hourly characters have not been considered. The analysis is now directed to that end. In the computation the monthly totals of hourly figures were re-arranged according to years and mean diurnal variations were obtained for the total and component characters. Then, since each year was to be treated on its own merits (not, as in the previous sections, making partial contributions to a heterogeneous total) it was essential that, as far as possible, any change of standard from one year to the next should be eliminated. The standardizing factors whose significance has been explained earlier, were therefore applied appropriately to each year and mean hourly values computed for years of less and years of greater sunspottedness, taking as representative of the former 1913, '14 and 1920, '21, '22 and '23 with a mean (relative) sunspot number of 15.8, and of the latter, 1915 to 1919, with a corresponding mean of 70.5. The means for the two groups of years (described in the tables as "S. min." and "S. max." years) are given in Table IX for total as well as for the two component figures. For the reasons stated above, the figures for the 2's alone appear as hourly totals throughout each year in question, not in the form of means as for "total" and 1 characters. Graphical representations appear in Fig. 10, Plate IV.

TABLE IX.—RELATION BETWEEN DIURNAL VARIATION OF TOTAL AND COMPONENT CHARACTERS AND SUNSPOT EPOCH.

(a) Mean "total" hourly characters.

Hour ..	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Mean
Mean ..	.70	.63	.54	.49	.44	.38	.34	.30	.29	.30	*	.34	.38	.43	.44	.46	.47	.49	.50	.51	.55	.59	.62	.66	.46
S. min.	.66	.59	.49	.45	.39	.34	.30	.25	.23	.22	(.18)	.26	.31	.36	.38	.39	.40	.42	.44	.46	.50	.53	.57	.61	.41
S. max.	.75	.69	.60	.56	.50	.43	.39	.35	.36	.39	(.36)	.45	.47	.53	.51	.55	.56	.58	.56	.56	.60	.65	.68	.71	.53
1913-15	.66	.58	.46	.43	.42	.43	.41	.35	.34	.36	(.32)	.39	.41	.46	.45	.48	.50	.51	.49	.46	.48	.52	.54	.58	.46
1916-19	.76	.71	.63	.59	.52	.42	.37	.33	.34	.37	(.34)	.43	.47	.52	.51	.55	.56	.57	.57	.57	.61	.66	.69	.73	.54
1920-23	.67	.60	.52	.45	.38	.31	.26	.22	.19	.18	(.14)	.21	.28	.33	.35	.37	.37	.40	.43	.48	.53	.57	.61	.63	.39

(b) Mean character figures from 1's alone.

Hour ..	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Mean
Mean ..	.54	.51	.43	.41	.37	.33	.29	.26	.25	.27	(.25)	.32	.34	.37	.36	.37	.35	.35	.36	.37	.36	.39	.43	.47	.36
S. min.	.50	.46	.37	.35	.31	.29	.25	.21	.19	.20	(.17)	.24	.28	.31	.30	.31	.30	.29	.31	.30	.31	.35	.39	.43	.31
S. max.	.59	.58	.50	.48	.44	.37	.35	.32	.33	.36	(.34)	.41	.42	.45	.42	.43	.41	.42	.42	.40	.41	.44	.49	.53	.43
1913-15	.58	.53	.41	.40	.38	.39	.38	.33	.33	.34	(.31)	.38	.38	.41	.40	.41	.42	.44	.41	.39	.40	.41	.44	.49	.41
1916-19	.60	.59	.53	.51	.46	.37	.33	.30	.30	.34	(.32)	.40	.42	.44	.42	.43	.40	.41	.42	.39	.41	.45	.49	.54	.43
1920-23	.45	.42	.36	.31	.28	.24	.19	.17	.15	.15	(.12)	.19	.23	.27	.26	.27	.25	.23	.27	.27	.28	.32	.37	.39	.27

* The significance of the brackets in Sections (a) and (b) is explained in § 3.

(c) Diurnal distribution of component 2.

Hour ..	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Mean
Mean ..	29.2	22.2	20.0	15.5	12.3	10.2	8.3	7.1	6.4	4.7	2.7	.46	7.6	11.5	14.1	17.7	21.7	25.9	25.2	28.9	34.0	35.2	33.7	33.3	18.0
S. min.	29.8	24.0	21.5	17.3	13.7	10.2	9.2	7.7	6.2	3.8	2.2	3.7	6.0	9.5	12.8	14.8	17.5	23.7	24.2	28.3	34.5	33.3	32.8	32.5	17.5
S. max.	28.4	20.0	18.2	13.4	10.6	10.2	7.2	6.4	6.6	5.8	3.4	5.8	9.6	14.0	15.6	21.2	26.8	28.6	26.4	29.6	33.4	37.4	34.8	34.2	18.7
1913-15	13.0	9.0	9.0	5.3	6.3	6.3	4.0	3.3	3.3	3.3	1.3	3.0	4.7	8.0	9.3	11.7	13.3	12.3	15.0	12.3	14.7	18.7	17.7	16.3	9.2
1916-19	30.2	21.9	19.0	14.0	10.7	10.2	6.7	6.5	7.0	5.7	3.7	6.0	9.7	14.2	16.5	21.9	28.2	29.7	27.2	32.0	36.7	38.5	35.7	35.2	19.5
1920-23	40.2	32.2	29.2	24.7	18.2	13.0	13.0	10.5	8.0	4.7	2.7	4.5	7.7	11.5	15.2	18.2	21.5	32.2	30.7	38.2	45.7	44.2	43.7	44.0	23.1

NOTE.—The entries in italics are the principal *real* minima for each mean daily variation, due regard being given to the 11h. discontinuity.

§ 11. DISCUSSION OF THE INFLUENCE OF SUNSPOTS ON THE DIURNAL VARIATION.

(a) *Total character*.—Examination of the figures (or graphs) of total character variations for sunspot-minimum and sunspot-maximum years discloses some features of interest.

- (1) While the maximum of the day remains fixed at 11h. the minimum shows a decided advance from 10h. to 8h. (or 8h. 30m.) in passing from years of less to years of greater sunspottedness.
- (2) The range of the mean daily run from a rounded minimum (i.e., omitting the 11h. irregularity) deepens from 0.395 in years of few to 0.445 in years of many spots. In terms of percentage of the mean for the separate groups, these are 109.6 per cent and 74.3 per cent respectively.
- (3) There is an indication of better development of the afternoon secondary maximum in sunspot maximum than in sunspot minimum years. This is more easily recognizable in the figures for separate years, especially those in the descending phase of the sunspot cycle. Thus in 1917 the secondary maximum is comparatively well developed whereas in 1923, in the trough of solar activity, its detection is difficult. (This same set of years, 1917-23, also provides conspicuous illustrations of the two preceding points.)
- (4) The mean hourly character figure over the five years of high spot value shows an increase of 31 per cent over that for the remaining six years.

