Dependence of the daily ranges of geomagnetic variations on $A_p$

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Abstract—After applying $D_m$ corrections, the daily range of geomagnetic $H$ variation at Trivandrum (Equator) and Alibag (mid-latitude) is separated into a positive ($\Delta S^+$) and a negative ($\Delta S^-$) component. Correlations of these between themselves as also with geomagnetic activity index $A_p$ are studied. It is found that on a majority of quiet days ($A_p = 0-7$), only the positive component exists and is poorly correlated with $A_p$ as also at different latitudes. For disturbed days, the negative component is large, well correlated at different latitudes and moderately correlated with $A_p$ but poorly correlated with the positive component. Several other details are presented as also evidence to indicate that the negative component may be of magnetospheric origin while the positive component may have magnetospheric as well as ionospheric origins, in different proportions in different seasons and at different latitudes.

1. Introduction

The $S_q$ variation of geomagnetic field is defined as the average solar daily variation for truly quiet days. In practice it is evaluated every month from the 5 international quiet days (Sugiura and Chapman, 1960) or, if the local time (LT) is very much different from universal time (UT), then from 5 local quiet days (Price and Stone, 1964). However, as pointed out by Matsushita and Maeda (1965), the 5 days so chosen may not be equally quiet in all months. The exact dependence of the daily range on geomagnetic activity index ($K_p$ or $A_p$) does not seem to be precisely known. We propose to examine in this paper the relationship between $A_p$ values and the daily range of the geomagnetic component $H$, both for quiet as well as disturbed periods during the quiet sun year 1964 when plenty of days of both types are available.

2. Analysis

The data used are for the equatorial station Trivandrum (Geomagnetic latitude $-1\cdot1^\circ$) and the mid-latitude station Alibag ($+9\cdot5^\circ$) both at about 75°E longitude. After correcting for long-term, non-cyclic changes, Fig. 1(a,b) shows plots of the hourly values of $H$ at Alibag ($H_{AL}$) and Trivandrum ($H_{TR}$) for a sample period of 9 days (30 December 1963–7 January 1964). The $A_p$ values are also indicated. On days of low $A_p$, it is easy to estimate the daily range of $S_q$ by the simple definition $H_{\text{max}} - H_{\text{min}}$. However, on disturbed days (e.g. 2 January 1964 when $A_p$ was 53), such a definition would yield faulty estimates of the range, due to pollution due to $D_{st}$ effects. Also, even on days of low $A_p$, there is no guarantee that the $D_{st}$ effects would be completely negligible. Hence, all data were corrected for $D_{st}$ effects using the hourly $D_{st}$ values given by Sugiura and Cain (1970) for equatorial location and assuming a cos $\theta$ dependence for geomagnetic latitude $\theta$. Figure 1(c,d) shows the $H$ values corrected for $D_{st}$ effects. By conventional definition, these represent the disturbance daily variation $S_d$ for disturbed days and $S_q$ for quiet days.
Fig. 1. Plot of $H$ values at (a) Alibag, and (b) Trivandrum for the period 30 December 1963–7 January 1964. In (c) and (d) the same are shown after $D_{st}$ correction. $A_p$ values for every day are also indicated.

An interesting feature of Fig. 1(c,d) is that the minima of $H$ values seem to be on a horizontal line (for both Alibag and Trivandrum) on all days except the very disturbed ones when values dip below this line. Thus, on quiet days, the day-to-day variability is caused mainly by variations of $H_{\text{max}}$ while on disturbed days, both $H_{\text{max}}$ and $H_{\text{min}}$ vary. Hence, assuming the average value of $H_{\text{min}}$ on a few successive quiet days ($A_p = 0$–7) as an appropriate base level $H_o$, the daily variation range for every day for these quiet days as well as the succeeding disturbed days ($A_p$ exceeding 7) was represented by three parameters as follows:

(i) Total range $\Delta Sd$ given by ($H_{\text{max}}$ minus $H_{\text{min}}$) of that day;
(ii) The positive range $\Delta Sd^+$ given by ($H_{\text{max}}$ of that day minus $H_o$ obtained as average of $H_{\text{min}}$ of the preceding quiet days); and
(iii) The negative range $\Delta Sd^-$ given by ($H_{\text{min}}$ of that day minus $H_o$). Thus, $\Delta Sd = \Delta Sd^+ - \Delta Sd^-$. 

