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A NEW RELATION BETWEEN ATMOSPHERIC ELECTRICITY *and* TERRESTRIAL MAGNETISM

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A NEW RELATION BETWEEN ATMOSPHERIC ELECTRICITY AND TERRESTRIAL MAGNETISM

By A. W. Lee

When discussing the atmospheric potential at Kew Observatory during the years 1898 to 1904, Dr. Chree pointed out that the lowest of the seven annual values of potential gradient occurred in the year with lowest sunspot number (1).* More recently Dr. Bauer, using data for a longer period and from several stations, adduced that both the mean gradient and the range of the diurnal inequality increase and diminish with sunspots (2, 3). Chree, however, discussed the same data, and came to the conclusion that they were insufficient to prove the existence of such a relationship (4, 5).

In view of the unsatisfactory results obtained from comparisons of mean potential gradient with sunspots, a further investigation employing some other measure of atmospheric electric activity appeared desirable. In the present paper the electrical activity has been compared with magnetic character, the intention being to follow up Chree's suggestion (6) that the difference between magnetically quiet and disturbed days may be regarded as similar to that between quiet days at sunspot minima and at sunspot maxima. The investigation, which is limited to the electrically quiet days (since the electrification of rain is only a local phenomenon), covers the values of potential gradient at Lerwick for the years 1927 and 1928, and at Kew from 1906 to 1928.

After several efforts to obtain a convenient daily measure of electrical activity, it was decided to employ the "hourly variability" of potential gradient, defined as the arithmetic sum of successive differences in the 25 hourly values.† It will be seen that the variability on quiet days which show no irregular movements is the sum of the ranges of the principal oscillations. Comparison of values for individual days with the variability computed from the diurnal inequalities shows that on the average about 40 per cent. of the variability depends upon the diurnal change, about 60 per cent upon more erratic movements.

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* The numbers in brackets refer to the list of references on p. 8.

† i.e., if $V_0\ V_1$, . . . etc. represent hourly values, the variability is $\sum_0^{24} (V_n \sim V_{n+1})$ or $\Sigma \mid \delta V \mid$.

Fig 1.

To face page 2.