(b) *Hours of intensity "1."*—Similar features are discernible in the case of the constituent character 1; the times of incidence of daily minimum and range of variation (from the graphs) being as follows:—

		<i>Time of Occurrence of Minimum</i>	<i>Range of daily Variation (as percentage of mean).</i>
		<i>h. m.</i>	
S. Min. years	..	9 30	78.4
S. Max. years	..	8 15	63.7

The mean hourly character figures show a 39 per cent increase in passing from the years of minimum to maximum activity.

(c) *Hours of intensity "2."*—In the case of the 2's, however, this most salient peculiarity of the shift of the minimum of the daily variation of disturbance is absent. The comparative paucity of 2's in the middle hours of the day is so marked in any case that the anomaly introduced into the other figures by a broken trace is not likely to have had a great influence on the frequency of 2's at that hour; and since, further, the general trend of the neighbouring figures also points to the same hour, it may reasonably be accepted as the hour of the permanent minimum of more intense disturbance. The range likewise shows little disposition to vary from one set of years to another, being 18.5 and 18.2 respectively for years of low and high frequency of sunspots when expressed as percentages of the appropriate means. The mean hourly frequency of occurrence increases but slightly from minimum to maximum years, the figures for these groups being 17.5 and 18.7 respectively.

§ 12. CHANGE OF VARIATION WITH EPOCH OF SUNSPOT CYCLE.

In order to ascertain whether the two main results of the above analysis, viz.:—

- (1) The apparent advancement of the time of occurrence of daily minimum with solar activity, and
- (2) The deepening of the range from sunspot maximum to sunspot minimum years,

actually arose from change in sunspottedness and were not accidental effects introduced by the grouping of years, the annual mean variations were re-arranged into three groups instead of two, taking 1913, '14 and '15 as preliminary years, 1916-19

as maximum years and the remainder 1920-23, as years of subsequent low activity. The final means for each of these groups have been incorporated in Table IX beside those of the simple grouping. The figures are represented graphically on Plate V (facing page 20). The main results of this re-arrangement are given below (Table X).

TABLE X.—CHANGE OF DIURNAL VARIATION CHARACTERISTICS WITH PHASE OF SUNSPOT CYCLE.

Group of Years used	Time of Incidence of Principal daily minimum			Mean Character			Range of Diurnal Variation.					
							In Absolute Measure			As Percentage of Mean		
	Total	1	2	Total	1	2	Total	1	2	Total	1	2
	h. m.	h. m.	h. m.									
1913-1915 ..	9 0	9 0	11 0	0.46	0.41	9.2	0.32	0.26	17.4	70	63	53
1916-1919 ..	8 15	8 15	11 0	0.54	0.43	19.5	0.43	0.30	34.8	80	70	56
1920-1923 ..	10 30	9 15	11 0	0.39	0.27	23.1	0.50	0.30	43.0	79	89	54

Section 1 of this table thoroughly substantiates the deductions made from the previous grouping :—

- (1) So far as the total characters and those derived from 1's alone are concerned the principal minimum of the diurnal variation advances by 45 minutes in passing from the first to the second group of years and is retarded by a decidedly longer interval in the succeeding period of diminishing solar activity. The incidence of the "2" minimum on the contrary remains persistent at 11h. throughout the entire cycle.
- (2) The results for the range of the variation on the other hand are not so consistent. For though percentages of the mean figure in the case of total characters show little difference in the maximum and descending phases of the cycle, those for 1's appear to increase progressively through the three groups, while the figures representative of larger disturbance follow the varying phases of the cycle. Thus, the result obtained from the direct grouping of years according to sunspot value appears to owe its origin largely to the occurrence of years of unusually large range at the latter end of the cycle in the group representative of lower solar activity. This conclusion, however, seems to require further investigation. For such a sequence of values as those provided by the three years, 1913, '14 and '15 (*vide infra*) seem to lend weight to the first result. It also corroborates the general impression formed during the actual process of assignment of characters, to the effect that periods of maximum solar activity (as judged by sunspottedness) are characterized rather by a more or less *continuous* state of small and moderate disturbance. The probability of the incidence of large well-defined storms, on the contrary, is greater for the less active years, especially those in the descending phase of the cycle.

Year.	Sunspot Number.	Mean Magnetic Character.	Range of Diurnal Variation.	Range as percentage of mean.
1913	1.4	0.39	0.37	95
1914	9.6	0.46	0.35	75
1915	47.4	0.52	0.26	50
1922	14.2	0.47	0.41	88
1923	5.8	0.32	0.52	162

Thus with the mid-day hours relatively calm, the well marked daily distribution in the incidence of 2's should ensure exaggeration of the diurnal variation in years of low sunspot value, while continuous moderate disturbance in periods of higher solar activity would serve only to level the mid-day with the midnight hours.

§ 13. SUNSPOT INFLUENCE ON THE MEAN SEASONAL DIURNAL VARIATION.

To investigate the change in the seasonal variation of the daily run of characters these latter were re-arranged to allow grouping of years according to their degree of sunspottedness, the same sets of years being accepted as representative of low and high sunspot conditions. (It should be noted here that any apparent slight discrepancies in the figures appearing in the following and other "deduced" tables are to be accounted for by the fact that all character entries were originally made in three figures and means obtained on this basis. Partly from the point of view of an economy of figures and partly from a sense of probably unwarranted efficiency arising from the use of a third figure even though derived from such an extended set of data, the tables were re-formed only two figures being retained in the new set.) Table XI contains the final mean variations and Fig. 11, Plate IV, shows the course of events graphically.

TABLE XI.—INFLUENCE OF SUNSPOTTEDNESS ON THE MEAN SEASONAL DIURNAL VARIATION OF TOTAL CHARACTER FIGURES.

Hour ..	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Mean.
Winter											*														
S. min.	.61	.53	.42	.37	.33	.31	.27	.23	.19	.18	(.14)	.20	.24	.26	.27	.29	.30	.33	.37	.40	.47	.50	.52	.53	.34
S. max.	.73	.66	.55	.48	.49	.43	.41	.36	.36	.39	(.33)	.40	.39	.46	.44	.45	.49	.54	.58	.56	.61	.67	.68	.73	.51
Equinox																									
S. min.	.73	.63	.55	.48	.45	.40	.35	.28	.27	.24	(.21)	.30	.35	.38	.39	.40	.42	.45	.49	.52	.57	.62	.67	.70	.45
S. max.	.80	.73	.65	.62	.56	.47	.45	.41	.40	.42	(.42)	.50	.54	.57	.55	.57	.60	.60	.59	.61	.67	.72	.74	.75	.38
Summer																									
S. min.	.64	.60	.51	.48	.38	.33	.28	.24	.22	.23	(.19)	.28	.35	.43	.47	.50	.48	.48	.47	.45	.47	.49	.53	.59	.42
S. max.	.71	.68	.61	.57	.46	.39	.31	.29	.32	.36	(.34)	.43	.47	.55	.54	.62	.59	.58	.54	.52	.54	.55	.61	.67	.51

* For the meaning of the brackets see § 3.

