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Identification of the Current System Associated with a Partially Reversed Equatorial Electrojet

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An abnormality among a series of geomagnetic quiescent days during July 1978 has been identified on 26 July using geomagnetic data from a network of 13 observatories in Indo-Russian longitude belt. This abnormality has been explained by invoking an additional clockwise loop current system centered around 5° dip latitude superimposed on the normal S_q current system centered at 20° dip latitude, thereby shifting the focus of the combined current system to 35° dip latitude. Probable causes of this additional currents in the low-latitude have been discussed.

1. Introduction

Abnormal increase of the solar daily variation of geomagnetic H field over the magnetic equator has been ascribed to the concentration of the S_q currents over the equator due to abnormal increase of the ionospheric conductivities with in 3° from the equator (Maeda, 1952; Baker and Martyn, 1953). However the solar daily ranges of H within and outside the equatorial electrojet belt have been found to be poorly correlated (Osborne, 1964; Kane, 1971; Rastogi, 1993). The correlation of the solar daily range of H between station pairs in low- and mid-latitudes was found to be spatially asymmetric being less for station pairs separated by latitude than for those separated by same distance in longitude (Schlapp, 1968). The equatorial counter electrojet events are found to have no visible effect on the variations of H field at low-latitude stations (Rastogi, 1974). These observations cast doubt to accept the suggestion that the equatorial electrojet current is an integral part of the global S_q current system. Comparing day-to-day variations of the daily range of H at thirteen geomagnetic observatories along the Central Asian longitude belt, James *et al.* (1996) have shown that the correlation between range of H at the electrojet stations and that of other stations decrease with increasing latitude and becomes significantly negative at 30° dip latitude. They suggested that the ionospheric current system at low- and mid-latitudes is a combined effect of the conventional S_q current system with the focus around 25° dip latitude and a current system controlled by lunar tides with focus around 15° dip latitude.

2. Data and Results

The coordinates of the stations whose data are utilized in the present analysis are listed in Table 1. It is to be noted that these stations extends from 0° to 45°N geomagnetic latitudes but are situated within a narrow geomagnetic longitudinal belt along 145°E. The latitudinal variations of the solar daily ranges of H (RH) on each of the days from 25 to 28 July, 1978 are shown in Fig. 1. On 25 July the RH was abnormally large (about 110 nT) at the station closest to the dip equator (TRD), it decreased monotonically with increasing latitude, changed sign at latitudes between Gulmarg (GUL) and Tashkent (TKT) and remained negative at all stations in USSR region. On 26 July, the range of H was very low (about 40 nT) at equatorial station, increased with latitude, reaching a maximum of 60 nT at Ujjain (UJJ) decreased sharply between GUL and TKT and attained normal values at former USSR stations. On 27 July there was

Table 1. List of stations along with the coordinates.

No.	Station	Geographic		Geomagnetic	
		Lat.	Long.	Lat.	Long.
1	Trivandrum (TRD)	8°29′ N	76°57′ E	0.88°S	148.24°E
2	Kodaikanal (KOD)	10°14′ N	77°28′ E	0.81°S	148.93°E
3	Annamalainagar (ANN)	11°22′ N	79°41′ E	1.77°N	151.20°E
4	Hyderabad (HYB)	17°25′ N	78°33′ E	7.86°N	150.20°E
5	Alibag (ABG)	18°38′ N	72°52′ E	9.64°N	145.39°E
6	Ujjain (UJJ)	23°11′ N	75°47′ E	13.50°N	147.00°E
7	Jaipur (JAI)	26°55′ N	75°48′ E	17.03°N	147.40°E
8	Sabhawala (SAB)	30°22′ N	77°48′ E	20.78°N	151.34°E
9	Gulmarg (GUL)	34°05′ N	74°24′ E	24.50°N	147.20°E
10	Tashkent (TKT)	41°20′ N	69°37′ E	32.51°N	145.52°E
11	Alma-Ata (AAA)	43°15′ N	76°55′ E	33.69°N	152.21°E
12	Karaganda (KGD)	49°49′ N	73°05′ E	40.56°N	150.04°E
13	Novosibirsk (NVS)	55°02′ N	82°04′ E	45.04°N	159.18°E

