

# A CATALOGUE OF HIGH-SPEED SOLAR-WIND STREAMS: FURTHER EVIDENCE OF THEIR RELATIONSHIP TO $A_p$ -INDEX

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**Abstract.** A reference catalogue of 430 well-defined high-speed plasma streams detected in solar-wind observations from 1972 to 1984 is presented. We have given the main characteristics of the streams as the beginning time and the duration of the stream, the interplanetary magnetic field polarity, etc. We have also separated them with respect to their origin into two categories: the corotating and the flare-generated streams. As a first application of this useful catalogue, a correlative study between the maximum speed of streams and the  $A_p$ -index of geomagnetic activity is carried out.

## 1. Introduction

During the last few years new measurements of the interplanetary medium and Sun have produced exciting and important changes in our knowledge of interplanetary phenomena. One of the most important of these phenomena for solar-terrestrial physics we believe these are the occurrent streams in the solar wind near the Earth. Various studies of the variability of the solar wind velocity in the ecliptic plane have revealed a tendency for a high-speed stream structure. Several researchers have studied the characteristics of these high-speed plasma streams giving various definitions of them (Intriligator, 1973, 1977; Gosling *et al.*, 1976; Iucci *et al.*, 1979) and many related reviews on earlier works have been presented by Hundhausen (1972), Burlaga (1975, 1979), Wu *et al.* (1977), Toptygin (1985), etc.

Lindblad and Lundstedt (1981) produced a list of high-speed streams recorded near the Earth during the period 1964–1975. This catalogue is a very useful one for studies of various solar-interplanetary and solar-terrestrial phenomena (e.g., Mavromichalaki and Petropoulos, 1985). The purpose of this study is to update the previous investigations on high-speed solar wind streams during the next solar cycle No. 21 (1975–1985). In this catalogue we have attempted to distinguish the streams (apart from their main characteristics) into two general kinds originated from two different sources (Iucci *et al.*, 1979; Venkatesan, Shukla, and Agrawal, 1982). The first kind is a long-lasting high-speed solar wind stream (HSWS) emitted by coronal holes that exhibited an apparent tendency to recur at intervals of  $\sim 27$  days – the so-called corotating streams – and the second one, characterized by lower solar wind speed, seems to be associated with strong active regions emitting solar flares and producing Forbush decreases at the Earth – the so-called flare-generated streams. Remarkable differences have been found between the interplanetary parameters characterizing the streams of these two different regions.

Moreover as a simple application of this catalogue of streams in the growth of our understanding of the physical processes involved in the solar wind-magnetosphere interaction we tried to study some of the interplanetary stream parameters which are most important in producing a varied geomagnetic activity. According to review papers of Akasofu and Chapman (1972) and Burlaga (1975) two general kinds of geomagnetic disturbances have been revealed. One called 'sudden storm commencements' (SSC events) which are attributed to interplanetary streams which are presented to be emitted by solar flares and the other one called 'recurrent storms' which are attributed to long-lived interplanetary streams emanating from unidentified regions on the Sun, the corotating or M-regions. Chapman (1964) has reported that there is a third type of interplanetary flow, the 'quiet wind' which was postulated to explain the continual presence of comet tails. Recently, Legrand and Simon (1985) identified four general categories of geomagnetic activity. The first category of geomagnetic activity, the sudden commencement storm, is related to a series of solar events occurring in relation to sunspot activity. The three other categories of geomagnetic activity, namely the 'recurrent storms', the 'quiet days', and the 'fluctuating activity', are related to the distribution of their sources around the Sun.

In this work we have examined the relations between the maximum speed of the two types of the interplanetary streams and the geomagnetic disturbances expressed by the  $A_p$  index and we have obtained some preliminary results.

## 2. Classification of High-Speed Streams

It is known that periods of enhanced speed lasting for several days are often observed in the solar-wind velocity data. In searching for streams various definitions for a high-speed stream have been used. Intriligator (1973, 1977) defines a high-speed stream as one having a rapidly rising increase in solar wind speed and a peak velocity greater than or equal to  $450 \text{ km s}^{-1}$ . Bame *et al.* (1976) and Gosling *et al.* (1976) define a high-speed solar wind stream as an observed variation of solar wind speed characterized by an increase of at least  $150 \text{ km s}^{-1}$  within a 5-day interval. Broussard *et al.* (1977) define a high-speed stream as a period in which the solar wind speed is  $\geq 500 \text{ km s}^{-1}$  averaged over a day. Lindblad and Lundstedt (1981) indicate a high-speed stream as a period in which the velocity difference  $\Delta v_0$  between the smallest 3-hr velocity value a given day ( $v_0$ ) and the largest 3-hr value the following day is equal or greater to  $100 \text{ km s}^{-1}$  and lasts for at least two days. Venkatesan, Shukla, and Agrawal (1982) define a high-speed solar wind stream as one having a rapidly rising increase in the solar wind speed ( $V$ ) over a short period ( $\Delta V \geq 200 \text{ km s}^{-1}$  in  $\leq 24 \text{ hr}$ ) reaching a maximum value of  $\geq 550 \text{ km s}^{-1}$  which persist at high values for at least 3 days after the increase.

In the present study we have defined a high-speed solar-wind stream as a period in which the difference  $\Delta V_{\text{max}}$  between the maximum daily mean speed ( $V_{\text{max}}$ ) and the mean value between the speeds immediately preceding and following the stream ( $V_0$ ) is greater or equal to  $100 \text{ km s}^{-1}$  lasting for at least two days. We consider that this definition for a HSWS is more adequate for the purpose of solar-terrestrial studies. The

velocity profile as well as other plasma and field data for the dates of large  $\Delta V_{\max}$  were studied by visual inspection of the intensity versus time profiles published in the *Interplanetary Medium Data Book* (King, 1977a, b, 1979, 1983, 1986a, b). The difference  $\Delta V_{\max}$  was computed for the solar wind streams of the time period January 1972 to December 1984. In order to fill out several data gaps observations of solar wind speed spacecraft data published in *Solar Geophysical Data* WDC-A, Boulder, were used.

Apart from these characteristics of the streams we have classified them into two types: the corotating stream (CS) and the flare-generated streams (FGS). In order to identify these two classes of the streams we have studied the most important interplanetary parameters: magnetic-field magnitude and polarity, bulk speed, proton density, and temperature of the solar wind.

The basic physical features of the corotating high-speed streams with respect to the above parameters can be summarized as follows:

(1) The proton density ( $n$ ) rises to unusually high values near the leading edges of the streams; the high densities generally persisted for  $\sim 1$  day. The density profile generally seems to be developed in inverse ratio to bulk speed ( $V$ ).

(2) The interplanetary magnetic field ( $B$ ) magnitude is proportional to bulk speed with a constant polarity throughout the stream except for some fluctuations lasting a few hours (Iucci *et al.*, 1979; Tsurutani *et al.*, 1987).

(3) The proton temperature ( $T$ ) varies in a pattern similar to that of the flow speed. It increases with speed and shows a slight decrease during the magnetic field descent phase.

On the other hand the behaviour of interplanetary parameters during flare-generated streams has a tendency to be irregular. Variation in solar wind properties, involving a large deviation of flow speed, is characterized by initial, abrupt rises in the density, flow speed, and proton temperature. Generally we can say that the structure of a flare-generated stream shows the following features:

(1) All the above interplanetary parameters show simultaneous increases possibly denoting radially outcoming fast shocks.

(2) The bulk speed, the proton density and magnetic field magnitude show large fluctuations in the maximum speed period, while the field polarity shows often inversions.

(3) The proton temperature behaviour tends to depart from speed behaviour.