The chief points of note arising from this table have been extracted (by the aid of the smoothed graphs in Plate IV) and are set out below (Table XII).

TABLE XII.—SUNSPOT INFLUENCE ON SEASONAL CHANGE OF DIURNAL VARIATION CHARACTERISTICS.

Season ..	Mean Total Character			Time of Incidence of Daily Minimum			Range of Diurnal Variation					
	W.	E.	S.	W.	E.	S.	In Absolute Measure			As Percentage of Mean		
Season ..	W.	E.	S.	W.	E.	S.	W.	E.	S.	W.	E.	S.
Sunspot minimum ..	.34	.45	.42	h. m. 10 30	h. m. 10 0	h. m. 9 0	.43	.49	.43	124	109	101
Sunspot maximum ..	.51	.58	.51	9 30	8 30	7 30	.37	.39	.42	74	68	83

- (1) From the first section showing the mean total character in years of few and years of many sunspots, winter appears to be most markedly influenced by sunspottedness, the percentage increase from the former to the latter group being 48 for this season compared with 28 and 17 for equinoctial and summer months respectively. This appears to corroborate results obtained by the application of Wolf's formula $R = a + bs$ to the investigation of the relations existing between sunspot frequency and terrestrial magnetism. For these have already shown that the relative influence of sunspottedness on magnetic variations reaches a maximum in the winter season of each year on the average.
- (2) Advancement of the time of incidence of the daily minimum of disturbance with increased solar activity is equally conspicuous in all seasons. The times given in the second section of this table are grouped on either side of the mean times for the entire run of days as given in §4. The mean variations for both sunspot maximum and sunspot minimum groups also show the

minimum occurring earlier in summer than in winter—a result already noted for the general seasonal variations.

- (3) In view of the remarks made above concerning the influence of solar activity on the range of daily variation of disturbance, the third section of Table XII is of interest, showing as it does a general *increase* of range with *decrease* of sunspottedness, and therefore, as the first part of the table makes clear, with decrease of total character. While no more than evident in summer this deepening of range is quite conspicuous in winter but most marked in the equinoctial months when the net increase amounts to 26 per cent of the mean sunspot maximum range. In order to eliminate spurious effects which would be introduced by change of standard in different groups of years, the ranges are also given as percentages of the means for the respective sequences involved.
- (4) A tendency for the afternoon secondary to exhibit better development in sunspot maximum than in minimum years was noted in another connexion and the present figures seem to substantiate the result.

PART III.—LARGER SCALE VARIATIONS OF CHARACTER FIGURES

§ 14. TREATMENT OF MONTHLY MEANS AND DISCUSSION OF ANNUAL VARIATION.

As in the case of the distribution of character figures throughout a large number of days contributed to equally by each of the 11 years, the probable subjective variation of the standard in the original assignment from one year to another or one group of years to another group could have little influence on the sequence of monthly totals of figures in individual years. Hence, in the examination of the intro-annual variation, the reduction to a common standard basis was in the first instance treated as an unnecessary refinement. In view, however, of some differences in the incidence of seasonal maxima and minima disclosed by the final means and those derived from the daily character figures assigned at Kew to the *D* and *H* curves the monthly characters were set on the common basis determined by the 2-monthly cross section; that is, the original runs were multiplied by factors varying from 0.737 in 1922 to 1.157 in 1923, as shown in Table I. This was done alike for total and component characters.

To justify such a procedure, it had to be assumed that the standards for the two components, 1 and 2, varied *pari passu*. The figures showing the separate totals derived from the independent characterizations of March and August, however, would rather tend to indicate that, while in both cases the standard for a 1 had remained practically steady, that for a 2 had been raised. Without discussing reasons for this change (they are sufficiently obvious), it can safely be assumed that the error introduced by treating the two variations as taking place concurrently is almost negligible. For, on the average, the contribution of the frequency of 2's to a month's total character does not exceed 5 per cent of the possible contribution, and therefore, the replacement of a fraction of this share by the smaller figure 1 leads to little change.

TABLE XIII.—ANNUAL VARIATION OF MEAN MONTHLY CHARACTERS ON TWO BASES.

Mean Daily Occurrence	Estimate	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1's	Original ..	9.35	9.69	10.63	10.68	10.87	9.36	9.89	10.47	10.69	9.53	8.21	7.94
	Revised ..	8.39	8.69	9.49	9.54	9.72	8.34	8.78	9.29	9.61	8.57	7.32	7.21
2's	Original ..	1.26	1.18	1.85	1.58	1.50	0.81	0.98	1.30	1.39	1.83	1.30	1.13
	Revised ..	1.10	1.04	1.65	1.39	1.33	0.69	0.84	1.15	1.25	1.63	1.13	1.04

The mean monthly totals (derived from $n_1 + 2n_2$, where n_1 is the number of occurrences of hours of character 1 and n_2 the number of occurrences of character 2) on the original and revised bases are presented in Tables XIII and XIV. They are evidence that no alteration in the incidence of minimum or maximum resulted from the standardizing process, and that the relative values of individual months were hardly affected.

The final figures for "total characters" (rounded to the first place of decimals) and component figure 2 in Sections (a) and (b) respectively of Table XIV are *daily* means for each particular month. Since corresponding monthly entries for 1's alone are deducible from the Sections (a) and (b) of the table only the final monthly means derived from the 11 years and those for years of greatest and least sunspottedness are reproduced for this component (Section (c)).

The mean annual variation of total characters for the 11 years shows the two maxima coincident with the equinoctial and the minima with the solstitial months, the principal maximum falling in March and the minimum in December. A retardation of the second maximum from September to October and a transference of the principal minimum from the winter to the summer solstice are the only changes introduced by a consideration of 2's alone. The figures for moderately disturbed hours leave the two minima and the autumn maximum in the same relative positions as indicated by the total characters but the spring maximum is retarded two months to May while still retaining its position as the highest monthly value.

TABLE XIV.—(a) MEAN DAILY CHARACTER FOR EACH MONTH (b) MEAN DAILY FREQUENCY OF 2'S FOR EACH MONTH AND (c) SUMMARY OF MEANS FOR CHARACTER 1.

(a) Total character.

