

## I-1. Morphology of Magnetic Storms

Chairman: S. CHAPMAN

Co-chairman: M. OTA

Date	Time	Paper Numbers
Sept. 4	11:30 - 13:30	from I-1-1 to I-1-5
Sept. 4	15:30 - 17:30	from I-1-6 to I-1-10
Sept. 5	09:00 - 11:00	from I-1-P0 to I-1-P3

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INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part I

### I-1-1. Satellite Observations of the Distant Field during Magnetic Storms: Explorer VI\*

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The earth satellite Explorer VI contained a search-coil magnetometer which measured the amplitude,  $B$ , and direction,  $\phi$ , of a vector component of the extraterrestrial magnetic field out to geocentric altitudes of 8 earth radii ( $R_E$ ). Fig. 1 shows the vector component, which is perpendicular to the spin axis of the spacecraft,  $\omega$ . Fig. 1 also shows the orientation of the Explorer VI orbit relative to the earth-sun direction,  $s$ .

Fig. 2 is a graph of the time variation of the field amplitude in the outer radiation

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zone and at the earth's surface. Each datum is the average, observed field amplitude in the vicinity of 24,000 kilometers during a single orbital pass. For each value of  $B_L$ , the corresponding value of the extrapolated geomagnetic field,  $G_L$  was computed from an 8 coefficient spherical harmonic expansion of the surface field. Fig. 2-a is a plot of the difference  $\Delta B = B_L - G_L$  during the first two weeks of Explorer VI observations. The data have been normalized so that  $\Delta B = 0$  on magnetically quiet days (August 11-12). It can be shown that  $\Delta B(t)$  approximates the magnitude of the disturbance field on the geomagnetic equatorial plane. Fig. 2-b is the daily mean of the horizontal intensity at

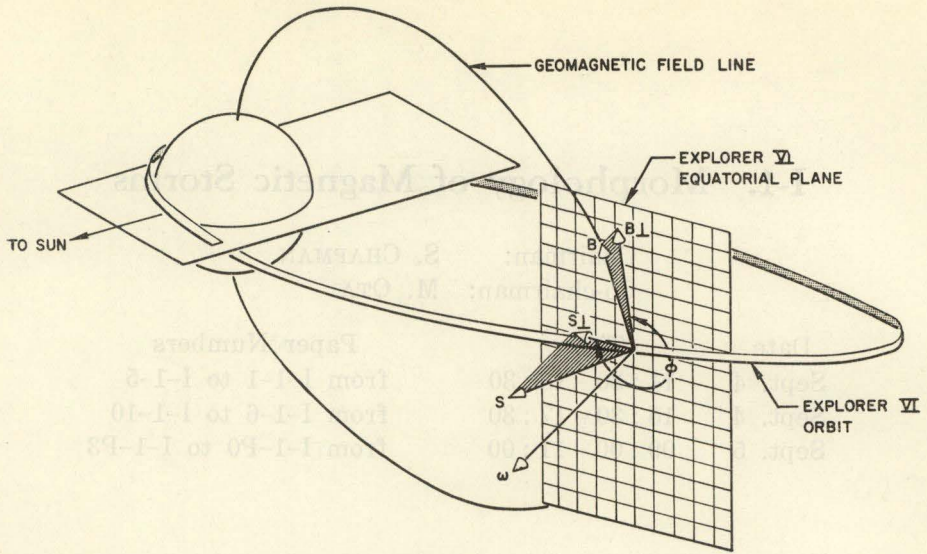


Fig. 1. Explorer VI orbit and spacecraft frame of reference.

