RELATION BETWEEN THE STRENGTH OF THE Sq CURRENT SYSTEM AND ITS FOCUS POSITION

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ABSTRACT

Day-to-day changes of the strength of the Sq current system are studied. It is shown that for Indian longitudes, larger strengths are associated (on the average) with an equatorward shift of the Sq focus as also with larger strengths of the equatorial electrojet.

1. INTRODUCTION

The daily variation of geomagnetic field during quiet days is supposed to be due to overhead Sq current systems at ionospheric E region heights. The systems are in the form of closed loops, one in each hemisphere mainly in the dayside. The center of the loops is known as Sq focus and is roughly at about 30° latitude, north and south. The strength of the current systems as also the focus position change appreciably with season as also from day to day (Hasegawa, 1936, 1960; Chapman and Bartels, 1940; Vestine et al., 1947; Ota, 1948, 1950). Changes in the focus position can be sometimes as large as 15° in latitude even on consecutive days. Studies at different longitude zones show that the unusually high or low position in one zone need not necessarily have a corresponding high or low in other zones (Matsushita, 1960). It is believed that the day-to-day changes are most probably due to changes in wind patterns rather than in ionospheric conductivity (Hasegawa, 1960).

In earlier communications (Kane, 1971, 1972 a), it was shown that the quiet day H ranges at equatorial and nearby low latitudes were not normally very well correlated; but the correlation improved (from +0.4 to +0.8) when day-to-day changes in the angular distances of the two locations from the Sq focus were taken into consideration. It is also known that the day-to-day variability of the equatorial electrojet strength (as represented
by $H$ range at equator) is intimately connected with ionospheric upheavals in the F region (Akasofu et al., 1969; Rastogi and Rajaram, 1971; Kane, 1972a). Thus, the day-to-day variability at equator is partly due to F region ionospheric drifts and partly due to changes in the strength and focus position of the Sq current systems. In the present communication we examine whether the day-to-day changes in the strength of the Sq current system are related to its focus position.

2. EXPERIMENTAL DATA AND ANALYSIS

The data used are for the equatorial stations Trivandrum (Geomag. lat. $-1.1^\circ$) and Kodaikanal ($+0.6^\circ$) and the low and mid-latitude stations Hyderabad ($+7.7^\circ$), Alibag ($+9.5^\circ$), Ahmedabad ($+13.9^\circ$), Sabhawala ($+20.5^\circ$), Tashkent ($+32.6^\circ$), Alma-Ata ($+33.0^\circ$) and Sverdlovsk ($+48.5^\circ$), all in the 60–80° E longitude belt. The data refer to the quiet sun year 1964 and for quiet days only ($Ap = 0$ to 7, about 170 days). The Sq focus is generally between Tashkent and Sabhawala.

Figure 1 shows plots of the average daily variation curves for the $H$ and $D$ components for Sverdlovsk, Tashkent, Sabhawala, Alibag and Trivandrum for the various seasons ($a$) Equinoxes, ($b$) J months, ($c$) D months for quiet days in 1964. Following may be noted:

(1) For the $H$ variations, the equinox patterns are as expected, the focus being between Tashkent and Sabhawala, the Sverdlovsk pattern reverse

![Fig. 1](image_url)
of that at Alibag and the H range at Sverdlovsk about 3/4th that at Alibag. However, whereas Tashkent shows a pattern almost similar to Sverdlovsk (just one minimum prior to noon), Sabhawala does not show a pattern similar to Alibag. Firstly, the hour of maximum is later than noon at Sabhawala but earlier than noon at Alibag. In addition Sabhawala, shows a significant morning (0800 L.T.) minimum and another minor minimum in the afternoon too. Such a pattern for H would obtain if the overhead Sq current contours are not concentric circles but are deformed and tilted. Figure 2 shows H curves for several stations at various longitudes in middle latitudes.

![Figure 2](image)

**Fig. 2.** Average daily variation curves for the H component at several pairs of stations Tucson (TUCS) and Trelew (TREL), Toledo (TOLE) and Hermanus (HERM), Tashkent (TASH) and Sabhawala (SABH), Kakioka (KAKI) and Kano (KANO) near the Sq loci in different longitudes for the three seasons E, J and D for 1958 (full lines) and 1964 (dashed lines).

