II—THE TECHNIQUE OF SCALING INDICES K AND Q OF GEOMAGNETIC ACTIVITY

by

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1 The K-index

1.1 *Introduction*

A skilled magnetic observer should be able to discern in his magnetograms the following two kinds of phenomena:

(1) as the effect of solar wave-radiation W: the quiet daily variations (non-K-variations) strongest in non-polar regions;
(2) as the effect of solar particle-radiation P: magnetic activity, or disturbance (K-variations) strongest near the auroral zones.

The K-index measures the intensity of the P-effects (called K-variations) at any station for each of the eight intervals 00 ... 03, 03 ... 06, ..., 21 ... 24 Universal Time. These intervals may be referred to as Eighths, E1 to E8, of the Greenwich day. K has a scale of 10 grades, $K = 0$ to 9. For each station, the K-scale must be chosen once for all from a limited number of standard scales (section 1·6); that choice is governed, in general, by the geomagnetic latitude of the station.

The professional requirements for K-scaling are definitely higher than those for the scaling of hourly means; but the time required is less, not more than one or two hours per month. It is possible to instruct an intelligent computer without scientific training to make preliminary K-scaling; but his results should be checked by a trained magnetic observer, especially for the lower grades of K, which are more difficult to scale than those for more disturbed intervals. Care should be taken that no change in the K-scaling practice occurs due to temporary absence of the chief observer or to change of personnel.

1.2 *Variability of* $(Sq+L)$

The first step is to gather information about the quiet daily variations at the station, produced by a superposition of the solar daily variation, Sq, and the lunar daily variation, L. Both have marked systematic changes with season, sunspot-number, and (in L) the moon's position, as expressed in average results derived from long series of observations. There are, however, also distinct individual changes, expressing a more or less irregular variability of Sq and L, which are of the same order of magnitude as the systematic changes.

The best way to gain the necessary experience regarding the total variability of $(Sq+L)$ is to collect a model stock of tracings of the magnetograms for as many quiet days as available. A selection shall be made, from the annexed list (Table 1) of quiet intervals, of a sufficient number of intervals showing the day-time swing (say, between 03 and 21 *local* time) in the magnetograms and tracings made, grouped in bi-monthly divisions according to the sun's position, namely, Dec.+Jan., Nov.+Febr., Oct.+March, Sept.+April, August+May, June+July, perhaps sub-divided according to sunspot-number. If the series of observations is long enough, it will be useful for tropical observatories to group the days, for the summer months of the hemisphere, according to the moon's age; this will give an impression of the lunar effect L and its variability, which is large near the magnetic equator (e.g. Huancayo). Such a collection of tracings will provide the information necessary to be prepared for the variable appearance of $Sq+L$, and to guard against a dangerous mistake, namely, to take the long-time average of Sq as an invariable non-K-variation and to count all deviations from that "iron-curve" as K-variations.

1.3 *Solar-flare Effects*

Another non-K-variation, which is not too frequent, is the solar-flare effect, coinciding with intense solar flares. It is described as a temporary augmentation of Sq on the sunlit-hemisphere. If the observer is not yet familiar with this phenomenon, he should compare in his magnetograms a few of the s.f.e.'s reported in the annual Bulletins on K and C since 1949. The stronger solar-flare effects of recent years have been collected here in Table 2. See also section 1.8, and VELDKAMP's reproductions in *I.A.T.M.E. Bulletin* No. 12f, (for 1951), p. 77.

1.4 *Post-perturbation*

This is described as the depression of the H-level after a magnetic storm and the slow recovery within the next days and weeks, appearing on quiet days as non-cyclic variation. It is most pronounced in low latitudes. It is considered as a non-K-variation, just as, of course, is the secular variation.

1.5 *K-variations*

All other variations are K-variations, including the additional solar daily variation on disturbed days, called SD, further bays, sudden commencements, storms, pulsations.

1.6 *Definition of K*

The meaning of K may be described as follows: At an individual station recording the field components X, Y, and Z, the magnetic field at a given instant may be conceived as a three-dimensional vector in an orthogonal co-ordinate system with a vertical axis and two horizontal axes (northward and eastward). If H, D, and Z. are recorded, the two horizontal axes are along the magnetic meridian of the station and normal to it. Suppose this vector, as a function of time, plotted from a fixed origin. The actual magnetic time-variation at that station would then be given by the curve described by the end-point of that vector; the curve would have time-marks at suitable intervals. For a particular three-hour interval, assume a non-K-variation given by a smooth curve; in this choice of the non-K-variation—in which past experience on $Sq+L$ as well as the appearance of the actual curve under consideration serve as guides—scientific judgment must be exercised. The difference-vectors connecting simultaneous points on the smooth non-K-curve and the actual curve express the K-variation.

