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Phase Variability of $S_q(H)$ & the Ionospheric Equatorial Anomaly

J HANUMATH SASTRI
Indian Institute of Astrophysics, Bangalore 560034

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A study is made of the behaviour of the equatorial ionization anomaly in the Indian region on days with an abnormal $S_q(H)$ phase limited to the electrojet belt. The anomaly is found to disappear or reduce in strength quite consistently within about 2 hr of the onset of complete or partial counter-electrojet conditions, responsible for the shift of the $S_q(H)$ phase from the normal time interval. Further, the remarkably poor development of the anomaly in the afternoon period in the Indian region as compared to that in the East Asian region has been shown to occur only on days with an abnormal $S_q(H)$ phase in the Indian equatorial region. These results lend further support to the view that the occurrence of an abnormal $S_q(H)$ phase at electrojet locations is closely associated with perturbations in the electrojet electric field

The marked day-to-day variability of the amplitude and phase of $S_q(H)$ is a characteristic feature noticeable from ground based magnetometer data. Brown and Williams[1] and Brown[2] studied the occurrence behaviour of phase variability of $S_q(H)$ at midlatitudes using the concept of 'abnormal quiet days' (AQD). Similar studies using data of equatorial stations revealed that although AQDs do occur at these locations, prominent differences in the morphology of the AQD phenomenon exist between equatorial and midlatitude regions[3-5]. It has been shown recently[6] that the occurrence of an abnormal $S_q(H)$ phase at equatorial latitudes owes its origin to a suppression of the normal quiet day S_q and electrojet field around the time of its diurnal maximum by the superposition of a southward field of limited geographical extent. A subsequent investigation showed that on days with an abnormal $S_q(H)$ phase limited to the electrojet belt, perturbations in the electrojet electric-field characteristic of complete or partial counter-electrojet (CEJ) conditions prevail around the normal time interval of the diurnal maximum of H field, leading to a shift of the S_q phase[7]. It is well known that the latitudinal distribution of F-region ionization is anomalous at equatorial latitudes during daytime and is described by the Appleton or equatorial anomaly. It has been established from theoretical studies[8] and analyses of experimental data[9,10] that the formation of the equatorial anomaly occurs primarily through the 'fountain' mechanism, wherein ionization lifted vertically upwards at the dip equator by the eastward electric field associated with the equatorial electrojet and diffuses down the magnetic field lines resulting in a trough of ionization at the dip equator and crests in the north and south of it. Significant changes in the diurnal development of the equatorial anomaly are, therefore, to be expected on days with CEJ conditions due to the changes in the eastward electric field and hence the 'fountain' effect. In fact, some supportive evidence already exists in the literature[11-13]. None of the earlier studies, however, pertain to AQD. It is, therefore, felt important and necessary to investigate the diurnal development of the equatorial anomaly on AQD to establish the inference of our earlier studies regarding the origin of abnormal $S_q(H)$ phase at electrojet stations. In this communication the results of such a study are presented.

As reported earlier[7], out of the five IQDs of each month over the period 1958-75, there are 26 days with an abnormal $S_q(H)$ phase limited to the electrojet belt in the Indian equatorial region. The CEJ conditions (complete or partial) have been noticed on 19 out of the 26 days. Scrutiny of the latitudinal profiles of f_0F2 on the days of abnormal $S_q(H)$ phase showed the presence of significant departures of the diurnal development of the anomaly from the normal pattern on 9 out of the 11 days studied. It may be pointed out here that due to the absence or incomplete f_0F2 data at individual ionosonde stations, anomaly behaviour could be studied only for 11 AQDs. Typical examples of this feature as observed on 21 Dec. 1965 (AM AQD) and 14 Feb. 1966 (PM AQD) are illustrated in Fig. 1. To facilitate a study of the changes in the anomaly in relation to those in the equatorial electrojet, latitudinal profiles of ΔH at specified times for the two days are also shown in Fig. 1. On 21 Dec. 1965 (Fig. 1) the usual dip equator enhancement of ΔH is evident in the morning hours and the formation of the anomaly is seen around 21° magnetic dip. The CEJ conditions set in on this day around 1000 hrs LT and continued till late in the afternoon. In response, the anomaly which is quite evident in the morning hours disappeared by