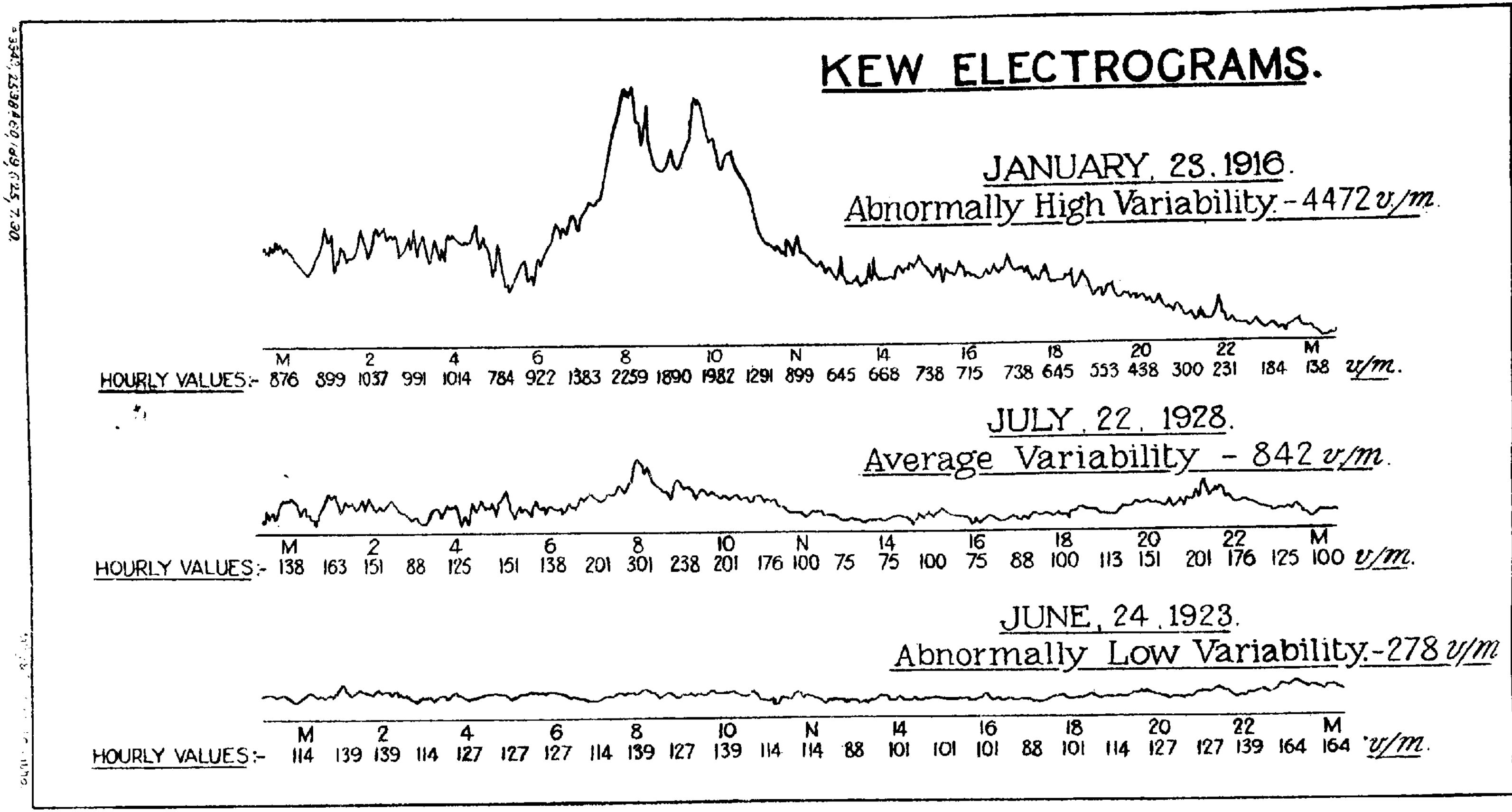

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TABLE I.—LERWICK. MONTHLY MEANS OF $\Sigma \mid \delta V \mid$, 1927–28 (V./M.). (0*a* days only).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Mean $\Sigma \mid \delta V \mid$	Annual Mean Potential v./m.
1927	718 (3)	686 (5)	858 (3)	670 (3)	429 (5)	1445 (5)	1153 (14)	964 (17)	677 (5)	1065 (6)	679 (2)	635 (10)	833	213
1928	247 (1)	725 (7)	463 (7)	899 (10)	468 (16)	851 (6)	513 (10)	599 (15)	878 (9)	485 (5)	690 (4)	481 (2)	608	166
Mean Variability v./m.	481	705	661	785	449	1148	833	781	777	775	693	558	721	189
Mean Potential (V) v./m.	145	258	240	203	141	254	193	179	171	201	151	138	—	189
Ratio of Means Variability/ Potential	3·32	2·73	2·75	3·87	3·18	4·52	4·32	4·36	4·54	3·86	4·59	4·04	—	—

TABLE II.—KEW, 1920–28. MONTHLY MEANS OF $\Sigma \mid \delta V \mid$ (V./M.) ON SELECTED QUIET DAYS (usually 10 in each month).