For example, for 2 January 1964 for Trivandrum (Fig. 1(d)), $H_o$ (the average of $H_{\text{min}}$ for the preceding 3 quiet days) was 458 gamma whereas the values of $H_{\text{max}}$ and $H_{\text{min}}$ on 2 January were 565 and 398 gamma (zero level arbitrary). Hence, for 2 January $\Delta Sd = 167$ gamma, $\Delta Sd^+ = 107$ gamma and $\Delta Sd^- = -60$ gamma. The value 458 gamma of $H_o$ was used for the period 30 December–5 January when the disturbance ended. For the succeeding quiet and disturbed days, a fresh value of $H_o$ was evaluated from the $H_{\text{min}}$ of the quiet days 6–8 January and so on.

The three parameters $\Delta Sd$, $\Delta Sd^+$ and $\Delta Sd^-$ were obtained for every day of 1964 for Trivandrum and Alibag separately. Figures 2–4 show a plot of these
parameters vs. $A_p$ for the three conventional seasons $D$ (Jan., Feb., Nov., Dec.), $E$ (Mar., Apr., Sep., Oct.) and $J$ (May., Jun., Jul., Aug.). In each figure, the upper half refers to $\Delta Sd$, $\Delta Sd^+$ and $\Delta Sd^-$ for Trivandrum (TR) and the lower half for similar quantities for Alibag (AL). In 1964, more than half the number of days (about 200) were confined to $A_p$ values between 0 and 7. Hence, the abscissa scale is taken logarithmic and $A_p = 7$, indicated by a vertical line lies almost in the middle of the diagram. Since $A_p = 0$ cannot be shown on a logarithmic scale, such a day (only one, 28 March 1964), is included in the $A_p = 1$ group.

To get a measure of the relationship between the various parameters and $A_p$, correlation coefficients were calculated (i) for $A_p = 0-7$ only, (ii) for $A_p = 8-53$, and (iii) for the whole range of $A_p = 0-53$. These are shown in Table 1.

Following may be noted from Figs. 2-4 and Table 1:

(1) For all values of $A_p$, $\Delta Sd$ and $\Delta Sd^+$ have a very large scatter. This indicates that the relationship with $A_p$, if any, is rather loose. However, the characteristics for low and high $A_p$ are somewhat different.
Fig. 3. Same as Fig. 2, for E months.

Fig. 4. Same as Fig. 2, for J months.
Table 1. Correlation coefficients of $\Delta S_d$, $\Delta S_d^+$, $\Delta S_d^-$ at Trivandrum and Alibag with $A_p$ values in the 0–7, 8–53 and 0–53 ranges

