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COMPARISON OF GEOMAGNETIC RECORDS AND NORTH ATLANTIC RADIO PROPAGATION QUALITY FIGURES - OCTOBER 1943 THROUGH MAY 1945.

In using geomagnetic data for forecasting and evaluating radio propagation disturbance, it is important to determine the type of geomagnetic trace which correlates with radio propagation disturbance. For this purpose the North Atlantic radio propagation quality figures, prepared as described in report IRPL-R13, were compared with geomagnetic records of the Cheltenham, Md., station of the U.S. Coast and Geomagnetic Survey. On the magnetograms, the horizontal intensity trace was the one analyzed, since any relationships thus found would then make immediately applicable the horizontal intensity trace on the visual magnetograph at the Sterling, Va., radio receiving station of the IRPL.

The minimum value of magnetic intensity recorded on the Cheltenham magnetograms at any time during the Greenwich day was scaled for each day. The geomagnetic traces were divided into "high-" and "low-level" days, based on a frequency distribution curve of the minima, the dividing point being set at the same percentage as that of radio propagation disturbance determined from the North Atlantic radio propagation quality figures for the period October 1943 through May 1945. Low traces had their minima within 45 gammas of the reference line, (assumed to average 18,100 gammas during the period), and high traces had their minima over 45 gammas from the reference line.

Table 1 shows the geomagnetic storm days, as reported in the daily Cheltenham ursigram, compared with disturbed or quiet days according to the North Atlantic radio propagation quality figures. Table 2 summarizes Table 1, and indicates that radio propagation disturbances correlated much more closely with low-level geomagnetic storms than with high-level geomagnetic storms. For example 81% of the low-level geomagnetic storm days were days of radio propagation disturbance, as against only 18% for the high-level geomagnetic storm days. All the radio propagation disturbances did not occur on geomagnetic storm days; in fact, 31% of the radio disturbances were on quiet days.

The correlations between the half-day K_A sums and the corresponding half-day North Atlantic radio propagation quality figures for low-level geomagnetic storm days and for high-level geomagnetic storm days are shown respectively in Figs. 1 and 2. These Figs. clearly show radio disturbance occurring with the low-level geomagnetic storm days rather than with the high, since 65% of the North Atlantic radio propagation quality figures

(over)

associated with low-level geomagnetic storm days were 4 or less (disturbed), as against 10% of those associated with the high-level days. For the low-level geomagnetic storm days, the coefficient of linear correlation $r = 0.44 \pm 0.03$ with a standard deviation of 3.01; for the high-level geomagnetic storm days $r = 0.53 \pm 0.03$ with a standard deviation of 1.73. This indicates, as can be seen in the Figs., that there was less scatter of the radio propagation quality figures on high-level than on low-level geomagnetically disturbed days.

Since so many of the radio propagation disturbances occurred on quiet geomagnetic days, all days were compared with the North Atlantic radio propagation quality figures on the basis of whether the geomagnetic trace reached a low or high minimum. This comparison is shown in Table 3 indicating the days of fair radio propagation as well as the disturbed days. In Table 4, which is a summary of Table 3, it can be seen that 76% of the radio propagation disturbances occurred on low-level days. However, if radio disturbance warnings had been issued every time the geomagnetic trace was low, 23% of the warnings would have been superfluous. Of these superfluous warnings 71% would have been accompanied by only fair radio propagation conditions. Actually, however, only 24% of the fair radio propagation days were on days of low-level geomagnetic traces. Of the low-level days 77% were disturbed, and of the high-level days 91% were quiet, on the basis of radio propagation conditions. The percentage of disturbance on low-level geomagnetic days is highly significant compared to random choice of disturbed days. The explanation for more "hits" with warnings on all low-level geomagnetic days, whether they were days of geomagnetic disturbance or not, is that after many geomagnetic storms the horizontal intensity trace remained at a low level, and, as can be seen in Table 1, radio propagation disturbances tended to last longer than the geomagnetic disturbances and to extend into the days when the geomagnetic trace was still at a low level but no longer disturbed. Except for a few isolated cases; i.e. 30 April, 5 May, 31 May, and 19 August 1944, no radio propagation disturbance patterns began until the horizontal intensity trace had dropped to a low level. Toward the end of a pattern, days of radio disturbance sometimes fell on high-level geomagnetic trace days.