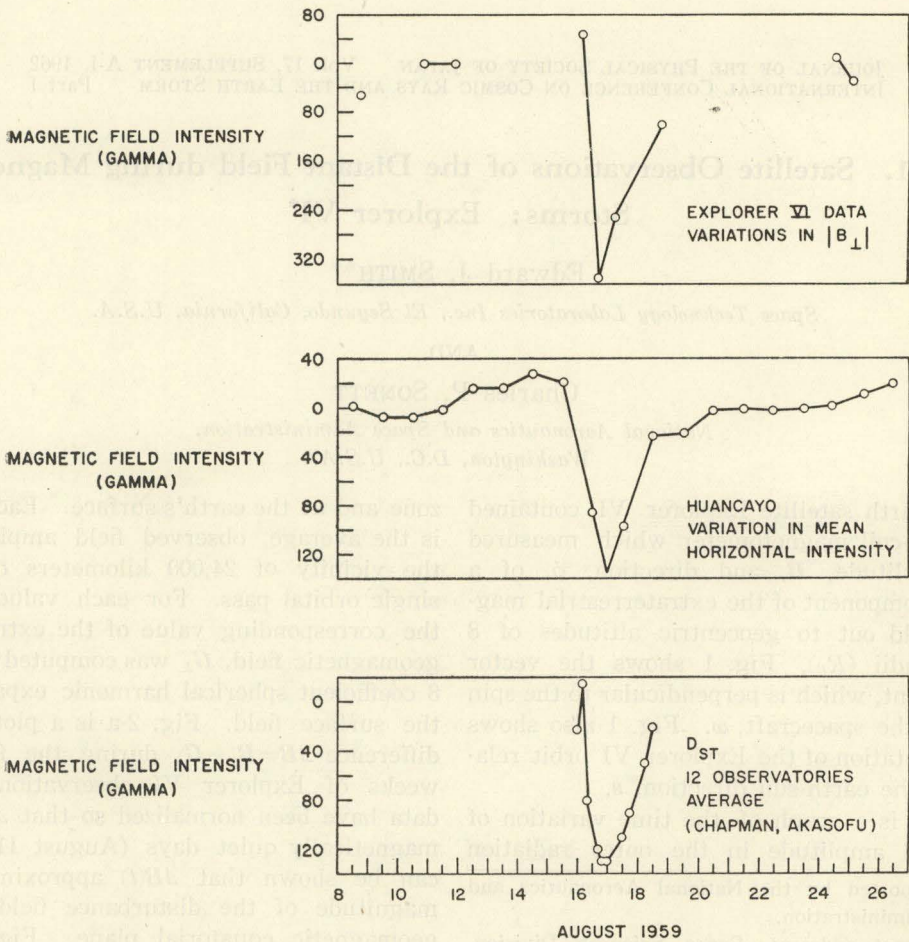


Fig. 2. Time variation of disturbance field amplitude at  $4R_E$  and at the earth's surface.

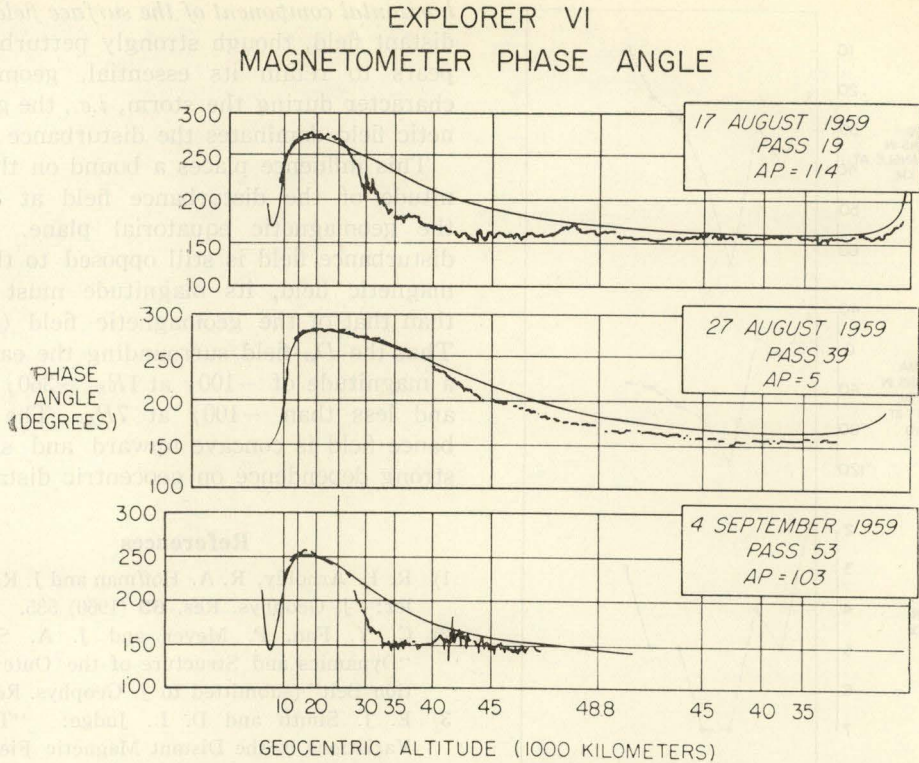


Fig. 3. Observed field direction during storm and non-storm periods.

Huancayo. Fig. 2-c is the  $D_{st}$  curve for the August 16 storm.

Comparison of Figs. 2-a, b, c indicates that there is a main phase decrease and recovery of the field at  $4R_E$  coincident with the storm field at the surface. The magnitude of the decrease is about 2.5 times greater at  $4R_E$  than it is at  $1R_E$ . This suggests that a ring current in the magnetosphere is responsible for the  $D_{st}$  field. Fig. 2-a has been compared with the time dependence of the peak intensity of the outer zone radiation<sup>(1), (2)</sup>. The latter undergoes a large increase during the recovery phase of the storm. The comparison establishes that the increased particle flux cannot be caused by a simple "betatron" acceleration of the trapped particles existing in the outer zone before the storm. Therefore, particles have either been injected into the outer zone during the storm or pre-existing particles have been accelerated by some mechanism other than the "betatron" mechanism.