<table>
<thead>
<tr>
<th>$A_p$</th>
<th>$\Delta S_d$</th>
<th>$\Delta S_d^+$</th>
<th>$\Delta S_d^-$</th>
<th>$\Delta S_d$</th>
<th>$\Delta S_d^+$</th>
<th>$\Delta S_d^-$</th>
<th>$\Delta S_d$</th>
<th>$\Delta S_d^+$</th>
<th>$\Delta S_d^-$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trivandrum</td>
<td></td>
<td></td>
<td>Alibag</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–7</td>
<td>+0.15</td>
<td>+0.13</td>
<td>-0.09</td>
<td>-0.13</td>
<td>-0.19</td>
<td>+0.07</td>
<td>-0.03</td>
<td>-0.27</td>
<td></td>
</tr>
<tr>
<td>8–53</td>
<td>+0.41</td>
<td>+0.19</td>
<td>-0.47</td>
<td>-0.00</td>
<td>-0.29</td>
<td>+0.23</td>
<td>-0.01</td>
<td>-0.42</td>
<td></td>
</tr>
<tr>
<td>0–53</td>
<td>+0.33</td>
<td>+0.06</td>
<td>-0.56</td>
<td>+0.14</td>
<td>-0.05</td>
<td>-0.42</td>
<td>+0.31</td>
<td>-0.01</td>
<td>-0.61</td>
</tr>
<tr>
<td></td>
<td>Alibag</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–7</td>
<td>+0.28</td>
<td>+0.13</td>
<td>-0.38</td>
<td>-0.01</td>
<td>-0.14</td>
<td>+0.13</td>
<td>+0.01</td>
<td>-0.34</td>
<td></td>
</tr>
<tr>
<td>8–53</td>
<td>+0.62</td>
<td>+0.38</td>
<td>-0.58</td>
<td>+0.29</td>
<td>-0.03</td>
<td>-0.41</td>
<td>+0.47</td>
<td>+0.30</td>
<td>-0.46</td>
</tr>
<tr>
<td>0–53</td>
<td>+0.69</td>
<td>+0.47</td>
<td>-0.65</td>
<td>+0.35</td>
<td>-0.04</td>
<td>-0.57</td>
<td>+0.53</td>
<td>+0.18</td>
<td>-0.68</td>
</tr>
</tbody>
</table>
The low $A_p$ range (0–7) is characterised by a very small value (within ±10 gamma) of the negative component $\Delta Sd^-$ at Trivandrum as well as at Alibag. Hence the total range $\Delta Sd$ is mainly contributed by $\Delta Sd^+$. For low $A_p$, this represents the $Sq$ range and its day-to-day variability (which is quite large, several tens of gamma) seems to be unconnected with the $A_p$ changes. The correlations are very low, in all seasons (see Table 1).

It may be noted, however, that on some of these quiet days, $\Delta Sd^-$ is not small. Table 2 gives instances when the negative component was 10 gamma or more either at Trivandrum (TR) or at Alibag (AL) on quiet days ($A_p = 0–7$).

Table 2. $\Delta Sd^-$ in gamma. Asterisk (*) denotes simultaneously high values at Trivandrum (TR) and Alibag (AL)

<table>
<thead>
<tr>
<th>Dates (1964)</th>
<th>$A_p$</th>
<th>$\Delta Sd^-_{TR}$</th>
<th>$\Delta Sd^-_{AL}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Jan.</td>
<td>7</td>
<td>-8*</td>
<td>-10*</td>
</tr>
<tr>
<td>14 Jan.</td>
<td>1</td>
<td>-18</td>
<td>+7</td>
</tr>
<tr>
<td>18 Feb.</td>
<td>5</td>
<td>-8*</td>
<td>-10*</td>
</tr>
<tr>
<td>29 Mar.</td>
<td>3</td>
<td>-17</td>
<td>-3</td>
</tr>
<tr>
<td>30 May</td>
<td>6</td>
<td>-17*</td>
<td>-10*</td>
</tr>
<tr>
<td>12 Jul.</td>
<td>6</td>
<td>-19</td>
<td>+4</td>
</tr>
<tr>
<td>24 Jul.</td>
<td>4</td>
<td>-11</td>
<td>0</td>
</tr>
<tr>
<td>31 Jul.</td>
<td>7</td>
<td>-13</td>
<td>+2</td>
</tr>
<tr>
<td>21 Sep.</td>
<td>5</td>
<td>-15</td>
<td>-3</td>
</tr>
<tr>
<td>17 Oct.</td>
<td>0</td>
<td>-15*</td>
<td>-19*</td>
</tr>
</tbody>
</table>

Out of the 10 cases, $\Delta Sd^-$ is high at Trivandrum and Alibag simultaneously in four cases. On examination of hourly records of several stations, it was found that these were effects occurring at the same UT at different longitudes and latitudes, indicating a non-ionospheric origin. In the other six cases, $\Delta Sd^-$ is large only at the Equator (Trivandrum) indicating a predominantly equatorial electrojet effect. Such effects have already been reported by Gouin and Mayaud (1967, 1969) who interpret them as indicative of a counter electrojet. Hutton and Oyinloye (1970) have shown that such occurrences are associated with the disappearance of the equatorial sporadic-E, i.e. $E_{\alpha-q}$. It seems, therefore, that this phenomenon as well as the general phenomenon of day-to-day variability of $Sq$ are connected with dynamic processes in the ionospheric regions (Kane, 1972).