Plotted from a fixed origin, the ends of these vectors showing the K-variations would form a continuous, more or less irregular curve which, with time marks, is a complete representation of the K-variations. Enclose this curve, for the three-hour interval considered, in a tight-fitting rectangular box with edges along the three co-ordinates. Measure, in γ, the longest edge of that box. This is the range (amplitude), say a, which determines the K-index, according to a scale chosen for each observatory once for all. One of these scales, valid for stations in about 50° geomagnetic latitude, assigns:

$K =$	0	1	2	3	4	5	6	7	8	9 if the range exceeds
$a =$	0	5	10	20	40	70	120	200	330	500 γ.

The other scales are proportional and can therefore be described by the lower limit for $K = 9$, for which the following choice is given: 300 γ, 350 γ, 500 γ, 600 γ, 750 γ, 1000 γ, 1200 γ, 1500 γ, 2000 γ. If the observatory is already working with a certain scale, adhere to it.

Equatorial stations having difficulties to distinguish between $K = 0$, 1, and 2, may contract these low grades into the symbol Q (= quiet), so that their scale is Q, 3, 4, 5, ..., 9.

Stations taking up K-scaling for the first time are advised to communicate with the Committee (see section 1·12).

1.7 *Practical Procedure*

The idea is to plot, on the magnetogram for a particular field component and for the three-hour interval considered, two parallel smooth curves representing the non-K-variation, the one touching the actual trace from below, the other one touching it from above: the vertical distance of these two smooth curves, multiplied by the scale-value, gives the range for that field-component. Of course, what is meant by "actual trace" is the centre-line of the photographic trace—no matter how wide the trace may be, due to optical conditions.

From the definition of K, it is clear that these two smooth curves will, in general, not be continuous across the limits of the three-hour intervals; there will be quite considerable vertical shifts from one interval to the next. For instance, if a short storm of, say, only 10 hours duration leaves H much depressed, the level of the non-K-variation is shifted accordingly and chosen to correspond to the possibly great recovery (non-cyclic variation).

Actually, it is not necessary to plot those two smooth curves: it is sufficient to imitate them by the sweep of a *K-gauge*. These gauges are prepared corresponding to the scale-values (in γ/mm) for each field-component as follows (according to a recommendation made by N. H. HECK): On a piece of cleared photographic film or transparent paper, about seven by ten inches in size, a common zero-line is ruled horizontally across the base of the sheet. The K-scales for the three components appear side by side, as a number of horizontal lines about one inch long. They are ruled, at the appropriate distances (corresponding to the range-limits a) from the zero-line of the gauge, and marked 0, 1, 2, ..., 8. Since K over 7 occurs rarely, it may be convenient to make the gauge in two parts, a smaller one for $K = 0$ to 6, and a longer strip for $K = 7$ to 9; in times of great storms, special gauges for use on the storm-magnetograms will be of advantage. In order to avoid parallax, the scales should be plotted on the underside of the film.

In scaling K, the gauge is always kept vertical and attention is centred on the left-hand border of the scale. The gauge is moved from left to right across the three-hour interval following the sweep of the assumed non-K-variation and so that the zero-line just touches the magnetogram curve from below. It is noted into which range limit the curve is fitting; among the three components, the greatest K-index is adopted. An experienced observer will mostly recognize at once the component with the greatest range; the ranges for the two other components need not be considered.

The curvature of the non-K-variation will, in general, not permit the straight lines of the gauge being used for fitting; it is then necessary to regard nothing but the left edges of the scale and to move the gauge from left to right. Only during the night hours, when the non-K-variation may be straight, the procedure may be simplified by using the straight lines of the gauge. It is then even permitted, since the cosine-error is negligible, to hold the gauge slightly inclined—up to 5° from the vertical—to allow for a slow uniform rise or fall of the non-K-variation. The gauges for the storm-magnetogram may be produced by simply marking the range-limits on the left-hand edge of a piece of transparent paper.