The top two curves refer to E months, the next two to J months and the bottom two to D months, each for a pair of stations in a particular longitude zone and near the Sq focus. In almost all cases, the patterns show significant deviations from the expected pattern of either a horizontal line or a small single maximum or minimum near noon. This is consistent with the observations by Matsushita (1965) who reports strong but deformed current loops with considerable longitudinal as well as hemispherical inequalities. Mayaud (1967) has also mentioned similar distortions of $S_R$ in various geographical
regions. In principle, these could be due not only to variations in the $C_M$ systems, i.e., current system having foci at middle latitudes (same as $S_q$ above) but also due to $C_P$ current systems having centers in the polar regions. However, for locations in middle and low latitudes the effects of $C_P$ are expected to be negligible. More important is the invasion of the $C_M$ current systems of one hemisphere into another as also changes in the form, strength and focus position of the $C_M$ current systems. In Fig. 2, the full curves refer to 1958 (obtained from Price and Stone, 1964) and dashed curves to 1964. Apart from the increased amplitudes in 1958 which will be due to increased solar flux resulting into increased ionisation, the positions of maxima and minima also vary. This should have an important bearing on the ionospheric wind patterns too which seem to change from low to high solar activity.

![Graph of H component variations for different latitudes](image)

**Fig. 3.** Average daily variation curves for the $H$ component at Sverdlovsk, Tashkent, Sabhawala, Alibag and Trivandrum for the five groups corresponding to increasing $S_q$ current strengths $\Delta Y^* = 20-29, 30-39, 40-49, 50-59$ and 60 or more gamma, for equinoxes in 1964.

In Fig. 1, $H$ variations for J months are similar to those for E months, but for D months, the $H$ patterns are very irregular and the $H$ ranges are small near the focus and to some extent at equator too.

(2) For variations of the D component (Fig. 1), the amplitudes are highest in mid-latitudes during J months and the pattern consists of a morning
maximum and afternoon minimum, the cross-over occurring at about 1000 L.T. Trivandrum D also shows a similar pattern, indicating that the equatorial region is under the influence of the northern Sq current system in this longitude. For equinoxes too, similar patterns are obtained. However, for the D months, the patterns are very erratic, showing a considerable weakening and irregularity of the Sq current system during winter, perhaps due to the "invasion" of the southern hemisphere C_M system into the northern hemisphere (Mayaud, 1967).

Let us now consider the changes of the Sq current strength. Since the focus position may also change from day to day, the magnitude of the H variation will be a poor indicator of the Sq current strength. Instead, the range of the Y (= $H \sin D$, where D = Declination) component would be a satisfactory indicator (Price and Stone, 1964). We obtained the Y ranges (maximum minus minimum) for Tashkent and Sabhawala separately and found these very well inter-correlated (Kane, 1971). Hence $\Delta Y^*$, an average of the two Y ranges, was used as a measure of the strength of the northern Sq current system in this longitude belt. $\Delta Y^*$ had an average value of about 55 gamma in J months, 40 gamma in E months and 25 gamma in D months. However, wide variations from these values were seen from day to day in the same season, particularly in equinoxes when $\Delta Y^*$ ranged from about 20 to 80 gamma. Figure 2 shows the average daily variation curves for the H component at several stations for five groups of quiet days during equinoxes having increasing ranges $\Delta Y^*$ as 20--29, 30--39, 40--49, 50--59 and 60 or more gamma. Following may be noted:—

(i) For days of the lowest $Y^*$ ranges, Sabhawala H shows a clear maximum near noon similar to Alibag while Tashkent shows a small, irregular H variation. Thus, the Sq focus is over Tashkent. However, as we approach days of higher and higher $Y^*$ ranges, i.e., days of increasing Sq current strengths, the Sabhawala H pattern gets irregular while Tashkent H looks like Sverdlovsk H. Thus, the Sq focus position seems to have shifted from Tashkent towards Sabhawala indicating that a larger Sq current strength is accompanied by an equatorward shift of the Sq focus.

(ii) The equatorial electrojet strength (H range at Trivandrum) is also larger when $\Delta Y^*$ is larger. Thus, the two are definitely inter-related at least partially.

Similar diagrams for J and D months showed roughly similar results though not so conspicuous,
Is the equatorward shift of Sq focus with increasing Sq current strength observed even on a day-to-day basis? Hasegawa (1936) reported changes as large as 15° in latitude in the Sq position even on consecutive days. Figure 4 shows a plot of D and H components at Tashkent and Sabhawala for six consecutive quiet days, 23–28 July 1964. The Ap values were 5 or less. The Sq current strength ΔY* was 71 gamma on 24 July, 56 gamma on 26 July and 50 gamma or less on other days. From the H plots, the focus seems to be to the south (equatorward) of both Tashkent and Sabhawala on 23 July, over Sabhawala on 24 July and between Tashkent and Sabhawala on other days. According to the average behaviour mentioned above, the focus should be nearer equator on 24 July as compared to the other days. This is observed for 24–28 July; but 23 July is an exception in the sense that even though Sq current strength is not high, the focus is equatorward of even Sabhawala. Thus, whereas the average pattern is in general followed, considerable deviations can occur on individual days.