It may also be noted, that whereas $\Delta Sd^-$ at Trivandrum is unconnected with $A_p$ (in 0–7 range), $\Delta Sd^-$ at Alibag does show a slight correlation (about 0.35 ± 0.12) during $D$ and $J$ months. Thus, developing of $\Delta Sd^-$ at Alibag does indicate to some extent increasing geomagnetic activity even in the $A_p = 0–7$ range.

(3) For high $A_p$ (8–53), $\Delta Sd^-$ contributes significantly to the total range $\Delta Sd$ at both Trivandrum and Alibag. Also $\Delta Sd^-$ has a moderate correlation
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This indicates that larger values of $\Delta Sd^-$ are characteristic of increased geomagnetic activity ($A_p$). However, the correlations are still not very high indicating that at least a part of $\Delta Sd^-$ has a source unconnected with the source causing high $A_p$. In fact, as seen from Figs. 2–4, $\Delta Sd^-$ values for $A_p$ as low as 8–10, are sometimes comparable to $\Delta Sd^+$ at much higher $A_p$, in all seasons.

The positive component $\Delta Sd^+$ seems to be rather poorly correlated with $A_p$ for equatorial regions (Trivandrum, correlation 0.20 or less) in all seasons; but for middle latitudes (Alibag), correlations are better (0.30 or more), for $D$ and $J$ months only. Thus, the source of high $A_p$ is almost unconnected with the source of high $\Delta Sd^+$ at the Equator and partially connected with the source of high $\Delta Sd^+$ at middle latitudes.

Table 3 (a, b) gives the inter-correlations between the three components at the same place.

The following may be noted:

(i) For low $A_p$ (lower triangles of Table 3), since $\Delta Sd^-$ is negligibly small, $\Delta Sd$ is mainly composed of $\Delta Sd^+$ and hence, is highly correlated with the same, as expected. Whenever $\Delta Sd^-$ does occur, it is uncorrelated with $\Delta Sd^+$, both at Trivandrum and Alibag. Thus, these two parameters seem to have different sources of origin even at the same place, for low $A_p$.

(ii) For high $A_p$ (upper triangles of Table 3), $\Delta Sd^-$ is contributing substantially to the total range $\Delta Sd$ and hence, correlations between $\Delta Sd$ and $\Delta Sd^-$ are higher, but the correlation between $\Delta Sd$ and $\Delta Sd^+$ is still high and that between $\Delta Sd^+$ and $\Delta Sd^-$ still low, indicating that $\Delta Sd^+$ and $\Delta Sd^-$ have mostly different sources of origin even during disturbed days.

It is clear from the above evidence that the positive and negative components $\Delta Sd^+$ and $\Delta Sd^-$ of the total range $\Delta Sd$ show a somewhat different behaviour for high and low $A_p$ and for equatorial and middle latitudes. It would be interesting to study the correlations between these parameters at different latitudes. In an earlier communication (Kane, 1971), it was shown that the daily ranges $\Delta H (= H_{\text{max}} - H_{\text{min}})$ at Trivandrum and Alibag for quiet days in 1964 were poorly correlated and that the correlation improved considerably firstly, when $D_s$ corrections were applied and secondly, when the position of $Sq$ focus was taken into account. In the present analysis, $D_s$ corrections are already applied before obtaining $\Delta Sd$, $\Delta Sd^+$ and $\Delta Sd^-$. Figures 5–7 show plots of these parameters at Trivandrum versus those at Alibag for high and low $A_p$ separately and for the $D$, $E$, $J$ months respectively. The correlations coefficients are given in Table 4.