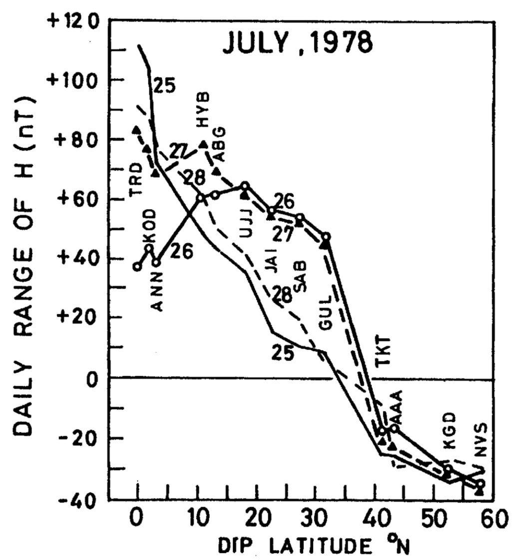


Fig. 1. Daily ranges of H against dip latitude for a chain of 13 stations in the Indo-Russian longitudinal belt for 4 consecutive days in July 1978 (— for 25, o—o for 26, -▲-▲- for 27, - - - for 28).

slight increase in RH at equatorial stations but for stations between UJJ and GUL the latitudinal profile was similar to that of 26 July. On 28 July, the latitudinal profile over the entire region became very similar to that of 25 July, indicating the normal pattern. Thus, there seems to be a disturbance causing an unexpectedly larger decrease of ranges in H at the equatorial latitudes and an increase at low-latitudes south of S_q focus.

The daily variations of ΔH, ΔY and ΔZ components of the geomagnetic field on 25 and 26 July at an equatorial station Kodaikanal (KOD) and at a station close to the S_q focus, Sabhawala (SAB) are presented in Fig. 2. At KOD, on 25 July, ΔH was maximum while ΔY and ΔZ were minimum around mid-day. The equatorial electrojet component of the current represented by ΔH at KOD minus ΔH at ABG [ΔH(K – A)] was also maximum around noon. These were the typical variations of a normal electrojet day. On 26 July, maximum ΔH at KOD occurred before noon, with magnitudes less than half of that on 25 July, ΔH(K – A) was negative during the daytime with a minimum around 14 hr and ΔZ was positive during the daytime. The negative part of the normal ΔY variation was absent on 26 July and it was positive throughout the day. These are the general characteristics of a partial counter electrojet event observed at low-latitudes.

At SAB, hourly variations of ΔH, ΔY and ΔZ on 25 July show a normal pattern as described by Patil *et al.* (1985). ΔY and ΔZ on 26 July followed the normal pattern as on 25 July with a minimum in the forenoon and a maximum in the afternoon hours. But the ΔH pattern on 26 July showed a significantly different pattern with strengthening of afternoon peak and weakening of forenoon minimum. These are characteristics of a day with abnormally large mid-latitude currents (James *et al.*, 1996). Thus, it seems that disturbance of unusually large mid-latitude current and strong counter equatorial electrojet have modified the global S_q current system on 26 July, 1978.

The day-to-day variations of ΔH and ΔY at different stations defining the horizontal currents for 25 to 28 July, 1978 are shown in Fig. 3(a). The day-to-day variations of ΔZ at these stations defining the meridional gradient of the current are shown in Fig. 3(b). On 25 July, ΔH showed a large mid-day peak at TRD which decreased gradually with increasing latitude. The hourly variations of ΔH become almost semidiurnal in character at JAI and the ΔH values were negative throughout the day with minimum around 12 hr LT at stations north of GUL. These features are characteristic of normal S_q current system with focus slightly south of TKT. On 26 July, the mid-day peak of ΔH at TRD was significantly reduced, and this peak