Year	Jan.	Feb.	Mar	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1913 ..	10.5	10.7	12.0	11.6	11.2	3.1	7.9	9.9	12.0	10.2	6.9	6.2	9.4
1914 ..	7.2	7.7	12.2	13.2	10.9	13.0	13.8	13.7	11.8	11.6	10.3	7.6	11.1
1915 ..	9.4	11.7	13.3	13.5	13.3	11.4	11.8	13.8	12.7	14.1	15.2	10.3	12.5
1916 ..	12.5	8.4	14.4	12.2	14.4	12.8	13.1	12.8	14.8	13.7	15.2	11.3	13.0
1917 ..	19.3	15.1	13.0	12.6	12.2	10.2	9.5	13.9	9.9	11.9	8.2	11.3	12.3
1918 ..	10.1	13.8	13.0	14.6	12.5	10.0	12.1	14.8	16.9	15.7	14.1	14.9	13.5
1919 ..	14.4	15.3	17.7	13.7	16.2	8.9	8.8	11.5	14.8	15.0	5.5	8.6	12.5
1920 ..	7.4	7.1	11.9	10.8	9.8	7.4	8.3	9.6	14.7	9.5	7.5	8.8	9.4
1921 ..	7.3	7.0	9.4	10.9	14.5	7.5	9.8	9.2	7.6	9.5	10.2	10.9	9.5
1922 ..	12.3	13.9	15.2	14.4	12.3	13.0	13.0	11.9	11.2	9.5	5.5	3.6	11.2
1923 ..	6.3	7.9	7.0	7.7	8.8	9.7	6.8	5.8	7.8	9.6	7.0	8.5	7.7
Mean ..	10.6	10.8	12.7	12.3	12.4	9.7	10.5	11.5	12.1	11.8	9.6	9.3	11.1
S. min. ...	8.5	9.1	11.3	11.4	11.3	8.9	10.0	10.0	10.7	10.0	7.9	7.6	9.7
S. max. ...	13.1	12.9	14.3	13.3	13.7	10.7	11.1	13.4	13.8	14.1	11.6	11.3	12.8

(b) Component " 2 "

1913 ..	0.42	0.36	0.68	0.67	0.41	0.00	0.19	0.07	0.27	0.62	0.17	0.21	0.34
1914 ..	0.16	0.00	0.48	1.07	0.32	0.53	0.94	0.71	0.33	0.52	0.50	0.29	0.49
1915 ..	0.35	0.71	0.90	1.00	0.61	0.97	0.42	0.77	1.20	2.29	2.30	0.65	1.02
1916 ..	1.03	0.34	1.90	1.17	1.23	0.70	1.03	1.16	1.20	1.71	1.63	0.81	1.16
1917 ..	2.00	0.96	0.58	0.67	0.48	0.70	0.77	2.52	0.43	1.16	0.73	1.33	1.03
1918 ..	1.10	0.86	1.13	1.33	0.77	0.63	0.42	1.48	1.43	1.61	1.87	1.94	1.21
1919 ..	2.06	1.88	2.94	1.80	2.90	0.43	0.81	1.52	1.97	2.71	0.60	1.16	1.73
1920 ..	0.77	0.93	3.28	1.47	1.19	0.43	0.77	0.94	2.23	0.84	0.50	1.13	1.21
1921 ..	1.13	1.36	1.42	1.80	3.65	0.67	1.06	1.71	1.40	2.23	2.50	2.97	1.83
1922 ..	2.61	2.86	4.07	3.30	2.16	1.93	2.52	1.58	1.93	2.03	0.87	0.23	2.17
1923 ..	0.52	1.21	0.94	1.00	0.94	0.57	0.29	0.23	1.33	2.16	0.80	0.68	0.89
Mean ..	1.10	1.04	1.67	1.39	1.33	0.69	0.84	1.15	1.25	1.63	1.13	1.04	1.19
S. min. ...	0.93	1.12	1.81	1.55	1.45	0.69	0.96	0.87	1.25	1.40	0.89	0.92	1.15
S. max. ...	1.31	0.95	1.49	1.19	1.20	0.69	0.69	1.49	1.25	1.50	1.43	1.18	1.43

(c) Component " 1 "

Mean ..	8.4	8.7	9.5	9.5	9.7	8.3	8.8	9.3	9.6	8.6	7.3	7.2	8.7
S. min. ...	6.6	6.8	7.8	8.4	8.4	7.5	8.0	8.4	8.2	7.2	6.1	5.8	7.4
S. max. ...	10.5	10.9	11.5	10.9	11.3	9.3	9.7	10.4	11.3	10.3	8.8	8.9	10.3

§ 15. RELATION OF THE ANNUAL VARIATION OF MAGNETIC CHARACTERS TO SOLAR ACTIVITY.

In view of the effects on the diurnal variation already discussed, the influence of changes of sunspottedness on the annual variation is of interest, for similar features seem to present themselves in the two cases.

(a) *Total character*.—(1) Advancement of the spring maximum from April to March and retardation of the second maximum from September to October are immediately noticeable changes in the passage from years of few to years of many sunspots. This is in substantial agreement with the results obtained from the absolute range of declination at Kew in the decade 1901-1910.†

(2). The two minima remain steady at the solstitial months. June, however, becomes the least disturbed month in sunspot maximum years.

(b) *Component figure "1."*—(1) Although the place of maximum activity in low sunspot frequency years is almost equally shared by April and May, a similar advance to March in years of increased frequency is evident and a corresponding retardation of the autumnal value by one month (from August to September) quite noticeable.

(2). June continues to be the month of chief minimum in both sets of years but the winter minimum is one month earlier in the more active years.

(c) *Component figure "2."*—Here the outstanding feature, in contrast with the other characters and in similarity to the results for the same constituent in the diurnal variation, is the persistence of the maxima in March and October; the principal sunspot minimum month being March and sunspot maximum October—though March has an almost equal claim to the latter position.

To test the validity of these results the 11 years were re-grouped as shown in Table XV.

TABLE XV.—CHANGE OF ANNUAL VARIATION OF CHARACTER WITH EPOCH OF SUNSPOT CYCLE.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Total char.													
1913-15	9.0	10.0	12.5	12.8	11.8	9.2	11.2	12.5	12.2	11.9	10.8	8.1	11.0
1916-19	14.1	13.2	14.5	13.3	13.8	10.5	10.9	13.2	14.1	14.0	10.7	11.5	12.8
1920-23	8.3	9.0	10.9	10.9	11.4	9.4	9.5	9.1	10.1	9.5	7.6	7.9	9.5
1's alone.													
1913-15	8.4	9.3	11.1	11.0	10.9	8.1	10.2	11.7	11.0	9.7	8.8	7.3	9.8
1916-19	11.0	11.1	11.5	10.8	11.1	9.2	9.4	9.9	11.6	10.5	8.3	8.9	10.3
1920-23	5.8	5.8	6.3	7.2	7.4	7.6	7.2	6.9	6.6	5.9	5.2	5.5	6.5
2's alone.													
1913-15	0.31	0.36	0.69	0.94	0.45	0.50	0.52	0.52	0.60	1.14	0.99	0.38	0.61
1916-19	1.55	1.01	1.64	1.24	1.35	0.61	0.76	1.67	1.26	1.80	1.21	1.31	1.28
1920-23	1.26	1.59	2.43	1.89	1.99	0.90	1.16	1.11	1.72	1.81	1.17	1.25	1.52

So far as concerns the incidence of the months of maximum disturbance the corroborative evidence thus gained seems unmistakable. Though the autumn maximum of combined ($n_1 + 2n_2$) figures appears to remain steady at September in passing from the second to the third group of years, the contribution from 1's shows a decided tendency to return to the conditions of the ascending phase of the cycle. The apparent stationariness of the spring maximum of 1's from 1913 to 1919 is also not representative of the true state of affairs. For the calculation of a centre of gravity of the mean figures for this character in the first half of the year would certainly decide a maximum in favour of April rather than March.

