The Indian equatorial electrojet in IGY and IQSY

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ABSTRACT. The parameters of the Indian equatorial electrojet are obtained for the months April to August of the solar maximum year, 1958 and the solar minimum year, 1964. The half-width for the two epochs are found to be 297 km and 276 km respectively, showing only a small change with solar activity. The total peak current intensity for 1958 is 186 A/km and for 1964 it is 97 A/km. The factor by which the normal current intensity is augmented in the electrojet is, however, found to be a little more for 1964 than for 1958.

1. Introduction

The first estimate of the width of the equatorial electrojet in India was given by Pisharoty and Srinivasan (1962). Using ratios of quiet day ranges in H at different places in South India and Ceylon to that at Kodaikanal, they arrived at 110 km as the half-width of the electrojet for the years 1950 to 1953. Bhargava (1964) found the same order of width for the period and indicated the probable height at which the electrojet flows is 105 km, rather than 110 km as assumed by Pisharoty and Srinivasan. Using quiet day H ranges, based on continuous records obtained at Trivandrum, Annamalainagar and Alibag, Yacob and Khanna (1963), however, found that the half-width of the Indian electrojet for the period April to August of 1958 and 1959 was nearly 300 km. The large disparity in the values of the half-width arrived at was presumed to be the result of solar-cycle variation in the width of the electrojet. With the availability of magnetic data for the Indian region for 1964, the parameters of the electrojet are here determined both for the IGY (1958) and for the first year of IQSY (1964) in order to ascertain their dependence on solar activity. The years 1958 and 1964 represent periods of extreme solar activity, the sun attaining peak activity (maximum for all recorded time) during the former year and minimum of the cycle during the latter year. The mean relative sunspot number for 1958 was as high as 189, while for 1964 the number was only 12.

2. The data

The stations whose magnetic data are utilised for the present study are Trivandrum, Kodaikanal, Annamalainagar and Alibag. Relevant details regarding these stations are given in Table 1. Trivandrum, Kodaikanal and Annamalainagar are close to the magnetic dip equator. Alibag is quite distant from it and the diurnal variations of magnetic elements at the stations are not expected to be sensibly influenced by the equatorial electrojet.

In arriving at the distances of the stations from the dip equator, first that of Trivandrum is computed using its dip latitude (dip latitude $= \tan^{-1}\frac{1}{2}\tan I$). The geographic locations of the other stations relative to that of Trivandrum are considered together with the trend of the dip equator in the region as given in the chart of the United States Coast and Geodetic Survey for the year 1955. The magnetic dip at Trivandrum has changed from $-0^\circ\ 38'$ in 1958 to $-0^\circ\ 49'$ in 1964. The dip equator is, therefore, taken to have moved northward by 10 km from 1958 to 1964 and the distances have been indicated accordingly in Table 1.

The data used for arriving at the parameters of the electrojet are the hourly mean values (centred at full hours GMT) of the horizontal component H of magnetic force on international quiet days (five per month) for the months April to August of 1958 and 1964. The data for 1958 are from published annual volumes, while those for 1964 are from tabulations from magnetograms. If for any station data are not available for any international quiet day, the day's data are omitted for all stations. The number of international quiet days that could be taken for April to August of 1958 was 21, while all the 25 days of April to August of 1964 were available. The study is confined to the months April to August of 1958 and 1964, since the solar zenith angle at local noon has the same range of about 20° for all the four stations. The normal diurnal range of especially H is to a large measure dependent on solar zenith angle at noon. By considering a period when the range of solar zenith angle is the same for all stations the difference in normal range from station to station is expected to be largely eliminated, so that the mean range at Alibag for the period may reasonably be taken to be the normal range at the other three stations, with a possible error of only a few gammas.

For each of the two periods, namely April to August 1958 and April to August 1964, the quiet

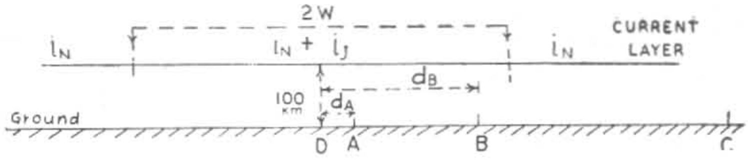

Fig. 1

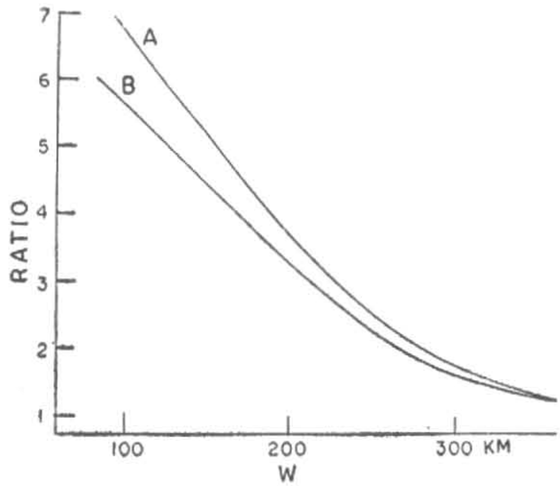

Fig. 2

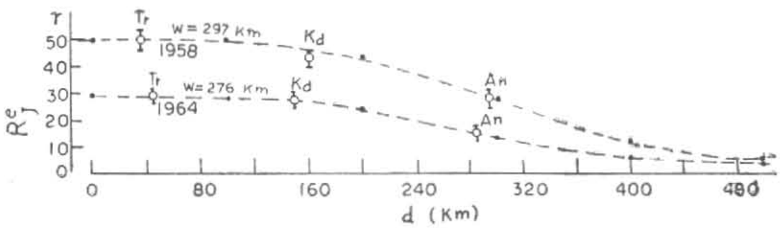

Fig. 3

TABLE 1

Co-ordinates and distances from the dip equator of stations

	Geographic		Geomagnetic		Distance from the dip equator (km)	
	Lat. (°N)	Long. (°E)	Lat.	Long.	1958	1964
Trivandrum	8·5	76·9	1·1S	146·4	35	45
Kodaikanal	10·2	77·5	0·6N	147·1	160	150
Annamalainagar	11·4	79·7	1·5N	149·4	295	285
Alibag	18·6	72·9	9·5N	143·6	1030	1020

day hourly values of each station are averaged to give mean hourly values. The average of the mean hourly values at 18^h, 19^h and 20^h GMT (the average value around local midnight) is then subtracted from the maximum mean hourly value (always near local noon) to give the mean quiet day range, R_T. This range is corrected for the non-cyclic change in the following way. For each international quiet day the non-cyclic change is determined by subtracting the hourly value at 19^h GMT (the hour closest to local midnight for all the stations) of the previous day from that at 19^h GMT of the international quiet day. The values of non-cyclic variation for all the international quiet days of each period are averaged to give the mean value, N. The corrected mean quiet day range is then given by $R_T + N_t/24$, where t is the difference between the GMT hour of maximum mean hourly value and 19^h GMT. The range R_T corrected for non-cyclic change for each station and for each of the two periods under consideration is given in Table 2.

3. Parameters of the electrojet

The method for deriving the parameters of the electrojet is exactly the same as employed earlier by Yacob and Khanna (1963). It is based on the simple ionospheric current model shown in Fig. 1, as explained in detail in an earlier paper (Yacob 1966).

Trivandrum and Annamalainagar are selected to represent the pair of stations A and B. The curves of ratio $R^e_{J,A}/R^e_{J,B}$ *versus* W for the pair of stations for 1958 and 1964 are given in Fig. 2. The observed ranges, R_J at Trivandrum and Annamalainagar are obtained by subtracting the normal range R_N at Alibag (which is the same as R_T, since the effect due to jet current at Alibag is negligible) from R_T at these stations. The ratio of observed R_J at Trivandrum by that at Annamalainagar works out to 1·78 for April to August 1958 and to 1·86 for April to August 1964. With these ratios the half-widths are picked up from the

TABLE 2

Mean quiet-day ranges (in γ) in H for the months April to August

	1958		1964	
	R_T	R_J	R_T	R_J
Trivandrum	157±5	76±3	79±3	43±2
Kodaikanal	146±5	65±3	77±3	41±2
Annamalainagar	123±3	42±1	59±2	23±1
Alibag	81±2	0	36±1	0

R_T —total range ; R_N – range due to normal ionospheric current; R_J — range due to jet current. The indicated errors are standard errors of mean values of ranges

TABLE 3

Half-width (W) and normal current intensity (i_N) and jet current intensity i_J of the electrojet

	W (km)	i_N (A/km)	i_J (A/km	$i_T = i_N + i_J$ (A/km)	i_T/i_N
Apr–Aug 1958	297±2	86±2	100±4	186±6	2·16±0·02
Apr–Aug 1964	276±1	38±1	59±3	97±4	2·55±0·04

The indicated errors are based on standard errors of mean quiet day ranges

respective curves of Fig. 2. The half-widths so obtained are shown in Table 3.

