Flare index of solar activity and global geomagnetic variability

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The associations of solar flare index (SFI) and global geomagnetic variability (A_p) with annual mean sunspot number (SSN) during the period 1986–96 have been analysed. It is found that the SFI in the northern hemisphere, southern hemisphere and total disk surface of the sun shows close correspondence with the SSN on long- and short-term basis. An internal association between SSN, SFI and A_p has also been analysed. We have found that A_p poorly correlated with SFI and SSN during the aforesaid period.

SUNSPOTS are the active regions which represent exceptionally strong concentration of magnetic flux on an average, and possess a well-known cyclic variation of 11 years. The association of different solar source activities and large geomagnetic disturbances with annual mean sunspot number (SSN) has been reported by many authors who have suggested that the different coronal transients and large geomagnetic disturbances vary with the 11-year sunspot cycle. During maximum period of solar activity, huge amounts of solar energetic particles are released from the sun. They enter the earth's magnetosphere and are found to be responsible for large geomagnetic disturbances. Whereas, during minimum period of solar activity, small geomagnetic disturbances are observed. Solar flare is also known as solar storm and is a major cause of geomagnetic disturbances. A good association of large geomagnetic disturbances with large solar flares and coronal mass ejections was indicated in our previous studies[1–3]. The total energy emitted by the solar flare is represented by the solar flare index (SFI). Kleczek[4] introduced a relation, $Q = i \times t$, for representation of total energy emitted by solar flares. In this relation, i denotes the intensity scale of importance of the solar flare, t the time duration (in min) of the solar flare emission and Q the total energy emitted by solar flares, which is also known as SFI. Recently, according to the occurrence of solar flares in the northern hemisphere, southern hemisphere and total solar surface, SFI was calculated by Atac and Ozguc[5] for the period January 1986 to October 1996. From these values, we have calculated the monthly and yearly mean values of SFI in the northern hemisphere, southern hemisphere and total solar surface (Table 1).

The long-term behaviour of the geomagnetic field disturbances is available through measurements of planetary A_p (global geomagnetic variability) and K_p indices. The values of K_p index are available on 3-h interval logarithmic scale, whereas planetary index A_p represents the degree of global geomagnetic variability of each day. So, here A_p is used for representing the long-term variability of the geomagnetic field and is compiled and distributed by the Adolf-Schmidt-Observatorium für Geomagnetisum, Geo-ForschungsZentrum, Potsdam. The annual mean values of A_p index have been estimated for the period 1986–96. The yearly mean values of A_p index from the period 1986–96, are listed in Table 1.

The solar cycle 22 was exceptional among the other 21 solar cycles, containing two peaks during the year 1989 and 1991. So, the maximum phase of solar cycle 22 has been measured during the period 1989–91. The periods 1986–88 and 1992–96 are measured as ascending solar minimum and descending solar minimum periods. In the present analysis, the association of SFI in the northern hemisphere, southern hemisphere and total disk surface of the sun with SSN during the aforesaid period, are plotted in Figure 1. From this plot, it is found that the yearly mean value of solar flare index in the northern hemisphere, southern hemisphere and total disk surface of the sun shows close correspondence with SSN. The SFI varies with the 11-year sunspot cycle like the other solar transients. It is also found that the average SFI in the southern hemisphere is higher in comparison to the northern hemisphere. So, the southern hemisphere of the

Table 1. Yearly mean value of solar flare index of solar activity in the northern hemisphere, southern hemisphere, total disk surface of the sun and global geomagnetic variability

Year	Northern hemisphere	Southern hemisphere	Full disk of Sun	Yearly mean value of A_p
1986	0.61	0.53	1.13	12.6
1987	0.86	1.79	2.26	11.0
1988	4.10	4.13	8.14	12.6
1989	9.90	8.30	17.39	19.3
1990	6.43	5.74	12.20	16.4
1991	5.57	9.58	15.16	23.3
1992	2.71	5.20	7.74	16.5
1993	1.99	2.29	4.23	15.0
1994	0.70	0.87	1.58	18.1
1995	0.30	0.56	0.86	12.5
1996	0.08	0.25	0.32	9.4

