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Communications

Nature of Geomagnetic Field Variation on AQDs at Equatorial Latitudes

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From a comparative study of the diurnal variation of equatorial geomagnetic field during abnormal quiet days (AQDs) and normal quiet days (NQDs), it is shown that an additional field exists in the equatorial region during AQDs superposed on a normal quiet day S_q and electrojet field. The H-component of the additional field exhibits a prominent southward maximum around 1100 hrs LT and a secondary northward maximum around 0800 hrs LT on AM AQDs and around 1400 hrs LT on PM AQDs. The associated effects in the Z-component at a station about 2·5°N of the dip equator support these features of the additional field on AQDs.

It is well known that the amplitude and the time of extremum of the diurnal variation of geomagnetic field at any particular station exhibit considerable day-to-day variability even on geomagnetically quiet days. Although the day-to-day variability of the amplitude of the S_q field (i.e. the field due to the quiet day current system of solar origin) has been extensively studied, that pertaining to S_q phase has not received due attention. Brown and Williams[1] for the first time introduced the concept of abnormal quiet days (AQDs), defined as those of the five international quiet days in each month on which the extreme value in the diurnal variation of H-field falls outside a specified time interval, depending on the particular station concerned, centred at 1100 hrs LT. The method of Brown and Williams has been applied by several workers in recent times to the data at equatorial stations[2-4]. These studies revealed that unlike at midlatitudes, the phase variability of S_q at equatorial latitudes is fairly localized in spatial extent[3,4]. This feature suggests that the occurrence of AQD at equatorial latitudes may be due to a perturbation in the equatorial geomagnetic field by a geographically localized dynamo-region (90-130 km) source. It is, therefore, felt worthwhile to examine, in comparison, the diurnal variation of equatorial geomagnetic field on abnormal and normal quiet days (NQDs) to see whether any additional field, superposed on a normal S_q and electrojet field, exists in the equatorial region on AQDs, and, if so, to infer its characteristics. In this communication the results of such an attempt are presented. Of course, the presence of such an additional field at and in the vicinity of the dip equator was inferred earlier during counter-electrojet conditions[5,6].

The present study is based on the published hourly values of geomagnetic elements covering the period 1958-75 at the four stations in the Indian equatorial region, i.e. at Trivandrum (dip lat., 0·4°S), Kodaikanal (dip. lat., 1·5°N), Annamalainagar (dip. lat., 2·7°N) and Alibag (dip. lat., 12·0°N). Careful scrutiny of the H-field data pertaining to the international quiet days of each month over the above mentioned period following the criteria adapted in earlier studies[1,4], showed the presence of 38 AQDs in the equatorial region. Out of these 38 days, 11 were AM AQDs, i.e. days on which the time of maximum in H-field occurred before 0430 hrs UT and 27 were PM AQDs, i.e. days on which the time of maximum of H-field was after 0730 hrs UT. Further, on 26 days the abnormal S_q phase was found to be common to only the stations within the electrojet region and, on remaining 12 days it was common to all the stations in the equatorial region. The 38 days thus selected have been subjected to analysis to infer the presence and nature of additional field on AQDs. For each one of the 38 days of abnormal S_q phase, a 'control' day with a normal S_q phase (time of maximum in H-field between 0430 and 0730 hrs UT) throughout the equatorial region is selected amongst the other international quiet days of that month to ensure similarity in the seasonal and solar-cycle-associated trends in the H-field between the two days. For each of the days in the two groups, i.e. AQD and 'control' day, twentyfour hourly values were obtained by eliminating the noncyclic variation and subtracting the nighttime 'base'. Considering that the field values on the 'control' day are associated with the quiet day S_q and electrojet, the differences between the twentyfour hourly values, deduced from the above procedure, on each of the days with abnormal S_q phase and the corresponding 'control' day, have been taken to represent the additional field.

Fig. 1 shows the mean diurnal trends in the H-

component of the additional field at Trivandrum, Kodaikanal, Annamalainagar and Alibag and in Z-component at Annamalainagar for the days with abnormal S_q phase observed only at stations within the equatorial electrojet belt. The behaviour of the additional field is depicted separately for AM and PM AQDs. Error bars representing the 95% confidence interval for the mean values (computed following standard procedures[7]) are also shown in Fig. 1 at hourly intervals. The behaviour of the additional field for the days with an abnormal S_q phase throughout the equatorial region is presented in Fig. 2.

