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A Detailed Study of the Geomagnetic Storm of 8-10 March 1970

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A comprehensive study of the geomagnetic oscillations during the storm of 8-10 March 1970 is made, using data obtained from equatorial stations. The oscillation characteristics during the three main phases of the storm have been computed from detailed spectral analysis of close-spaced horizontal force data. Simultaneity or otherwise of the various modes of oscillations has been ascertained by coherence analysis of records of different pairs of stations. The results are discussed in the light of various observational results and magnetospheric models postulated thereon.

1. Introduction

THE existence of long-period fluctuations in the geomagnetic elements in and outside the disturbed periods has been investigated by several workers in recent years[1-3]. Availability of satellite data of high quality has considerably helped in locating the possible sources of these fluctuations[4-6]. The characteristics of these fluctuations in the quiet magnetosphere have been theoretically investigated by many workers who have attributed different oscillation periods to different modes of interaction in various parts of the magnetosphere[7-13]. The geomagnetic fluctuations recorded on terrestrial surface are believed to be further modified by the propagation characteristics of the intervening medium between the earth and the magnetosphere[14-22].

The irregular patches in the solar plasma are bound to have their imprints on the geomagnetic fluctuations, and so the position becomes more intriguing during magnetic storms. Sudden large variations in the density, composition and energy of the solar wind might induce several additional modes of magnetospheric response, besides those noticeable in the quiet magnetosphere. Several attempts to study such responses have been made earlier[23-25]. The present communication describes one such analysis for the storm of 8-10 March 1970, which is considered to be one of the major storms of the current solar cycle. A preliminary report on the analysis has already been published[26]; the present paper gives a more detailed analysis covering several aspects of the whole storm.

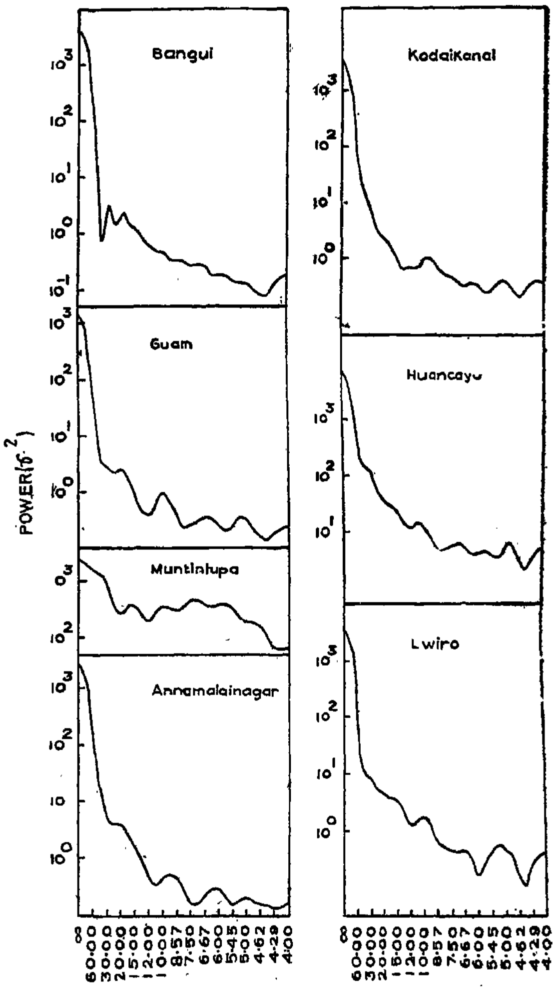

Fig. 1—Power spectra for the complete storm

2. Analysis

The main aim of the analysis is to detect characteristic oscillations in one of the magnetic