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Mean $\Sigma \mid \delta V \mid$	Annual Mean Potential.
1920	1257	1188	1279	930	762	694	796	851	923	1029	1362	1403	1039	315
1921	1012	1379	1119	1160	692	833	583	686	911	978	1442	986	982	281
1922	1435	1301	1404	1234	753	732	703	967	933	1106	1267	1000	1070	318
1923	1336	1564	1215	1428	1007	620	907	703	836	956	1355	1357	1107	318
1924	1097	1514	1239	1624	862	761	764	828	725	1141	926	1082	1047	329
1925	1122	1058	1071	1371	1009	1062	704	716	873	823	957	1209	998	326
1926	1211	920	940	1131	706	746	732	591	846	1026	1507	1003	947	279
1927	923	1191	1123	852	926	924	927	847	877	1204	1418	1285	1041	315
1928	1399	1179	1255	1137	960	792	606	734	961	905	937	1486	1029	298
Mean Variability v./m.	1199	1255	1183	1207	853	796	747	769	876	1019	1241	1201	1029	309
Mean Potential (*V*) v./m.	404	403	372	328	228	200	193	191	226	304	429	427	—	309
Ratio of Means Variability/Potential ..	2·96	3·11	3·18	3·68	3·74	3·98	3·87	4·03	3·88	3·35	2·89	2·81	—	—

variability on the "more disturbed" and "less disturbed" days are given in Table III, together with the difference between the variabilities on these days. It should be noted that the sign of the difference between the "more disturbed" and "less disturbed" days is independent of the electrograph scale value

TABLE III.—KEW. MEAN VALUES OF $\Sigma \mid \delta V \mid$ ON DAYS OF HIGHER AND LOWER MAGNETIC CHARACTER, 1920–28. (V./M.)

Year.	Mean Values of $\Sigma \mid \delta V \mid$ v./m.		
	More disturbed days (d).	Less disturbed days (q).	d–q.
1920	1027	1050	− 23
1921	916	1048	−132
1922	1096	1042	+ 54
1923	1038	1161	−123
1924	1061	1031	+ 30
1925	996	1001	− 5
1926	1008	893	+115
1927	1121	967	+154
1928	1037	992	+ 45

and of the reduction factor. Table III shows considerable scatter from year to year, but the differences from 1926 to 1928 are similar to the results obtained from Lerwick data; the difference values in earlier years are generally lower.

Further comparisons, which extend from 1906 to 1928, refer only to the electrical data for days on which magnetic disturbance was conspicuously small or conspicuously large. Since the inauguration of the international characterisation in 1906, five days of each month, termed the international "Q" days, have been selected at de Bilt as the most representative of quiet conditions. A similar selection of five representative disturbed days ("D" days) has also been made since 1923 (7); for each month of earlier years the five days of largest international character have been taken as the "D" days. About one third of the D and Q days of each year usually appear among the electrically quiet days.

Table IV gives the mean variability on D and Q days, mean potential gradient, and sunspot number from 1906 to 1928; bracketed figures indicate the number of days from which the adjoining mean values have been computed. Fig. 3 illustrates the annual changes in sunspots, in variability on D and Q days, and in the difference between these variabilities.

