The Observational Aspects of the Three Largest Solar-Energetic Particle Fluxes: 19-20/10/1989, 14/7/2000 and 9/11/2000

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Abstract

The study of the largest solar energetic particle (SEP) events gives important information about the physical process in the solar corona and in the heliosphere. The hourly solar energetic particles and interplanetary (IP) and geomagnetic measurements of the three largest SEP events have been compared. The results indicate that there is a quite different in IP and geomagnetic disturbances and in turn, the mechanism of particle accelerations among the three events. The acceleration of fluxes was not a function of the IP shock's efficiency. The IP shock was hardly deteriorated in its path to the Earth. Different dynamics structures in the heliosphere during the considered events, have been found.

1. Introduction

It is now acceptable most of the solar energetic particle (SEP) events are associated with interplanetary (IP) shock driven out from the Sun by coronal mass ejections (CMEs) [1, 2]. SEP events are typically classified into two distinct types: gradual or impulsive events [3]. The acceleration of gradual SEP events is believed to take place at a shock driven by a CME as it moves through the corona and out into the solar wind (SW). The SW is assumed to provide the seed particles that are accelerated, and later observed at 1 AU; which may be lasted for several days. Impulsive SEP events (which are generally associated with solar flares and its duration of a fraction of a day or less) are of less intense, occur more frequently and enrich of heavy elements (Ne-Fe) and some rare isotopes (3He).

The relationship between solar and geomagnetic activity parameters has been investigated [4,5]. The results indicated that the geomagnetic activity had two discrete components attributed to solar flare and corotating solar wind streams. This part of work is focused on the comparison of the three largest high-energy peak flux events (19-20 Oct' 89, 14 Jul' 00, and 9 Nov' 00) that characterized by a quite different in the particle intensity-time profiles. The study of the considered events can play an important role in improving our understand-

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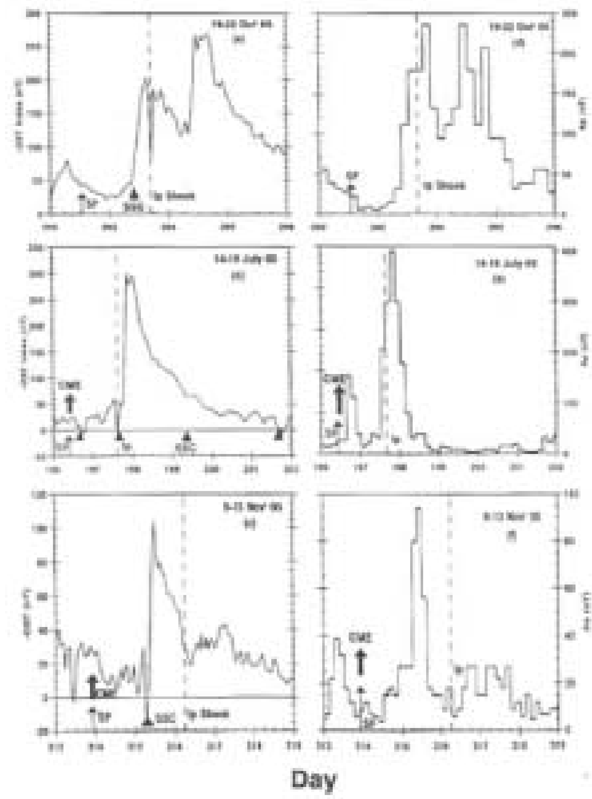

Fig. 1.

ing of the acceleration particle processes in the Heliosphere. Detailed discussions of hourly IP and solar plasma observations according to interplanetary medium factors were given elsewhere [6-10]. Fig. 1 shows the variations of the Dst ring current (left plots a-c) and the Ap index of the geomagnetic activity (right plots d0f) during the events of 19 October 1989, 14 July 2000, and 9 November 2000.