1.8 *The Diagnosis of Solar-flare Effects*

Additional information on solar eruptions and radio fade-outs is often needed. If a s.f.e. occurs in otherwise quiet times, it may result in a higher K-index, which is in conflict with the conception of K as an index for corpuscular radiation. If, through reports from other sources such as the quarterly reports from the De Bilt K- and C-centre, it is recognized that the raw K-index is raised by a solar-flare effect, please notify the De Bilt centre and estimate a corrected (non-flare) index K' for the pure effect of particle radiation. The best way is to give K and K' for each three-hour interval with a s.f.e. during daylight, even if K' is *not* smaller than K.

1.9 *Suggestions for new Observatories and Expeditions*

If no previous records are available, experience on the variability of $Sq+L$ cannot be gathered as described in Section 1.2. The observer should then make himself familiar with the variations to be expected at his station by studying the excellent series of published magnetograms for the observatories of the U.S. Coast and Geodetic Survey (Annual Publication MHV for the stations College-Alaska, geomagnetic latitude 64°, Sitka-Alaska 60°, Cheltenham 50°, Tucson 40°, San Juan 30°, Honolulu 21°), or the records of other stations in approximately the same geomagnetic latitude as his own. Furthermore, he should not start to scale any indices before he has produced at least two or three months of his own records. All indices issued should be "final", apart from possible later corrections for solar-flare effects (Section 1.8).

K-indices will not be so urgently needed from new tropical stations or from stations in non-polar regions supplementing a dense network of existing observatories. The additional information gained by such indices would be not worth while the labour spent on scaling and could be used more profitably with other geomagnetic studies.

1.10 *Incomplete Records*

If the recording has failed during a three-hour interval, indicate the gap by a dash. If only one component or part of the record is missing, measure K from the available record; indicate this by typing a +-sign superimposed over the figure or, if the table has enough space, place the + behind the index 0+, 1+, etc. This is most important in case of heavy disturbance: if, for instance, the actual K-index is 9, while the magnetogram yields only $K = 7$ because the light-spots were off the paper, it would be a gross mis-information if the 7 is given without any hint; the correct indication would be 7+.

1.11 *References and Further Information*

This article deals only with aspects of the K-index which should be known to derive good K-indices. The use of these indices including further measures of geomagnetic activity based on them will be explained in a further article.

Information on K-indices and related subjects will be given by the Committee on Magnetic Characterization of the IAGA (present Chairman: J. BARTELS, Herzberger Landstr. 180, (20b) Göttingen, Germany). It is also contained in the following papers:

BARTELS J. 1938. Potsdamer erdmagnetische Kennziffern. *Ztschr. f. Geophysik* **14**, 68–78.

This paper introduces the K-index for Potsdam-Niemegk and a series of fourteen communications giving tables for K. A few of them contain summaries and discussions: *Ztschr. f. Geophysik* **15**, 214–221 (1939); **16**, 185–194 (1940); **17**, 317–327 (1941/42), dealing with the international adoption of the K-index.

BARTELS J. HECK N. H. and JOHNSTON H. F. 1939. The three-hour-range index measuring geomagnetic activity. *Terr. Magn.* **44**, 411–454.

This paper followed the tentative introduction of the K-index at the Washington 1939-Meeting of the International Association of Terrestrial Magnetism and Electricity. Its present value consists mainly in the collection of typical *magnetograms* from seven widely distributed observatories (see especially p. 419 and pp. 422–423 with plots of non-K variations, and the magnetograms with solar-flare effects). Some of the parameters introduced in that paper (such as Km, B) have later been improved upon: Km has been replaced by Kp, and the daily index B has been replaced by the planetary character-figure Cp and the equivalent amplitude Ap.

BARTELS J. and JOHNSTON H. F. 1939. Main features of daily magnetic variations at Sitka, Cheltenham, Tucson, San Juan, Honolulu, Huancayo, and Watheroo. *Terr. Magn.* **44**, 455–469.

This paper gives graphs expressing the main features of Sq and their changes with season and sunspot-number, but not their variability; also average SD.

BARTELS J. and JOHNSTON H. F. 1940. Geomagnetic tides in horizontal intensity at Huancayo. *Terr. Magn.* **45**, 269–308, 485–512.

Exhibits on pp. 275f. and 279f., the extreme variability of $Sq + L$ in H at Huancayo.

BARTELS J. HECK N. H. and JOHNSTON H. F. 1940. Geomagnetic three-hour-range indices for the years 1938 and 1939. *Terr. Magn.* **45**, 309–337.