A typical example of these two types of high-speed streams is given in Figure 1.

Based on the above considerations we produce an up-to-date catalogue of high-speed streams recorded near the Earth during the period 1972–1984 (Table I). In this table the three first columns give the year, month, and day, respectively, of the beginning time of a high-speed stream, defined as the 3-hr interval of the smallest speed value a given day. The fourth and fifth columns list the Bartel's rotation (number and day) corresponding to the first day of the stream. The sixth column gives the dominant polarity of the interplanetary magnetic field for the duration of the stream (Lindblad, 1981). The following three columns give the day, month, and hour, respectively, of the maximum speed appearance (FDMA). The tenth and eleventh columns give the mean value ( $V_0$ )

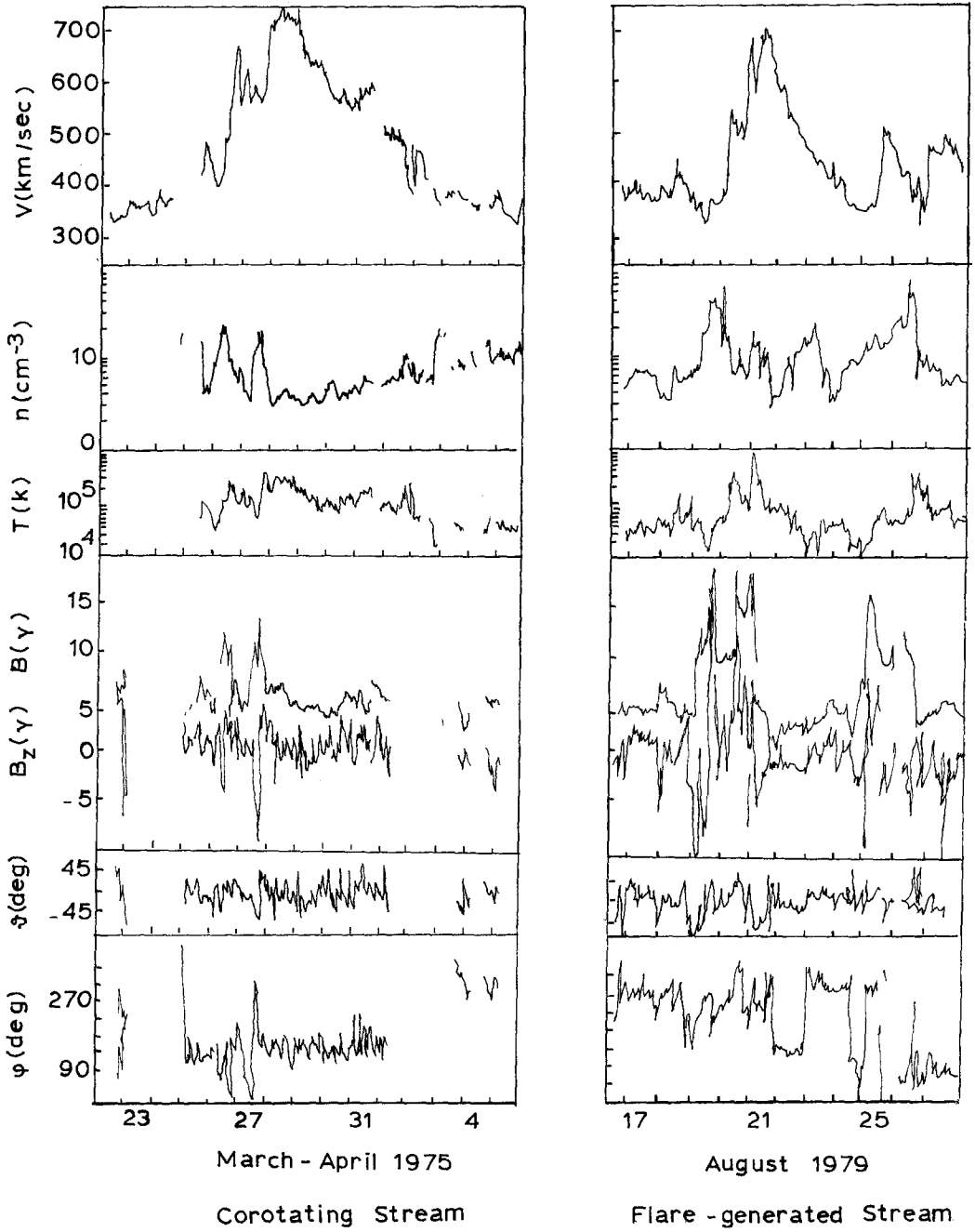


Fig. 1. A typical example of the two types of high-speed solar-wind streams: corotating and flare-generated streams.

TABLE I

A catalogue of high-speed solar-wind streams for the years 1972–1984 giving the year, month and day of the beginning time of a high-speed stream, the Bartel's rotation (number and day) of the first day of the stream, the interplanetary magnetic field polarity for the duration of the stream, the day, month and hour of the maximum speed appearance (FDMA), the mean value ( $V_0$ ) between the speeds immediately preceding and following the stream, the maximum daily mean speed ( $V_{max}$ ) the duration (DUR) and the type of the high-speed stream (CS or FGS)

Y	M	D	Bartel Rotation No D	IMF POL	FDMA			$V_0$	$V_{max}$	DUR	TYPE
					D	M	Hr				
72	01	16	1894 01	+	18	01	10	415	649	05	FGS
72	02	13	1895 02	+	13	02	19	395	628	05	CS
72	02	24	1895 13	-	24	02	18	340	521	05	CS
72	03	06	1895 24	+	07	03	10	430	637	04	FGS
72	03	16	1896 07	+	17	03	16	310	515	04	CS
72	04	03	1896 25	+	05	04	05	377.5	647	07	CS
72	04	28	1897 23	+	02	05	18	307.5	522	11	CS
72	05	14	1898 13	-/+	16	05	03	355	600	06	FGS
72	05	27	1898 25	-	28	05	21	440	595	03	FGS
72	10	31	1904 21	-	31	10	19	390	740	06	CS
72	11	15	1905 08	+	16	11	19	300	517	05	CS
72	11	24	1905 17	+	26	11	09	310	497	08	CS
72	12	06	1906 02	-	08	12	01	265	404	06	CS
72	12	12	1906 08	+/-	14	12	01	300	512	09	FGS
72	12	22	1906 18	-	24	12	04	335	505	05	CS
73	01	03	1907 03	+	11	01	21	340	749	15	CS
73	01	18	1907 18	+/-	20	01	07	305	518	04	CS
73	01	21	1907 21	-	28	01	12	320	753	09	CS
73	02	06	1908 10	+	08	02	19	305	653	08	CS
73	02	21	1908 25	-	25	02	18	405	770	08	CS
73	02	28	1909 05	-	02	03	05	355	659	04	CS
73	03	05	1909 10	+	09	03	18	310	557	11	CS
73	03	18	1909 23	-	24	03	22	375	783	13	FGS
73	03	31	1910 09	+	04	04	01	400	635	07	CS
73	04	13	1910 22	-	19	04	20	375	797	13	FGS
73	04	26	1911 08	+	29	04	12	375	744	10	CS
73	05	06	1911 18	-	07	05	20	355	612	06	FGS
73	05	13	1911 25	-	14	05	17	350	796	13	FGS
73	05	27	1912 12	+	28	05	05	295	500	03	CS
73	06	02	1912 18	+	04	06	11	325	746	07	CS
73	06	10	1912 26	-	11	06	16	395	779	08	CS
73	06	18	1913 07	-	20	06	11	405	753	05	CS
73	06	28	1913 17	+	30	06	16	350	753	08	CS
73	07	08	1913 27	-	09	07	04	330	466	04	FGS
73	07	13	1914 05	-/+	15	07	13	375	689	05	CS
73	07	26	1914 18	+	31	07	07	385	717	15	FGS
73	08	20	1915 16	+	24	08	13	550	683	12	CS
73	09	15	1916 15	-	16	09	08	340	569	04	CS
73	09	19	1916 23	+	23	09	22	350	692	09	FGS
73	10	09	1917 12	-	10	10	19	360	676	11	FGS
73	10	20	1917 23	+/-	21	10	22	390	678	05	CS