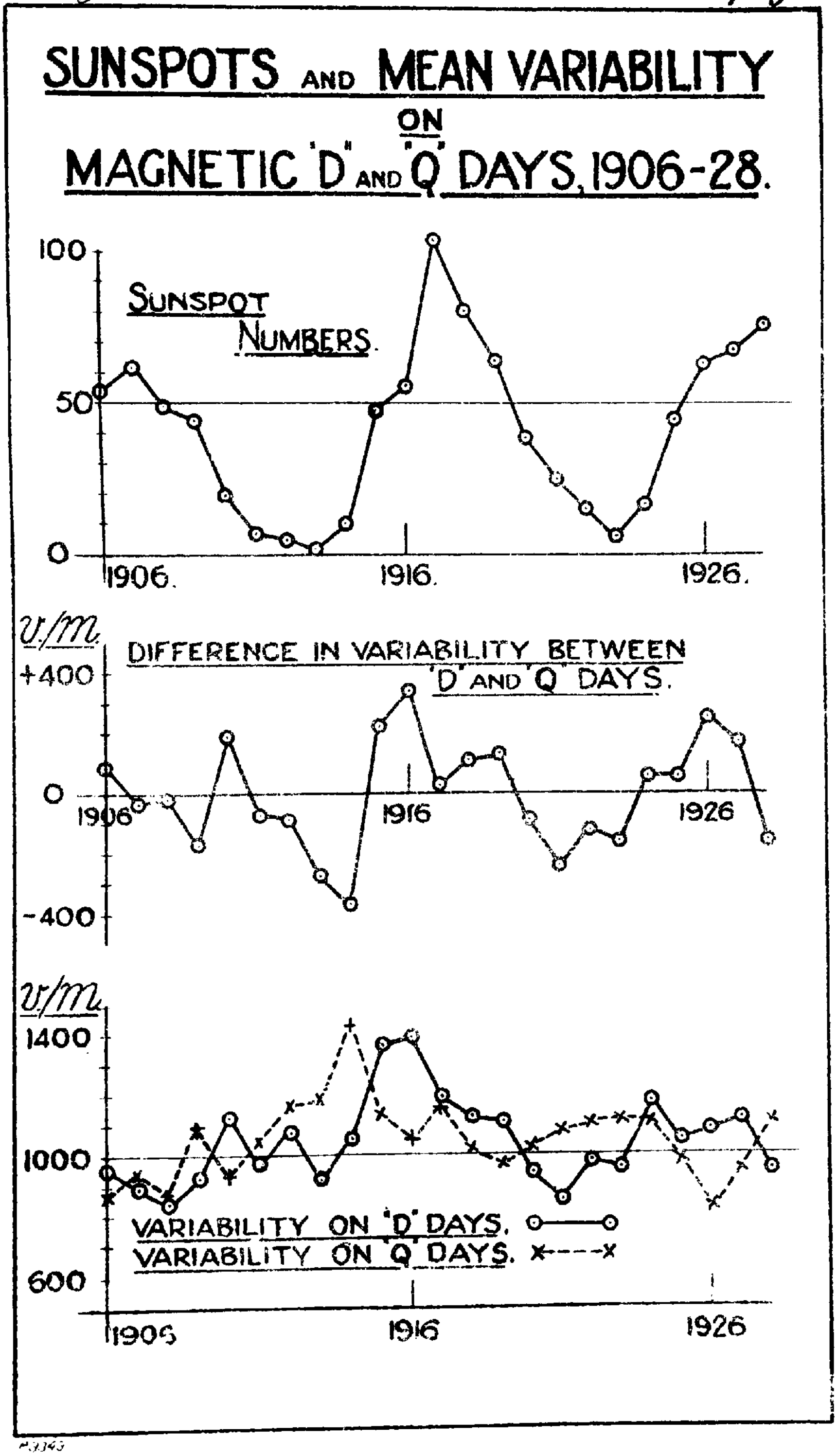
SUNSPOTS AND MEAN VARIABILITY ON MAGNETIC 'D' AND 'Q' DAYS, 1906-28.
SUNSPOT NUMBERS.
100
50
0
1906.
1916.
1926.
V/M.
DIFFERENCE IN VARIABILITY BETWEEN 'D' AND 'Q' DAYS.
+400
0
-400
1906
1916
1926
V/M.
1400
1000
600
VARIABILITY ON 'D' DAYS.
VARIABILITY ON 'Q' DAYS.
1906
1916
1926

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TABLE IV.—KEW. MEAN VALUES OF Σ | δ V | ON INTERNATIONAL D AND Q DAYS, POTENTIAL GRADIENT AND SUNSPOT NUMBERS, 1906–28.