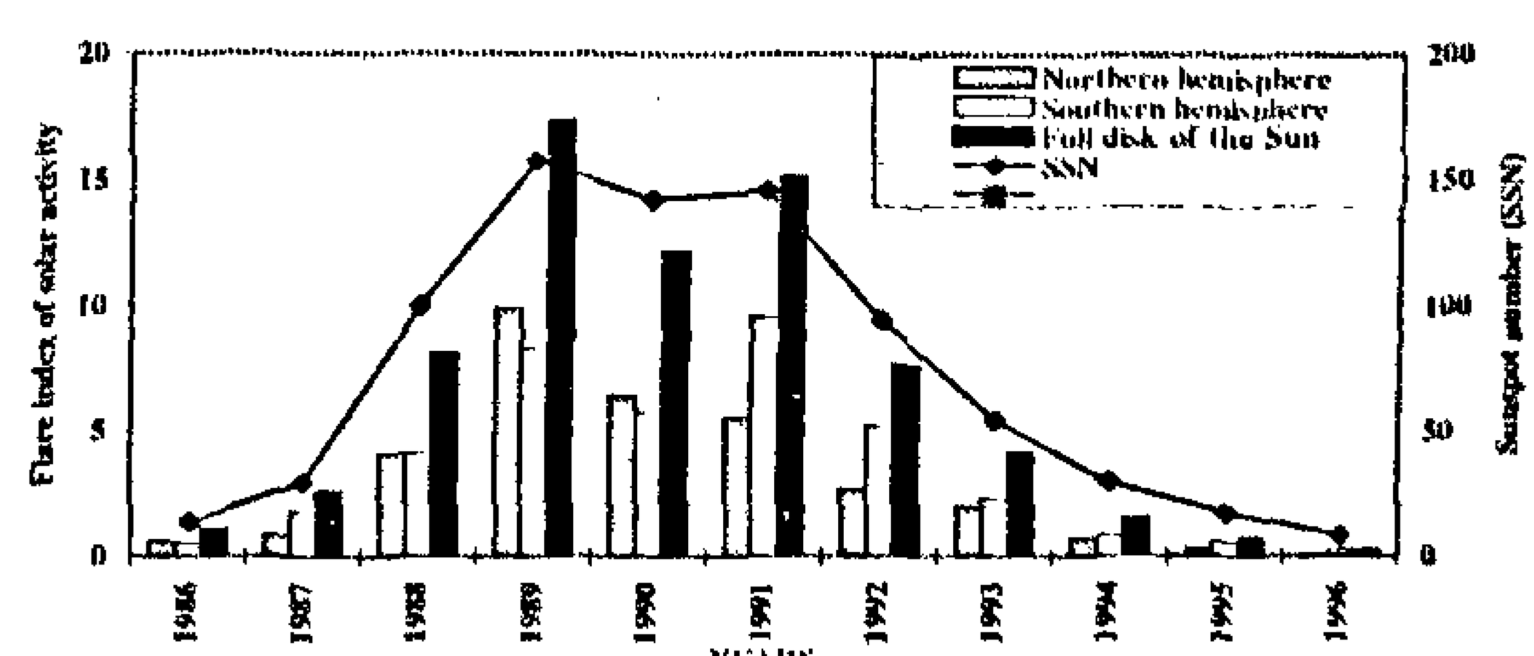

Figure 1. Association of the yearly mean value of solar flare index in the northern hemisphere, southern hemisphere and total solar surface with annual mean sunspot number during 1986–96.

