to look for such relationships. The data do suggest, however, that a longitude dependence is involved, which could imply propagation along field lines. Second, we see a projection of the rotation of the field lines and do not observe the amplitude directly. Knowing the total geomagnetic field amplitude, we can estimate a lower bound by assuming that the disturbance field is normal to the geomagnetic field line. The disturbances derived in this way are roughly 50 to 100 gammas. The corresponding disturbances at the surface are 500–1000 gammas in amplitude.

Jacobs, J. A.: Is the maximum value of ΔB always at 4 earth radii?

Smith: First, we only have data for one storm, and second, we cannot really say that the minimum is always located at 4 earth radii.

JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN Vol. 17, SUPPLEMENT A-I, 1962
INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part I

I-1-2. Magnetic Impulses and Sun-Earth Relations

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Earlier work[1], using the magnetic 3-hourly a_p index during a relatively quiet period in 1952, revealed periodicities of from one to four days in the earth's magnetic field variations. There was a close connection between these periodicities and the occurrence of magnetic impulses. The present paper examines the occurrence of magnetic impulses from 1949–59. The time interval between these impulses is not random, but shows marked periodicities, even when considered over the entire sunspot cycle. These results are supported by an investigation of the time interval between flares and SSC's during IGY.

Solar disturbance events may be categorized as either sporadic or long enduring with reference to the solar rotation period of 27 days. Similarly, terrestrial disturbances are either sporadic or 27 day recurrent events. SID's and PCD's [Polar Cap Disturbances] whose sun-earth transit time is short, can in theory be unambiguously associated with specific solar events. However, once the transit time becomes comparable to the mean time between solar disturbances, it is necessary to use statistical techniques, and it is much more difficult to obtain unambiguous associations. In particular, the existence of long enduring disturbance regions on the sun could produce spurious transit time effects, if the angular separation of these regions was not random.

Periodicities of less than 27 days in geophysical disturbance data have been investigated for many years, with inconclusive results, due to inherent difficulties in determining the statistical significance of the computations. The same difficulty arises in the present analysis. However, there is now an increasing amount of evidence, arising from the study of independent data samples, to support the existence of such periodicities.

Auto-correlation of the 3-hourly magnetic planetary index, a_p, during short moderately disturbed intervals in 1952 disclosed periods of from one to four days[1]. Moreover, the times of occurrence of magnetic impulses seemed to be closely connected with the amplitude of these periodicities, and with changes from one periodicity to another.

Ward[2] computed the variance spectrum of the daily *Ci*, *Kp*, and *Ap* indices for some portions of 1941–56, and found periods of $27/n$ days, with $n=1, 2, 3, 4, 5$ and 6. The 27–, 14– and 9– day periods were the most pronounced, but when the *Kp* data were subdivided into 6 month periods, the 14– and 9–day periods occurred independently of the

27-day periods and of each other. Ward considered that his data were insufficient to resolve the problem, and did not attempt an interpretation of the existence of overtones of the 27-day period.

Another technique for examining periodicities of less than 27 days is to consider the time separation between specific disturbance events. Two disturbance phenomena sharply defined in time are solar flares and terrestrial magnetic impulses. The results of a study of the time separation, between the occurrence of magnetic impulses is the main topic of this paper. A parallel investigation[3] of the time separation between solar flares and SSC impulses will also be discussed.

The time separation, ΔT, between 817 magnetic impulses occurring from 1949–59 was tabulated, for time separations up to 70 days. The declining portion of the sunspot cycle, from 1949–54, shows maxima in the number of occurrences $N(\Delta T)$ at about the period of solar rotation. Similar maxima do not occur in $N(\Delta T)$ for 1955–59, Fig. 1.

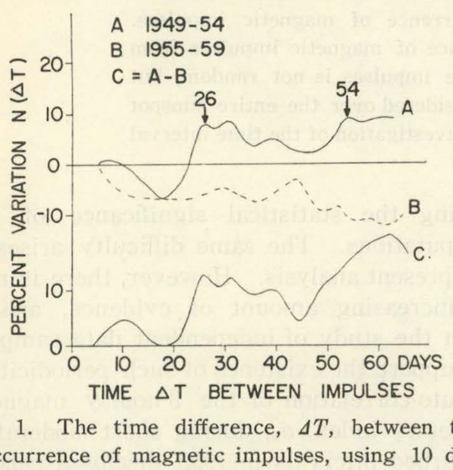

Fig. 1. The time difference, ΔT, between the occurrence of magnetic impulses, using 10 day running averages, 1949–59.

The same data were examined for higher frequencies, Fig. 2. In 1949–54, in addition to the solar rotation maxima, maxima in $N(\Delta T)$ appeared at multiples of about 3 1/2 days in the interval 0 to 12 days. These $N(\Delta T)$ maxima are consistent with the hypothesis that four long-enduring sources of impulses were located about 53° apart from each other on the sun's surface, and that the rotation period was 26 1/2 days. This is seen in Table I.