Year.	Mean Values of Σ | δ V | v./m.			Mean Potential. v./m.	Sunspot. Number.
	International D days.	International Q days.	D–Q.		
1906 ..	953 (19)	868 (23)	+ 85	298	53·8
1907 ..	890 (23)	927 (20)	− 37	311	62·0
1908 ..	834 (17)	852 (21)	− 18	283	48·5
1909 ..	925 (21)	1098 (21)	−173	313	43·9
1910 ..	1121 (22)	931 (19)	+190	310	18·6
1911 ..	966 (17)	1041 (23)	− 75	301	5·7
1912 ..	1078 (19)	1164 (17)	− 86	300	3·6
1913 ..	917 (11)	1192 (26)	−275	335	1·4
1914 ..	1051 (25)	1426 (17)	−375	345	9·6
1915 ..	1364 (14)	1132 (17)	+232	354	47·4
1916 ..	1393 (22)	1051 (14)	+342	367	55·4
1917 ..	1190 (19)	1164 (19)	+ 26	354	103·9
1918 ..	1121 (20)	1019 (18)	+102	346	80·6
1919 ..	1107 (15)	975 (20)	+132	331	63·6
1920 ..	944 (15)	1031 (15)	− 87	315	38·7
1921 ..	847 (24)	1093 (19)	−246	281	24·7
1922 ..	986 (17)	1107 (17)	−121	318	14·7
1923 ..	959 (19)	1121 (16)	−162	318	5·5
1924 ..	1178 (15)	1121 (13)	+ 57	329	16·7
1925 ..	1052 (18)	992 (24)	+ 60	326	44·6
1926 ..	1083 (19)	826 (22)	+257	279	62·4
1927 ..	1112 (18)	946 (14)	+166	315	67·8
1928 ..	949 (18)	1110 (16)	−161	298	76·5

Although there are irregularities from year to year, Table IV and Fig. 3 show that during the last two sunspot cycles there has been a tendency for the electrical variability on D days to vary directly, and for that on Q days to vary inversely with sunspots. The correlation coefficient between the D–Q difference and sunspot number has been computed, and found to be $0 \cdot 48 \pm 0 \cdot 16$. The coefficient becomes $0 \cdot 69 \pm 0 \cdot 12$ if the years 1910, 1917, and 1928 are omitted.

Table V gives the mean variability on D and Q days in years of high and low sunspot number; two periods, 1906–17 and 1918–28, are treated separately. The distinction between high and low sunspots has been chosen arbitrarily at sunspot number 45. According to Table V the electrical variability on D days in years of high sunspot number is about 10 per cent

TABLE V.—MEAN VALUES OF $\Sigma \mid \delta V \mid$ ON INTERNATIONAL D AND Q DAYS IN YEARS OF HIGH AND LOW SUNSPOT NUMBER.

	1st Sunspot Period, 1906–17.		2nd Sunspot Period, 1918–28.		Mean of two Sunspot Periods.	
	Years of Low Sunspot Number (<45).	Years of High Sunspot Number (>45).	Years of Low Sunspot Number (<45).	Years of High Sunspot Number (>45).	Years of Low Sunspot Number (<45).	Years of High Sunspot Number (>45).
D days ..	1010	1104	983	1071	997	1087
Q days ..	1142	999	1095	978	1119	989
Mean	1076	1051	1039	1025	1058	1038

higher than in years of low sunspot number ; a reverse effect of slightly larger magnitude is found for the Q days. During each sunspot period the mean of the values on D and Q days (given at the bottom of Table V) was slightly higher in the years of low sunspot number.

From Chree's hypothesis we should have expected a regular sequence of mean variability descending in the following order :—

1. D days at sunspot maxima.
2. D „ „ minima.
3. Q „ „ maxima.
4. Q „ „ minima.

The actual sequences shown in Table V are 4, 1, 2, 3. Such a distribution would result if fog occurred most frequently on the Q days at sunspot minima, but whether the explanation is to be found in some such dependence of local weather on cosmical activity, or whether the electrical phenomena are more directly affected, must be the subject of further investigation.

In conclusion I should like to express my thanks to Dr. F. J. W. Whipple for the interest he has taken in this work and for much valuable criticism.

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