**For correspondence

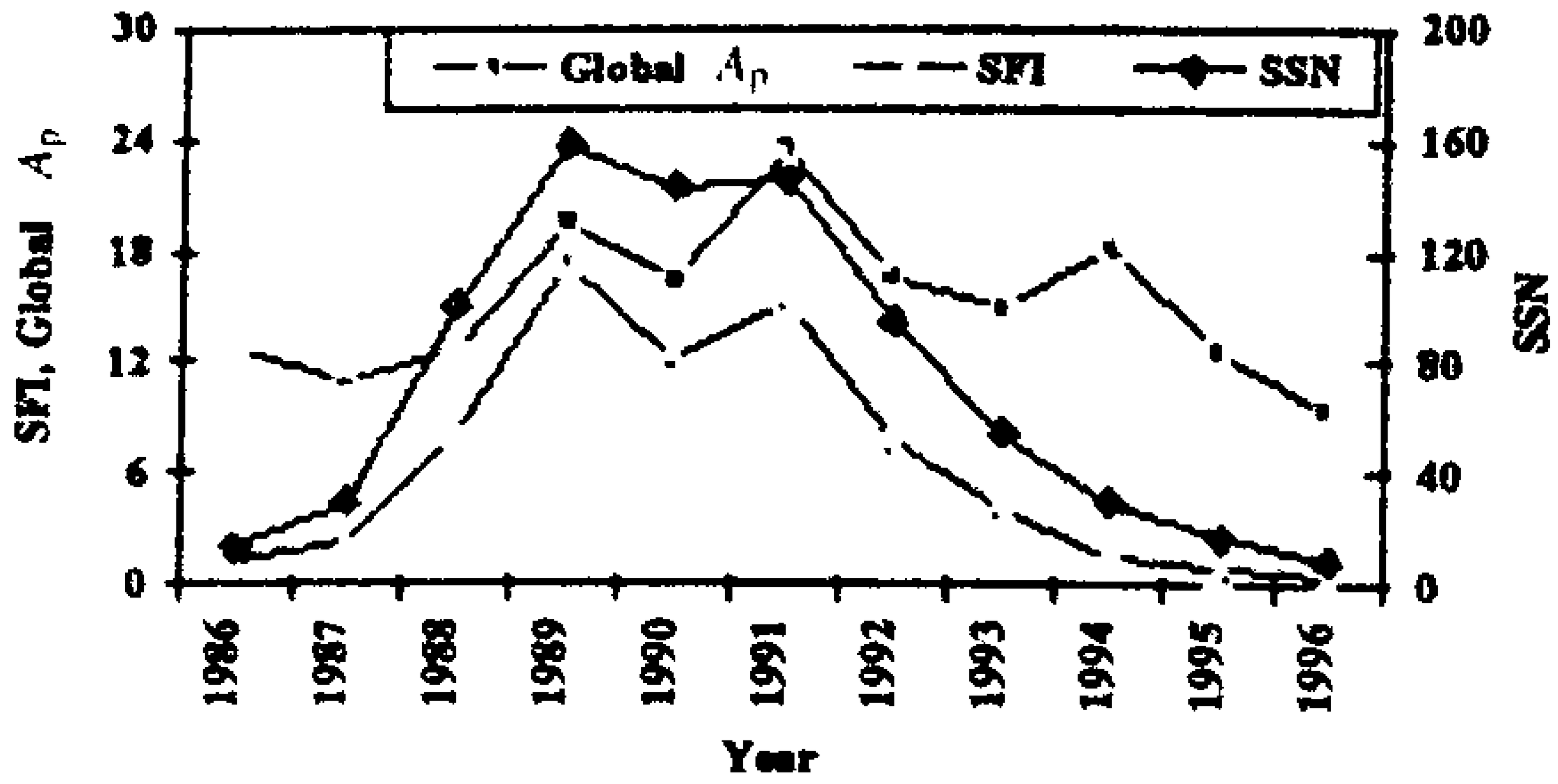

Figure 2. Comparison of the SFI, A_p and SSN during 1986–96.