† *Geophysical Memoirs*, Vol. III, No. 29, 1926.

Thus these results all point to the fact that in annual as in diurnal variation the behaviour of the constituent character "2" is characterized by a greater relative fixity and constancy than is shown by the figures representing feebly or only moderately disturbed conditions.

§ 16. THE 11-YEAR SEQUENCE OF MEAN ANNUAL CHARACTER FIGURES.

Although the adaptation of such a method of estimating disturbance is not primarily calculated to lead to any reliable conclusions in the arrangement of *entire years* in order of their magnetic activity, the extraction of the 11 annual values of total and component characters from the separate tables was thought worthy of further notice. They are reproduced below (Table XVI).

TABLE XVI.—ANNUAL SEQUENCES OF VARIOUS CHARACTER, RANGE AND ACTIVITY FIGURES, 1913-23.

Year	Days used for Hourly Characters	Annual Means for Total Hourly Characters	Mean daily Number of Occurrences of		Annual means of daily character figures.			Kew inequality range (Quiet Days)		Kew absolute daily ranges D (all days)	Eskdale-muir mean annual activity IV	Wolfer's Sunspot Numbers
			2's	1's	Kew	Eskdale-muir	International	D	H			
1913	352	.39	0.33	8.72	.41	.58	.49	6.87	18.1	9.54	—	1.4
1914	365	.46	0.50	10.11	.49	.71	.53	6.13	22.2	10.16	199	9.6
1915	365	.52	1.01	10.53	.74	.86	.62	7.30	24.8	13.29	483	47.4
1916	366	.54	1.16	10.64	.77	.74	.71	8.73	30.0	15.03	549	57.1
1917	360	.51	1.03	10.21	.70	.65	.67	10.18	34.0	15.40	591	103.9
1918	365	.56	1.21	11.09	.75	.68	.75	9.23	30.1	16.00	698	80.6
1919	361	.52	1.75	9.09	.69	.73	.73	8.52	28.0	16.28	813	63.6
1920	366	.39	1.19	7.01	.63	.57	.62	7.91	28.3	14.66	526	37.6
1921	365	.40	1.83	5.86	.64	.63	.61	7.07	22.6	13.37	591	26.1
1922	364	.47	2.17	6.95	.68	.65	.65	6.68	22.3	13.05	451	14.2
1923	365	.32	0.89	5.96	.42	—	.48	5.87	21.3	9.76	—	5.8

In the examination of the table attention will be immediately directed to one or two special points:—

- (1) The year of maximum magnetic disturbance (as judged by this criterion) was 1918, and the year of least disturbance 1923.
- (2) The positions of the two years 1917 and 1922 when considered along with those of Wolfer's relative sunspot numbers seem anomalous.

In the latter connexion, while the position of the earlier year might well be accounted for by the procedure followed in obtaining the figure (since 1917 was an isolated one of the four groups characterized), the group 1921-1923 was the first attempted. With the first and last years of the group in approximately correct position in the column (from the sunspot point of view), it is therefore unlikely that 1922 should have suffered displacement to such an unusual extent unless the state of disturbance really went some way to warrant it. The column of component 2's does not elucidate matters. With the exceptions of 1917 and 1920 the total number of occurrences of relatively disturbed hours increases steadily from 1913 to 1922. The figures for moderate disturbance follow a more expected sequence though 1922 is still superior to 1921 in that respect.

When the characters from the two months March and August were re-assigned, it was of interest to examine the order in which the 11 years were arranged as regards activity by the resultant characters derived from the uninterrupted cross section (vide § 2). The result showed that (i) the maximum was postponed one year further behind that of the general estimate (i.e., to 1919), and therefore two years subsequent to sunspot maximum; but (ii) the position of the 1922 total remained relatively unaltered, exceeding both of the previous years in the solar cycle.

§ 17. COMPARISON OF HOURLY CHARACTERS WITH OTHER MEASURES OF MAGNETIC DISTURBANCE.

(a) *Local and international whole day character figures.*—The volumes of Hourly Values (Part IV of the *British Meteorological and Magnetic Year Book*) furnish