Discusses local features in K, and introduces the reduced index Kr and the world-wide index Kw, later replaced by the standardized index Ks and the planetary index Kp.

JOHNSTON H. F. 1941. Three-hour-range indices K for 1940. *Terr. Magn.* **46**, 301–308.

Reproduces a Circular Letter introducing K, remarks on the variability of Sq with respect to K-scaling, and the proposal of HECK on K-gauges.

The international publications on K-indices are the International Association of Terrestrial Magnetism and Electricity (IATME) Bulletins Nos. 12, 12a, ... 12j, to be obtained from the Secretary of the Association, Dr. V. LAURSEN, Meteorologisk Institut, Charlottenlund, Denmark. They deal with the years 1940–1946 (No. 12), 1947 (No. 12a), 1948 (No. 12b), 1949 (No. 12c), International Polar Year (No. 12d), 1950 to 1955 (in Nos. 12e to 12j, respectively). The years 1937 to 1939 are treated in 12g. References to former tables are always given at the end of the recent numbers of the Bulletin. From No. 12i, the Bulletin is now published by the IAGA: International Association of Geomagnetism and Aeronomy (this name replaces IATME).

The Bulletins contain two papers:

BARTELS J. The standardized index, Ks, and the planetary index, Kp (IATME Bull. No. 12b, for 1948, pp. 97–120; since that number is out of print, the article has been reproduced in IAGA Bull. No. 12i, for 1954, 88–116).

BARTELS J. An attempt to standardize the daily international magnetic character-figure (Bull. No. 12e, for 1950, 109–137).

CRICHTON J. 1949. The K-index at Eskdalemuir. *J. Geophys. Res.* **54**, 275–276.

MAYAUD, PIERRE-NOËL. 1955. Activité magnétique dans les régions polaires. Expéd. Polaires Françaises, Missions Paul-Emile Victor, Expéditions Antarctiques. Résultats Scient. No. S. IV. 2. Terre Adélie 1951–1952. *Magn. Terr. Fasc.* II. Paris. 1956. Summary in *Annales de Géophysique* **12**, 84–101, (1956).

This important contribution is based on K-indices mostly measured by the author. It gives a detailed discussion of the daily variations of activity in polar regions, and cites results by J. M. STAGG and A. P. NIKOLSKY: Problemy Arktiki, No. 4 (1938); No. 2 (1948)

Current monthly tables and graphs for Kp are mailed from Göttingen, Geophysikalisches Institut, about three weeks after the end of each month. Quarterly tables are distributed by the $C+K$-centre, Meteorologisk Instituut, De Bilt, and printed in every issue of *J. Geophys. Res.* since 1949. During the IGY, the Kp will appear twice monthly.

2 The Q-index

For certain studies—on aurora, the ionosphere, meteors, etc.—it is desirable to provide a measure of geomagnetic activity for time-intervals smaller than the three-hour intervals of the K-index. Since the aurora will be observed every 15 minutes, the author has proposed to express geomagnetic activity for 15-minute intervals centred at the observation times for aurora, by an index which is described in a joint paper by Dr. N. FUKUSHIMA (Tokyo) and myself, and which may be called Q-index, Q for quarterly. In order to distinguish our Q from other symbols (used, for instance, in radio propagation work), it may occasionally be written Qm. The choice of the letter Q is embarrassing, because q stands usually for quiet; but there is hardly any other letter available.

Q will be described as follows:

(1) Four indices Q will be given for each hour Universal Time. For instance, for 03 to 04 UT (= GMT), the four indices Q will express conditions in the four 15-minute intervals centred at 03.00, 03.15, 03.30, 03.45. A Q-index shortly referred to as valid for 03.15 will characterize the interval 03.07.30 to 03.22.30. This allows a comparison with the simultaneous auroral observation at 03.15.

(2) Q-measuring will be requested from polar stations only down to, say, about 58° geomagnetic latitude, 32° distance from the geomagnetic axis (just including

Lovö and Eskdalemuir). $Q = 4$ or greater may, however, be scaled down to, say, 50° latitude.

(3) Q will, like the K-index, be based on the amplitudes of the variations which remain after the non-K variations (see the article on K, Section 1.1 to 1.4) have been eliminated, especially $Sq+L$.