The following may be noted from Table 4 and Figs. 5–7:

(a) For low $A_p$, the correlations are very low except for $\Delta Sd^-$ which itself is small in magnitude for low $A_p$. This means that the day-to-day variability of $Sq$ at equatorial and middle latitudes is poorly correlated. However, whenever the negative component $\Delta Sd^-$ appears on quiet days, the inter-correlation is moderate, indicating a partly common source for this component.
Table 3. Intercorrelation between $\Delta S_d$, $\Delta S_d^+$ and $\Delta S_d^-$ for the three seasons $D$, $E$ and $J$ for (a) Trivandrum, and (b) Alibag.

Amongst the triangles formed by the diagonal lines, upper triangle is for $A_p = 8.58$ and lower triangle for $A_p = 0.7$.

<table>
<thead>
<tr>
<th></th>
<th>$D$</th>
<th>$E$</th>
<th>$J$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\Delta S_d$</td>
<td>$\Delta S_d^+$</td>
<td>$\Delta S_d^-$</td>
</tr>
<tr>
<td>(a) Trivandrum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta S_d$</td>
<td>+0.84</td>
<td>-0.58</td>
<td>+0.85</td>
</tr>
<tr>
<td>$\Delta S_d^+$</td>
<td>+0.97</td>
<td>-0.05</td>
<td>+0.97</td>
</tr>
<tr>
<td>$\Delta S_d^-$</td>
<td>-0.30</td>
<td>-0.05</td>
<td>-0.25</td>
</tr>
<tr>
<td>(b) Alibag</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta S_d$</td>
<td>+0.71</td>
<td>-0.88</td>
<td>+0.77</td>
</tr>
<tr>
<td>$\Delta S_d^+$</td>
<td>+0.90</td>
<td>-0.28</td>
<td>+0.93</td>
</tr>
<tr>
<td>$\Delta S_d^-$</td>
<td>-0.46</td>
<td>-0.03</td>
<td>-0.29</td>
</tr>
</tbody>
</table>
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**D MONTHS**

Fig. 5. Plots of $\Delta Sd$, $\Delta Sd^+$ and $\Delta Sd^-$ at Trivandrum (TR) vs. similar quantities at Alibag (AL) for (a) disturbed days ($A_p = 8-53$), and (b) quiet days ($A_p = 0-7$), for $D$ months. Average slopes and correlation coefficients are indicated.

**E MONTHS**

Fig. 6. Same as Fig. 5, for $E$ months.
Fig. 7. Same as Fig. 5, for J months.

Table 4. Correlations between $\Delta Sd$, $\Delta Sd^+$ and $\Delta Sd^-$ at Trivandrum and similar quantities at Alibag

<table>
<thead>
<tr>
<th></th>
<th>$A_p = 0.7$</th>
<th>$A_p = 8.53$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta Sd$</td>
<td>+0.22</td>
<td>+0.74</td>
</tr>
<tr>
<td>$\Delta Sd^+$</td>
<td>+0.07</td>
<td>+0.17</td>
</tr>
<tr>
<td>$\Delta Sd^-$</td>
<td>+0.50</td>
<td>+0.54</td>
</tr>
</tbody>
</table>

(b) For higher $A_p$, the $\Delta Sd^-$ component is very highly correlated indicating a common origin. However, the correlation for $\Delta Sd^+$ is also higher, at least for $D$ months, indicating a common source to some extent. However, for $E$ and $J$ months, correlations are still poor.