Fig. 1 shows that on the days with an abnormal S_q phase limited just to the electrojet belt, the H-component of the additional field at all the electrojet stations shows a significant southward maximum between 1100 and 1200 hrs LT and a forenoon northward maximum around 0800 hrs LT for AM AQDs and an afternoon northward maximum around 1400 hrs LT for PM AQDs. The variation in the vertical component of the additional field at Annamalainagar, situated at the fringe of the electrojet belt, with an increase around midday and a decrease in the forenoon (afternoon) for AM AQDs (PM AQDs), corresponds to the field changes in the H-component. In contrast to this, the additional field at Alibag, away from the influence of the electrojet, is not significant except in the forenoon period during AM AQDs when it is of marginal significance. These features of the additional equatorial field suggest that the shift in the S_q phase on AQDs owes its origin to a suppression of

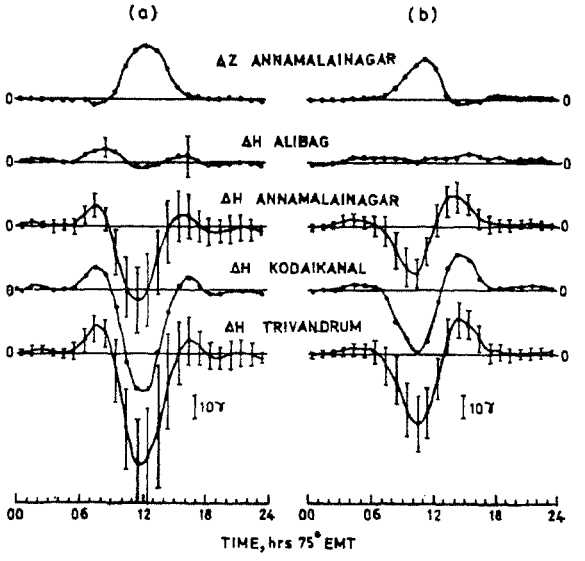

Fig. 1—Mean diurnal variation of the H-field at Trivandrum, Kodaikanal, Annamalainagar and Alibag, and of Z-field at Annamalainagar associated with the additional field during (a) AM AQDs and (b) PM AQDs at stations only within the equatorial electrojet belt (Vertical bars represent the 95% confidence intervals of the mean values)

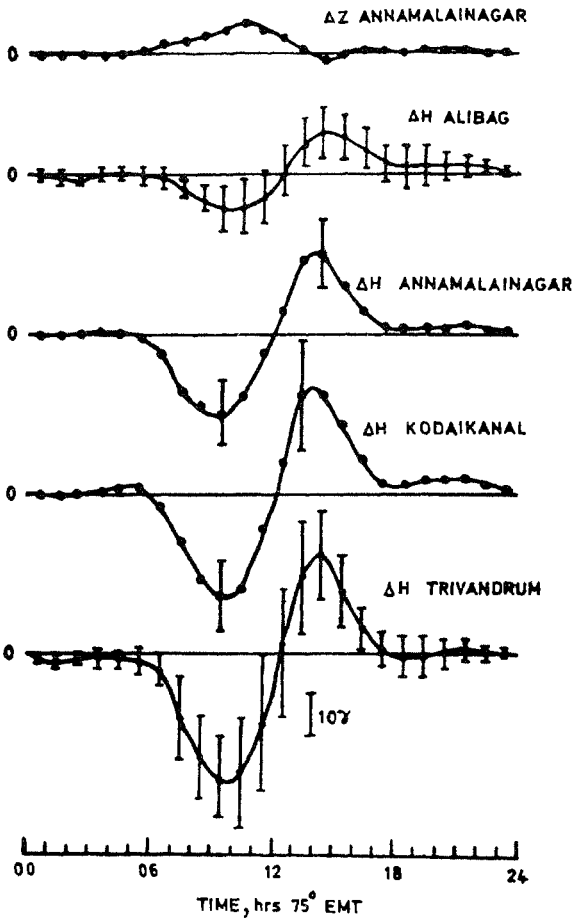

Fig. 2—Same as in Fig. 1 but showing the nature of the additional field during PM AQDs at stations all over the equatorial region

the usual quiet day S_q and electrojet field which maximizes around midday, this being supplemented by an increase in field either in the forenoon or afternoon resulting in AM and PM types of AQDs, respectively. On the days with an abnormal S_q phase at stations both inside and just outside the electrojet region, the H-component of the additional field shows a significant southward maximum around 1100 hrs LT and northward maximum around 1400 hrs LT at all the electrojet stations (Fig. 2). At Alibag, the midday southward maximum and afternoon northward maximum are of marginal significance. The variation in the vertical component at Annamalainagar corresponds to that in H-component at stations inside the electrojet belt. This implies that on these days the additional field extends over a slightly wider range of latitudes compared to the days when the AQDs occurrence is restricted just to the electrojet region. This inference is supported by the data presented in Table 1 which shows that the decrease (with increasing latitude) of the midday southward maximum and afternoon northward maximum in H-field is less rapid for the category of events with AQDs throughout the