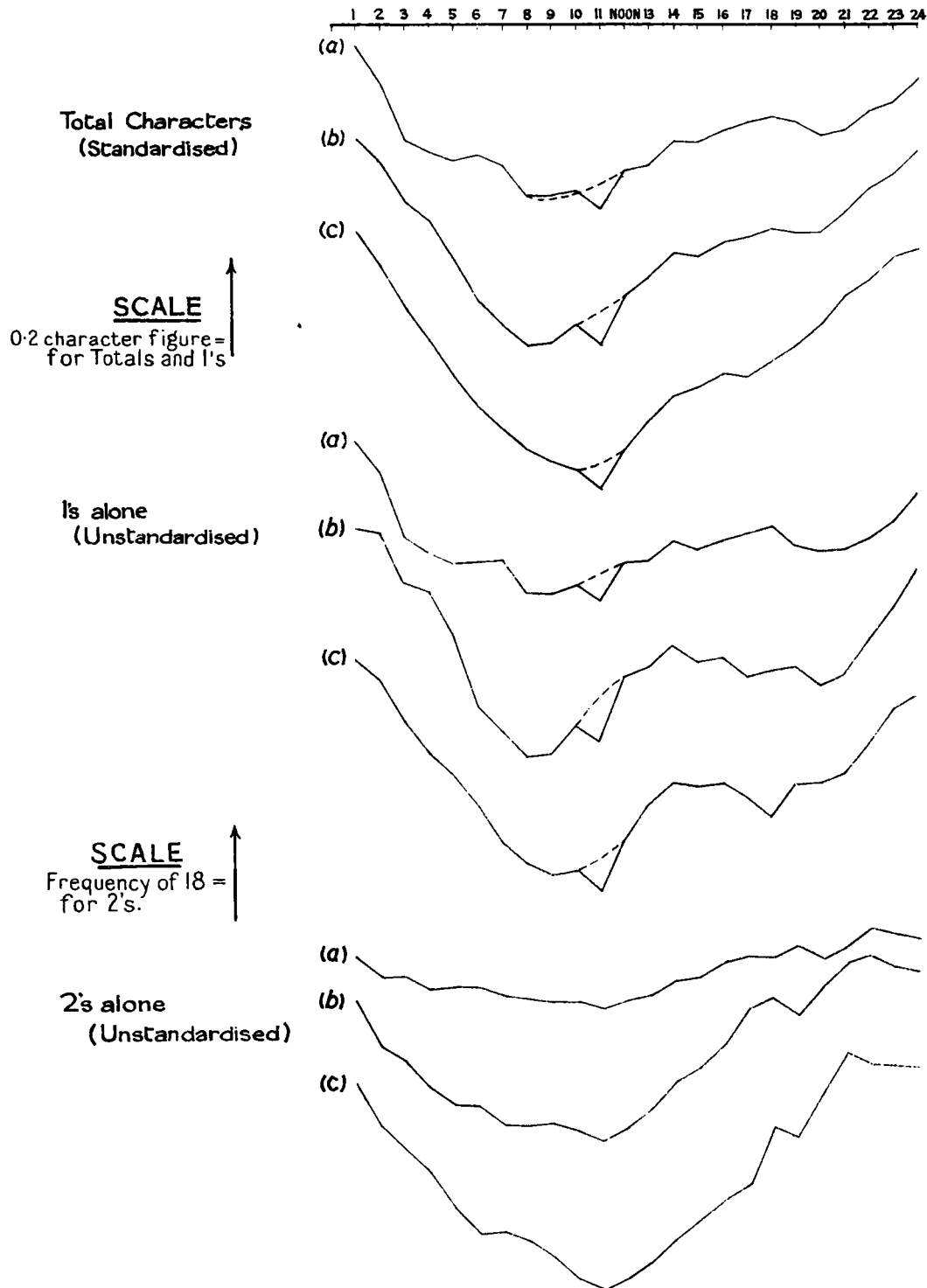


Fig.12 - The change in the Mean Diurnal Variation in the Total and Component Character Figures with the Epoch of the Sunspot Cycle. (a) Group 1913-15, (b) Group 1916-19, (c) Group 1920-23.

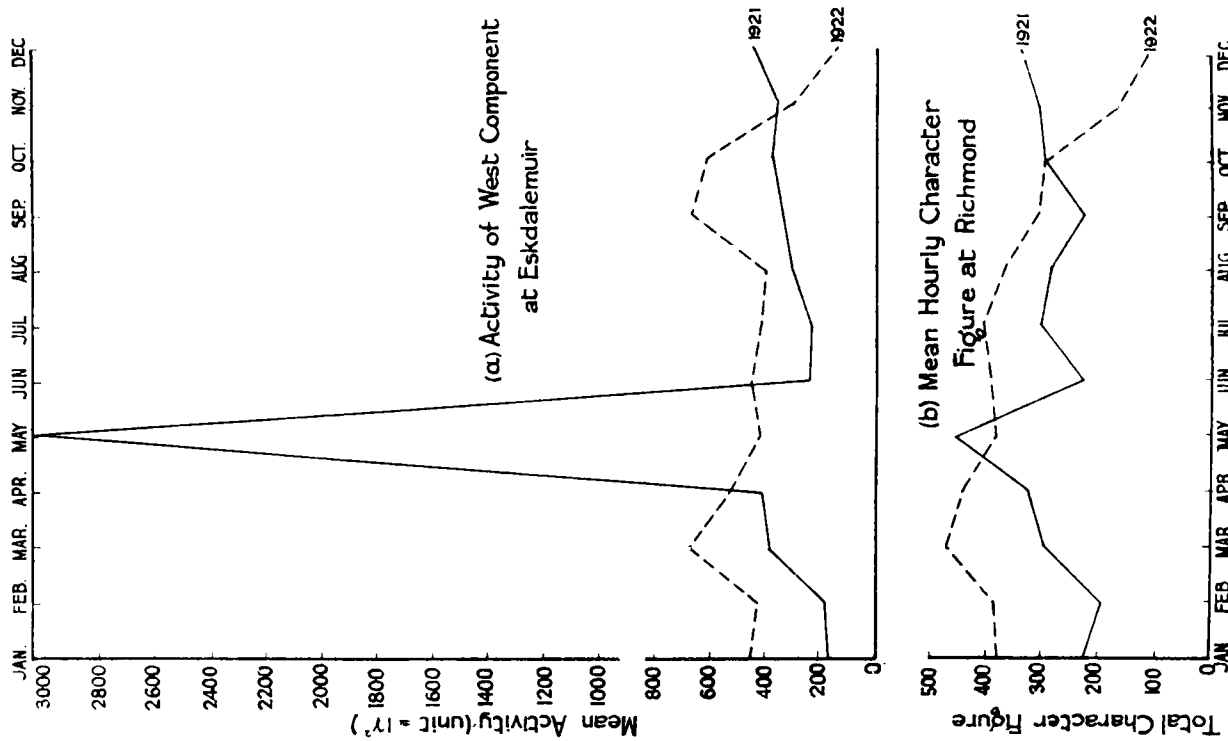
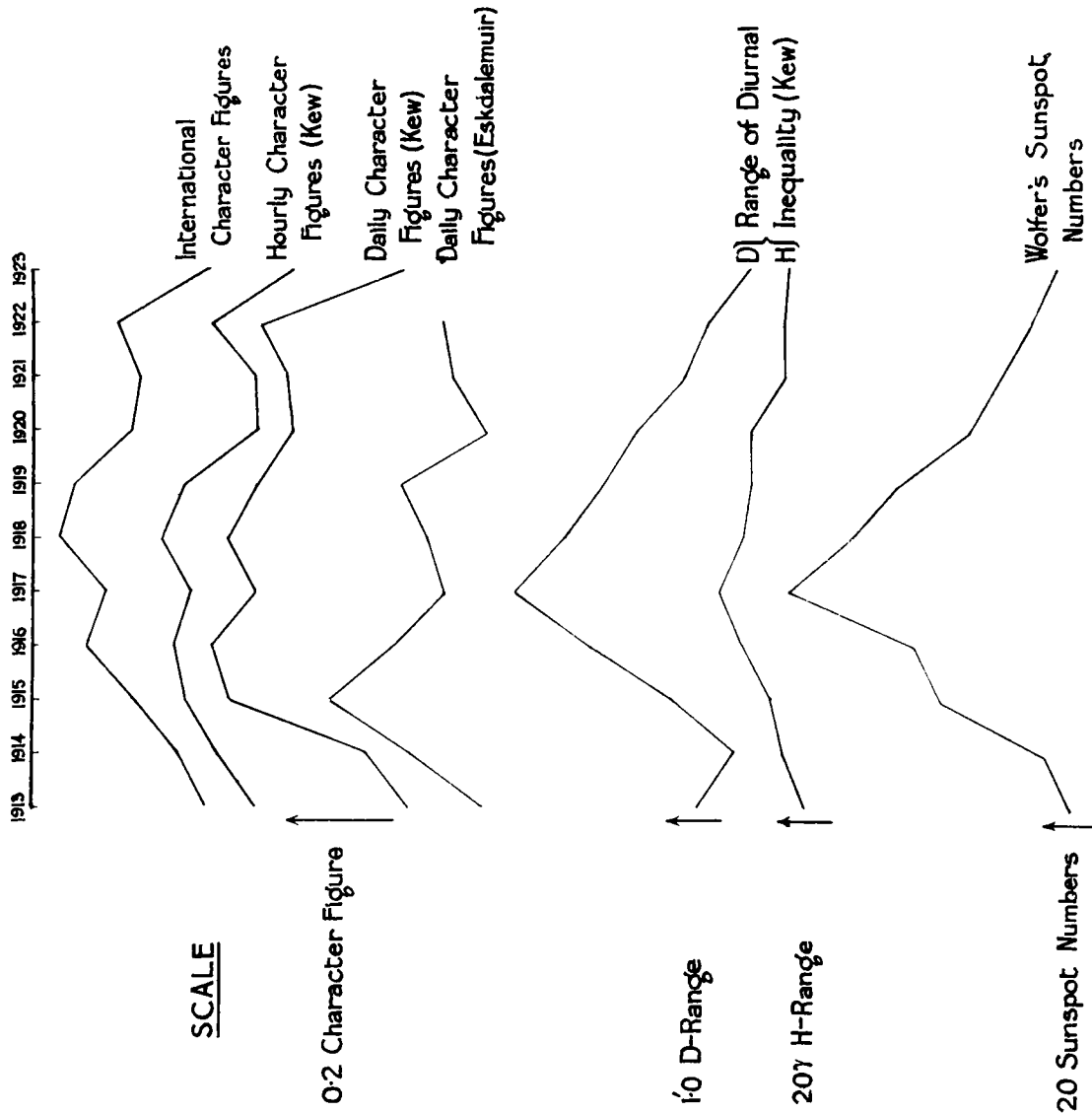