![Figure 4](image_url)

**FIG. 4.** Plots of the D component (upper two curves) and the H component (lower two curves) at Tashkent (TASH) and Sabhawala (SABH) for the six consecutive quiet days 23–28 July 1964. ΔY* (Sq current strengths) and Ap values are indicated.

To check whether various Y* range groups were connected with any ionospheric parameters, the average daily variation patterns for foF2 at Alma-Ata, Ahmedabad, Hyderabad and Kodaikanal, foE at Ahmedabad and
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h'F2 at Ahmedabad and Kodaikanal were obtained. In each case, average curves for the first range group (\(\Delta Y^* = 20-29\) gamma) was subtracted from the average curves of other groups. The deviations showed:

(a) Increasing \(\Delta Y^*\) was associated with noon-time decrease of foF2 at equator and increase of foF2 at Ahmedabad latitude, i.e., with the well-known fountain effect.

(b) The foE at Ahmedabad also increased slightly from about 3.3 MHz to 3.6 MHz. h'F2 at Kodaikanal and Ahmedabad also increased.

It would thus seem that the increase in \(\Delta Y^*\) is accompanied at least partly by lifting of the equatorial F region ionisation and its dumping at mid-latitudes. As shown in an earlier communication (Kane, 1972a) this effect was seen very conspicuously when days were grouped according to H ranges at Trivandrum.

During 1964, X-ray solar flux data were rather meagre. Nevertheless we evaluated the mean values of solar radiation parameters like 2,800 Mc/s flux, sunspot number and X-ray (44-60 A) flux, for the \(Y^*\) range groups. No significant changes were observed between the various range groups.

3. SUMMARY AND CONCLUSION

The main result of this investigation is that increases in the strength (\(\Delta Y^*\)) of the Sq current system are accompanied by an equatorward shift of the Sq focus (on the average) and also by an increase in the equatorial electrojet strength. In turn, all these are associated to some extent with large upheavals in the equatorial ionospheric (specially F) regions. The question arises, what is causing these large day-to-day changes? The Sq current system is situated mainly in the ionospheric E region and the day-to-day changes of E region electron density are at best only a few per cent. Thus, the changes must be due to variations in the dynamo driving force (the wind velocities) rather than ionospheric conductivity. (Similar conclusions have been drawn by other workers too, e.g., Hasegawa, 1960; Schlapp, 1968.) If so, it would seem that, analogous to ground meteorology, there should be a meteorology of wind systems at ionospheric levels too where rapid and violent changes occur more like the tropical cyclones and apparently unconnected with any direct solar radiation input. In the same longitude, changes at different latitudes are fairly correlated (as shown in this communication and in Kane, 1971) though not perfectly and the position of the Sq focus also plays a significant role. The longitudinal extent of the correlation is,
however, small (Schlapp, 1968; Kane, 1972 b). Thus, the wind irregularities (typhoons?) are restricted in their longitudinal extent and to a lesser extent, in their latitudinal extent. The deformed nature and tilt of the Sq current vortices and the equatorward shift of the Sq focus when the currents are enhanced could be valuable clues in the understanding of the ionospheric wind systems, both regular and irregular. Direct observations of both zonal and meridional ionospheric winds during day-time could throw valuable light on the ionospheric meteorology. The day-to-day changes in the profiles of the daily variation of geomagnetic field at equator (Kane, 1973) also indicate probably changes in the wind patterns exclusively in the equatorial region.

Regarding the shift of the Sq focus, another possibility should be kept in mind, viz., that of a non-ionospheric contribution to the observed daily variation of H at ground. For example, if there was a magnetospheric contribution of about 10 gamma near noon (Olson, 1970 a, b), a station like Tashkent to the north of the Sq focus which would have shown a day-time minimum of about 10 gamma would now show negligible H variation and one would conclude that the focus is above Tashkent. If now the Sq current strength increases to give a magnitude of 25 gamma instead of 10 gamma at Tashkent, the magnetospheric effect would neutralise only 10 gamma and Tashkent will still show a day-time minimum of about 15 gamma and the conclusion would be that the focus is to the south of Tashkent. Thus, an apparent southward (equatorward) shift of the focus associated with increase in the Sq current strength would be indicated. However, Sabhawala would show a prominent day-time increase in both cases. Thus, whereas such a magnetospheric effect is not ruled out, it seems from the H pattern of Sabhawala (Fig. 3) that the H pattern has become obscure and the Sq focus has really shifted equatorward.

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