Table 1—Ratios of the Amplitude at the Various Stations (with respect to Annamalainagar) of the Midday Minimum and Afternoon Maximum of the Additional Field (*H*-Component) Associated with the Occurrence of PM AQDs

Category	Ratios of amplitude at			
	Trivandrum	Kodaikanal	Annamalainagar	Alibag
For midday minimum				
(a) AQDs within the electrojet belt	1·49	1·34	1·00	0·04
(b) AQDs throughout the equatorial region	1·52	1·27	1·00	0·45
For afternoon maximum				
(a) AQDs within the electrojet belt	1·12	1·19	1·00	0·29
(b) AQDs throughout the equatorial region	1·28	1·27	1·00	0·53

Table 2—Characteristics in *H*-component of the Mean Additional Field at Trivandrum

Type of AQDs	Amplitude in gammas of		
	Forenoon maximum	Midday minimum	Afternoon maximum
AQDs only in the electrojet belt			
AM			
1st set	+12·2 (6·4)	−51·4 (22·1)	—
2nd set	+15·4 (7·7)	−43·5 (20·7)	—
PM			
1st set	—	−32·6 (13·1)	+15·9 (8·2)
2nd set	—	−31·8 (11·2)	+13·2 (8·7)
AQDs throughout the equatorial region			
PM			
1st set	—	−31·1 (10·1)	+24·4 (10·8)
2nd set	—	−43·3 (15·8)	+18·9 (12·7)

Note: Values within brackets indicate the 95 % confidence interval of the mean values.

equatorial region. To ensure that the inferred nature of the additional equatorial field is not fortuitous, the values of the additional field were computed with another set of 'control' days chosen in the same manner for the two categories of days. It is found that the characteristics of the additional field are almost identical to those calculated originally (Table 2) wherein the salient features of the additional field are presented for the two sets of 'control' days.

Another phenomenon that occurs conspicuously at equatorial latitudes during geomagnetically quiet days is the equatorial counter-electrojet[8]. This phenomenon manifests as a significant depression in *H*-field below the mean nighttime level, either in the afternoon or forenoon period, and occurs in close association with several phenomena in the lower and upper equatorial ionosphere, the most striking one among them being the sudden disappearance of Es-q traces on bottomside ionograms[9-11]. The characteristics of the counter-electrojet as reviewed recently by Mayaud[12] suggest it to be an abnormal feature of the regular quiet day variation of *H*-field near the dip equator. Further, the very recent statistical analysis of Marriott *et al.*[13] shows that at Huancayo, an electrojet station at 75°W, the normal electrojet is weakest and reaches its daily maximum strength earliest almost in the same months in which the occurrence of afternoon counter-electrojets is also a maximum at this station, thus indicating the possibility of an association between AM AQDs and afternoon counter-electrojet on quiet days. We have, therefore, investigated the counter-electrojet conditions for 38 days of abnormal S_q phase. This is done by using the *H*-field data and simultaneous ionogram data at Kodaikanal which were available for 34 days. It is found that out of the 10 days of the AM AQD type, on 5 days clear-cut counter-electrojet conditions (i.e. depression in *H*-field well below the mean nighttime level and concomitant disappearance of Es-q traces on ionograms) were present in the afternoon period. This percentage, which is rather high suggests that AM AQDs could be a part of the counter-electrojet phenomenon. However, out of the 24 days of PM AQD type, only on 2 days partial counter-electrojet conditions were noticed.

The present study thus shows that at equatorial latitudes, the abnormal shift of the S_q phase from its usual times on AQDs owes its origin to the presence of an additional field in the equatorial region, superposed on the normal S_q and electrojet field. The additional field in *H*-component is characterized by a prominent southward maximum around 1100 hrs LT and a secondary northward maximum either in the morning or afternoon periods. Further analysis is required to indicate the geomagnetic field variation at midlatitudes on days with abnormal S_q phase in the equatorial region and to establish that the additional field is indeed confined to the equatorial latitudes, as inferred in the present study.

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