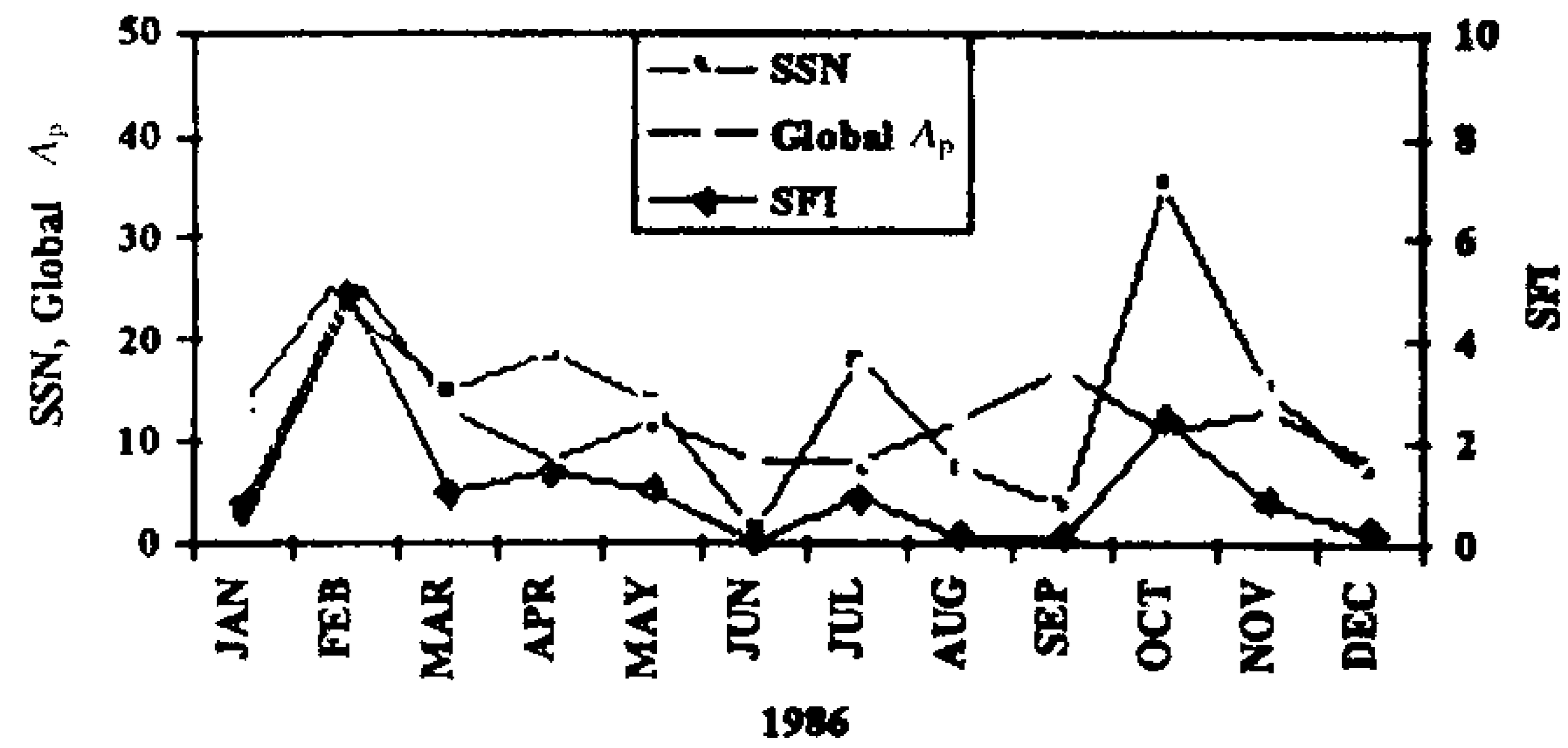

Figure 3. Comparison of the SFI, A_p and SSN during 1986.