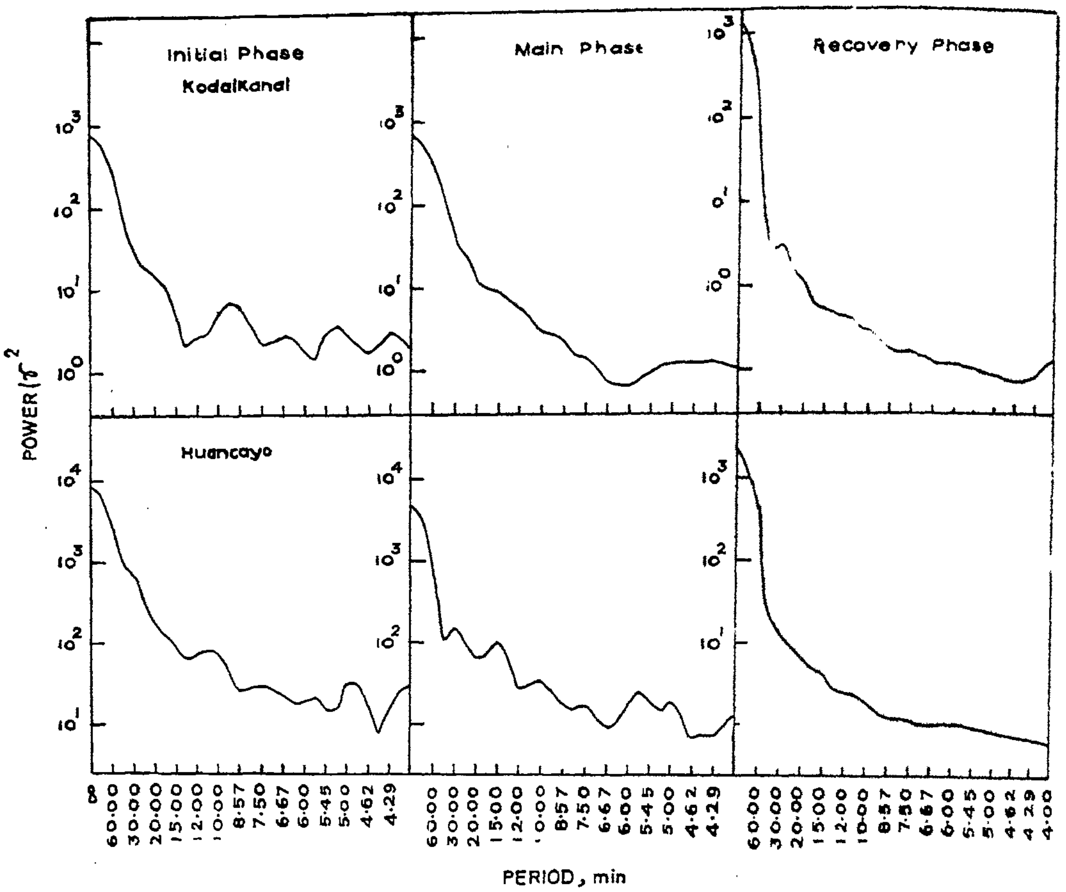

Fig. 2—Power spectra for the three phases of the storm for the D-field

TABLE 1—RELEVANT GEOGRAPHICAL DATA FOR THE STATIONS SELECTED FOR ANALYSIS

No.	Station	Dip angle	Geomagnetic		Geographic	
			Lat. (deg)	Long. (deg)	Lat.	Long.
1.	Hyderabad	20° 32′	7.6	148.9	17° 25′ N	78° 33′ E
2.	Bangui	−14° 37′.9	4.8	88.5	4° 26′ N	18° 34′ E
3.	Guam	12° 13′	4.0	212.9	13° 35′ N	144° 52′ E
4.	Muntinlupa	14° 0′	3.0	189.7	14° 22′ N	121° 01′ E
5.	Annamalainagar	5° 22′.3	1.5	149.4	11° 24′ N	79° 41′ E
6.	Trivandrum	0° 59′.2	1.1	146.4	8° 29′ N	76° 57′ E
7.	Kodaikanal	3° 1′.5	+0.6	147.1	10° 14′ N	77° 28′ E
8.	Huancayo	− 2° 21′	−0.6	353.8	12° 03′ S	75° 20′ W
9.	Lwiro	−23° 15′	−3.8	97.2	2° 15′ S	28° 48′ E

elements, viz. the horizontal force during the three principal phases of the storm. Attempts have been made to locate, broadly, the sources of such oscillations by repeating the analysis for symmetrical and asymmetrical components of the storm separately. As data from several stations have been used in this analysis, coherence between oscillating components recorded at various stations has been worked out, with a view to finding further confirmation about the existence of a common origin for these oscillations.