(c) For low $A_p$, dynamical processes are known to play a predominant role (Kane, 1972). This could be so during high $A_p$ also. However, an improvement in correlation is indicative of processes which are more coherent than turbulent. If so, it would be important to know whether these are occurring in the ionosphere or elsewhere. From considerations of the height-integrated conductivities at equatorial and non-equatorial latitudes (Maeda, 1953), the ratio of the observed effects at Trivandrum and Alibag should be about 2.9 (Nair et al., 1970). From the plots shown in Figs. 5–7, regression coefficients could be calculated. However, since the correlations are not always high, the two regression lines obtained by interchanging the dependent and independent variables would not be identical, leaving an ambiguity about the exact value of the slope. A
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better procedure may be to find the centroid for each set and connect the same to the origin. In Figs. 5–7, the centroids and the slope lines are marked and their slopes indicated. These should be compared to the expected number 2.9 if the effects observed are completely ionospheric. Table 5 gives the various slopes.

Table 5. Slopes, i.e. ratios $R$ between $\Delta Sd$, $\Delta Sd^+$ and $\Delta Sd^-$ at Trivandrum and Alibag

<table>
<thead>
<tr>
<th></th>
<th>$A_p = 0–7$</th>
<th>$A_p = 8–53$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$D$</td>
<td>$E$</td>
</tr>
<tr>
<td>$\Delta Sd$</td>
<td>2.10</td>
<td>2.26</td>
</tr>
<tr>
<td>$\Delta Sd^+$</td>
<td>2.12</td>
<td>2.26</td>
</tr>
<tr>
<td>$\Delta Sd^-$</td>
<td>uncertain</td>
<td>0.93</td>
</tr>
</tbody>
</table>

The following may be noted:

(i) For low $A_p$ (0–7), the slopes are about 2.15 ± 0.10, values for $E$ months being higher. This reflects the well-known equinoctial enhancement of the $Sq$ range at the Equator. However, in no case does the slope approach the value 2.9 expected for a purely ionospheric effect. If there is some non-ionospheric, particularly magnetospheric contribution, it would have roughly a $\cos \theta$ latitude dependence which, for a pair like Trivandrum ($\theta = -1.1^\circ$) and Alibag ($\theta = +9.5^\circ$), gives an expected ratio of about 1.03. If we assume that the ionospheric and magnetospheric contributions at Alibag are $x$ and $y$ respectively, the ranges $\Delta Sd_{TR}$ and $\Delta Sd_{AL}$ at Trivandrum and Alibag could be expressed as:

$$\Delta Sd_{AL} = x + y$$
$$\Delta Sd_{TR} = 2.9x + 1.03y.$$  

Hence, ratio

$$R = \frac{\Delta Sd_{TR}}{\Delta Sd_{AL}} = 2.90 - 1.87 \text{ K}$$

where

$$K = y/(x + y).$$

Using the ratio $R = 2.15$, the value of $K$ works out to about 40 per cent. Thus, about 40 per cent of the range $\Delta Sd$ or $\Delta Sd^+$ at Alibag would be magnetospheric and about 60 per cent ionospheric. For Trivandrum, the corresponding contributions would be 20 per cent magnetospheric and 80 per cent ionospheric. For $\Delta Sd^-$, the magnitudes for low $A_p$ at both Trivandrum and Alibag are small and hence ratios are uncertain.

(ii) For high $A_p$ (8–53), the ratio for $\Delta Sd^+$ is as low as about 1.5 for $D$ months and as high as about 2.5 for $E$ months, giving magnetospheric and ionospheric contributions of (75 per cent, 25 per cent) at Alibag and (50 per cent, 50 per cent) at Trivandrum for $D$ months and (20 per cent, 80 per cent) at Alibag and (10 per cent, 90 per cent) at Trivandrum for $E$ months. Values for $J$ months corresponding to a ratio $R$ of about 2.0 would be in-between values for $D$ and $E$ months.
For the $\Delta Sd^-$ component, the ratio $R$ is less than 1.03 for $D$ and $E$ months, which is baffling. However, considering possible errors in the estimations of these parameters, we are inclined to consider the ratio for $\Delta Sd^-$ to be about unity for all seasons, and thus indicative of a completely magnetospheric origin for $\Delta Sd^-$ at both Trivandrum and Alibag.