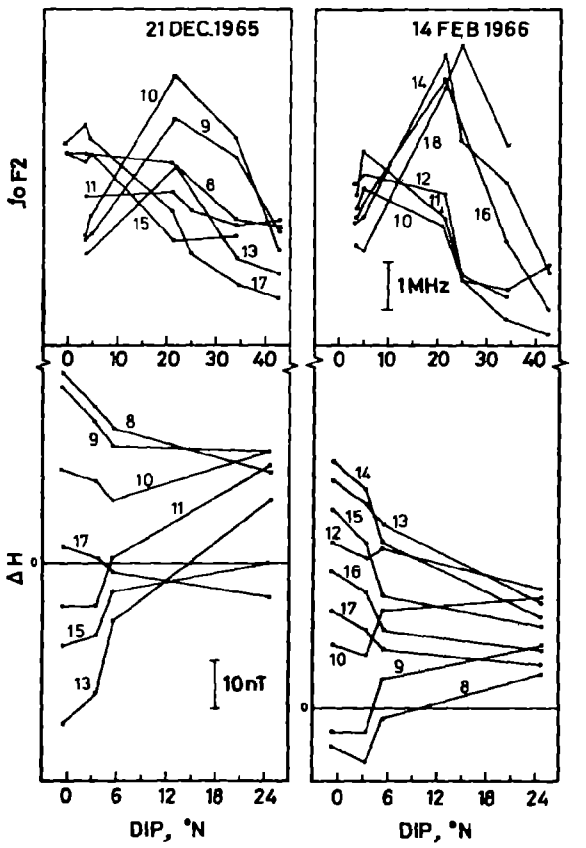

Fig. 1—Integrated picture showing the latitudinal profiles of ΔH and f_0F2 in the Indian equatorial region at specified hours during daytime on 21 Dec 1965 (AM AQD) and 14 Feb 1966 (PM AQD) [The numbers on the profiles of ΔH and f_0F2 represent local time. The times of diurnal maximum of H field at Trivandrum (dip 0.6°S), Kodaikanal (dip 3.0°N), Annamalainagar (dip 5.4°N) and Alibag (dip 24.5°N) in the Indian sector are, respectively, 0821, 0824, 0812 and 0944 hrs LT on 21 Dec 1965, and 1346, 1328, 1245 and 1146 hrs LT on 14 Feb. 1966]

1100 hrs LT and did not manifest again during the rest of the day. On 14 Feb. 1966 the CEJ conditions are seen in the morning period till around noon and the anomaly is not at all evident till around 1400 hrs LT.

Recently, Walker *et al.*[14] reported an interesting feature of the equatorial anomaly, namely, the remarkably poor development of the anomaly in the afternoon hours on certain days in the Indian region as compared to that in the East Asian region (longitude difference 40°). They found this behaviour to manifest only during northern winter months and on days with apparent indications of CEJ but confined to only the Indian region. A consideration of these features in the light of the results presented here and the known facts of the incidence pattern of AQD in the Indian equatorial region[4,5] (relatively high frequency of occurrence in local winter compared to other seasons and limited spatial extent) hints at a distinct possibility of AM AQD occurrence at electrojet stations in the

Table 1—Characteristics of the Diurnal Variation of H Field at Stations in the Indian Equatorial Region Pertaining to the Quiet Days Studied by Walker *et al.*[14]

Date	Time of diurnal maximum of H field (hrs LT)			
	Trivandrum	Kodaikanal	Annamalainagar	Alibag
		1964		
*11 Nov.	0935	0927	0936	0954
*12 Nov.	0900	0845	0845	1010
*13 Nov.	0919	0915	0935	0959
		1965		
9 Nov.	1110	1108	1108	1110
10 Nov.	1118	1120	1103	1114
11 Nov.	1045	1044	1045	1120
8 May	1036	1036	1037	1130
13 May	1122	1100	1030	1050
14 May	1018	0958	1003	1042

Note: *These are days on which the equatorial anomaly is less developed in the Indian longitude sector than in the East Asian sector.

Indian region on days of poor development of the anomaly in the afternoon period in the Indian region as compared to that in the East Asian region. To ascertain this, we have examined the times of diurnal maximum of H field at stations in the Indian equatorial region for the quiet days illustrated by Walker *et al.*[14] (Figs. 2 and 3 of Ref. 14). The relevant data presented in Table 1 clearly showed the occurrence of AM AQD in the Indian electrojet region, but only on days with dissimilar forms of anomaly development in the Indian and East Asian sectors as inferred.

In conclusion, the results of the present study demonstrate a decisive role of localized perturbations in the equatorial electrojet in the occurrence of abnormal $S_q(H)$ phase at locations in the immediate vicinity of the dip equator. This brings into focus the markedly different origins of the AQD phenomenon in the electrojet and midlatitude regions. At stations under the influence of the equatorial electrojet the phenomenon is closely associated with changes in the ionospheric dynamo region (CEJ), whereas at midlatitudes it is associated with events of extra-terrestrial or magnetospheric origin, as was shown by Butcher and Brown[15,16]. The physical mechanisms[7,14] underlying the spatially localized incidence of perturbations in the equatorial electrojet still need to be well understood.

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