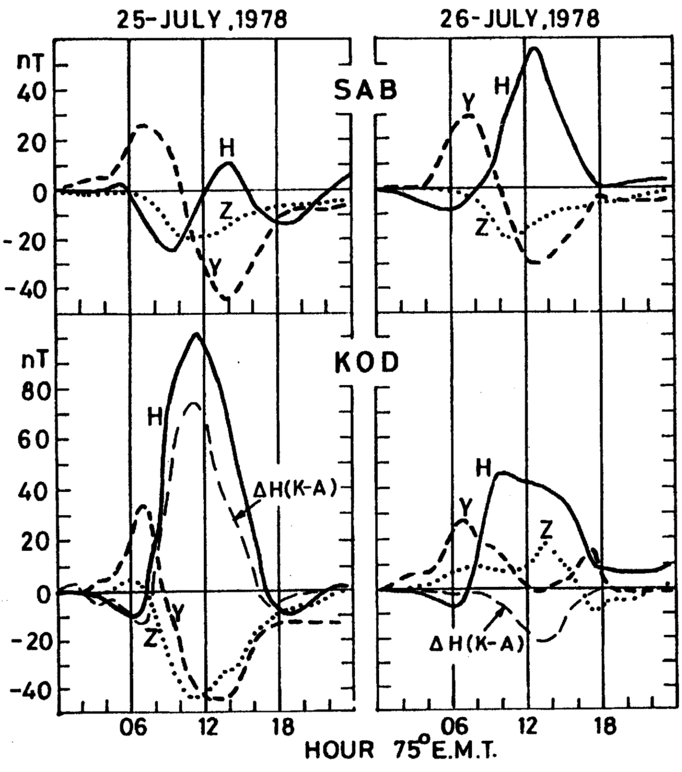
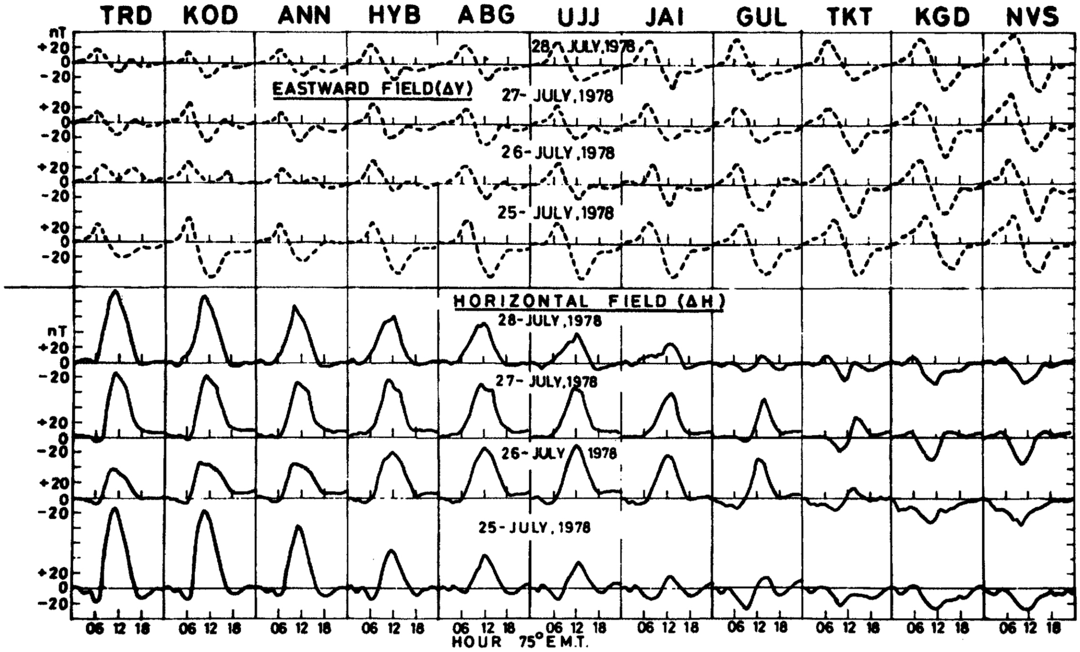


Fig. 2. Diurnal variations of H, Y, Z at Sabhawala and Kodaikanal and the electrojet strength parameter ΔH(K – A) for 25 and 26 July, 1978.