In 1955–59, the maxima in $N(\Delta T)$ occur at intervals of about 3 days. In this case, however, there is not an obvious solar rotation maximum, and a scheme similar to Table I cannot be constructed. The periodicity in $N(\Delta T)$ was particularly strong during IGY, with a mean period of 2 3/4 days, Fig. 3.

The above periodicities in the time separation between magnetic impulses can be associated with the sun only by inference. It has been tacitly assumed in the literature that SC storms necessarily arise from solar flares, and it might logically follow that all magnetic impulses, SSC and SI, are caused by flares.

Recurrent storm sequences, with 3 or more members, from 1948–57, were found to consist of about equal numbers of GC (gradual commencement) and SC storms. Six of the sequences are entirely SC, 10 are all GC, and 12 are mixed. The starting times of these recurrent storms and therefore the times of the SSC impulses preceding the SC members, cannot be directly associated with the occurrence of flares; although an indirect association is possible.

Considerations of this type led to an examination of the time separation, Δt, between the occurrence of solar flares and magnetic SSC impulses during IGY[3]. All flares listed, from 1^- to 3^+ were given equal weight in the analysis. Intervals of up to 14 days were tabulated to the nearest 1/4 day, from SSC to flare, $(-\Delta t)$, as well as from flare to SSC (Δt). The $N(+\Delta t)$ curves show a 1 3/4 day periodicity which is not present in $N(-\Delta t)$, and which could conceivably arise from the transit time of a disturbance from the sun to the earth. Removal of the 1 3/4 day component leaves a 3 day periodicity in $N(+\Delta t)$, of about the same amplitude as a 2 1/2 day periodicity in $N(-\Delta t)$. It could not be determined from this analysis whether the above difference between 2 1/2 and 3 days is significant.

Division of this data into equinox and solstice periods, for strong and weak flares, is shown in Fig. 4. During the equinox, the $N(\Delta t)$ curves for strong and weak flares are remarkably similar, with maxima at about 2 1/2 and 5 days. During the solstices, however, the curve for strong flares has a pronounced maximum at 1 3/4 days. If this