Table I (continued)

Y	M	D	Bartel Rotation No D	IMF POL	FDMA			V <sub>O</sub>	V <sub>max</sub>	DUR	TYPE
					D	M	Hr				
73	11	04	1918 11	-	07	11	13	335	601	09	CS
73	11	16	1918 23	+	18	11	07	345	583	04	CS
73	11	22	1919 04	+	25	11	01	305	685	11	CS
73	12	04	1919 14	-	09	12	13	329.5	596	10	CS
73	12	19	1920 02	+	23	12	01	345	670	08	CS
73	12	27	1920 10	-	01	01	01	345	668	12	CS
74	01	08	1920 22	-	10	01	14	350	515	06	CS
74	01	14	1921 01	+/-	16	01	04	325	664	10	FGS
74	01	24	1921 11	-	26	01	02	305	790	12	CS
74	02	10	1922 01	+	11	02	02	320	706	06	CS
74	02	22	1922 13	-	23	02	19	300	722	15	CS
74	03	09	1923 01	+	10	03	22	370	762	07	CS
74	03	15	1923 07	+	16	03	24	360	551	05	CS
74	03	19	1923 11	-	21	03	22	365	754	15	CS
74	04	05	1924 01	+	06	04	07	360	729	04	CS
74	04	10	1924 06	+	10	04	22	403	748	07	CS
74	04	17	1924 13	-	21	04	07	340	702	14	FGS
74	05	02	1925 01	+	04	05	17	375	750	11	FGS
74	05	14	1925 13	-	19	05	15	370	649	16	CS
74	05	30	1926 02	+	01	06	17	367	769	10	CS
74	06	09	1926 12	-	16	06	08	380	698	10	CS
74	06	19	1926 22	-	20	06	01	390	615	05	CS
74	06	26	1927 02	+	27	06	16	350	815	08	CS
74	07	05	1927 11	-	07	07	18	380	802	12	FGS
74	07	22	1928 01	+	24	07	21	345	826	11	CS
74	08	02	1928 12	-	03	08	22	325	653	16	CS
74	08	18	1929 01	+	21	08	22	380	828	09	CS
74	08	28	1929 11	-	04	09	08	340	697	15	CS
74	09	12	1929 26	-	16	09	01	375	634	06	FGS
74	09	18	1930 05	+	21	09	17	450	699	05	CS
74	09	23	1930 10	-/+	25	09	19	520	732	04	CS
74	09	28	1930 15	-	01	10	07	475	729	07	CS
74	10	16	1931 06	+	17	10	09	450	650	06	CS
74	10	24	1931 24	-	27	10	24	360	770	09	CS
74	11	11	1932 05	+	12	11	19	355	787	07	CS
74	11	19	1932 13	-	22	11	01	327.5	805	12	FGS
74	12	07	1933 04	+	13	12	19	375	721	10	CS
74	12	17	1933 14	-	19	12	12	400	809	10	CS
74	12	27	1933 24	+	28	12	07	405	581	04	CS
75	01	03	1934 04	+	06	01	22	345	857	10	CS

Table I (continued)

Y	M	D	Bartel Rotation		IMF POL	FDMA			$V_o$	$V_{max}$	DUR	TYPE
			D	M		HR	D	M				
75	01	12	1934	13	-	17	01	07	347.5	761	13	FGS
75	02	01	1935	06	+/-	02	02	08	356	743	08	CS
75	02	09	1935	14	-	13	02	07	446	772	05	CS
75	02	15	1935	20	-/+	16	02	15	446	702	06	CS
75	02	20	1935	25	+	24	02	20	400	671	09	CS
75	02	28	1936	06	+	01	03	07	450	750	03	CS
75	03	03	1936	09	+	04	03	01	375	686	06	FGS
75	03	08	1936	14	-	11	03	02	330	799	12	CS
75	03	24	1937	03	+	28	03	08	340	769	09	CS
75	04	06	1937	16	-/+	09	04	01	322.5	713	10	CS
75	04	19	1938	02	+	23	04	20	305	754	11	CS
75	05	04	1938	17	-	06	05	09	340	683	10	CS
75	05	16	1939	02	+	17	05	13	375	759	03	CS
75	05	19	1939	05	+	22	05	07	450	663	05	CS
75	06	01	1939	17							09	CS
75	06	11	1940	01	+	13	06	15	445	756	04	CS
75	06	15	1940	05	+	16	06	17	430	699	09	CS
75	06	29	1940	19	-	01	07	04	377.5	608	07	CS
75	07	06	1940	26	+	09	07	16	390	596	06	CS
75	07	12	1941	05	+	13	07	20	420	653	09	CS
75	07	24	1941	17	-	27	07	10	340	659	07	FGS
75	08	04	1942	01	+	06	08	06	370	577	04	FGS
75	08	12	1942	09	+	14	08	11	325	548	06	CS
75	08	20	1942	17	-	21	08	20	337.5	671	07	FGS
75	09	05	1943	06	+				375		08	CS
75	09	17	1943	18	-	18	09	13	360	647	05	CS
75	10	02	1944	06	+	09	10	23	280	637	11	CS
75	10	14	1944	18	-	16	10	15	320	501	07	CS
75	11	02	1945	10	+	04	11	12	360	760	07	CS
75	11	17	1945	25	-	20	11	22	345	500	05	FGS
75	11	29	1946	10	+	02	12	07	385	732	06	CS
75	12	24	1947	08	+	27	12	23	340	683	09	CS
76	01	03	1947	18	-	03	01	19	380	546	03	CS
76	01	10	1947	25	-	12	01	02	312.5	571	05	CS
76	01	20	1948	08	+	23	01	18	422.5	744	05	FGS
76	01	31	1948	19	-	02	02	18	400	642	05	CS
76	02	13	1949	05	-/+	14	02	05	330	649	03	CS
76	02	17	1949	09	-/+	18	02	12	329	743	08	CS
76	02	27	1949	19	-	02	03	18	300	670	08	CS

Table I (continued)

