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Lower Ionospheric Response to IMF Polarity Reversals

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Noon measurements of radio wave absorption in the ionosphere available at Colombo, Waltair and Kokubunji over long periods of time are employed in the study of the effect of IMF polarity reversals on the lower ionosphere at tropical and middle latitudes. Nearly 60% of the reversals are found to give rise to modest enhancements in absorption. This percentage is a little higher for positive to negative reversals as compared to that for negative to positive events. Mesospheric heating due to increased geomagnetic activity following a reversal is suggested as the possible mechanism behind absorption enhancements.

1 Introduction

The interplanetary magnetic field (IMF) sector structure, in recent times, has been recognized as one of the key factors influencing the terrestrial environment including the geomagnetic field[1-4]. The F-region features like h'F, horizontal drift and TEC at low and middle latitudes were shown to respond to IMF polarity reversals[5-8]. The effect of IMF sector crossings on the D- and E-regions of the ionosphere was examined by Schlegel *et al.*[9] and Lastovicka[10-12], who detected perceptible responses by way of enhanced radio wave absorption following the sector crossings. Since, no such efforts have been made to detect lower ionospheric response at low latitudes, we have undertaken an investigation employing vertical incidence pulse absorption measurements at noon at stations covering equatorial to middle latitude zones.

2 Data Base and Analysis

Radio wave absorption determination in the ionosphere, affected by changes in the vertical profiles of plasma and neutral densities as well as temperature, provide a useful tool for a study of the D- and E-region response to IMF sector crossings. Noon absorption measurements of vertical incidence pulse (A1) at the equatorial station (Colombo), low latitude station (Waltair), and mid-latitude station (Kokubunji) are used in this investigation. A description of the data base is given in Table 1. The dates of IMF sector crossings are taken from the Tables given by Svalgaard[13].

Noon absorption values at each of the three stations are normalized to a common sunspot number on the assumption of a linear relation between the two variables. A simplified epoch analysis on the lines suggested by Schlegel *et al.*[9] has been adopted to examine the influence of IMF polarity reversals. This analysis envisages the averaging of absorption values on three days following and preceding a polarity reversal separately and determining the ratio (r) of the average following the reversal to that preceding for each of the reversals in the time frame of the observational data. If $r > 1$, the polarity reversal is associated with an enhancement in the absorption or vice versa. A superposed epoch analysis, as suggested by Chree and Stagg[14], has also been undertaken to study the effects of geomagnetic field variations following a polarity reversal on corresponding fluctuations in absorption. The planetary K index is adopted as the geomagnetic activity sensor in this investigation.

3 Results and Discussion

Results of the simplified epoch analysis are shown in Table 2. Nearly 60% of the total number of reversals are associated with enhanced absorption at the

Table 1—Data Base Employed in the Study of IMF Sector Crossings and Associated Absorption Variability

Station	Coordinates		Frequency MHz	Period of observation
	Lat. °N	Long. °E		
Colombo	6.9	79.9	2.55	July 1957-Dec. 1959
Colombo	6.9	79.9	2.55	Jan. 1964-Dec. 1968
Waltair	17.7	83.3	2.00	Jan. 1963-Dec. 1964
Waltair	17.7	83.3	2.40	Sep. 1971-Sep. 1973
Kokubunji	35.7	139.5	2.40	Jan. 1958-Dec. 1967

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three places. If no relation exists between IMF sector crossing and absorption increase, the ratio of the number of crossings giving rise to increased absorption to the total number of crossings equals 0.5, should the total number be large. Table 2 also lists the confidence level, (in %), of the observed increase in absorption at each station. The confidence levels of the results from Colombo and Waltair during 1971-73 are better than 90%, whereas the same are a little lower for Waltair during 1963-64 and Kokubunji, the primary reason being the smaller number of crossings involved.

The hypothesis that r equals 0.5 in the absence of a relation is tested by a random sampling in respect of Colombo data. Days equal to the number of sector crossings (220) are picked at random in the time frame of Colombo measurements as 'key' days. The ratio r of the 3-day mean of absorption following each of the 220 'key' days to the 3-day mean of that preceding each key day has been determined. This process is repeated for a hundred similar samplings. Ratio of the number of crossings that gave rise to enhanced absorption to 220 has been determined in each of the 100 trials and the mean of the 100 ratios is found to be 0.5 ± 0.03 (rms deviation), vindicating the hypothesis that an absorption enhancement is favoured following a sector crossing.

The ratios are separately evaluated for polarity reversals from positive to negative and negative to positive to distinguish the effects between the two

Table 2—Influence of IMF Polarity Reversals on Noontime Absorption at Colombo, Waltair and Kokubunji

Station	Total No. of events	Events with $r>1$	Events with $r<1$	Total No. of events with $r>1$ %	Confidence level %
Colombo	220	129	91	58.6	99
Waltair (1963 & 64)	92	54	38	60.0	92
Waltair (1971-73)	19	11	8	57.9	64
Kokubunji	35	21	14	58.6	82

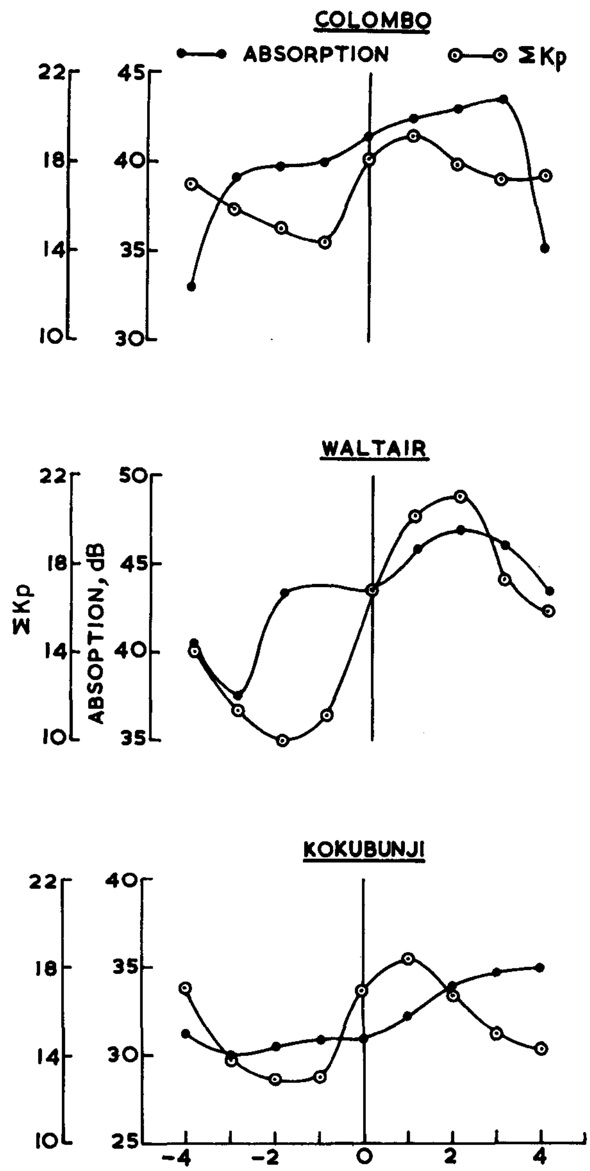

Fig. 1—Variation of average noon absorption and ΣK_p on days preceding and following a polarity reversal (0-day) at Colombo, Waltair and Kokubunji

Table 3—Same as in Table 2 but with r Shown Separately for Positive to Negative and Negative to Positive Reversals

Station	IMF polarity change: Positive to negative					Negative to positive				
	Total No. of events	Events with $r>1$	Events with $r<1$	% of events with $r>1$	Confidence level %	Total No. of events	Events with $r>1$	Events with $r<1$	% of events with $r>1$	Confidence level %
Colombo	109	65	44	59	91	111	64	47	57.6	91
Waltair (1963-64)	48	29	19	60	88	44	25	19	56.8	71
Kokubunji	20	12	8	60	74	15	9	6	60.0	70

types. Table 3 presents the results of the evaluation. It is apparent that both types give rise to an enhancement in absorption. Nevertheless, it appears that the positive to negative reversal is more likely to lead to an enhancement compared to the negative to positive reversal at the three stations.

The IMF sector crossings result in increased geomagnetic activity[1,15]. Ramana *et al.*[16], Bourne and Hewitt[17] and Marcz[18], among others, reported positive correlation between absorption and geomagnetic activity. If it can be established positively that IMF sector crossings are followed by enhanced geomagnetic activity, then that would provide the required connection between polarity reversal and absorption increment. A superposed epoch analysis employing averages of daily ΣK_p and noon absorption on day numbers $-4, -3, -2, -1, 0$ (day of reversal), 1, 2, 3, 4 is undertaken and the results of this analysis are presented graphically in Fig. 1. A remarkable feature of Fig. 1 is the depression in geomagnetic activity, a day or two preceding the reversal. Despite the fact that this is only a gross feature arrived at by averaging over a large number of reversals at each of the stations, it is noteworthy. A trend of increasing absorption through the reversal, lasting two to three days, is very much in evidence. Results of a seasonwise superposed epoch analysis illustrated in Fig. 2 do not bring out any seasonal characteristics apart from minor deviations in a few seasons.