Table 5 illustrates by means of "coefficients of association", after G.E.Yule*, the significant relations of low-level traces with radio propagation disturbance and high-level traces with quiet radio conditions. The coefficients, as determined by the equations in Table 5a, are such that complete association would give + 1, complete negative association would give -1, and the value of the "coefficient of association" increases as the numbers proceed from dissociation to association. If the values are independent the coefficients are 0. The three equations differ in that "V" is unity only if two numbers in Table 5a vanish while "Q" and "Y" are unity if only one number vanishes. This signifies that association is complete if all A's are B's even though all B's are not A's. For "V"

*M.G.Kendall, "The Advanced Theory of Statistics," C. Griffin & Co., Ltd., London, 1943, pp.308-312.

to be unity all A's are B's and all B's are A's, which condition might be called "absolute association". The values of "Q", "Y", and "V", all differ although they refer to the same intensity of association. "Q" always gives a coefficient nearer unity than does "Y" or "V". A "Q" near unity indicates the conditions under consideration are significantly associated with each other. "Y" indicates how well A's and B's are associated while "V" indicates whether the "not-A's" and "not-B's" are also significantly associated.

Table 5b gives the coefficients for the geomagnetic storm days and Table 5c for all days. The coefficients of association "Q" were 0.903 for the geomagnetic storm days and 0.922 for all days. The coefficients "Y" of 0.631 for the geomagnetic storm days and 0.664 for all days indicate that the correlation of radio propagation disturbance with low-level geomagnetic traces was significant. On the other hand the coefficients "V" of 0.592 for the geomagnetic storm days and 0.630 for all days, indicate that the correlation of quiet days with high-level traces was also significant.

The history of a specific radio propagation disturbance shows how these correlations may be used in the issuance of radio disturbance warnings. On 15 January 1945, a geomagnetic storm began at 0000 GCT, but the trace remained at a high level until between 1400 and 1500 GCT, when the horizontal intensity began to drop sharply. At 1825 GCT, in fact, it was about 48 gammas below the reference line. The horizontal intensity rose again at 1900 GCT and the geomagnetic storm ended at 1200 GCT on 16 January 1945. The North Atlantic radio propagation quality figures were 5 and 4 on 15 January and 3 and 5 on 16 January. Though the geomagnetic storm began at 0000 GCT on 15 January, the radio propagation disturbance did not begin until after 1200 GCT, at which time the horizontal intensity was dropping to a low level. The worst part of the radio disturbance occurred during the half day after the horizontal intensity trace had reached its minimum value and was recovering, though the geomagnetic trace did remain somewhat disturbed until 1200 GCT on 16 January. After this time both the geomagnetic and radio conditions were again quiet. Therefore a warning issued as the horizontal intensity was dropping to a low level would have hit the beginning of the radio propagation disturbance.

During the summer months many of the geomagnetic disturbances were of the high-level class, and there was little or no radio disturbance associated with them. May 1945 was an especially good example of this. This gives still further indication that radio propagation disturbance warnings should generally not be issued until the horizontal geomagnetic intensity trace drops to a low level, even though the trace might be disturbed.

From the above discussion, it can be concluded that (a) the use of a visual magnetograph can be of great value in the issuance of warnings of radio propagation disturbance, and (b) whenever the horizontal intensity trace drops to a low level, radio disturbance warnings should be issued.

Table 1. Geomagnetically disturbed days as reported by Cheltenham, Md., compared with radio propagation disturbance as shown by North Atlantic radio propagation quality figures.

L = Geomagnetic storm at low horizontal intensity.
H = Geomagnetic storm at high horizontal intensity.
X = Half or whole radio quality of 4 or less (disturbed).
Blank = Radio quality 5 or more (quiet).