Y	M	D	Bartel Rotation No D	IMF POL	FDMA			V <sub>o</sub>	V <sub>max</sub>	DUR	TYPE
					D	M	Hr				
76	03	08	1950 02	-	09	03	13	475	715	07	CS
76	03	15	1950 09	+	19	03	20	374	623	08	CS
76	03	25	1950 19	-	27	03	16	330	605	06	FGS
76	04	03	1951 01	-	07	04	15	485	736	06	CS
76	04	09	1951 07	+	14	04	14	370	673	12	CS
76	05	01	1952 02	-	03	05	01	380	784	06	FGS
76	05	11	1952 12	+	12	05	08	350	602	06	CS
76	05	17	1952 18	+/-	20	05	10	350	544	05	CS
76	06	03	1953 08	-	05	06	24	370	667	07	CS
76	06	17	1953 22	+/-	18	06	05	330	625	04	CS
76	06	30	1954 08	+	01	07	04	340	707	15	CS
76	07	15	1954 23	+	16	07	11	355	611	03	CS
76	07	27	1955 08	+	29	07	07	340	675	08	CS
76	08	08	1955 20	-/+	10	08	04	320	514	04	CS
76	08	23	1956 08	+	25	08	05	350	668	08	CS
76	09	01	1956 17	+	03	09	22	350	604	10	CS
76	09	16	1957 04	+				355		09	CS
76	09	24	1957 13	+/-	26	09	10	360	548	04	CS
76	10	14	1958 06	+	15	10	15	325	678	08	CS
76	10	30	1958 22	+	31	10	10	325	530	05	CS
76	11	11	1959 07	+	12	11	16	330	665	06	CS
76	12	10	1960 09	+	12	12	08	370	570	05	CS
76	12	16	1960 15	-	18	12	14	332.5	523	06	CS
76	12	31	1961 03	-	01	01	07	374	589	04	CS
77	01	11	1961 14	-	15	01	07	345	589	07	CS
77	01	27	1962 03	+	29	01	18	350	520	04	CS
77	02	05	1962 12		09	02	06	330	661	11	CS
77	02	17	1962 24	-	24	02	20	300	573	10	FGS
77	03	08	1963 16	-	09	03	12	330	635	07	CS
77	04	02	1964 14	-	08	04	07	325	689	13	CS
77	04	18	1965 03	-	19	04	23	365	618	05	CS
77	04	23	1965 08	+	25	04	16	350	514	06	FGS
77	05	14	1966 02	-	17	05	02	360	604	08	CS
77	05	22	1966 10	+	25	05	10	350	563	06	CS
77	06	16	1967 08	+	18	06	15	325	604	12	CS
77	07	06	1968 01	-	10	07	10	360	636	07	CS
77	07	12	1968 07	+	16	07	20	335	723	16	CS
77	08	03	1969 02	-	06	08	13	370	742	07	CS



Table I (continued)

Y	M	D	Bartel Rotation No D	IMF POL	FDMA			V <sub>o</sub>	V <sub>max</sub>	DUR	TYPE
					D	M	Hr				
77	08	16	1969 15	+	19	08	02	357.5	703	06	CS
77	09	02	1970 05	-	05	09	20	324	456	06	CS
77	09	12	1970 15	+/-	14	09	17	317.5	490	07	FGS
77	09	19	1970 22	+/-	22	09	06	375	744	06	FGS
77	10	11	1971 17	+	12	10	06	298	466	04	CS
77	10	17	1971 23	-	20	10	23	335	575	10	CS
77	10	26	1972 05	-	30	10	22	280	542	14	CS
77	11	10	1972 20	+/-	15	11	10	429	695	16	CS
77	11	25	1973 08	-/+	27	11	11	320	539	05	FGS
77	12	10	1973 23	+	13	11	10	285	548	10	FGS
77	12	25	1974 11	+	26	12	16	320	547	04	FGS
78	01	03	1974 20	-	04	01	08	395	756	05	FGS
78	01	23	1975 13	-	26	01	08	300	505	05	CS
78	01	28	1975 18	-	30	01	03	360	636	05	CS
78	02	13	1976 07	-	15	02	09	302.5	679	08	FGS
78	02	21	1976 15	+/-	23	02	07	335	514	03	CS
78	02	25	1976 19	-	26	02	19	342.5	714	08	CS
78	03	07	1977 02	+	09	03	10	350	545	07	FGS
78	03	14	1977 09	-	17	03	15	340	593	08	CS
78	03	25	1977 20	-	27	03	11	377.5	703	09	CS
78	04	03	1978 02	+	06	04	11	360	603	07	FGS
78	04	10	1978 09	-	10	04	19	354	662	07	FGS
78	04	17	1978 16	+	20	04	05	400	816	06	FGS
78	04	28	1978 27	-	01	05	20	400	996	10	FGS
78	05	09	1979 11	-	09	05	10	357.5	720	06	FGS
78	05	21	1979 23	-	24	05	12	325	575	08	CS
78	06	01	1980 06	-	02	06	14	350	697	09	FGS
78	06	10	1980 15	-	10	06	16	350	621	06	CS
78	06	20	1980 25	-	22	06	03	360	632	04	CS
78	06	24	1981 03	-	25	06	21	410	573	04	FGS
78	07	12	1981 21	+	14	07	07	345	507	05	FGS
78	08	02	1982 15	+	06	08	21	301	578	08	CS
78	08	16	1983 02	-	19	08	06	301	471	09	CS
78	08	27	1983 12	+	01	09	11	320	603	10	CS
78	09	23	1984 13	+	29	09	05	325	911	13	FGS
78	10	08	1985 01	+/-	16	10	02	330	548	10	FGS
78	10	17	1985 10	+	19	10	10	317.5	476	7	CS
78	10	24	1985 17	+	28	10	10	270	451	14	CS

Table I (continued)

Y	M	D	Bartel Rotation No D	IMF POL	FDMA			V <sub>O</sub>	V <sub>max</sub>	DUR	TYPE
					D	M	Hr				
78	11	07	1986 04	-	09	11	20	321.5	510	04	CS
78	11	12	1986 09	-/+	12	11	02	327.5	685	06	FGS
78	11	20	1986 17	+	20	11	18	350	688	05	CS
78	11	25	1986 22	+	27	11	07	352.5	632	06	CS
78	12	03	1987 03	-	05	12	03	265	486	09	FGS
78	12	12	1987 12	+/-	14	12	06	320	561	06	FGS
78	12	18	1987 18	+	18	12	11	365	703	07	CS
78	12	28	1988 01	-	30	12	13	362.5	741	06	FGS
79	01	02	1988 06	-	03	01	02	415	598	03	FGS
79	01	06	1988 10	-	07	01	12	372.5	581	03	FGS
79	01	15	1988 19	+/-	15	01	17	350	497	04	FGS
79	01	25	1989 02	-/+	26	01	01	430	649	05	CS
79	02	11	1989 19	-/+	12	02	05	315	467	04	FGS
79	02	17	1989 25	+	18	02	14	355	599	04	CS
79	02	21	1990 02	+	23	02	09	350	629	08	CS
79	03	01	1990 10	+/-	06	03	16	340	524	07	FGS
79	03	09	1990 18	+	11	03	07	300	486	05	CS
79	03	14	1990 23	+	17	03	13	309.5	631	07	CS
79	03	22	1991 04	-	25	03	01	375	539	05	CS
79	03	27	1991 09	-	28	03	12	390	664	05	FGS
79	04	01	1991 14	-	02	04	13	395	680	04	FGS
79	04	05	1991 18	+/-	06	04	18	380	724	03	CS
79	04	12	1991 25	-	17	04	06	395	682	08	CS
79	04	21	1992 07	-	22	04	18	367.5	532	04	CS
79	04	25	1992 11	-	25	04	15	345	651	10	FGS
79	05	17	1993 06	-	19	05	22	350	472	04	FGS
79	05	22	1993 11	-	26	05	12	375	652	08	CS
79	05	29	1993 18	-	30	05	05	335	638	06	CS
79	06	05	1993 25	+/-	09	06	07	309.5	655	08	FGS
79	06	15	1994 08	-	16	06	18	310	478	05	CS
79	06	19	1994 12	-	23	06	17	290	503	11	FGS
79	07	05	1995 01	+/-	06	07	22	337.5	648	07	FGS
79	07	12	1995 08	-	18	07	19	275	560	14	CS
79	07	28	1995 24	-	30	07	19	302.5	511	03	CS
79	08	01	1996 01	+	01	08	11	340	569	05	CS
79	08	05	1996 05	-	06	08	16	320	500	03	CS
79	08	11	1996 11	-	13	08	19	355	602	05	FGS
79	08	19	1996 19	-	20	08	22	342.5	707	05	FGS