(a)



(b)

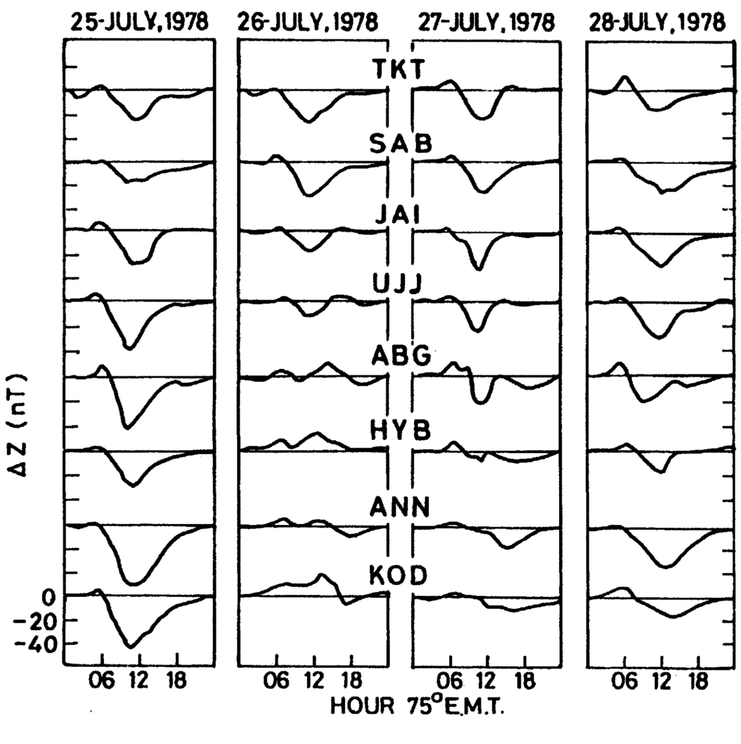


Fig. 3. (a) Hourly variation of ΔH and ΔY at 11 observatories for 25 to 28 July, 1978. (b) Hourly variation of ΔZ for 8 stations for 25 to 28 July, 1978.

value of ΔH increased progressively from TRD to UJJ, followed by a decrease at JAI and GUL. The hourly variations of ΔH was semidiurnal at TKT and almost negative throughout the day at KGD and NVS. This feature suggest that the S_q focus might have shifted to latitudes north of TKT. Thus even though hourly variations of ΔH at TRD does not show any minimum during the day time, still the daily range of H is decreasing from UJJ towards the equator. Therefore, according to the criteria of Fambitakoye *et al.* (1973) this day can be considered as a partial counter electrojet day. On 27 and 28 July, ΔH variations were somewhat similar to that on 25 July.

The hourly variations of ΔY on 25 July were normal with a morning maximum and mid-day minimum at equatorial stations and forenoon maximum and a minimum at noon hours at mid-latitudes. On 26 July, however, the noon minimum of ΔY at equatorial stations TRD, KOD and ANN were transformed into positive values and from stations HYB onwards these minimum values became negative but less than normal and increased in magnitudes towards higher latitudes; at stations north of JAI the variations were similar to those on 25 July. On 27 and 28 July, the daily variations of ΔY became normal with a forenoon maximum and a noon minimum at most of the stations.

The hourly variations of ΔZ on 25 July (Fig. 3(b)) showed a minimum around mid-day, a normal feature at northern hemispheric stations. On 26 July, ΔZ was positive during the daytime hours at KOD, ANN, HYB and ABG suggesting the presence of a westward current at low-latitudes over the normal eastward current (Rastogi, 1975). The magnitude and direction of the horizontal equivalent current vector at any time can be obtained by combining the magnitudes of ΔH and ΔY at that time. A plot of combination of these vectors for different hours at various latitudes, illustrate the ionospheric equivalent current system without any inherent problems of deriving spherical harmonic coefficients of the external current system. Such a vectorial representation of the current system for 25 July is shown in Fig. 4(a). This figure clearly shows a counter clockwise vortex centered around 1000 hr at about 20° latitude, between UJJ and JAI. Equatorial latitudes are characterized by very strong eastward current vectors with significant northward component during the afternoon hours.