Peak Current Intensity

With the half-widths arrived at the distribution of computed R^e_J with distance d, from the dip equator is found to fit the observed R^J values reduced in the ratio 2/3, at Trivandrum, Kodaikanal and Annamalainagar when the jet current intensity i_J is of such a strength as to make R^e_J at the dip equator ($d=0$) equal to 50γ for 1958 and 29γ for 1964. The distribution curves and the plot of $\frac{2}{3}\times R_J$ values observed at the three stations are shown in Fig. 3. The observed R_J values have been reduced in the ratio 2/3 in order to allow for the contribution to R_J by induced electric currents within the earth. The plot of observed $\frac{2}{3}\times R_J$ for Trivandrum in Fig. 3 is shown on the same side of the dip equator as for Kodaikanal and Annamalainagar, though Trivandrum is to the south of the dip equator and the other two stations are to its north, since the electrojet has been assumed to be symmetrical about the dip equator and the electrojet effect at equal distances north and south of the dip equator will, therefore, be the same. The jet current intensity i_J, is then obtained from equation (2) of the author's earlier paper (Yacob 1966), putting $d=0$ $h=100$ km, and $R_J^e=50\gamma$ for 1958 and $R_J^e=29\gamma$, for 1964. The normal current intensity i_N is obtained by using equation 1 (Yacob 1966) putting R_N^e equal to $\frac{2}{3}\times R_T$ at Alibag for the respective periods. The total current intensity i_T is given by the sum i_J+i_N. The results for the two periods are shown in Table 3.

In Table 3 are also shown the factors by which the normal current intensity is augmented in the electrojet during the two periods under consideration.

4. Discussion

Before proceeding to a discussion of the results obtained, it is necessary to examine the order of errors involved in the assumption that R_N at Trivandrum, Kodaikanal and Annamalainagar are the same and equal to R_T at Alibag for the months considered. The latitudinal separation between Trivandrum and Alibag is about 10° and that between Annamalainagar and Alibag is about 7°. Having taken such a period of the year as to make the range of solar zenith angle at noon about the same for all the observatories the error involved in R_N – based on standard error of mean $S_q\,(H)$ range in the region — is not expected to be more than 5γ for the solar activity maximum year and about half this for the solar activity minimum year. These possible errors in R_N introduce errors of less than 10 km in W and no appreciable change in the total current intensities, i_T.

The half-width of the Indian electrojet in 1958 is 297 ± 2 km and that for 1964 is 276 ± 1 km. The change from the solar maximum epoch to the minimum epoch is thus only 20 km. Though the trend is a decrease, the magnitude of change is certainly not commensurable with the order of decrease in solar activity from 1958 to 1964. The same order of small change in W with solar activity is reported for the Nigerian electrojet by Ogbuehi and Onwumechilli (1963). It is concluded that the width of the electrojet is not sensibly affected by solar activity. The finding is consistent with the explanation put forward by Baker and Martyn (1953) for the enhancement of electric conductivity over the region of the dip equator, which is the inhibition of the vertical Hall currents in the relatively thin E-layer of the ionosphere. The Hall current flow is normal to the direction of total geomagnetic field and therefore with increasing dip, the effective thickness of the E-layer, in which the inhibition of Hall currents occurs and the resultant polarization field is set up, increases. Beyond a certain dip latitude the polarization field obviously becomes ineffective in enhancing the electric conductivity of the current layer. This value of dip latitude, which ultimately determines the width of the electrojet, is apparently the same for the solar maximum and minimum epochs.

The total current intensity i_T in the electrojet for 1958 is seen to be about double that for 1964, which is only to be expected from the magnitudes of diurnal ranges in H in the two epochs. The cause is the well-known direct dependence of electron concentration of the current layer (E region) on solar activity so that both the electric conductivity of the current layer as well as the electric field of the S_q current system are of greater magnitude in 1958 than in 1964.

The factors by which i_N is augmented in the electrojet are 2·17 and 2·55 for the 1958 and 1964 epochs respectively. It is surprising that the augmentation is greater for the solar minimum epoch.

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