3. CONCLUSION AND DISCUSSION

The results of the present investigation may be summarised as follows:

(a) The hourly $H$ values at the equatorial station Trivandrum and the mid-latitude station Alibag were corrected for $D$-effects using values of Sugura and Cain (1970).

(b) A plot of these showed that on successive quiet days ($A_p = 0-7$), the minimum values had an almost constant level. Using the average of these as a $H_0$ level and subtracting this from the $H_{\max}$ and $H_{\min}$ of each of the above quiet days as well as the succeeding disturbed days, the daily range of geomagnetic $H$ variation on any day was expressed as

(i) the total range $\Delta Sd = H_{\max} - H_{\min}$;

(ii) the positive component $\Delta Sd^+ = H_{\max} - H_0$;

(iii) the negative component $\Delta Sd^- = H_{\min} - H_0$.

(c) Relationships between $\Delta Sd$, $\Delta Sd^+$ and $\Delta Sd^-$ at Trivandrum and Alibag between themselves and with $A_p$ were studied. The following was noted:

(i) For low $A_p$ (0-7), $\Delta Sd^-$ is negligibly small in general. However, whenever it exists at Alibag, it is moderately correlated with $A_p$, but occurrence at Trivandrum is not correlated with $A_p$. For low $A_p$, the major component of $\Delta Sd$ is $\Delta Sd^+$ and represents $Sq$ range and shows a large day-to-day variability unconnected with $A_p$ changes. Also $\Delta Sd^+$ at Trivandrum and Alibag are poorly correlated on a day-to-day basis. Also $\Delta Sd^+$ and $\Delta Sd^-$ at the same place are poorly correlated.

(ii) For high $A_p$ (8-53), $\Delta Sd^-$ forms a considerable fraction of the total range $\Delta Sd$. Values of $\Delta Sd^-$ at Trivandrum and Alibag are highly inter-correlated (especially in $D$ months) but are only moderately correlated (about 0.5) with $A_p$. The positive component $\Delta Sd^+$ is also large and for Trivandrum it is uncorrelated with $A_p$ while for Alibag, it is slightly correlated (about 0.3) with $A_p$. Values of $\Delta Sd^+$ at Trivandrum and Alibag are moderately inter-correlated in $D$ months but poorly correlated in $E$ and $J$ months. Also $\Delta Sd^+$ and $\Delta Sd^-$ at the same place are uncorrelated at Trivandrum and only slightly correlated at Alibag.

(iii) If any one of the parameters $\Delta Sd$, $\Delta Sd^+$ or $\Delta Sd^-$ is of ionospheric origin, the height-integrated conductivities in the equatorial and near-by mid-latitude regions are such that a ratio of about 2.9 for values at Trivandrum and Alibag is expected. On the other hand, if the origin is far away from the Earth (say, in the magnetosphere), the expected ratio is about 1.0. Since the day-to-day variability of $\Delta Sd^+$ at the two places is poorly correlated, day-to-day ratios vary in a very wide range. However, if this variability is ignored and ratios are obtained
from mean values for the $D$, $E$, $J$ seasons separately, the ratios are between 2.9 and 1.0, indicating possibly a part contribution from magnetospheric as well as ionospheric sources for the positive component $\Delta Sd^+$ and an exclusively magnetospheric contribution for the negative $\Delta Sd^-$ component.

It seems, therefore, that the daily range of geomagnetic variation is a very complex affair and has two distinct components positive and negative, which are mostly unrelated to each other and have different latitude dependences. Whereas the negative component seems to be exclusively of magnetospheric origin, the positive component seems to be contributed by both ionospheric and magnetospheric sources in varying proportions in different seasons and at different latitudes. If so, this should prove a powerful tool in studying the processes of interaction of inter-planetary plasma with geomagnetic field. Some relationship between the day-to-day variability of $Sq$ and the inter-planetary magnetic field is already reported (Kane, 1972). Further work is in progress.

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References

Maeda H. 1953 J. Geomagn. Geoelect. 5, 94.

Reference is also made to the following unpublished material: