Solar Wind Stream Characteristics &
Low Latitude Geomagnetic Field Changes*

G K RANGARAJAN
Indian Institute of Geomagnetism, Colaba, Bombay 400 005

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The passage of high speed solar wind streams past the earth enhances geomagnetic activity. The equatorial magnetic field changes associated with passage of solar wind streams of different durations, density spike and stream interfaces are computed in the present study which reveals that the maximum field change is associated with the short duration streams. The diurnal asymmetry of the disturbance is least for stream interface passage. However, a significant enhancement of the daily range is found to be associated with the diurnal asymmetry of the disturbance.

1 Introduction
Observations by spacecrafts have revealed several interesting characteristics of solar wind parameters. Intrilligator\(^1\) provided a catalogue of high speed solar wind streams for the period July 1965-June 1971. Rangarajan and Arora\(^2\) studied the low latitude geomagnetic field changes associated with these streams and showed that when they were accompanied by solar magnetic sector boundary passage there was a significant increase in the intensity of the equatorial ring current leading to enhanced depression of the geomagnetic field, whose magnitude was a function of local time. Intrilligator's catalogue also incorporated details of duration of the high speed streams. Analysis of Rangarajan and Arora\(^2\) combined all the dates irrespective of duration but divided according to the occurrence of solar magnetic sector boundary in the vicinity. It was, therefore, considered worthwhile to study as a sequel, the exact nature of low latitude field changes related to streams of different durations.

Apart from this, two other interesting features of solar wind have also been reported. Gosling \textit{et al.}\(^3\) found large proton density enhancement in solar wind observed by Vela-3 satellites. A total of 33 proton density spikes were identified, in association with the rise in flow speed. Of these, 8 were probably linked with interplanetary shocks. All the events were non-recurrent in nature. According to them, a well defined sector boundary was not nearly as good as a density spike in indicating a stream interaction event, though many density spikes appear to be associated with sector boundaries, as the spatial change in solar wind speed and polarity of IMF have common origin in the large scale field structure of the inner corona.

Los Alamos Scientific Laboratory (LASL) instrumentation aboard Imp 6, 7 and 8 spacecrafts revealed\(^4\) that about one third of all high speed streams near the earth's orbit contained a sharp boundary at the leading edge, called "stream interface". The interface is a narrow region in space across which solar wind density drops suddenly, proton temperature increases sharply and flow speed also increases. Gosling \textit{et al.}\(^3\) identified 23 discontinuous interfaces, of which only one was a possible sector boundary.

Thus we have several categories of solar wind, distinguished by (i) short duration (\(< 3\) days), (ii) average duration (4-6 days), (iii) long duration (>6 days), (iv) proton density spikes and (v) stream interface. For each of these classes key days have been listed\(^1,3,4\).

2 Data
Basic data are derived from hourly observations of horizontal intensity at Trivandrum (dip, 0.5°S) and Alibag (dip, 24°N). The 3-hourly non-overlapping averages for each day lead to 8 groups [(1) 0000-0200, (2) 0003-0005, ..., (8) 2100-2300 hrs UT]. Results derived from data of Alibag are practically similar to that from data of Trivandrum and, therefore, are not presented. As mentioned in an earlier study\(^2\), the inference is that the equatorial ionospheric conductivity is not appreciably altered by the passage of solar wind of various characteristics. A superposed epoch analysis, as modified by Ambroz\(^2\) is then performed with these data using as key days the list of dates for the five different categories of solar wind velocities. As mentioned earlier, these results aim at supplementing the earlier findings of solar wind stream interaction with low latitude geomagnetic field\(^2\) and, therefore, the format of presentation will be nearly identical.

3 Results and Discussion

The change in the horizontal intensity with the passage of high speed solar wind streams of short duration (≤ 3 days) and long duration (> 6 days) are presented in Fig. 1. The features for the category of average duration streams (4-6 days) lie between these two and are, therefore, not presented.

Clear difference in the nature of response of the field with passage of high speed streams dependent on the duration is noticed (Fig. 1). In particular, longer duration streams are less geo-effective and ring-current intensity variation related to those types of streams is also minimal. The range of diurnal variation shows enhanced magnitude in post-passage intervals (a day later) indicating both enhanced geomagnetic disturbance and difference in the nature of response between noon and nighttime. Similar feature of low latitude field was observed with the passage of sector boundary by Rangarajan and Murthy. Another interesting aspect, similar to the earlier results of Rangarajan and Arora is the local time dependence of the post-passage depression, especially for short duration streams. Rangarajan and Arora showed that the diurnal asymmetry (greater field depression during late afternoon hours and less during forenoon hours) in the response was a consequence of strengthening of the asymmetric component, centred in the evening sector, of the equatorial ring current. The magnitude of field change for each group is computed and the difference between the largest and least value of the response over the 8 intervals is taken as a measure of the diurnal asymmetry. This is presented in Table 1.

Low latitude field response to passage of solar wind streams characterized by isolated proton density spikes are shown in Fig. 2. The proton density enhancements typically represent a three-fold increase above average and last for about one day. These are

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<tr>
<th>Stream type</th>
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<th>Daily range</th>
<th>Diurnal asymmetry</th>
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<td>17</td>
<td>27</td>
<td>28</td>
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<td>4-6 days</td>
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<td>Dec. 1965</td>
<td>14</td>
<td>16</td>
<td>13</td>
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<td>≥ 6 days</td>
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<td>June 1971</td>
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Fig. 1—Curves showing the equatorial magnetic field changes associated with passage of high speed streams of short (left panels) and long (right panels) duration [The numbers next to the curves indicate the 3-hourly (UT) intervals. DMN is the mean daily field and ‘range’ is the difference of maximum and minimum hourly values for each day. SE is a typical standard error associated with the mean.]

Fig. 2—Curves showing the equatorial magnetic field changes associated with passage of solar wind streams characterized by a proton density spike (Other details are as in Fig. 1.)
followed by prolonged periods of depressed densities. Local time dependence of the response becomes evident from a comparison of the variations 12 hr apart (for example groups 1 and 5). Here again range of diurnal variation has a significant peak on the day of passage followed by a rapid transition to minimum a day later.

Features of low latitude and equatorial field associated with passage of stream interfaces are shown in Fig. 3. In contrast to the details in Figs. 1 and 2, the field depression occurs rather abruptly for the different groups but the mean daily field does not respond equally significantly. Change in diurnal range related to the stream interface passage is by far the largest (in excess of 50 nT). All relevant information regarding the response for the five categories are given in Table 1. Percentage of occasions, when the response associated with individual key days was similar to the average pattern, is quite high (~75%), indicating high repeatability of the features. The percentage was largest for stream interface (83%) and least for long duration stream (61%).

The mean daily field changes in magnitude by 15 to 20 nT on an average, and the least variation is associated with long duration streams and proton density spikes. The magnitude of diurnal asymmetry too is quite small for these two categories. It becomes clear from Table 1 that when earth is immersed in a high speed solar wind stream of long duration the interaction of solar wind and magnetosphere is minimal. The observed response may be attributed to the initial abrupt change in solar wind characteristics. The reduced magnitude relative to other classes of streams may then be due to the absence of variability in the solar wind parameters in streams of long duration, as it is well known that the variance of solar wind is an equally important factor in enhanced geomagnetic activity. Large diurnal asymmetry resulting from enhanced partial ring current in the evening sector is associated with the streams of short and average duration. The changes in the range of diurnal variation are comparable for the three classes of streams marked by density spike, short and average duration but are significantly larger for stream interface. It, therefore, appears that geomagnetic disturbance of greater magnitude, on an average, is triggered by stream interface when slow denser plasma is overtaken by fast rarer plasma. An aspect which is not taken into consideration is the fact that the period of analysis for this class of streams covers the declining phase of solar activity known to be geomagnetically active due to recurrent solar disturbances, whereas the other epochs cover the ascending and maximum phase of the solar cycle.

References
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