Day	Oct. 1943	Nov.	Dec.	Jan. 1944	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan. 1945	Feb.	Mar.	Apr.	May
1	LX	LX	X	X			LX	LX					L						LX	H
2	LX	X	L				LX	LX				LX							LX	H
3	LX		LX				HX	X			LX		H							
4	LX		X			H	X	H	H											
5	X		X	X		H	LX	HX						L			L	L	L	
6	X	LX				LX	LX	HX						HX				L	LX	
7	L	X			LX	LX	LX	LX											H	
8	LX	X			LX	LX	LX	X										L	L	
9	LX				X	LX	LX			H										H
10	LX			L	LX	LX	LX									LX				
11	X			LX	LX	LX	X						LX					LX	L	LX
12				LX	HX	LX	X											LX	LX	
13				LX	L	LX						H			H			X	HX	
14				LX	LX	X			H			H			LX			X	HX	
15				LX	LX	X	H		H				LX			LX	L	LX	H	
16		H	LX	LX	X	X	LX						X		LX	X	X	LX		
17			LX	LX	X		X						X		LX	LX		X		
18			LX	LX		L					H				LX			X		H
19		LX	LX	X		LX					X				X					H
20		LX	LX	X	L	X								L				L		H
21		LX	LX	X	X				H			H								
22		LX	LX			X			L											
23	X	LX	X		X				H				H							H
24	LX	LX					H				H	L	H						H	H
25	LX	LX		X													L			H
26	LX	LX	X			LX			H							H	L	LX		H
27	LX	LX				LX									LX		L	LX		H
28	LX	LX				X	H				H				LX			LX		
29	LX	LX				LX										LX		X		
30	LX	X				X	HX	H				L				LX			H	H
31	LX					X		HX								X				
LX	15	13	8	8	6	12	9	3	0	0	1	1	2	0	6	5	0	7	4	1
L	1	0	1	1	2	1	0	0	1	0	0	2	1	2	0	0	5	4	3	0
HX	0	0	0	0	1	0	2	3	0	0	0	0	0	1	0	0	0	0	2	0
H	0	1	0	0	0	2	3	2	6	1	3	3	3	0	1	1	0	0	4	12
X	4	1	5	6	5	8	4	2	0	0	1	0	2	0	1	2	1	5	0	0

Table 2.

Summary of Table 1.

LX	101°
L	24°
HX	9°
H	42°
X	50°

81% of L days accompanied by radio propagation disturbance.

82% of H days accompanied by no radio propagation disturbance.

31% of radio propagation disturbances on quiet geomagnetic days.

Table 3. Comparison of low and high horizontal intensity minima on Cheltenham magnetograms vs. radio propagation disturbance as shown by North Atlantic radio propagation quality figures.

L = Magnetic trace minimum within 45 gammas of reference line.
H = Magnetic trace minimum above 45 gammas from reference line.
X = Half or whole day radio quality 4 or less (disturbed).
F = Half or whole day radio quality 5 (fair).
Blank = Radio quality 6 or better (quiet).

