Solar Wind Streams, Sector Boundary Passage & Low Latitude Geomagnetic Field

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The influence of high speed solar wind streams on equatorial magnetic field is studied using Vela satellites data. It is shown that the passage of the high speed streams past the earth results in the depression of the field mainly through the intensification of the symmetric ring current. When the streams are accompanied by passage of solar magnetic sector boundaries, the asymmetric ring current in the evening sector also gets intensified which manifests as enhanced depression at ground during late evening hours.

1. Introduction
Geomagnetic activity can be triggered by several magnetospheric processes activated by changes in the interplanetary medium. Of all the interplanetary parameters, the solar wind and the interplanetary magnetic field seem to play crucial roles. 'In situ' observations of the solar wind by spacecrafts have shown that the bulk speed is not constant but shows intervals during which the speed is elevated above the background average. These are called high speed streams. They begin with an abrupt increase in solar wind speed above a quiet period. The maximum speed usually lasts from a few hours to a few days. The duration of the streams vary widely. Relationship between high speed streams and sector boundaries of IMF was studied by Sawyer who found that the streams occur primarily in the middle of the sector and show a recurrence pattern with solar rotation. However, no regularity of their occurrence with respect to sector. Sectors with no stream or with more than one stream are common. Sawyer and Haurwitz considered association of geomagnetic activity index, $A_p$, with the passage of high speed stream in solar wind and showed that $A_p$ was better organized in this case in comparison to sector boundaries. Geomagnetic activity was found to be highest on the day preceding peak velocity in the stream. Intrilligator has catalogued high speed streams in solar wind observed in the interplanetary medium by the heliocentric Pioneer spacecrafts and near-earth Vela satellites for the period between July 1965 and June 1971. The aim of this paper is to identify and discuss the influence of passage of such high speed streams past the earth on equatorial and low latitude geomagnetic fields in the Indian region as also on the equatorial $Dst$ index, representing the symmetric ring current intensity. The days of beginning of the high speed stream observed by Vela satellites have been used as key days in a modified version of superposed epoch analysis recently suggested by Ambroz. In this method, apart from deriving the average features of variation associated with the key days, prediction of the effect based on probability of occurrence is also possible.

The parameters considered for the present study are the three-hourly means of the $H$ field at Tromsdalen (dipole lat. 78°S, an equatorial electrojet station in the Indian region for the periods July 1965–June 1971). Results derived from data of Alibag (dipole lat. 17°N), 11°F in the same longitudinal zone are nearly identical to show that the main influence is through the magnetic equator and that the equatorial electrojet currents are not modified by the high speed streams of solar wind.

It is shown that with the passage of sector boundary of IMF, solar wind velocity structure and gets modified significantly and, therefore, an association between high speed streams and sector boundaries in the vicinity will be worth looking into. In view of this, the key-day list is divided into four categories. namely, (A) all key days, (B) no sector boundary in the vicinity ($\pm$ 2 days), (C) sector boundary on key day or a day later and (D) sector boundary on key day or a day earlier.

2. Results and Discussion
The responses of the equatorial field parameters to the passage of high speed streams past the earth derived from the four choices of key days are shown in Fig. 1. It is found that, in general, the variance associated with the mean is less on the day of the minimum field in the post-passage period as compared to that for the maximum field. Another aspect that can be mentioned in this connection is that the field values...
are not corrected for any long-term variations so that the errors indicated include this component also.

The salient features brought out by this analysis can be summarized as follows.

(i) When all the key days are used, there is a clear asymmetry with respect to the 0 day with a marked depression of the field following the passage. The response shows characteristic amplitude change for the different UT hour groups. The nature of the associated field variation is similar to that observed at low latitudes with the passage of solar magnetic sector boundaries.

(ii) When the key-day list is restricted to high speed streams without IMF polarity transition in the vicinity, similarity to the response of the previous category is still seen but amplitude change with time is not discernible. This suggests that high speed streams not related with sector boundaries can independently influence the low latitude field. Present results are similar to Hirshberg and Colburn who have shown that AE increased as clearly following passage of high speed streams as it did following the passage of IMF transition in direction.