Data from nine stations (listed in Table 1) have been utilized in the present analysis. The records have been scaled at a uniform interval of 2 min. The three main phases of the storm are divided somewhat arbitrarily: initial phase 0-6 hr, main phase 6-12 hr and the recovery phase 12-48 hr. Separation of the disturbance field components has been effected by standard methods, then the series subjected to power spectra and coherence analysis. All computations have been performed with the CDC 3600 computer at the Tata Institute of Fundamental Research, Bombay.

3. Results

The sensitivities and scales of the instruments used are not intended for study of these fluctuations, and hence it is anticipated that the detection of these oscillating components will be marginal. In the spectral curve for the whole storm, it is difficult to find positive evidence for the existence of discrete periods of these oscillations (Fig. 1). The general shape of the curves corresponds to that of white noise with maximum concentration around zero frequency. A few humps are noticeable in the case of a few stations at periods predicted from some theoretical magnetospheric interaction, but they are within low-confidence intervals and are not consistent. A close scrutiny of the spectral curves for the individual phases shows that most of the 'peakiness' originates from fluctuations during the initial phase. During the main phase, the power densities around selected periods show much less deviation from the smooth white noise curve and the deviation is practically absent during the recovery phase (Fig. 2). Since the fluctuations investigated pertain to the magnetic storm, the disturbance field is expected to show clearer indications of the presence of fluctuations. Both the symmetrical and asymmetrical components of the storm-time fields are, therefore, subjected to scrutiny. Fig. 3 shows the spectral curves for the three phases of the symmetrical fields. It is seen that the evidence of discrete periods is better in this plot. A symmetric change is also noticed in the period of the largest value resolved in the present case. In the initial phase, the largest resolved peak is at 20 min period, its occurrence during the main and recovery phases being at 15 min and 11 min respectively. Other peaks noticed at 10 min and 7 min during the initial phase appear to have similar shifts in periods during the succeeding two phases. In the asymmetrical case, all the stations, although showing general agreement among themselves, have individual characteristics. For stations which are close geographically the spectral curves show good simultaneity. Fig. 4 shows the spectral curves for the initial phase for the three Indian stations, Kodaikanal, Annamalainagar and Hyderabad. The peaks are more prominent in the electrojet location at Kodai-