Incidentally, Murty[19] studied daily range of H at Kodaikanal in the vicinity of a sector boundary and found that the notable feature is not just the increase following the passage of the boundary but the occurrence of a minimum in H before the crossing, the response across positive to negative boundary being larger. We too observed the response to be more probable in a positive to negative crossing, implying thereby that the absorption response is a consequence of geomagnetic field variations connected with a boundary crossing and it is greater if the change in the field is larger. Schlegel *et al.*[9] attributed the small enhancements in absorption at Lindau to additional ionization in the lower D-region arising from increased GCR flux. The present study does not favour this to be the sole agency as GCR flux contribution to low latitude D-region ionization is negligible. On the other hand, Seshamani and Ramakrishna[20] reported an increase in mesopheric temperature by 5-10 K following IMF sector crossings. It is well known that the changes in geomagnetic activity influence mesos-

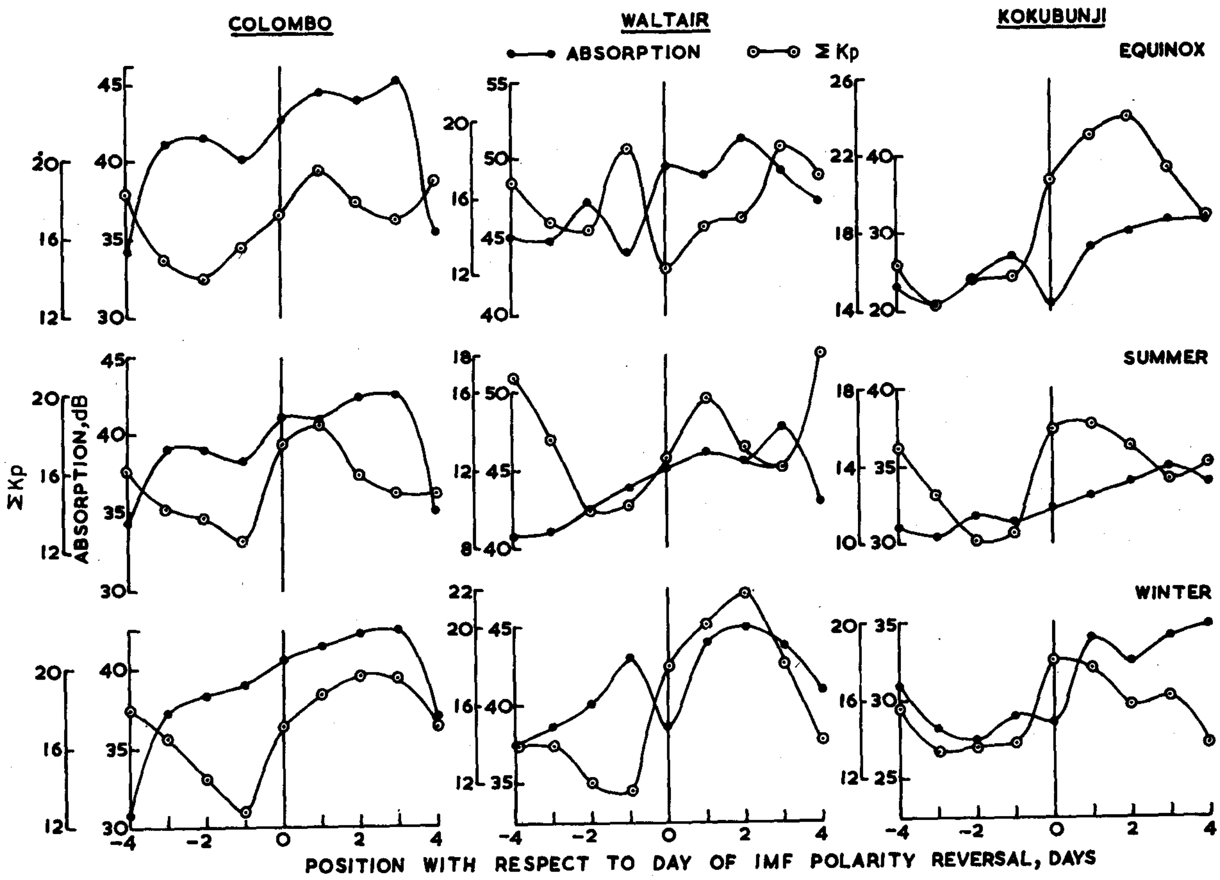

Fig. 2—Seasonwise break up of variation of average noon absorption and ΣK_p on days preceding and following a polarity reversal (0-day) at Colombo, Waltair and Kokubunji

pheric temperatures on a global scale through changes in heat flux from the auroral regions. An increase of 5-10 K in mesospheric temperature can certainly lead to an increment in radio wave absorption through increased collision cross-sections of electrons with neutrals.

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