Similar current vectors for 26 July are depicted in Fig. 4(b). Even though the general characteristics of the vectors are the same as on 25 July, with a counter clockwise loop current around 1000 hr, the focus of the loop appears to be shifted northward and is centered around 35° dip latitude. The current vectors for the equatorial and low-latitude stations show comparatively weaker zonal and meridional currents.

The plots of the difference vectors, that is, vector on 26 July minus those on 25 July for the same hours and stations are shown in Fig. 4(c). These would represent the vectors due to the additional current system on 26 July. A very clear clockwise current loop is seen at low-latitudes with focus as low as 5° dip latitude.

Thus, from the above analysis, it is evident that the abnormal variations of the geomagnetic field during the partial counter electrojet event is due to the superimposition of clockwise current system over the normal S_q current system. The focus of the additional current system is found to be much closer to the dip equator than that of the latitude of the S_q focus.

3. Discussion

Since the geomagnetic indices, K_p, did not exceed 3 on 25 and 26 July, 1978, any disturbance effect on ΔH on these days can be excluded. On 25 July, the ΔH can be ascribed to eastward current while on 26 July, ΔH has to be ascribed to the presence of westward current superimposed on the normal eastward electrojet current in the ionospheric region. The phenomenon of equatorial counter electrojet has been reviewed by Rastogi (1974, 1989), Mayaud (1977), Marriott *et al.* (1979), and Forbes (1981). Using the geomagnetic data over a network of observatories extending from equator to high-latitudes, Sastri and Bhargava (1980) and Rastogi (1991) shown that effects of strong counter electrojet events at ground over Indian longitude sector can be noticed not only in the narrow belt near the dip equator but also to an extended latitudes.

Stening (1977) has shown that the effects of equatorial counter electrojet events are seen as departures elsewhere at higher latitudes at same time. He suggested that the counter electrojet are caused by an