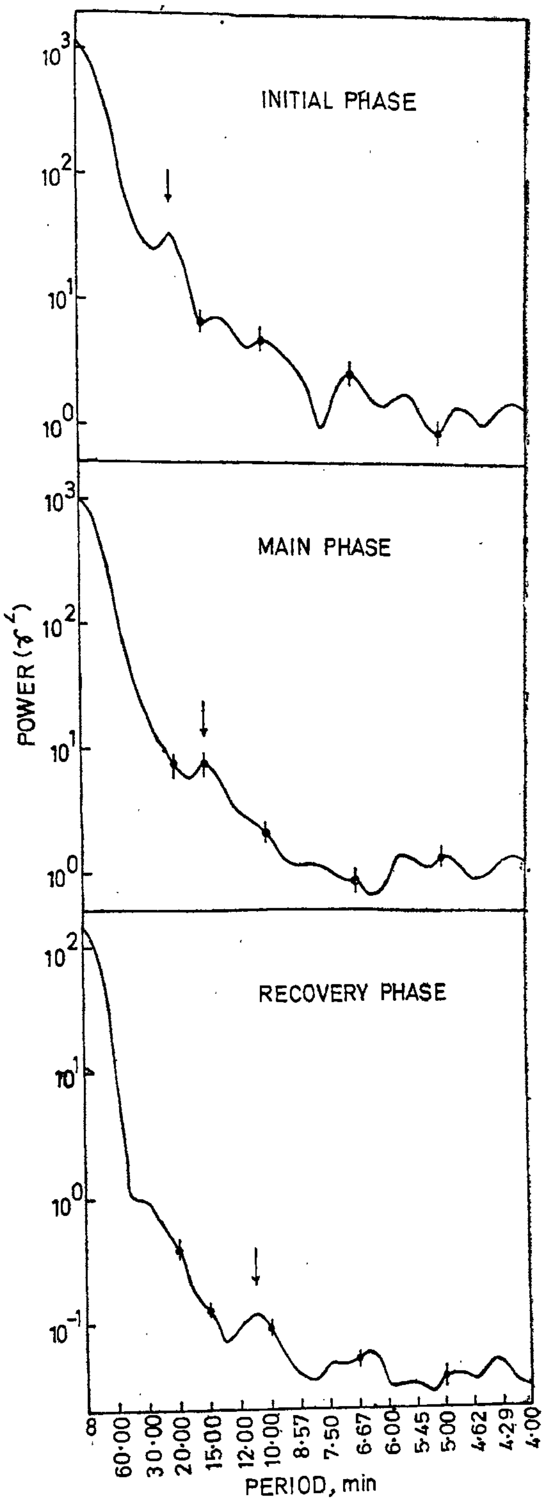

Fig. 3—Power spectra for the Dst-field

TABLE 2—AMPLITUDES IN GAMMAS CORRESPONDING TO THE PEAK PERIODS PICKED OUT FROM THE POWER SPECTRA

No.	Station	Peak periods (in min)																						
		15.0	13.33	12.0	10.91	10.0	9.23	8.57	8.0	7.5	7.06	6.67	6.32	6.0	5.71	5.45	5.22	5.0	4.8	4.62	4.44	4.29	4.14	4.0
1.	Hyderabad			4.9 ± 1.6			4.0 ± 1.3						4.8 ± 1.7							3.5 ± 1.2			3.0 ± 1.0	
2.	Bangui		4.8 ± 1.6				3.8 ± 1.3					3.0 ± 1.0		2.7 ± 0.9				2.6 ± 0.9						
3.	Guam	5.3 ± 1.8							3.5 ± 1.2	3.7 ± 1.2						2.8 ± 0.9	2.8 ± 0.9				2.8 ± 0.9			
4.	Muntinlupa	6.9 ± 1.3			5.6 ± 1.8	5.6 ± 1.8			4.6 ± 1.5								3.8 ± 1.3					3.2 ± 1.1		
5.	Annamalainagar				5.1 ± 1.9						3.9 ± 1.3					4.3 ± 1.4		4.8 ± 1.6						
6.	Kodaikanal						6.1 ± 2.0									4.3 ± 1.4						3.8 ± 1.2		
7.	Huancayo			17.4 ± 5.6							10.8 ± 3.5				9.8 ± 3.2			9.8 ± 3.2						
8.	Lwiro						4.2 ± 1.4	4.3 ± 1.4				3.3 ± 1.1			3.0 ± 1.0				3.7 ± 1.2			3.0 ± 1.0		