(4) While K measures ranges, the Q-index will measure the total deviation from the normal curve. If the extreme deviations from the normal curve in an interval are (say)

$$+200 \text{ and } +50\,\gamma, \quad \text{or } +100 \text{ and } -50\,\gamma, \quad \text{or } -50 \text{ and } -300\,\gamma,$$

the relevant amplitudes are, for the K-index

$$150\,\gamma, \qquad 150\,\gamma, \qquad 250\,\gamma,$$

in the three cases, but, for the Q-index

$$200\,\gamma, \qquad 150\,\gamma, \qquad 300\,\gamma.$$

The reason for this different practice in K and Q is as follows: When K was introduced, it was originally intended to use the same procedure as now proposed for Q. However, at non-polar stations it proves very difficult to determine the level of the normal curve with the exactness of a few γ needed for $K = 0$, 1, or 2. Therefore for the K-index, which has been introduced for all stations, it was decided to use simply the ranges without reference to the absolute level of the normal curve, and this decision turned out to have been adequate. But at the polar stations which are asked to scale Q, it is generally quite easy to determine the absolute level of the normal curve, from which the absolute maximal deviations can then be measured. Q is based on the sum of the absolute maximal deviations towards the plus and the minus side; these, of course, need not be measured individually and very often one of them will be zero, especially in case of strong SD (= solar daily variation on disturbed days).

(5) Unlike for the K-index, there will be a uniform scale for Q, valid for all stations, for which Fukushima and I propose the following:

$Q =$	0	1	2	3	4	5	6	7	8	9	10 $= T$	11 $= E$
Upper limit of amplitude	10	20	40	80	140	240	400	660	1000	1500	2200	inf. γ

In trial measurements, the grades T (short for 10) and E (short for 11) have been found occasionally at College, Alaska.

(6) A further distinction between K and Q will be that, while K measures the range of the most disturbed component *including* the vertical component Z, the measurement of Q will be restricted to the two *horizontal* components, and will indicate the amplitude of the most disturbed horizontal component. Q will thereby express the intensity of the ionospheric currents above the station, and not the intensity of a line-current along the auroral zone, possibly 1000 miles away.

Practical Procedure

The idea is to plot, on the magnetograms for the two components X and Y, or H and D, one normal curve considered as "non-K variation" for each component. In this choice of the normal curve, the observer is guided by past experience on $Sq+L$ as well as by the appearance of the magnetograms under consideration, just as in the case of K-scaling (see Section 1.7 in the preceding article on K); but in addition, for Q-scaling, he has to choose the correct level of the normal curve, which may be obtained by judicious interpolation between the curves for quiet times preceding and following the interval considered. This prescription " Find the normal curve which would have been recorded if there had been no disturbance in the interval" sounds more difficult than it actually is, especially for polar observatories where the effects of disturbance (including SD, solar daily variation on disturbed days) are so much more pronounced than $Sq+L$. According to extensive experience gained in Q-scaling for such observatories as Meanook, Sodankylä, and Eskdalemuir, there will, in general, be no difficulty in judging the normal curve accurately enough to be able to scale Q correctly, even when $Q = 0$, 1, or 2.

Q-scales will be required, one for each field-component, showing the limits of the various degrees of Q, plotted on the underside of a strip of cleared photographic film or transparent paper, by the distances of the horizontal scale-lines computed with the scale-value (γ/mm) of each individual variometer. These will also indicate, by vertical lines, the limits of the 15-minute time-intervals. The scale should, from left to right, extend over five intervals, that is 75 minutes, with the centres of the first and last intervals marked to coincide with the time-marks for the full hour Universal Time.

As in the case of K, it will not be necessary actually to plot the normal curves; it will be sufficient, with a little practice, to indicate them by the sweep of the left edge of the Q-gauge. The gauge is always kept vertical.

It will be convenient to make two Q-scales for each component: one for Q from 0 to (say) 6 ($= 400\ \gamma$), for the standard magnetograph records, and another one for $Q = 6$ and higher, to be used with the storm magnetograph.

In the cases in which the records fail partly or wholly to furnish the magnetograms necessary to scale the correct Q, proceed as described in Section 1.10 of the preceding K-article.

In case of a solar-flare effect, proceed just as for the K-index as outlined in Section 1.8 of the preceding description of the K-index: give the raw Q-index and, in addition, a corrected (non-flare) Q'-index.

From the definition of Q, it is clear that it is easy to derive from Q also measures for longer intervals, for instance hours. Four successive intervals could simply be characterized by the highest of the four Q-indices.