Fig.13- Variation of Various Measures of Magnetic Disturbance and of Sunspot Numbers, 1913-23

Fig.14- Annual Variation 1921 and 1922 of (a) Activity of West Component at Eskdalemuir (b) Mean Hourly Character Figure at Richmond.

for each day of each year character figures expressive of the degree of general quiet and disturbance obtaining over the whole day both for Kew and Eskdalemuir Observatories. When meaned for the year they might be expected (subject to small variations of the standard from year to year) to represent the relative positions of a run of years with regard to magnetic disturbance. These annual means of daily character figures were therefore obtained and entered, together with the international (de Bilt) mean annual characters, in Table XVI. (See also Plate VI Fig. 13.)

From this table the points brought out by the hourly character means are adequately confirmed, viz. :—

- (1) That 1917, though a sunspot maximum year, was inferior to the immediately adjacent years in magnetic disturbance. The Kew daily figures make the disturbance maximum precede the year of greatest sunspottedness by one year, the Eskdalemuir figures by two years. On the other hand the international figures agree with the hourly character means in putting the maximum at 1918. Indeed the closeness of parallelism between these two sequences is very specially marked—the correlation co-efficient being as high as 0.93. (No examination of the de Bilt figures was made until the hourly character investigation was completed.)
- (2) Without exception 1922 shows signs of a recrudescence of disturbance in the diminishing phase of the sunspot cycle. In the Kew and Eskdalemuir as well as the international sequences, the 1922 mean surpasses the means of the two previous years as was the case with the hourly characters for Kew.

(b) *Potsdam and Eskdalemuir "activity" figures.*—From criteria of disturbance intensity and, more comprehensively, magnetic activity published by other observatories, it appears that the maximum epoch of the magnetic cycle was reached subsequently rather than prior to the corresponding sunspot maximum. Thus the figures from Potsdam Observatory deduced from the "Interdiurne Veranderlichkeit der Horizontal Componente des Nachstörungs Vectors"* give 1919 as year of maximum activity and this agrees with the epoch which would be selected at Eskdalemuir on the basis of the activity of the west component of force derived from the squares of hourly ranges. This will be seen from the activity figures in column 12 of Table XVI, which were supplied by Dr. C. Mitchell, recently Superintendent of Eskdalemuir Observatory.

(c) *Absolute daily range of D at Kew Observatory.*—Additional corroboration of these results has been available in the form of annual means of absolute daily range of declination at Kew, which have recently been got out for another purpose. The means for the years in question are inserted in column 11, Table XVI. On this criterion the epoch of maximum magnetic activity in the cycle is definitely 1919, and though the value for 1922 apparently occupies its proper position in the downgrade of the cycle, it is attributed a mean range about three minutes of arc in excess of that for 1914 with whose sunspot number 1922 most closely corresponds.

(d) *Comparison with inequality ranges.*—In marked contrast with the differences shown by the sequence of any of these measures of activity or disturbance and that of the 11 annual means of relative sunspot numbers, it is of interest to compare the sequence formed by the mean diurnal inequality range derived from "quiet" days at Kew Observatory either for *D* or *H*. These have been extracted from the volumes of "Geophysical Hourly Values" † and are entered in Table XVI, columns 9 and 10. Except for the 1913 mean range exceeding that for 1914, in the case of declination alone, both series follow the solar figures exactly, rising to a well defined maximum at 1917 in each case and showing no suggestion of a renewal of energy at the latter end of the cycle.

This is a state of affairs to be expected if it be assumed that sunspots show a greater efficacy in the production of magnetic storms as they decrease in solar latitude.‡

* *Veröffentlichungen des Preussischen Meteorologischen Instituts*, No. 332, 1925, Berlin, pp. 45-51.

† *British Meteorological and Magnetic Year Book*, Part IV.

‡ J. Barrels, *Meteorologische Zeitschrift*, April, 1925, pp. 147 to 152.

For since the general radiation output of the sun may most naturally be expected to vary with spottedness, the amplitude of the ordinary diurnal variation should proceed in harmony with such a measure of solar activity as provided by the *Relativzahlen*. As, however, the mean latitude of the spots decreases in the descending phase of the cycle, disturbance will not normally decline immediately after the maximum has been obtained, but will, as in the present cycle, continue to increase despite the diminished size and number of individual spots. The increase in the amplitude of the ordinary inequality range which accompanies disturbance will not, however, be sufficiently marked or long continued to offset the normal decline arising from the progressive diminution of general solar radiation.

§ 18. FURTHER NOTE ON THE POSITION OF 1922.

Since an apparent resuscitation of magnetic activity near the end of a cycle is a somewhat unusual phenomenon any other evidence concerning the anomalous position of 1922 seemed worth further notice. The activity figures for the west force at Eskdalemuir were therefore examined.