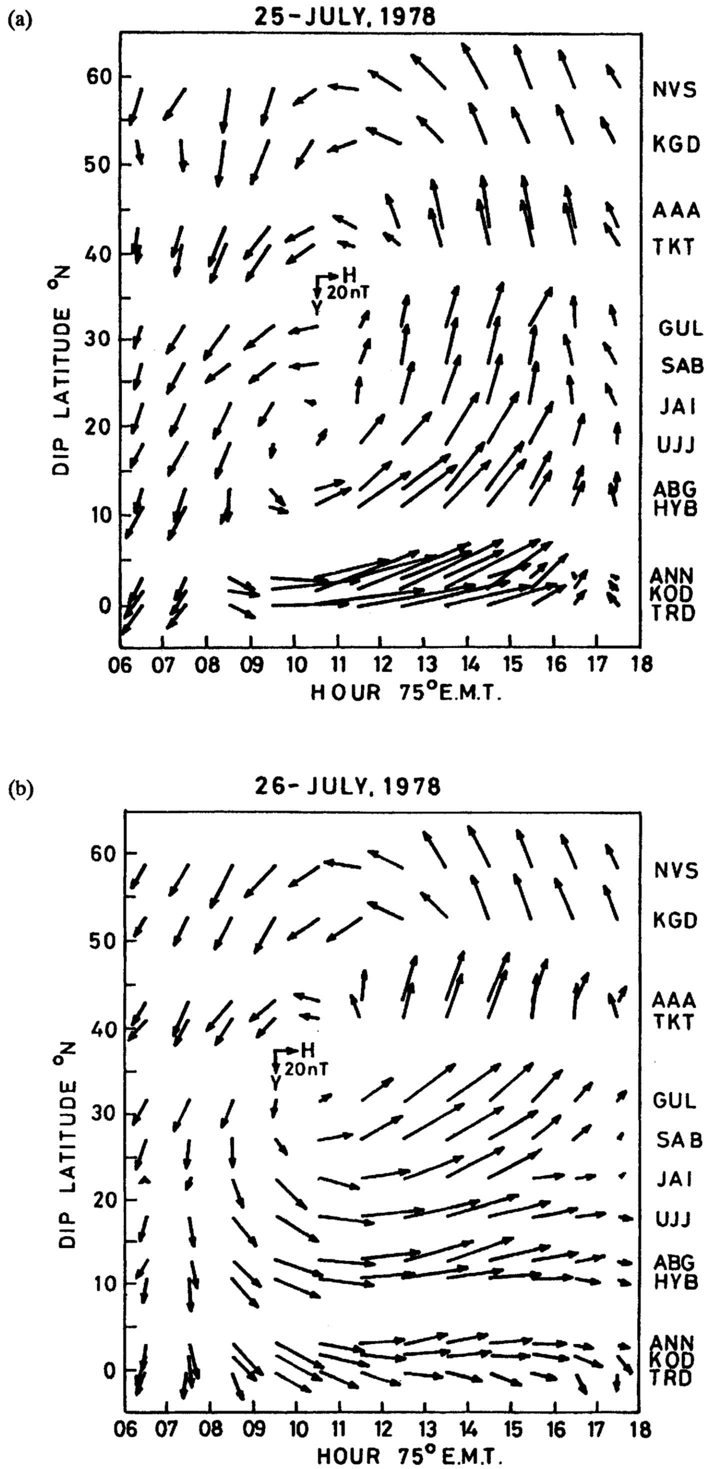


Fig. 4. Equivalent overhead current vectors at 13 stations (a) 25 July, 1978, (b) 26 July, 1978, and (c) for the difference in fields of 26 over 25, July, 1978.

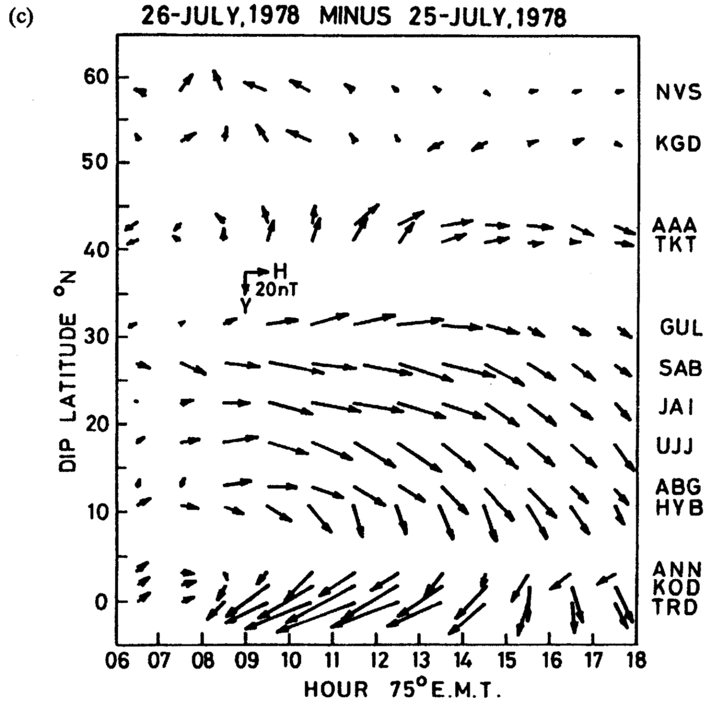


Fig. 4. (continued).

additional current system in dynamo region generated by thermo-tidal mode. The wind and temperature profiles in the mesosphere may allow some tidal modes to penetrate to dynamo region during some periods (Geller, 1970). Using an equivalent circuit method Stening (1989) has identified the effects of higher order tidal modes (2, 3) and (2, 5) on ionospheric electric current. Fambitakoye *et al.* (1976) have shown that a westward high altitude (above 125 km) diurnal wind system can produce geomagnetic effects at dip equator. This wind system, which could form part of a planetary wave pattern, would yield other smaller changes at non-equatorial stations.

In conclusion, among the four adjacent quiescent days in July 1978, the day 26 has been identified as an abnormal day with extremely low solar daily range of H at equatorial stations. These features of geomagnetic variations over Indian sub-continent on 26 July has been explained in terms of additional clockwise current system with focus at 5° dip latitude superimposed on the normal S_q current system.

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