Fig. 3 contrasts the departure of the observed field direction ( $\phi$ ) from the direction of the geomagnetic field ( $\phi_G$ ) on storm days

(August 17, September 4) and days that are magnetically quiet (August 27). The perturbation of the distant field during a storm is qualitatively similar to that which exists on non-storm days.  $\Delta\phi = \phi - \phi_G$  is generally positive along the trajectory at northern geomagnetic latitudes and negative at southern geomagnetic latitudes. This result is qualitatively consistent with the effect of a disturbance field caused by a westward current in the magnetosphere. Fig. 3 also shows that field fluctuations with periods of minutes are characteristic of magnetic storms. Distinct transients (30,000 kilometers on August 17 and 42,000 kilometers on September 4) correlate with rapid transient increases in the Explorer VI scintillator count rate and with bay-like, storm variations at Antarctic ground stations<sup>(3)</sup>.

Fig. 4-a is a plot of  $\Delta\phi$  at an altitude of 40,000 kilometers during the storm period. Fig. 4-b shows the simultaneous variation in horizontal intensity at the earth's surface. Fig. 4-c is a plot of the corresponding values of  $K_p$ . The direction of the distant field out to  $7R_E$  is correlated with variations in the

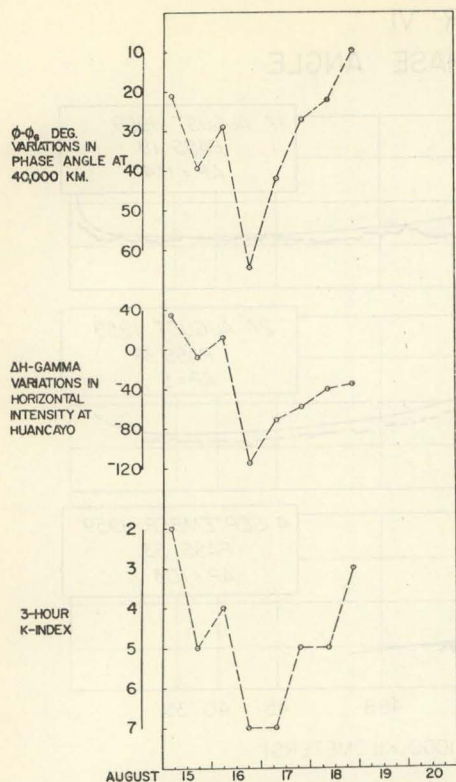


Fig. 4. Time variation of the direction of the distant field at 40,000 kilometers.

horizontal component of the surface field. The distant field, though strongly perturbed, appears to retain its essential, geomagnetic character during the storm, *i.e.*, the geomagnetic field dominates the disturbance field.

This influence places a bound on the magnitude of the disturbance field at  $7R_E$  on the geomagnetic equatorial plane. If the disturbance field is still opposed to the geomagnetic field, its magnitude must be less than that of the geomagnetic field ( $\sim 100\gamma$ ). Thus the  $D_{st}$  field surrounding the earth has a magnitude of  $-100\gamma$  at  $1R_E$ ,  $-360\gamma$  at  $4R_E$ , and less than  $-100\gamma$  at  $7R_E$ . The disturbance field is concave upward and shows a strong dependence on geocentric distance.

### References

- 1) R. L. Arnoldy, R. A. Hoffman and J. R. Winckler: *J. Geophys. Res.* **65** (1960) 535.
- 2) C. Y. Fan, P. Meyer and J. A. Simpson: "Dynamics and Structure of the Outer Radiation Belt" (submitted to *J. Geophys. Res.* 1961).
- 3) E. J. Smith and D. L. Judge: "Transient Variations in the Distant Magnetic Field: Explorer VI" in preparation.

### Discussion

**Vestine, E. H.:** In your last summarizing diagram you showed a derived reversal in the superposed disturbance field at about  $6\frac{1}{4}$  earth radii. Was this an indication of zero field in the 21h local time meridian, and in which direction was the field vector just inside this region of reversal?

**Smith, E. J.:** The earth's north pole was up. The disturbance field was obtained for points above and below the geomagnetic equatorial plane, and was seen to rotate. The data indicate that, as we go to higher altitudes, the field is at first opposed to the geomagnetic field and then rotates to where it has a component in the same direction as the geomagnetic field. For points of observation in the equatorial plane there should be a radial distance at which the disturbance field vanishes. Inside that radial distance the storm field would be down and outside it the disturbance field would be up.

**Singer, S. F.:** I believe your data indicate that the magnetic effects of trapped electrons in the outer radiation belt are rather small. Is this interpretation correct?

**Smith:** Yes. This is most clearly seen in the responses of the radiation particle detectors flown on Explorer VI during the magnetic storm. The count rates of the University of Minnesota and University of Chicago detectors are *decreased* during the beginning of the main phase of the storm, so that the particles to which these detectors are responding cannot be responsible for the storm field.

**Cole, K. D.:** What relationships had been observed between satellite-measured magnetic disturbance and that at the foot of the geomagnetic field line connected to the satellite? What is the ratio of the magnitudes of these two disturbances?

**Smith:** In general we do not have a sufficient number of ground station records

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  $\Delta B$  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.

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

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Earlier work<sup>1)</sup>, 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 deter-

mining 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<sup>1)</sup>. 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<sup>2)</sup> computed the variance spectrum of the daily  $C_i$ ,  $Kp$ , and  $A_p$  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