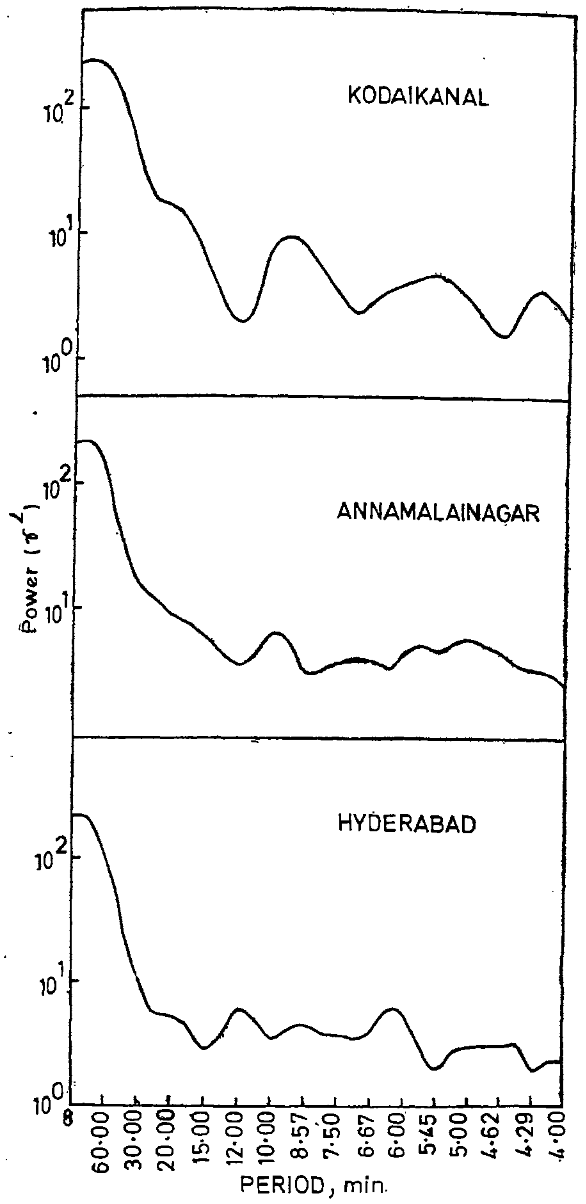

Fig. 4—Power spectra of the DS-field for the initial phase for the three stations, viz. Kodaikanal, Annamalainagar and Hyderabad

kanal and somewhat subdued in the other stations. The unusual characteristic is the dissimilarity of Trivandrum—another electrojet station—from the above stations in its spectral curve. Fig. 5 shows the spectral curves of Kodaikanal and Trivandrum illustrating this point. Similarity of spectral curves is also noticed between Bangui and Lwiro towards the high frequency end of the spectrum. Table 2 gives a summary of the preferential periods noticed and the corresponding amplitudes in gammas computed from the spectral curves.

The power spectral curves do not tell us anything about the respective phases of the oscillatory components. For this investigation, the cross spectral method described by Balakrishnan *et al.*[26] has been followed. The coherence between different pairs of stations has been estimated for the prominent peaks in the spectral curves. Table 3 shows the coherence of the various oscillatory components observed at different stations. It may be seen that although the oscillatory power densities are more during the initial phase, the oscillations at different periods are more coherent during the main phase. The recovery phase, besides showing a much lower power density, is also characterized by incoherent oscillations at stations situated around the globe.

The cross spectral analysis also tells us about the consistency of phases of the oscillatory components. Fig. 6 shows a plot of the phase differences between one of the stations (Trivandrum) and the remaining stations arranged in the order of the dip angle during the higher coherent main phase of the storm. The phase differences have wide scatter around zero with no indication of any dependence with the dip

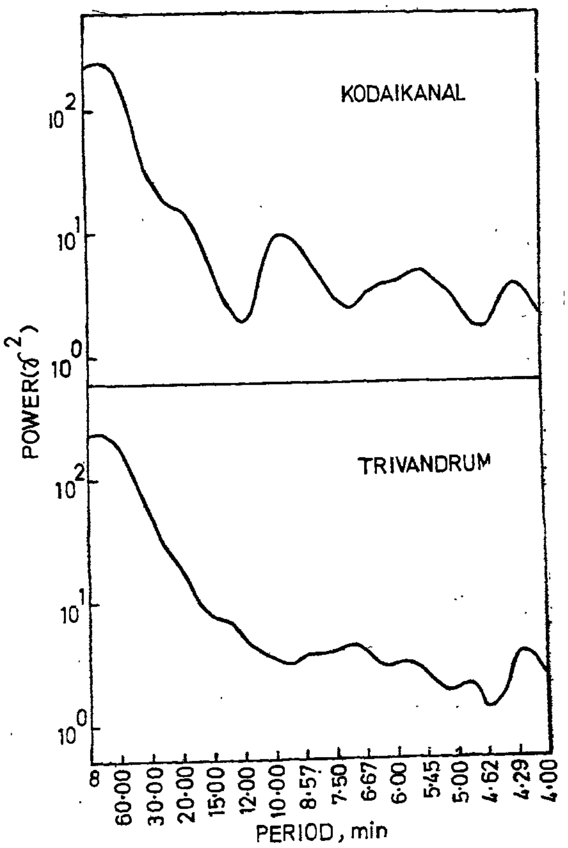

Fig. 5—Power spectra of the DS-field for the initial phase for the two stations, viz. Kodaikanal and Trivandrum

TABLE 3—COHERENCE OF VARIOUS OSCILLATORY COMPONENTS AT DIFFERENT STATIONS
(BASE: DS OF TRIVANDRUM)

Station	Initial phase (min)					Main phase (min)					Recovery phase (min)				
	20	15	10	6	4	20	15	10	6	4	20	15	10	6	4
Hyderabad	0.53	0.34	0.40	0.58	0.25	0.59	0.31	0.56	0.71	0.08	0.53	0.32	0.16	0.39	0.28
Bangui	0.58	0.15	0.32	0.62	0.33	0.94	0.67	0.54	0.73	0.52	0.63	0.70	0.26	0.18	0.05
Guam	0.13	0.35	0.34	0.12	0.03	0.43	0.64	0.42	0.60	0.30	0.34	0.60	0.25	0.30	0.37
Muntinlupa	0.66	0.31	0.55	0.40	0.13	0.93	0.81	0.65	0.59	0.08	0.17	0.47	0.31	0.42	0.34
Annamalainagar	0.20	0.30	0.49	0.29	0.37	0.48	0.62	0.78	0.69	0.55	0.27	0.55	0.44	0.25	0.26
Kodaikanal	0.63	0.51	0.30	0.53	0.42	0.86	0.72	0.63	0.51	0.56	0.51	0.63	0.38	0.39	0.55
Huancayo	0.43	0.31	0.41	0.51	0.11	0.22	0.76	0.80	0.81	0.16	0.71	0.50	0.45	0.39	0.11
Lwiro	0.25	0.40	0.62	0.03	0.33	0.72	0.79	0.95	0.91	0.15	0.71	0.83	0.49	0.56	0.52

angle. Other arrangements with respect to geomagnetic and geographic coordinates also failed to show any systematic phase differences between different pairs of stations.

4. Discussion

The broad features of the characteristics of the geomagnetic fluctuations, as observed from the present analysis, can now be briefly stated. The oscillatory parts are present mainly during the initial and main phases of the storm; the recovery phase is characterized by a significant drop in the spectral densities of these oscillation periods. The oscillations all over the equatorial belt are noticed to be coherent for several discrete periods in the range 6-20 min during the main phase of the storm and somewhat less coherent during the initial phase. During the recovery phase, the oscillations are completely random showing no coherence between geographically separated stations and are probably merged with the background noise of the recording. The coherent oscillatory components noticed during the main phase indicate no phase differences between stations suggesting common origin of the disturbances.

The systematic change in the selective periods of low frequency component is perhaps significant. The earlier and the later phases of the magnetic storm are characterized by the incident particle density variations in the magnetosphere. The changes of the period of P_c4 and P_c5 micropulsations with the levels of solar activity have