(iii) The field change brought about by the passage of the streams, which are accompanied by IMF polarity change on the key day or a day later, indicates a significant enhancement of the field depression of +1 day when compared to the earlier categories.

(iv) Most pronounced effects in the equatorial region is clearly associated with the passage of high speed streams with sector boundary occurring on the key day or a day earlier.

Apart from the three-hourly averages of the field, we also utilized the mean daily field and the range of daily variation \( H_{\text{max}} - H_{\text{min}} \). Mean daily field can be considered to be representative of the DR field at low latitudes associated with the symmetric ring current and the 'range' provides a measure of magnitude of diurnal variation. The response in these parameters as a function of passage of the four categories of streams are shown in Fig. 2. If the change in equatorial field associated with high speed streams were the same at all hours, the range of diurnal variation will not exhibit any dependence on the stream passage. On the other hand if the response is a function of time (as it is indeed) the magnitude of the range will also be dependent on the stream passage.

The mean daily field may include a component due to the strength of the \( S_q \) variation. To study whether the field due to symmetric ring current (DR) gets modified by the high speed streams as indicated by the mean daily field, we have also utilized the mean daily values of equatorial \( Dst \) index. The responses of \( Dst \) for the four categories are also shown in Fig. 2. The progression of the mean daily field and equatorial \( Dst \) index with the passage shows that the symmetric ring current strength gets significantly enhanced when the high speed stream is preceded by an IMF polarity change. The range of daily variation exhibits a sharp rise close to the key day and the magnitude of the increase relative to pre-passage level is a function of the type of key days chosen, with group D again having largest change.
The percentage of occasions when the field response for individual key days is significantly correlated with the average for the category is shown in Table I for all the parameters and for the subdivisions. Apart from the statistical significance of the post-passage depression of the field (or the elevation of the range) we find that nearly 70% of the individual events exhibit the average characteristics. The percentage increases to nearly 80 for the group D, indicating the high degree of probability of a reduction in the mean equatorial field following the passage of a high speed solar wind stream which is preceded or accompanied by an IMF sector boundary passage. No significant diurnal trend in the percentage is discernible from Table I.

It was shown above that the magnitude of the depression in the equatorial field is dependent on the 3-hr group considered. Fig. 3 brings out the local time dependence of this feature showing the difference in the field levels of (a) − 3 day and − 1 day, (b) − 3 day and 0 day, (c) − 3 day and + 1 day, and (d) 0 day and + 1 day for the three types of key days. It is noticed that the high speed streams without associated sector boundaries do not have any LT component in the magnetic field change at low latitudes. On the other hand, for the most favourable combination (group D) of sector boundary and high speed streams there is a clear diurnal modulation, reminiscent of the classical SD, in the field change on + 1 day relative to either prepassage level [Fig. 3(c)] or to that on the key day [Fig. 3(d)]. A similar but less pronounced modulation is seen from group C days also.

The absence of any diurnal modulation of the field in association with high speed streams coupled with the significant response in the mean daily field (Fig. 2) for group B days clearly indicates that the primary mechanism for field reduction is the intensification of the symmetric ring current. From an analysis of the $H$ field at Indian stations, Rangarajan$^7$ showed that the response on the key day of the field to sector boundary passage was nearly in phase opposition for day and nighttime conditions and indicative of a strong local time dependence. The fact that the high speed streams in conjunction with sector boundaries produce a field variation as a function of local time implies that only polarity transition is mainly responsible for the diurnal modulation of the field. This modulation is a manifestation of the intensification of the asymmetric ring current in the evening sector. It can also be inferred from Fig. 3(c) and 3(d) that the symmetric ring current field also gets enhanced for group D days as compared to group B days.

It may, therefore, be concluded that the low latitude field is sensitive to the passage of both high speed streams and IMF polarity change and that largest field change is brought about when the passage of high speed stream is accompanied by a sector boundary. It is suggested that while high speed streams, without associated sector boundaries, intensify the symmetric ring current, the IMF polarity related effects modify both the symmetric and asymmetric ring currents. Similar analysis using key days from Pioneer observations corrected for the corotation delay time.
given in the catalogue of Intrilligator\(^3\) did not provide results of appreciable magnitude indicating that the features of the stream responsible for low latitude field changes are altered during its passage from the sun to the earth.

References
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