Day	Oct. 1943	Nov.	Dec.	Jan. 1944	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan. 1945	Feb.	Mar.	Apr.	May
1	LX	LX	HX	LX	HF	H	LX	LX	H	H	H	HF	L	H	H	HF	LF	H	LX	H
2	LX	LX	LF	LF	HF	H	LX	LX	H	H	H	LX	H	H	H	HF	LF	HF	LX	H
3	LX	HF	LX	HF	HF	HF	HX	HX	H	H	LX	HF	HF	H	LF	HF	L	HF	HF	H
4	LX	HF	LX	H	HF	HF	LX	HF	H	H	HF	H	H	H	H	HF	H	H	L	H
5	HX	LF	LX	LX	H	HF	LX	HX	H	H	H	HF	H	L	H	HF	L	LF	LF	H
6	HX	LX	HF	H	H	LX	LX	HX	H	H	H	H	H	HX	HF	HF	LF	L	LX	H
7	LF	LX	H	H	LX	LX	LX	LX	H	H	H	H	H	H	H	L	HF	HF	HF	H
8	LX	HX	HF	HF	LX	LX	LX	HX	H	H	H	H	H	HF	H	H	HF	HF	LF	H
9	LX	HF	H	H	LX	LX	LX	H	H	HF	H	H	H	H	H	HF	HF	H	H	H
10	LX	H	H	L	LX	LX	LX	H	H	H	H	H	HF	H	H	LX	HF	H	H	HF
11	HX	H	H	LX	LX	LX	HX	H	H	H	H	H	LX	H	H	HF	HF	LX	LF	LX
12	HF	HF	H	LX	HX	LX	HX	H	H	H	HF	HF	HF	H	H	H	H	LX	LX	LF
13	HF	H	H	LX	LF	LX	HF	H	H	H	H	H	H	H	H	HF	H	LX	HX	H
14	H	H	L	LX	LX	LX	H	H	H	H	H	H	HF	H	LX	H	H	LX	HX	H
15	HF	H	H	LX	LX	HX	H	H	HF	H	H	H	LX	H	HF	LX	LF	LX	HF	H
16	H	H	LX	LX	HX	HX	LX	H	H	H	H	H	HX	H	LX	HX	HX	LX	HF	H
17	H	H	LX	LX	HX	HF	HX	H	H	H	H	H	HX	H	LX	LX	LF	HX	H	H
18	H	H	LX	LX	HF	L	H	H	H	H	HF	H	HF	H	LX	HF	H	LX	H	H
19	H	LX	LX	LX	HF	LX	H	H	H	H	HX	H	HF	H	LX	LF	H	HF	H	H
20	L	LX	LX	LX	LF	HX	H	H	H	H	HF	HF	H	LF	LF	HF	H	LF	H	H
21	LF	LX	LX	HX	HX	HF	H	H	H	H	HF	HF	H	HF	LF	H	H	HF	HF	H
22	LF	LX	LX	HF	HF	HX	H	H	LF	H	H	LF	H	H	H	H	H	H	H	H
23	LX	LX	LX	HF	HX	HF	H	H	HF	H	HF	HF	H	H	L	H	H	H	H	H
24	LX	LX	LF	HF	HF	HF	H	H	H	H	HF	LF	H	H	H	H	H	HF	HF	H
25	LX	LX	LF	HX	H	H	HF	HF	H	H	H	HF	HF	H	H	H	L	HF	HF	H
26	LX	LX	LX	LF	HF	LX	HF	H	H	H	H	H	HF	H	H	H	L	LX	H	H
27	LX	LX	H	LF	H	LX	HF	H	HF	H	H	HF	H	H	LX	H	LF	LX	H	H
28	LX	LX	HF	HF	HF	LX	HF	H	H	H	HF	H	H	H	LX	H	HF	LX	H	H
29	LX	LX	LF	HF	H	LX	HF	HF	H	H	HF	H	H	H	LF	LX		LX	H	H
30	LX	HX	HF	HF		LX	HX	HX	H	H	HF	L	H	H	LF	LX		HF	H	H
31	LX		LF	LF		HX		H		H	HF		H		HF	HX		H		H
LX	16	15	12	12	7	15	10	3	0	0	1	1	2	0	7	5	0	11	4	1
LF	3	1	5	4	2	0	0	0	1	0	0	2	0	1	5	1	6	2	3	1
L	1	0	1	1	0	1	0	0	0	0	0	1	1	1	1	1	4	1	1	0
HX	3	2	1	2	5	5	5	5	0	0	1	0	2	1	0	2	1	1	2	0
HF	3	4	4	8	10	7	6	3	3	1	11	9	8	2	3	11	6	9	7	1
H	5	8	8	4	5	3	9	20	26	30	18	17	18	25	15	11	11	7	13	28

Table 4

Summary of Table 3

LX	122°
LF	37°
L	15°
HX	38°
HF	116°
H	281°

76% of the radio propagation disturbances hit by L's.

77% of L days accompanied by radio propagation disturbance.

91% of H days accompanied by no radio propagation disturbance.

71% of the L superfluous warnings accompanied by fair radio propagation conditions.

24% of fair radio propagation days on L days.