2. The Geomagnetic Data During the Considered Events

The studies of [11, 12] proposed that the speed and plasma density of solar wind affect on the cyclic behavior of the frequency of SC appearance, caused mainly by a number of solar flares. In this work, we investigate the Ap index which measures geomagnetic activity on a global basis and the Dst index representing the ring current (which affects the geomagnetic activity), during the considered events. Figure 1 shows the variations of Dst ring current (left plots; 1a-c) and the Ap index of geomagnetic activity (right plots; 1d-f). The timings of SC of geomagnetic storms are marked by triangles in left plots. Generally, the geomagnetic indices reflected strong variations during the considered periods. Plots 1a-c show that the observations of Dst index correlate well with the SC of geomagnetic storm onsets. Just at the time SSC, the magnitudes of Dst index varied from 50 to 200 nT, 0 to 300 nT, and from -10 to 100 nT during the three events, respectively. The rate of Dst changes that happened in 14-19 July 2000 was about two times larger than other events. Also, the Dst values during 8-13 Nov' 00 show clearly that the IP shock wave has no significant role. On the other hand, plots 1d-f displayed nearly similar behaviors. The rate of change in Ap index during the Bastille day was about six times larger that observed in 8-13 Nov' 00 event and two times stronger than the event of 19-22 Oct' 89.

3. Events of 19-20 October 1989, 14 July 2000 and 9 November 2000

During the maximum of solar cycle 22 (1989-91), there was an unprecedented sequence of 13 cosmic ray GLEs. The GLE of 19 October 1989 is quite different in structural from the other. It is the first of three GLEs that were associated with the same solar active region [13]. The SEPs typically have a slow rate of rise to maximum intensity and a slow decay. Around the flare onset, the event was not associated with significant changes in the interplanetary parameters in comparison with the IP shock onset. The intensity time profiles of the SEP are functions not only of the shock's efficiency for accelerating particles, but also of the transport conditions in the upstream and downstream regions of the shock [10]. The peak intensity of SEP is observed at the time before the arrival of IP shock. Neither SC of geomagnetic storms at 0916 UT on 20 Oct' 89 nor IP shock at 1650 UT produced a significant variation Following the IP shock onset (1650 UT on 20 Oct' 89) the solar plasma seems to be more dense, cooler, and faster and the field magnitude is stronger than at the boundary regions of the shock. Similar picture has been recently observed south of the HCS during the negative IMF polarity period [9]. The SEP fluxes of the 14 July 00 immediately started after the parent flare SF. During the rising phase, about a few minutes after the event onset, a CME and the SSC pass by. The event was produced by very fast CME, with initial speed of 1800 Km/s. Maximum intensity was reached in less than 5 hrs. Intensities stayed constant for 20 hrs. With the passage of the shock (of high order of speed) at 1415 UT on 15 Jul' 00, the proton fluxes decreased fast for the next 12 hrs. In fact, we do not observe a shape changes after the shock. Therefore, we can say that the particles are not locally accelerated at the shock. Thus, the time profile of the second largest event was not similar to that of October 1989. The arrival of the shock at Earth was associated with strong interplanetary changes. The SW speeds started after the flare onset by 4 hrs. Over the interval 1500-1900 UT of 14 July 00, the SW speeds were ranging between 600 Km/s to 780 Km/s, and decreased until mid of the next day. Following the IP shock, the measurements of SW registered 1050 Km/s. We observed a sudden commencement at 1438 UT, 15 July 00, when a mean velocity of the shock was " 1500 Km/s. The SWS was " 1000 Km/s at 1500 UT, 15 July 00, indicating the IP shock decelerated in its path in the inner heliosphere and confirming that the shock's efficiency was not an essential factor in proton intensity profiles of such event. The event of 9 Nov' 00 (not shown) was the second largest major SEP ever occurred in 2000's. The considered event was not recorded as a GLE. The SEPs started a rapid rise just at the flare and CME observations. In 3 hrs the intensity had reached their maximum level. Then, it decreased smoothly until the arrival time of IP shock (at 0605 UT on 11 Nov' 00). Generally, the shape of the decay phase may be affected by interplanetary disturbances. The IP shock was decelerated strongly in its path to the Earth. To the best of our knowledge the reasons may be are: the suppression effect of the proton intensities from the Sun by the strong variation of solar magnetic fields, the deterioration of the proton acceleration efficiency during the sectorization-phase of IMF, or escaping particles in the inner heliosphere. Although the 9 Nov' 00 event was not a GLE, its fluxes were extremely high.

4. Conclusions

Hourly intensities of the three largest high-energy peak flux events 19 October 1989, 14 July 2000 and 9 November 2000 and their interplanetary, solar, and geomagnetic disturbances have been examined. The particle-intensity increases that observed around the time of the shock passage are composed not only of particles locally accelerated at the shock region by the strong disturbances of the magnetic field, but also of particles previously accelerated and that, by different mechanisms, remain around the shock. The particles are locally accelerated by and inside the shock region.

5. References

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