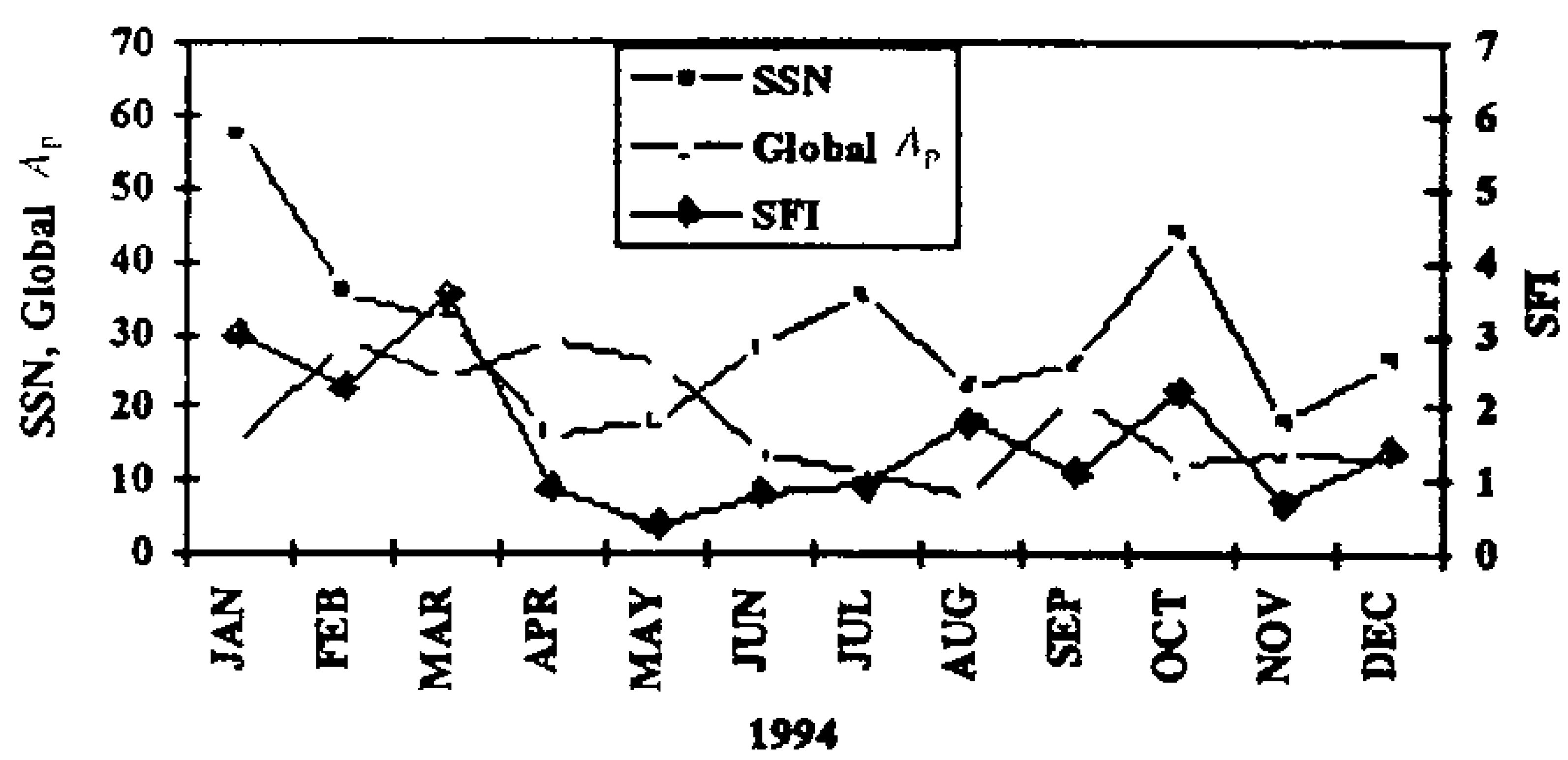

Figure 4. Comparison of the SFI, A_p and SSN during 1994.

solar disk is more active for producing maximum number of large solar flares during solar cycle 22.

Yearly mean value of SFI actively follows the SSN, but we have not found reasonable association between A_p and SSN. A_p and SFI are plotted vs SSN for the aforesaid period in Figure 2. From this plot, it is found that during two extreme peaks of solar cycle 22, A_p and SFI are maximum. This phenomenon is associated with electromagnetic coupling of velocity of solar wind streams and interplanetary magnetic field, $\mathbf{V} \times \mathbf{B}$, in the geomagnetosphere. The southward directed IMFs provide an opportunity to enter the solar plasma and magnetic field in the geomagnetic sphere. The energy transfer efficiency is about 10% during intense geomagnetic storms[6]. Viscous interaction, the other prime energy transfer mechanism proposed, has been shown to be only < 1% efficient during intense northward directed IMFs. Neugebaur[7] has shown that interplanetary magnetic field increases approximately 40% during solar maximum period. So, the presence of large southward directed IMFs in the presence of higher solar wind velocities can produce large geomagnetic disturbances and vice versa. During solar maximum, the maximum number of geomagnetic disturbances are caused by transient disturbances in solar wind streams. This produces large southward directed IMFs. So, we find global geomagnetic field disturbances are maximum, during the two extreme solar peak years, 1989 and 1991.

During solar minimum, maximum number of geomagnetic disturbances are caused by corotating flows in solar wind streams, that are not always able to produce large southward directed IMFs. From Figure 2, it has been observed that A_p is comparatively less than the solar maximum period and also shows the asymmetric variation during ascending and descending solar maximum period. It was also found that during ascending phase 1986–88, A_p is comparatively less than the declining phase 1992–96 of solar cycle 22. We have also found that the A_p at one ascending solar minimum year (1986) and one descending solar minimum year (1994) shows an inverse correlation with SSN and SFI. The monthly mean values of SSN, global A_p and SFI, during the years 1986 and 1994 are plotted in Figures 3 and 4. From these plots, it is found that the monthly mean values of SFI show a good correlation with monthly mean values of SSN like the annual mean of these values. The monthly mean values of A_p index have not shown clear association with monthly mean values of SSN. So, it is concluded the geomagnetic activities are poorly correlated with SSN. Actually, the geomagnetic activities depend upon the electromagnetic coupling, $\mathbf{V} \times \mathbf{B}$, in the presence of large southward directed IMFs. During the years 1986 and 1994, which are the years of solar minimum period, it is found that SSN and SFI are strongly correlated. SFI is a measurement of total energy of solar flare emission. The solar flares are responsible for transient disturbances in solar wind streams that provide on opportunity for large southward directed IMFs. So, we find that A_p is higher due to presence of large southward directed IMFs during the years 1986 and 1994. We also find two peculiar results during these years on both long and short-term basis.

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