Table I (continued)

Y	M	D	Bartel Rotation No D	IMF POL	FDMA			$V_O$	$V_{max}$	DUR	TYPE
					D	M	Hr				
79	08	29	1997 02	+	29	08	17	322.5	555	04	FGS
79	09	25	1998 02	+	27	09	01	370	546	04	CS
79	09	29	1998 06	+	29	09	22	340	568	03	CS
79	10	02	1998 09	-/+	03	10	09	322.5	518	04	CS
79	10	06	1998 13	+	08	10	18	340	596	04	FGS
79	11	01	1999 12	+	01	11	16	305	519	07	CS
79	11	07	1999 18	+/-	12	11	08	285	574	09	FGS
79	11	17	2000 01	+	18	11	10	285	519	06	CS
79	11	30	2000 14	+	02	12	02	300	467	06	CS
79	12	08	2000 22	-	08	12	20	290	474	06	CS
79	12	14	2001 01	+	17	12	06	305	474	07	FGS
79	12	25	2001 12	+	29	12	17	345	552	07	CS
80	01	03	2001 21	-	04	01	01	375	651	05	CS
80	01	10	2002 01	+/-	13	01	07	330	492	06	FGS
80	01	16	2002 07	+/-	18	01	01	350	528	05	CS
80	01	28	2002 19	-	30	01	12	325	524	07	CS
80	02	06	2003 01	+	06	02	20	300	545	08	FGS
80	02	25	2003 20	+/-	27	02	15	275	590	05	CS
80	03	05	2003 27	+	06	03	24	325	448	04	FGS
80	03	18	2004 15	+/-	19	03	11	275	390	03	FGS
80	03	25	2004 22	-	26	03	15	280	458	05	CS
80	04	03	2005 06	+/-	06	04	18	355	658	07	FCS
80	04	11	2005 14	-	12	04	23	305	666	04	CS
80	05	11	2006 15	-	11	05	20	305	679	05	CS
80	05	24	2007 01	+/-	25	05	13	281.5	473	05	FGS
80	06	06	2007 14	+/-	10	06	19	300	734	13	FGS
80	06	23	2008 04	-	24	06	04	320	452	07	FGS
80	07	05	2008 16	-	08	07	01	315	542	06	CS
80	07	18	2009 02	-	21	07	17	327.5	574	06	FGS
80	07	25	2009 09	+	27	07	07	320	557	05	FGS
80	08	04	2009 19	-	06	08		415	750	05	CS
80	08	14	2010 02	-	20	08	04	335	453	10	FGS
80	09	06	2010 25	+	08	09	20	297.5	463	05	FGS
80	09	15	2011 07	-	17	09	02	305	447	07	CS
80	09	29	2011 21	-	30	09	14	297.5	425	03	CS
80	10	03	2011 25	+	05	10	04	342.5	557	04	FGS
80	10	08	2012 03	-	10	10	02	385	646	04	CS
80	10	12	2012 07	+/-	12	10	22	327.5	559	04	FGS

Table I (continued)

Y	M	D	Bartel Rotation No D	IMF POL	FDMA			V <sub>O</sub>	V <sub>max</sub>	DUR	TYPE
					D	M	H <sub>r</sub>				
80	10	22	2012 17	-	25	10	03	280	643	08	CS
80	10	30	2012 25	+	03	11	08	294	565	04	CS
80	11	10	2013 09	-	12	11	02	387.5	655	04	FGS
80	11	18	2013 17	+						05	CS
80	11	24	2013 23	-	26	11	16	425	576	03	FGS
80	12	02	2014 04	+/-	03	12	20	385	579	04	CS
80	12	08	2014 10	-	11	12	20	345	640	05	FGS
80	12	15	2014 17	+	16	12	20	370	568	04	CS
80	12	19	2014 21	-/+	20	12	24	335	607	05	FGS
80	12	30	2015 05	+/-	31	12	22	327.5	559	03	CS
81	01	02	2015 08	-	05	01	04	369	528	07	CS
81	01	10	2015 16	+	11	01	05	345	551	04	CS
81	01	30	2016 09	-	02	02	23	365	617	06	FGS
81	02	05	2016 15	+	06	02	11	370	551	06	CS
81	02	18	2017 01	+	20	02	02	322.5	471	04	CS
81	02	26	2017 09	-	27	02	15	392.5	589	03	FGS
81	03	01	2017 12	+/-	02	03	13	380	550	04	FGS
81	03	05	2017 16	+	05	03	08	355	645	05	CS
81	03	12	2017 23	+	14	03	13	324	672	11	CS
81	03	24	2018 08	-	25	03	21	322.5	626	06	FGS
81	03	30	2018 14	-	01	04	09	365	606	04	FGS
81	04	11	2018 26	-/+	13	04	05	350	633	03	CS
81	04	20	2019 08	-	23	04	11	455	852	05	CS
81	04	25	2019 13	-	26	04	13	467.5	763	04	FGS
81	04	30	2019 18	+	01	05	09	330	520	04	CS
81	05	10	2020 01	+/-	11	05	13	362.5	550	03	FGS
81	05	14	2020 05	-	16	05	12	427.5	704	03	CS
81	05	17	2020 08	-	18	05	09	380	799	06	CS
81	05	31	2020 22	+	01	06	13	330	480	06	CS
81	06	06	2021 01	-	07	06	22	340	500	05	FGS
81	06	25	2021 20	+	26	06	15	372.5	557	04	FGS
81	07	10	2022 08	+	13	07	13	302.5	511	05	CS
81	07	22	2022 20	+	27	07	17	365	802	07	FGS
81	07	31	2023 02	+	03	08	08	335	575	07	CS
81	08	09	2023 11	-	12	08	03	335	719	07	FGS
81	08	27	2024 02	+/-	27	08	22	355	538	04	FGS
81	09	04	2024 11	-	05	09	18	357.5	487	04	CS
81	09	08	2024 14	-/+	08	09	24	305	444	10	FGS

Table I (continued)

Y	M	D	Bartel Rotation No D		IMF POL	FDMA			$V_o$	$V_{max}$	DUR	TYPE
						D	M	Hr				
81	09	18	2024	24	-	20	09	08	282.5	439	05	CS
81	09	23	2025	02	+	27	09	06	310	435	05	FGS
81	09	29	2025	08	+/-	03	10	11	322.5	710	07	CS
81	10	07	2025	16	-/+	10	10	17	335	561	06	CS
81	10	13	2025	22	+/-	16	10	03	285	670	04	FGS
81	10	17	2025	26	+/-	20	10	02	390	716	05	FGS
81	11	08	2026	21	+/-	08	11	24	346	477	03	CS
81	11	11	2026	24	+	12	11	02	425	695	05	FGS
81	11	16	2027	02	+	16	11	24	442.5	802	04	CS
81	11	25	2027	11	-	25	11	14	300	524	06	CS
81	12	01	2027	17	+	03	12	15	285	435	07	CS
81	12	09	2027	25	+/-	12	12	15	300	531	05	CS
81	12	28	2028	17	+	29	12	13	345	608	10	FGS
82	01	20	2029	13	+/-	24	01	14	320	582	08	FGS
82	01	28	2029	21	-	30	01	21	340	665	03	CS
82	02	02	2029	26	-	03	02	09	357.5	769	09	CS
82	02	10	2030	07	-/+	11	02	16	357.5	668	07	FGS
82	02	17	2030	14	+	18	02	13	360	803	07	CS
82	02	23	2030	20	+	26	02	05	405	667	06	CS
82	03	01	2030	26	+	01	03	24	400	768	07	FGS
82	03	08	2031	06	-/+						10	CS
82	03	20	2031	18	+/-	21	03	01	357.5	630	03	FGS
82	03	23	2031	21	+	25	03	13	355	657	10	CS
82	04	03	2032	05	-	06	04	10	350	577	05	CS
82	04	14	2032	16	+	21	04	14	400	727	10	CS
82	04	23	2032	26	+/-	24	04	23	455	641	05	FGS
82	05	02	2033	07	-	04	05	08	365	702	08	CS
82	05	13	2033	19	+	16	05	12	370	577	05	CS
82	05	17	2033	22	+	18	05	12	364	621	09	CS
82	05	25	2034	03	+/-	30	05	07	311.5	799	12	FGS
82	06	06	2034	15	+	12	06	22	313.5	688	17	FGS
82	06	24	2035	06	-	30	06	05	276	637	12	CS
82	07	06	2035	18	+	07	07	23	302.5	579	05	CS
82	07	11	2035	23	+	14	07	01	446	986	05	FGS
82	07	16	2036	01	+	17	07	01	476	805	03	CS
82	07	19	2036	04	-	20	07	03	428.5	682	06	CS
82	07	25	2036	10	-	27	07	11	430	679	05	CS
82	08	01	2036	17	+	03	08	13	400	612	05	CS
82	08	06	2036	22	+/-	07	08	01	412.5	643	03	FGS