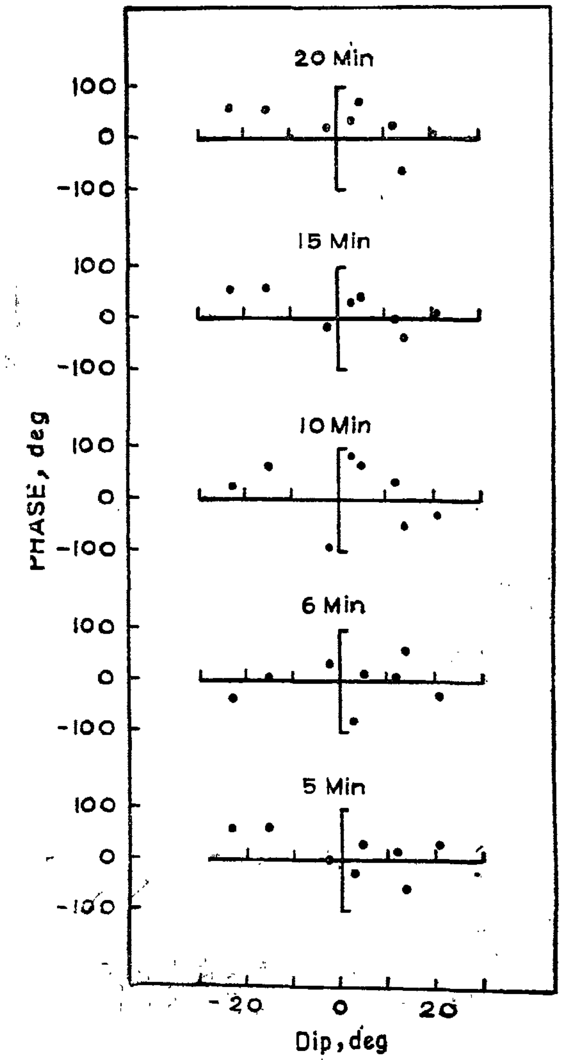

Fig. 6—Plot of phase versus dip for selected periods for the main phase

been noticed earlier[27]. It has been inferred as due to the expansion of the magnetospheric boundary and it is logical to expect similar changes of oscillations of longer periods also with magnetospheric particle density. Whether the drift of characteristic periods noticed during the present analysis pertains to such an effect can be judged from similar analyses for more number of storms. An attempt in this direction is being made and the results will be reported later.

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References

1. ONWUMECHILLI, A. & OGBUEHI, P. O., *J. atmos. terr. Phys.*, **24** (1962), 173.
2. PAI, G. L. & SARABHAI, V. A., *Planet. Space Sci.*, **12** (1964), 855.
3. BHARGAVA, B. N. & RAO, D. R. K., *Planet. Space Sci.*, **18** (1970), 1381.
4. LIN, R. P. & ANDERSON, K. A., *J. geophys. Res.*, **71** (1966), 1827.
5. FAIRFIELD, D. H. & NESS, N. F., *J. geophys. Res.*, **75** (1970), 6050.
6. DWARKIN, M. L., ZMUDA, A. J. & RADFORD, W. E., *J. geophys. Res.*, **76** (1971), 3668.
7. AXFORD, W. I., *Planet. Space Sci.*, **12** (1964), 45.
8. DUNGEY, J. W., *The physics of the ionosphere* (The Physical Society, London) 1955, 229.
9. PARKER, E. N., *Physics Fluids*, **1** (1958), 171.
10. AXFORD, W. I., *Can. J. Phys.*, **40** (1962), 654.
11. SEN, A. K., *Physics Fluids*, **6** (1963), 1154.
12. SEN, A. K., *Planet. Space Sci.*, **13** (1965), 131.
13. DESSLER, A. J. & FEJER, J. A., *Planet. Space Sci.*, **11** (1963), 505.
14. CAROVILLANO, R. L. & RADOSKI, H. R., *Physics Fluids*, **10** (1967), 225.
15. FIELD, E. C. & GREIFINGER, C., *J. geophys. Res.*, **70** (1965), 4885.
16. FIELD, E. E. & GREIFINGER, C., *J. geophys. Res.*, **71** (1966), 3223.
17. FRANCIS, W. E. & KARPLUS, R., *J. geophys. Res.*, **65** (1960), 3593.
18. GREIFINGER, C. & GREIFINGER, P., *J. geophys. Res.*, **70** (1965), 2217.
19. GREIFINGER, C. & GREIFINGER, P. S., *J. geophys. Res.*, **73** (1968), 7473.
20. JACOBS, J. A. & WATANABE, T., *J. atmos. terr. Phys.*, **24** (1962), 413.
21. LEHNERT, B., *Tellus*, **8** (1956), 241.
22. PRINCE (Jr.), C. E., & BOSTICK (Jr.), F. X., *J. geophys. Res.*, **69** (1964), 3213.
23. MARIANI, F., BAVASSANO, B. & NESS, N. F., *J. geophys. Res.*, **75** (1970), 6037.
24. FAIRFIELD, D. H., *J. geophys. Res.*, **74** (1969), 3541.
25. JUDGE, D. L. & COLEMAN, (JR.), P. J., *J. geophys. Res.* **67** (1962), 5071.
26. BALAKRISHNAN, T. K., VARADARAJAN, R. & BAGHAVATH SINGH, S., *Indian J. Radio Space Phys.*, **1** (1972), 205.
27. TROITSLAYA, V. A., BOLSHAKOVA, O. V., MATVEEVA, E. T. & SCHCHEEPETNOV, R. V., *Annals of International Quiet Sun Year*, Vol. **5**, edited by A. C. Stickland (M.I.T. Press Ltd., London), 1969, 439.