While the K-index has been officially adopted, after a prolonged trial stage, by the International Association of Geomagnetism and Aeronomy, the Q-index so far is simply a proposal, whose final adoption will await extensive tentative application and discussion, on the basis of experience to be gained during the IGY.

Details and first tables with Q-indices are given in a paper by J. BARTELS and N. FUKUSHIMA "A Q-index for the geomagnetic activity in quarter-hourly intervals", *Abhandlungen Akad. Wiss. Göttingen, Math.-Phys. Klasse*, Sonderheft, No. 3, 1956. Copies of this paper will be made available to all those interested, including a complete English translation of the German text.

Table 1

Quiet times of 36 hours' duration or longer with Kp not higher than 1·o, in the Polar Year 1932/33 and Jan. 1937 to April 1957, arranged according to calendar months.

n = number of successive three-hour-intervals with Kp 1·o or less.
R = Zürich Relative Sunspot-number
ν = Age of the Mean Moon, for main partial tide M_2 in the middle of the quiet time. $\nu = 0$ New Moon, $\nu = 3$ first eighth, $\nu = 6$ first quarter, etc.
for $\nu = 12$ (Full Moon) to 23, (ν —12) has been entered.

								n	R	ν
1933	Jan.	4 d	03 h	...		6 d	03 h	16	17	7
1933	Jan.	9 d	18 h	...		12 d	12 h	22	17	0
1937	Jan.	18 d	00 h	...		19 d	21 h	15	108	5
1937	Jan.	22 d	15 h	...		26 d	06 h	29	178	10
1939	Jan.	25 d	15 h	...		28 d	15 h	24	102	6
1942	Jan.	30 d	21 h	...	Feb.	1 d	12 h	13	20	0
1943	Jan.	14 d	00 h	...		16 d	12 h	20	0	7
1945	Jan.	10 d	21 h	...		12 d	12 h	13	30	10
1945	Jan.	23 d	06 h	...		26 d	09 h	25	23	9
1946	Jan.	20 d	06 h	...		21 d	18 h	12	5	2
1947	Jan.	8 d	18 h	...		15 d	09 h	53	119	4
1955	Jan.	25 d	06 h	...		27 d	06 h	16	25	2
1933	Feb	16 d	00 h	...		18 d	12 h	20	0	6
1939	Feb.	11 d	15 h	...		13 d	18 h	17	73	7
1940	Feb.	17 d	18 h	...		19 d	21 h	17	50	8
1945	Feb.	20 d	18 h	...		22 d	06 h	12	7	7
1953	Feb.	6 d	21 h	...		8 d	09 h	12	14	7
1937	Mch.	7 d	00 h	...		8 d	24 h	16	105	8
1938	Mch.	17 d	18 h	...		21 d	09 h	29	80	2
1938	Mch.	30 d	09 h	...	Apr.	1 d	09 h	16	86	0
1940	Mch.	17 d	03 h	...		18 d	24 h	15	56	8
1941	Mch.	26 d	09 h	...		27 d	21 h	12	43	0
1944	Mch.	16 d	18 h	...		18 d	06 h	12	14	6
1953	Mch.	12 d	06 h	...		13 d	21 h	13	7	10
1956	Mch.	7 d	15 h	...		9 d	21 h	18	104	9
1933	Apr.	11 d	12 h	...		13 d	09 h	15	0	2
1937	Apr.	9 d	03 h	...		10 d	21 h	14	71	0
1940	Apr.	8 d	18 h	...		11 d	09 h	21	59	2
1943	Apr.	23 d	00 h	...		24 d	24 h	16	36	4
1944	Apr.	12 d	15 h	...		14 d	09 h	14	0	4
1944	Apr.	21 d	18 h	...		23 d	24 h	18	0	0
1947	Apr.	21 d	12 h	...		23 d	03 h	13	81	1
1947	Apr.	23 d	18 h	...		25 d	09 h	13	110	3
1933	May	26 d	00 h	...		27 d	15 h	13	0	2
1942	May	25 d	15 h	...		27 d	06 h	13	15	9
1943	May	8 d	00 h	...		10 d	09 h	19	18	4
1944	May	15 d	09 h	...		16 d	24 h	13	0	7
1944	May	19 d	15 h	...		21 d	21 h	18	0	10
1947	May	7 d	15 h	...		10 d	06 h	21	158	3
1949	May	28 d	12 h	...		30 d	12 h	16	119	2