Table I (continued)

Y	M	D	Bartel Rotation No D	IMF POL	FDMA			$V_o$	$V_{max}$	DUR	TYPE
					D	M	Hr				
82	08	09	2036 25	-	12	08	11	352.5	593	07	CS
82	08	17	2037 06	-/+	23	08	09	335	726	11	CS
82	08	28	2037 17	+	30	08	10	360	597	06	CS
82	09	03	2037 23	+	06	09	15	400	874	05	FGS
82	09	08	2038 01	-	09	09	05	385	897	11	CS
82	09	19	2038 12	-	21	09	07	335	1021	07	FGS
82	09	26	2038 19	+	27	09	15	335	530	04	CS
82	10	10	2039 06	-	10	10	20	325	546	05	CS
82	10	15	2039 11	-	27	10	06	382.5	720	11	CS
82	10	26	2039 22	-	29	10	21	420	739	03	FGS
82	10	31	2039 27	+	01	11	05	375	675	05	CS
82	11	11	2040 11	-	12	11		375	630	08	CS
82	11	21	2040 21	+/-	25	11	07	402.5	783	06	FGS
82	12	06	2041 09	-	10	12	13	360	723	06	FGS
82	12	16	2041 19	+	20	12	02	480	805	09	FGS
82	12	26	2042 02	-	29	12	17	380	709	07	FGS
83	01	09	2042 16	+	12	01	04	370	648	07	CS
83	01	15	2042 22	+	17	01	15	360	753	14	CS
83	01	29	2043 09	+				345		06	CS
83	02	04	2043 15	-	05	02	22	340	572	07	FGS
83	03	01	2044 13	-/+	03	03		305	610	09	CS
83	03	09	2044 21	-/+	14	03	23	362	754	10	CS
83	03	19	2045 04	+/-				375		05	CS
83	03	28	2045 13	-	31	03	02	357.5	565	09	CS
83	04	04	2045 20	-	09	04	22	437.5	788	08	CS
83	04	12	2046 01	-	14	04	24	402.5	750	10	CS
83	04	21	2046 10	-	24	04	24	350	633	09	CS
83	05	01	2046 20	+/-	05	05	20	372.5	633	10	CS
83	05	11	2047 03	+/-	12	05	01	387.5	731	10	FGS
83	05	20	2047 12		25	05	19	360	752	11	FGS
83	05	29	2047 21		02	06		367.5	510	07	CS
83	06	10	2048 06	+/-	13	06		367.5	595	07	FGS
83	06	17	2048 13	-/+	18	06	12	367.5	645	10	CS
83	06	25	2048 21		28	06	02	350	540	11	CS
83	07	06	2049 05		09	07	11	365	511	07	CS
83	07	12	2049 11					365		10	CS
83	07	22	2049 21	+/-	25	07	02	355	572	09	CS
83	08	01	2050 04		03	08	24	337.5	660	07	FGS
83	08	19	2050 22					345		11	CS

Table I (continued)

Y	M	D	Bartel Rotation		IMF POL	FDMA			$V_o$	$V_{max}$	DUR	TYPE
			No	D		D	M	Hr				
83	08	30	2051	06	+	31	08	10	325	691	10	CS
83	09	08	2051	15	-	10	09	11	337.5	574	08	CS
83	09	23	2052	03	+	26	09	16	320	703	12	CS
83	10	03	2052	11	+	08	10	17	357.5	632	07	CS
83	10	15	2052	25	+	18	10	10	355	546	06	CS
83	10	28	2053	11	+	29	10	21	325	545	05	CS
83	11	01	2053	15	-	02	11	18	350	677	06	CS
83	11	06	2053	20	+	10	11	03	395	654	08	CS
83	11	23	2054	10	-				350		11	CS
83	12	04	2054	21	+	07	12	04	387.5	650	06	CS
83	12	11	2055	01	-	12	12	19	380	669	08	CS
83	12	25	2055	15	+				375		10	CS
84	01	03	2055	24	+	05	01	13	374	633	04	CS
84	01	19	2056	13	+				347.5		09	CS
84	01	26	2056	20	+	30	01	15	365	751	07	FGS
84	02	22	2057	20	+/-	24	02	10	370	651	04	FGS
84	03	01	2058	01	-	03	03	01	400	769	05	CS
84	03	05	2058	05	-	06	03	15	370	594	05	CS
84	03	16	2058	16	+/-	19	03	13	345	533	06	CS
84	03	21	2058	21	+				340		07	CS
84	03	28	2059	01	-	29	03	10	455	744	05	CS
84	05	07	2060	14					370		13	FGS
84	05	19	2060	26		23	05	21	380	654	11	CS
84	06	02	2061	13					360		13	CS
84	06	13	2061	24		16	06	08	427.5	706	05	CS
84	04	28	2062	12					355		15	CS
84	07	31	2063	18		01	08	16	355	663	08	CS
84	08	14	2064	05		15	08	07	350	615	06	CS
84	08	26	2064	19		28	08	24	330	639	06	CS
84	09	08	2065	03		10	09	20	385	790	15	CS
84	09	22	2065	17		24	09	05	375	783	13	CS
84	10	04	2066	02	-	09	10	11	352.5	719	14	CS
84	10	17	2066	15	-	20	10	08	342.5	754	13	CS
84	10	31	2067	02	-				370		15	CS
84	11	14	2067	16	-							FGS
84	12	10	2068	15	+				360		11	CS

between the speeds immediately preceding and following the stream and the maximum daily mean speed ( $V_{\max}$ ), respectively. The next one gives the duration (DUR) of the high-speed stream in days. Finally the last column indicates the type of the high-plasma stream.