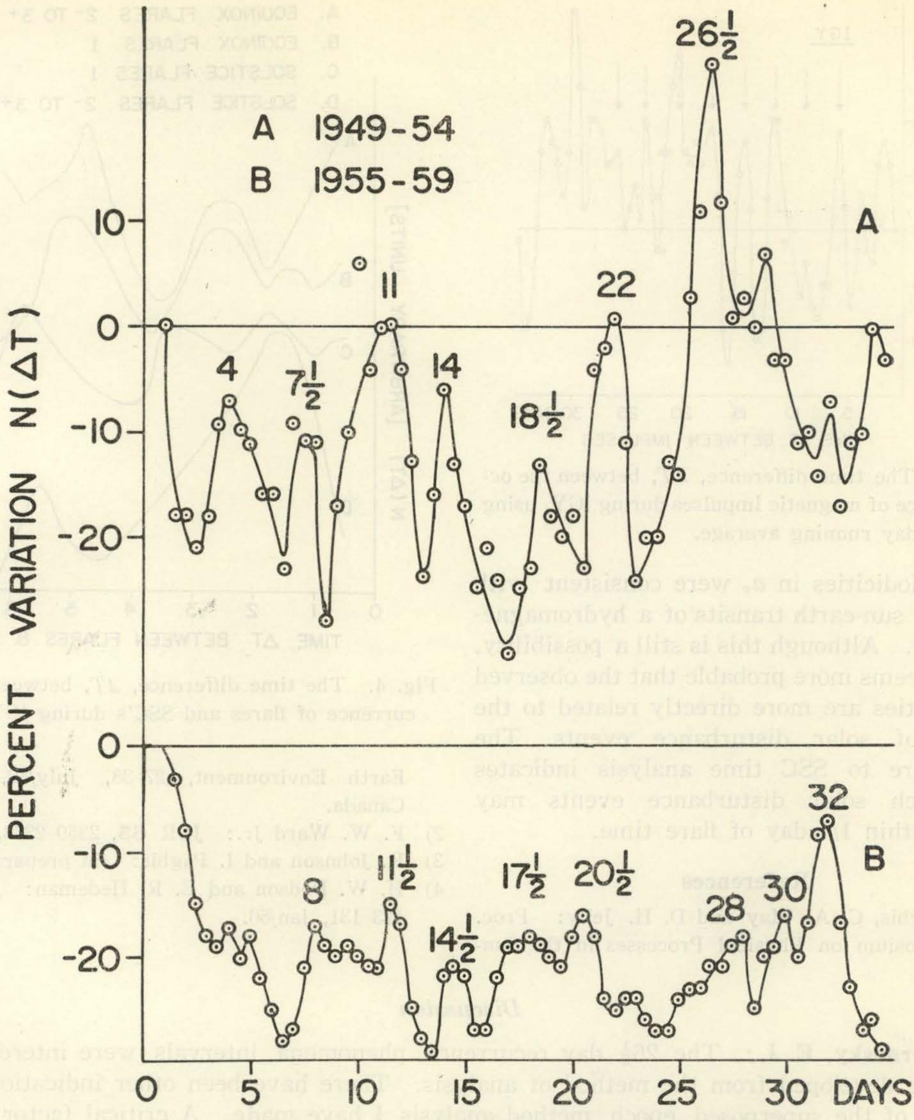

Fig. 2. The time difference, ΔT, between the occurrence of magnetic impulses, using a one day running average, 1949-59.

Table I.

Maxima in $N(\Delta T)$, 1949-54)

Computed	Observed
4 days	4 days
4+ 4= 8	7
4+ 8=12	11 1/2
26 1/2−12=14 1/2	14
26 1/2− 8=18 1/2	18 1/2
26 1/2− 4=22 1/2	22
26 1/2	26 1/2

is, in fact, a transit time effect, a similar effect should occur in the strong equinoctial flares. With the resolution of the present analysis, all that can be stated is that, if such a transit time peak is present, it is at less than one day. [A one day periodicity in the IGY flare listings[4] made it impossible to decide whether $N(\Delta t)$ contains a non-spurious one day component.]

A great deal of further analysis is required to establish the physical nature of these periodicities. It was previously suggested[1]

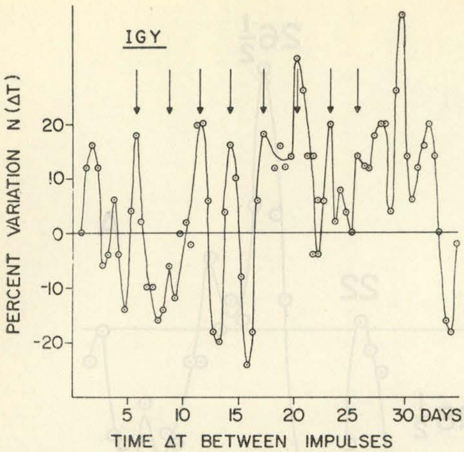

Fig. 3. The time difference, ΔT, between the occurrence of magnetic impulses during IGY, using a one day running average.

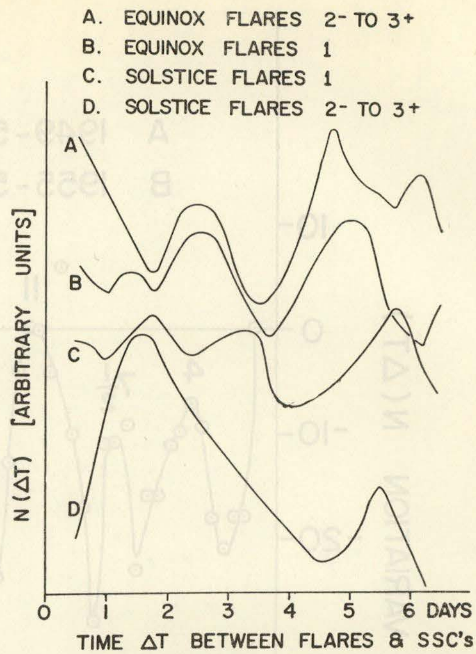

Fig. 4. The time difference, ΔT, between the occurrence of flares and SSC's during IGY.

that periodicities in a_p were consistent with repeated sun-earth transits of a hydromagnetic wave. Although this is still a possibility, it now seems more probable that the observed periodicities are more directly related to the timing of solar disturbance events. The solar flare to SSC time analysis indicates that such solar disturbance events may occur within 1/4 day of flare time.

References

1) I. Paghis, C. A. May and D. H. Jelly: Proc. Symposium on Physical Processes in the Sun-Earth Environment, 27-38, July/59, Ottwa, Canada.
2) F. W. Ward Jr.: JGR **65**, 2359-2373, Aug/60.
3) R. Johnson and I. Paghis: (in preparation).
4) H. W. Dodson and E. R. Hedeman: JGR, **65**, 123-131, Jan/60.

Discussion

Chernosky, E. J.: The $26\frac{1}{2}$ day recurrence phenomena intervals were interesting to see developed from the method of analysis. There have been other indications in some of the superposed epoch method analysis I have made. A critical factor here to make these periodicities evident is the time grouping (in the solar cycle) of the magnetic data where the effects are not averaged or smoothed away by combining of groups whereon different periodicities may exist.

Paghis, I.: It is encouraging to hear that on entirely different set of data, and different analytic procedures, also produces periodicities shorter than the rotation; there is possibly the best way to establish their physical significance.