Table 1—continued

								n	R	ν
1938	Jne.	22 d	12 h	...		24 d	06 h	14	101	9
1941	Jne.	3 d	12 h	...		5 d	06 h	14	53	8
1942	Jne.	9 d	09 h	...		10 d	24 h	13	8	9
1942	Jne.	21 d	15 h	...		23 d	06 h	13	19	7
1943	Jne.	17 d	03 h	...		19 d	03 h	16	7	0
1944	Jne.	12 d	00 h	...		13 d	12 h	12	0	5
1945	Jne.	21 d	06 h	...		23 d	06 h	16	56	10
1948	Jne.	15 d	09 h	...		16 d	24 h	13	157	8
1933	Jly.	14 d	09 h	...		16 d	09 h	16	0	6
1939	Jly.	7 d	00 h	...		8 d	12 h	12	151	4
1940	Jly.	26 d	09 h	...		27 d	24 h	13	50	6
1942	Jly.	3 d	15 h	...		5 d	06 h	13	24	5
1944	Jly.	11 d	09 h	...		12 d	21 h	12	0	5
1947	Jly.	4 d	06 h	...		5 d	18 h	12	131	2
1955	Jly.	4 d	09 h	...		5 d	21 h	12	48	0
1932	Aug.	9 d	12 h	...		11 d	21 h	19	0	7
1932	Aug.	16 d	03 h	...		17 d	21 h	14	0	0
1933	Jly.	31 d	21 h	...	Aug.	2 d	21 h	16	0	8
1933	Aug.	3 d	00 h	...		4 d	21 h	15	0	10
1933	Aug.	30 d	09 h	...		31 d	21 h	12	0	9
1937	Aug.	15 d	15 h	...		17 d	03 h	12	119	8
1937	Aug.	23 d	15 h	...		25 d	03 h	12	150	2
1938	Aug.	15 d	00 h	...		17 d	12 h	20	119	4
1938	Aug.	19 d	21 h	...		21 d	12 h	13	76	8
1939	Aug.	2 d	09 h	...		5 d	21 h	28	94	3
1940	Aug.	16 d	09 h	...		17 d	21 h	12	109	11
1940	Aug.	23 d	21 h	...		25 d	18 h	15	94	5
1945	Aug.	9 d	03 h	...		10 d	24 h	15	35	2
1945	Aug.	17 d	21 h	...		21 d	09 h	28	33	9
1946	Aug.	22 d	06 h	...		23 d	18 h	12	8	8
1946	Aug.	28 d	21 h	...		30 d	18 h	15	6	2
1949	Aug.	24 d	06 h	...		26 d	06 h	16	148	1
1953	Aug.	20 d	03 h	...		22 d	03 h	16	17	9
1955	Aug.	21 d	09 h	...		23 d	06 h	15	23	3
1956	Aug.	18 d	09 h	...		20 d	06 h	15	192	10
1939	Sep.	28 d	09 h	...		30 d	06 h	15	131	1
1941	Sep.	3 d	09 h	...		4 d	21 h	12	53	11
1941	Sep.	5 d	00 h	...		6 d	18 h	14	49	11
1945	Sep.	23 d	03 h	...		25 d	03 h	16	77	2
1948	Sep.	27 d	12 h	...		28 d	24 h	12	143	8
1949	Sep.	18 d	15 h	...		21 d	21 h	26	164	10
1956	Sep.	18 d	03 h	...		19 d	21 h	14	214	0
1940	Oct.	13 d	03 h	...		14 d	24 h	15	66	10
1940	Oct.	22 d	21 h	...		25 d	09 h	20	41	7
1941	Oct.	3 d	09 h	...		4 d	21 h	12	33	11
1945	Oct.	2 d	18 h	...		4 d	24 h	18	82	9
1945	Oct.	9 d	18 h	...		12 d	06 h	20	31	4
1952	Oct.	23 d	18 h	...		25 d	09 h	13	33	5