In this search we have tried to emphasize well-defined streams. A stream is listed only if the data coverage was reasonably complete. Each appearance of a stream is listed

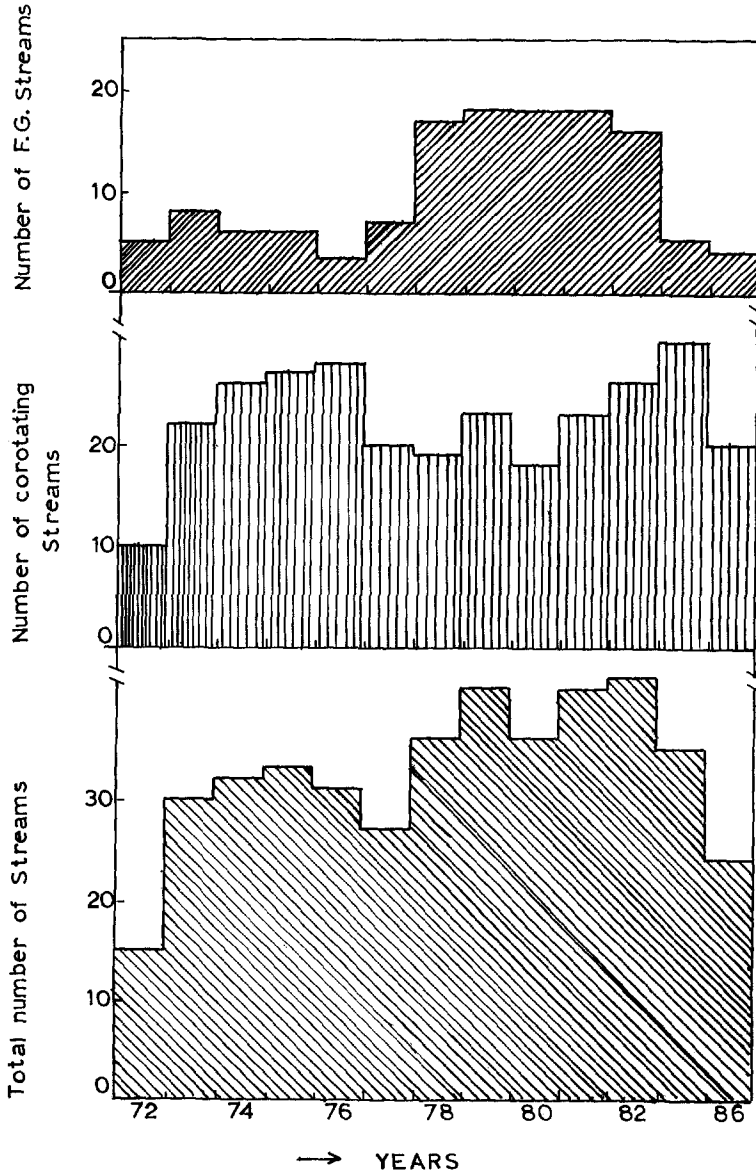


Fig. 2. Histograms showing the distribution of the number of total high-speed solar-wind streams (*below*), flare-generated streams (*above*) and corotating streams (*middle*) for the period 1972-1984.



separately regardless of whether or not it is a member of a recurrent series. In Table I a total of 423 individual high-speed streams are listed. Among them a total of 294 (69%) corotating streams and 131 (31%) flare-generated streams are found. It is obvious that the number of corotating streams appears to be greater than the number of flare-generated streams during the solar cycle No. 21 (1975–1984). This result is also confirmed from a statistical analysis of the two types of high-speed streams obtained the distributions of Figure 2. According to this figure a large number of flare-generated streams appear during solar maximum, whereas the existence of coronal holes during solar minimum most likely gives such a lot of corotating streams.

### 3. General Effects of Streams on Geomagnetic Activity

It is known that the consideration of the relation between interplanetary streams and geomagnetic activity promises to be the key link between interplanetary dynamics and the dynamics of the solar wind–Earth interaction. But the problem of relating the physical processes and the configuration of the solar wind to the physical parameters that produce geomagnetic activity has not been solved.

A series of statistical correlative studies have been presented with opposite results. Snyder, Neugebauer, and Rao (1963) reported a strong correlation between solar wind

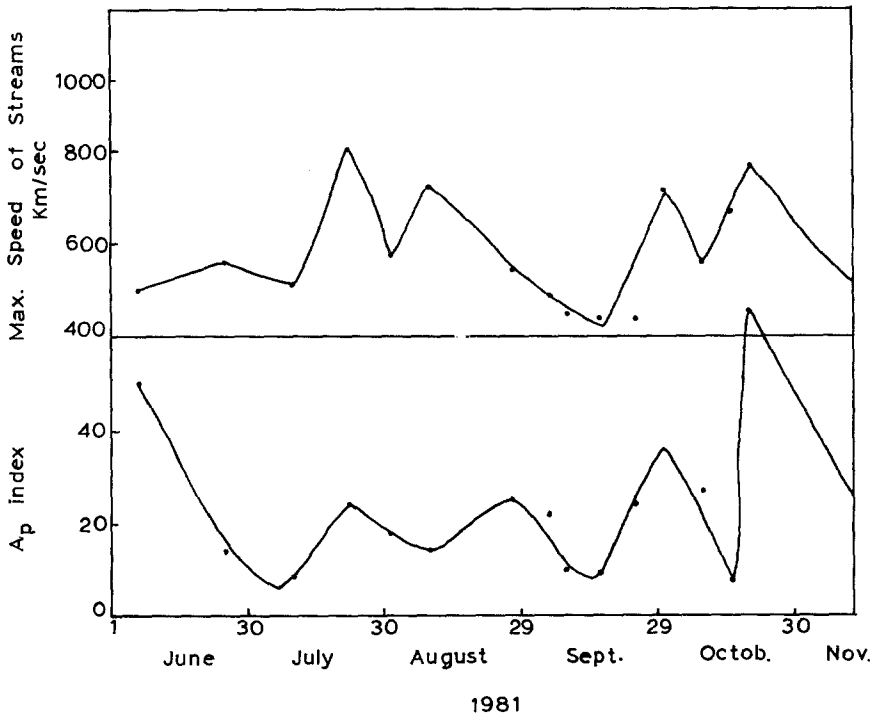


Fig. 3. Relation between the index  $A_p$  and the maximum speed of high-speed streams from June to November 1981.

velocity and the three-hour geomagnetic index  $K_p$ . Later Gosling *et al.* (1972) showed that the persistence of streams is not as great as Snyder, Neugebauer, and Rao (1963) originally suggested. Bobrov (1973) suggests that geomagnetic activity is high during the passage of the interaction regions from both corotating and flare-associated streams because both the negative southward component of the interplanetary magnetic field and the fluctuations of magnetic field are high in the interaction regions. He showed that the  $K_p$  index was high in the trailing part of corotating streams due to the presence of large fluctuations of magnetic field there.

In this work with the solar wind parameters we have chosen the maximum speed of the high-speed solar-wind streams which is not influenced by the north-south effect (Tsurutani *et al.*, 1987) to correlate with the  $A_p$  index of geomagnetic activity. The  $A_p$  index is a daily index of geomagnetic activity on a linear scale (*Solar Geophysical Data*). A typical example of the relation between the maximum velocity of streams and the  $A_p$  index for a short time period is presented in Figure 3. Even though the eye tends to see a high correlation, a close look at this figure shows that  $A_p$  is not always proportional to  $V_{\max}$ , but presents an almost similar behaviour with it. The correlation for the years 1972-1984 is generally satisfactory (correlation coefficient  $r = 0.50$ ), particularly considering that both variables are not free from errors.