The more immediately pertinent data together with monthly totals of hourly characters for Kew during the years 1921 and 1922 are shown in Table XVII.

TABLE XVII.—MEAN ACTIVITY OF WEST COMPONENT OF MAGNETIC FORCE AT ESKDALEMUIR AND TOTAL MONTHLY CHARACTERS FROM THE KEW *H* AND *D* MAGNETOGRAMS.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Activity, 1921	166	181	382	408	3708	238	226	296	336	372	347	438
Activity, 1922	459	426	677	524	405	444	409	385	660	600	287	137
1922/1921 as percentage ..	277	235	177	128	11	187	181	130	196	161	83	31
Total Character 1921 ..	227	196	292	328	451	225	305	286	229	294	307	338
1922 ..	382	388	472	441	382	391	404	369	305	295	166	111
1922/1921 as percentage ..	168	198	162	134	85	174	132	129	133	100	54	33

Although 1921 shows a renewal of activity after the decline from 1919 to 1920 (*vide* column 12, Table XVI), the position of 1922 at Eskdalemuir appears at first sight quite normal. The anomaly, that is, has been transferred from 1922 to 1921. When the separate contributions of each month to the total figures for these two years are examined, however, the reason for the interchange is partially elucidated (see also Fig. 14 Plate VI). For it then becomes evident that 1921 owes its position among activity figures almost entirely to the unprecedented magnetic storms of May of that year, and that, apart from a superiority of the November and December (1921) figures over those for 1922, the latter year is uniformly the year of higher activity. The percentage 1922/1921 figures given in the table are a good indication of the relations between the individual monthly runs, the mean values of this ratio for activity and character, expressed as percentages, being 150 and 125 respectively.

§ 19. ANNUAL MEASURES OF DISTURBANCE PROVIDED BY THE 2-HOURLY DISTURBED PERIODS OF § 9.

Attention might further be directed to the sequence of yearly totals of two-hourly periods of unusual disturbance shown in Table VIII. Assuming that 1918 was uniformly disturbed, a reasonable estimate of a 12-monthly total for that year would be $\frac{4}{3} \times 143 = 191$, which is almost exactly that of the following year. Thus, these Mining Engineer figures would tend to provide 1918 and 1919 with equal claims to be the year of maximum disturbance in the period covered. Then, while 1920 and 1921 are both decidedly less disturbed, 1922 shows an unmistakeable increase, exceeding both of its predecessors in the frequency of occurrence of these specially noted 2-hourly periods. A rapid fall to 1923 and 1924 puts these years in a more or less expected position in the cycle.

Since some previous investigations* showed that apparent anomalies in the parallel run of sunspot numbers and absolute daily ranges of magnetic declination at Kew Observatory between the years 1900 and 1910 had partially disappeared when the mean sunspot "variability" figures† were substituted for directly observed Wolfer's numbers, the variability figures were computed for the 10 years 1913-1922 from the total projected area of sunspots given in the Greenwich ledgers.‡ 1923 was not available. The final results, however, did not disclose any such recrudescence of day to day changes in sunspot areas as might have accounted for the enhanced magnetic activity during the year 1922.

* *Geophysical Memoirs*, Vol. III, No. 29, Met. Office, London, 1926.

† Sunspot variability was defined as the difference in the total projected areas of spotted surface between one day and the succeeding day. It was reckoned in millionths of the sun's apparent disc and taken as positive when the area increased.

‡ Greenwich Photoheliographic Results for the years in question.

APPENDIX

HOURLY MAGNETIC CHARACTER FIGURES AT WILHELMSHAVEN OBSERVATORY, 1910-12

In pursuance of researches on magnetic activity, Bidlingmaier assigned characters to each hour of the $2\frac{1}{2}$ years, January, 1910 to June, 1912, on the basis of the Wilhelmshaven magnetograms. Diagrams showing the figures awarded to each hour were published in the *Veroffentlichen des Kaiserlichen Observatoriums in Wilhelmshaven* for the years studied, and from these it is possible to derive monthly and annual distributions. Bidlingmaier used local time in his hourly assignment throughout the first 12 months and Greenwich mean time for the subsequent 18 months. Since the former is a little over one half hour ahead of Greenwich time, it is not possible to combine the two sets of data into a single sequence of hourly means. Separate totals are therefore given for the two periods :—

- (1) for the "total" ($n_1 + 2n_2$) character of each hour throughout the period, and
- (2) for simple frequency of "2" hours (n_2).

Seasonal means are also given for the total character, but the entire number of 2's occurring in the $2\frac{1}{2}$ years precludes any examination of a seasonal variation in the incidence of this constituent character alone. The figures are set out in Table XVIII.

TABLE XVIII.—TOTAL AND CONSTITUENT "2" CHARACTERS, WILHELMSHAVEN.

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Total Characters—																								
Year—																								
1910	155	147	135	113	97	86	72	54	40	41	43	52	82	91	106	126	157	152	107	189	191	185	188	107
1911-12	154	174	141	125	85	85	65	49	39	20	47	65	67	87	114	123	146	180	181	194	207	188	186	174
Winter—																								
1910	56	45	34	26	17	19	19	13	7	6	9	14	20	23	30	34	48	49	61	59	70	71	75	58
1911-12	49	54	39	39	25	14	10	9	11	5	16	20	18	25	37	42	58	65	72	74	79	68	65	47
Equinox—																								
1910	59	64	61	50	46	38	32	26	21	24	22	24	32	37	39	52	68	63	66	75	75	71	70	71
1911-12	49	61	47	45	28	32	27	13	15	9	18	24	23	25	27	32	41	56	59	69	75	70	59	56
Summer—																								
1910	40	38	40	37	34	29	21	15	12	11	12	14	30	31	37	40	41	40	40	55	46	43	43	38
1911-12	56	59	55	41	32	39	28	27	13	6	13	21	26	37	50	49	47	59	50	51	53	50	63	71
2's alone—																								
Year—																								
1910	11	15	8	12	7	4	3	4	1	—	1	1	5	4	4	18	27	19	21	28	28	27	22	16
1911-12	3	11	6	8	3	2	—	—	—	—	—	—	—	2	6	11	21	29	18	26	29	16	15	12

From a general examination, it can be deduced that the hourly sequence of totals derived from Bidlingmaier's characters shows a very similar trend to that obtained from the more extended Kew data except in a few details. Thus, while the Kew figures revealed a principal maximum about one hour after midnight together with a distinct and separate afternoon maximum, Bidlingmaier's material leads to the main maximum being put definitely in the late afternoon at approximately 21h. In addition, his figures point to a persistent minimum of daily disturbance variation at about 10h. in contrast with the Kew variability of incidence with year and season. These differences may be largely attributed to the paucity of the available material. Consideration of the sequences of character "2" alone, however, results in a frequency distribution of hours of large disturbance whose minimum and maximum epochs closely agree with those derived from the Kew magnetograms.