Table 1—continued

								n	*R*	*v*
1954	Oct.	11 d	15 h	...		13 d	21 h	18	7	0
1955	Oct.	11 d	21 h	...		13 d	21 h	16	61	9
1955	Oct.	18 d	00 h	...		19 d	15 h	13	0	2
1956	Oct.	13 d	03 h	...		16 d	03 h	24	134	8
1932	Nov.	23 d	15 h	...		25 d	03 h	12	0	9
1937	Nov.	5 d	09 h	...		6 d	24 h	13	49	2
1937	Nov.	14 d	15 h	...		17 d	06 h	21	74	10
1938	Nov.	30 d	03 h	...	Dec.	2 d	06 h	17	97	7
1939	Nov.	21 d	15 h	...		23 d	06 h	13	66	9
1940	Nov.	10 d	06 h	...		11 d	21 h	13	60	9
1944	Nov.	12 d	09 h	...		14 d	18 h	19	8	10
1944	Nov.	21 d	03 h	...		22 d	15 h	12	20	5
1944	Nov.	23 d	06 h	...		25 d	24 h	14	24	7
1944	Nov.	26 d	18 h	...		28 d	18 h	16	17	10
1945	Nov.	5 d	18 h	...		8 d	12 h	22	38	2
1945	Nov.	18 d	12 h	...		20 p	03 h	13	57	0
1945	Nov.	20 d	06 h	...		21 d	18 h	12	46	1
1946	Nov.	28 d	09 h	...		30 d	12 h	17	7	4
1947	Nov.	6 d	00 h	...		7 d	12 h	12	76	6
1948	Nov.	29 d	12 h	...	Dec.	1 d	12 h	16	58	11
1950	Nov.	6 d	12 h	...		7 d	24 h	12	80	10
1952	Nov.	10 d	00 h	...		11 d	15 h	13	26	6
1953	Nov.	9 d	09 h	...		11 d	12 h	17	0	3
1953	Nov.	29 d	12 h	...	Dec.	1 d	24 h	20	0	7
1954	Nov.	15 d	03 h	...		17 d	06 h	17	7	5
1932	Dec.	21 d	03 h	...		22 d	18 h	13	0	8
1938	Dec.	26 d	03 h	...		27 d	21 h	14	73	4
1939	Dec.	19 d	06 h	...		20 d	18 h	12	45	7
1940	Dec.	7 d	03 h	...		8 d	24 h	15	82	7
1942	Dec.	31 d	03 h	...	Jan.	1 d	15 h	12	11	7
1945	Dec.	3 d	03 h	...		5 d	15 h	20	36	0
1946	Dec.	13 d	21 h	...		15 d	09 h	12	7	5
1947	Dec.	20 d	21 h	...		22 d	12 h	13	97	7
1954	Dec.	10 d	12 h	...		12 d	03 h	13	0	1
1954	Dec.	14 d	03 h	...		16 d	24 h	23	11	4
1955	Dec.	22 d	18 h	...		24 d	12 h	14	64	7
1955	Dec.	28 d	21 h	...		30 d	15 h	14	72	0

Table 2

Some important geomagnetic solar-flare-effects, January 1949 to December 1956

1949	Jan.	15 d	21 h	46 m
1949	Jan.	17 d	10 h	40 m
1949	Jan.	23 d	01 h	10 m
1949	Feb.	01 d	12 h	19 m
1949	Feb.	09 d	16 h	45 m
1949	Feb.	10 d	02 h	30 m
1949	Feb.	11 d	11 h	00 m
1949	Mch.	26 d	14 h	15 m
1949	Apr.	20 d	18 h	45 m
1949	May	07 d	20 h	44 m
1949	May	10 d	20 h	01 m
1949	Sep.	05	12 h	30 m
1949	Sep.	13 d	13 h	03 m
1949	Sep.	17 d	17 h	16 m
1949	Sep.	18 d	09 h	45 m
1949	Oct.	02 d	14 h	01 m
1949	Nov.	19 d	10 h	30 m
1950	Feb.	13 d	19 h	13 m
1950	Feb.	17 d	01 h	20 m
1950	Apr.	12 d	14 h	53 m
1950	Apr.	14 d	12 h	45 m

1950	Apr.	14 d	13 h	35 m
1950	Apr.	15 d	12 h	57 m
1950	May	06 d	13 h	30 m
1950	May	27 d	08 h	14 m
1950	Sep.	19 d	17 h	08 m
1951	Jan.	22 d	16 h	25 m
1953	Oct.	14 d	09 h	50 m
1955	Nov.	14 d	04 h	38 m
1955	Dec.	03 d	11 h	02 m
1956	Feb.	13 d	14 h	41 m
1956	Feb.	14 d	05 h	39 m
1956	Feb.	23 d	03 h	34 m
1956	Mch.	17 d	13 h	50 m
1956	May	31 d	07 h	50 m
1956	Nov.	18 d	08 h	33 m
1956	Dec.	19 d	06 h	05 m
1956	Dec.	20 d	04 h	44 m