From a regression analysis between the  $A_p$  index and the maximum speed of total streams, the flare-generated streams, and the corotating streams we have obtained

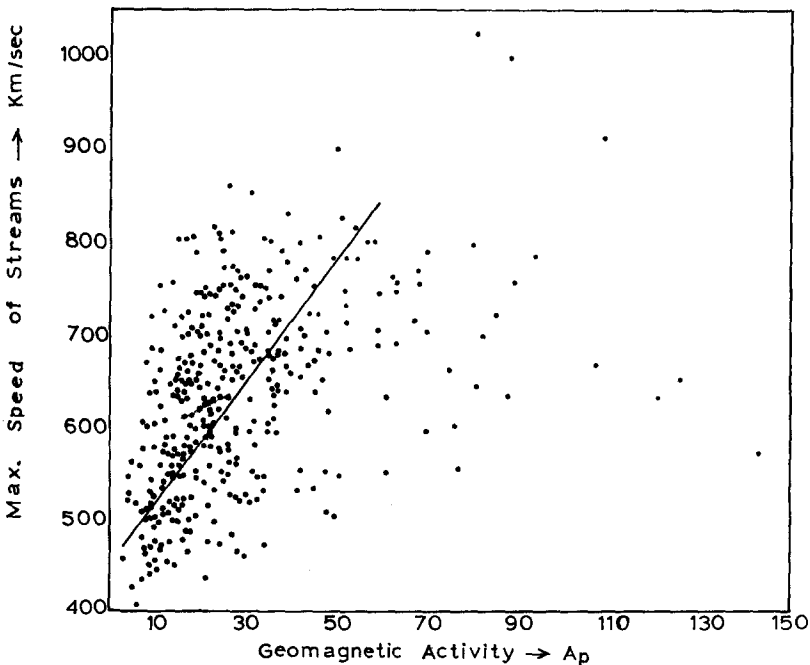


Fig. 4. Correlation diagram and 'best fit' line between the maximum speed of all streams defined in this study and the geomagnetic index  $A_p$  for the 21st solar cycle.

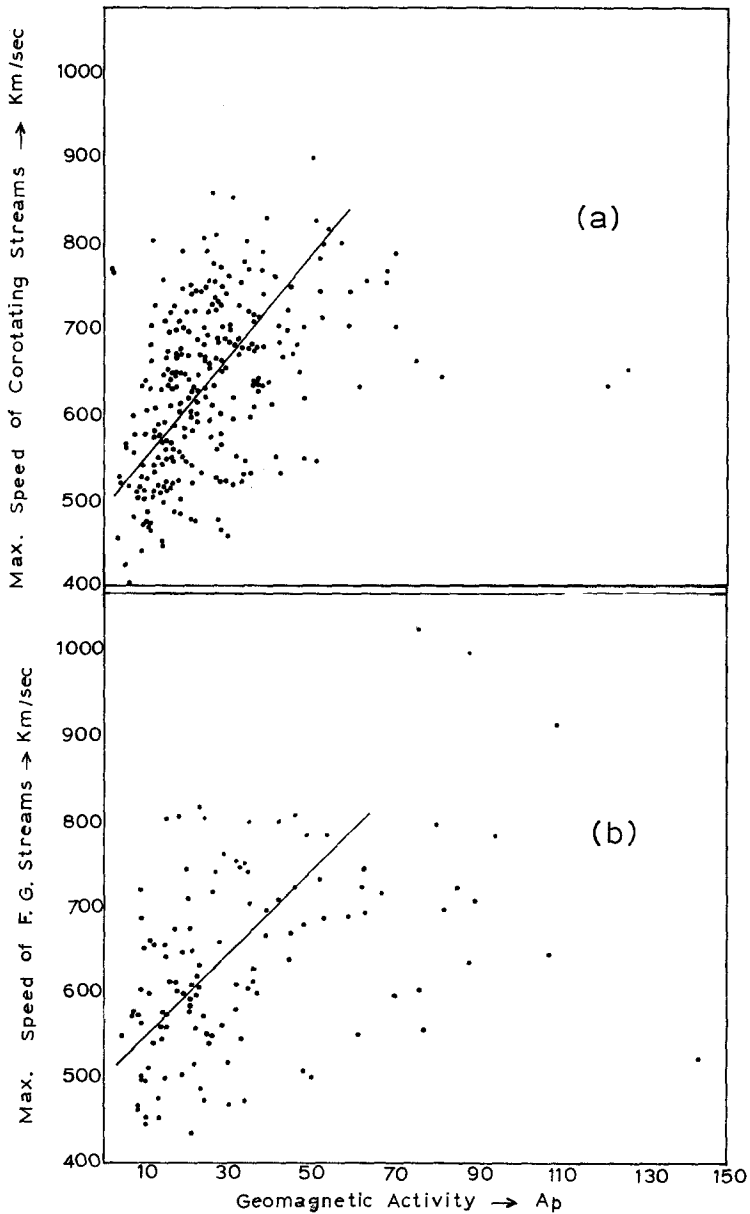


Fig. 5. Correlation diagram and 'best fit' line between the  $A_p$  index and the maximum speed of (a) the corotating streams and (b) the flare-generated streams, respectively.

Figures 4 and 5. A linear relation between  $V_{\max}$  of the high-speed streams and the  $A_p$  index can be given. The constant, the slope and the correlation coefficient of this analysis for the total, the corotating and the flare-generated streams are given in Table II. According to the Fisher's  $Z$ -transformation of significance of correlation coefficients we have found that the above estimated correlation coefficients for the data series of

TABLE II

Linear regression analysis of  $V_{\max}$  of high-speed solar-wind streams (total, corotating, and flare-generated) and  $A_p$  index for the period 1972–1984 giving the constant, the slope, the correlation coefficient, and the significance level

	Constant	Slope	Correlation coefficient	Significance level
Total streams	523	4.5	-0.45	0.05
Corotating streams	510	5.4	-0.43	0.05
Flare-generated streams	521	4.0	-0.52	0.05

maximum speed of streams and the  $A_p$  index are at a 0.05 significance level. A similar relation between the solar wind speed and the geomagnetic index  $C$  has been evaluated by Chirkov and Kuzmin (1977).

Searching through Figures 5(a) and 5(b) we note that high values of geomagnetic activity appear to be caused by the flare-generated streams. Indeed there is an accumulation of the maximum speed values of corotating streams around small values of  $A_p$ -index (Figure 5(a)) while the maximum speed values of flare generated streams are extended around greater values of  $A_p$ -index (Figure 5(b)). From a first attempt these high values of  $A_p$  correspond to sudden storm commencements which are attributed to interplanetary streams and seem to be emitted by solar flares. According to Simon and Legrand (1986) these events are related to a series of solar events occurring in relationship with the sunspot activity. They noticed that most of the geomagnetic activity, i.e., 85% of the occurring activity is of solar wind origin. These shock events contribute weakly to the geomagnetic activity but with high values. On the other hand the corotating streams give geomagnetic events with a low activity. These disturbances are attributed to long-lived interplanetary streams emanating from unidentified regions on the Sun, the corotating or M-regions (Burlaga, 1975). According to Legrand and Simon (1985) these geomagnetic events of corotating regions are related to the distribution around the Sun of the corotating sources of solar wind and include three categories of geomagnetic activity: the recurrent storms, the quiet days and the fluctuating activity. So any increase or decrease of such geomagnetic activity is related to the rotation with the Sun of alternate sources, i.e., coronal holes of the high and low speed wind which successively reach the Earth magnetosphere.

#### 4. Conclusions

From all the above the following conclusions can be drawn:

It is believed that the catalogue of high-speed solar-wind streams containing all their main characteristics may be useful in studies of various solar interplanetary and terrestrial phenomena.

Indeed the streams are the key link in the chain that connects solar and geomagnetic activity. The factors that most influence geomagnetic activity are probably related to

streams and determined by the dynamics of streams. In the study of understanding the solar wind parameters which are most important in producing geomagnetic activity, we found that the maximum speed of the flare-generated streams gives large values of geomagnetic activity if produced by the sudden storm commencement events, as opposite to corotating streams.

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