Table 5a

	Number of B's	Number of not-B's	Totals
Number of A's	a	b	a + b
Number of not-A's	c	d	c + d
Totals	a + c	b + d	N

Coefficient of association $Q = \frac{ad - bc}{ad + bc}$

$$Y = \frac{1 - \sqrt{\frac{bc}{ad}}}{1 + \sqrt{\frac{bc}{ad}}}$$

$$V = \frac{ad - bc}{\sqrt{(a + b)(a + c)(b + d)(c + d)}}$$

Table 5b

Correlation coefficient (Geomagnetic storm days only)

	Radio propagation disturbance	No radio propagation disturbance	Totals
Low-level geomagnetic storm	101	24	125
High-level geomagnetic storm	9	42	51
Totals	110	66	176

Coefficient of association $Q = 0.903$

$Y = 0.631$

$V = 0.592$

Table 5c

Correlation coefficients (all days)

	Radio propagation disturbance	No radio propagation disturbance	Totals
Low-level geomagnetic trace	122	52	174
High-level geomagnetic trace	38	397	435
Totals	160	449	609

Coefficient of association Q = 0.922

Y = 0.664

V = 0.630

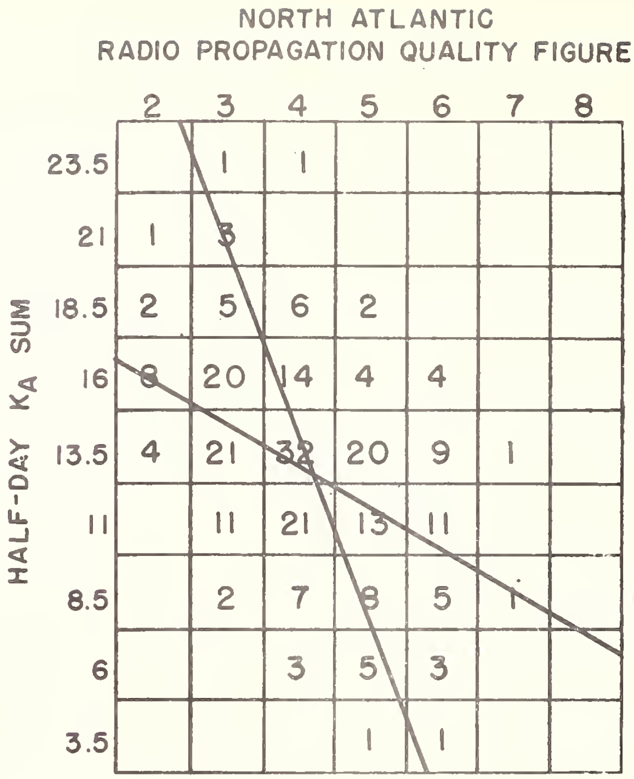

FIG. I. CORRELATION OF RADIO PROPAGATION AND GEOMAGNETIC DISTURBANCE ON LOW-LEVEL GEOMAGNETICALLY DISTURBED DAYS.

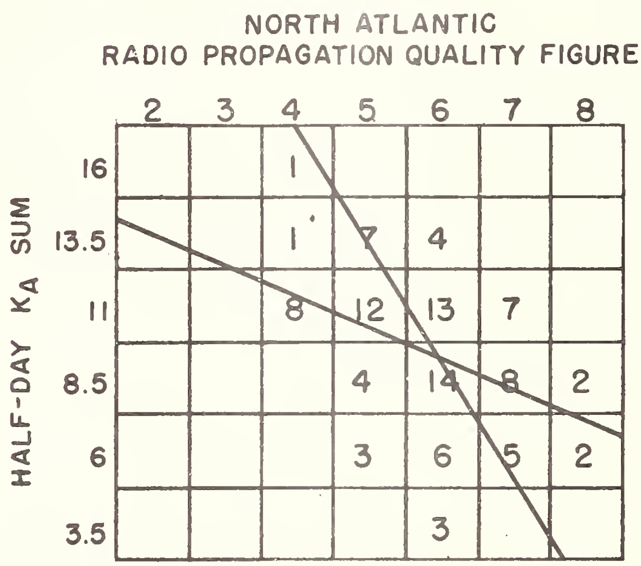

FIG. 2. CORRELATION OF RADIO PROPAGATION AND GEOMAGNETIC DISTURBANCE ON HIGH-LEVEL GEOMAGNETICALLY DISTURBED DAYS.