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Observation of the Interplanetary and Solar Parameters in Major Solar-energetic Particle Fluxes

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Abstract. The hourly solar energetic particles (SEP) and interplanetary (IP) measurements for the three considered-largest SEP events have been compared. The study determined the most relevant physical factors which determine the largest SEP properties. The particle-intensity increases that are 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 by different mechanisms around the shock. Following the IP shock passage, the solar plasma tended to be more dense, cooler and faster than at the boundary regions of the shock. The rate of geomagnetic disturbances during 14-19 July 2000 was stronger than the other events and included high changes. In contrast, the third event of 9 November 2000 was not shed a ground level enhancement (GLE). Fast rise and long decay in particle intensities which may be originated from different sources on the sun.

Keywords: Solar energetic particles; the ground level enhancements; the particle-acceleration in the heliosphere; the interplanetary and solar parameters; the geomagnetic disturbances.

Introduction

It is now acceptable that large and most of the solar energetic particle (SEP) events are associated with interplanetary (IP) shock driven out from the sun by coronal mass ejections [1, 2]. SEP events are typically classified into two distinct types: gradual and impulsive events [3]. The acceleration of gradual SEP events is believed to take place at a shock driven by a coronal mass ejections (CMEs) 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. In a gradual event, a coronal mass ejection drives a shock wave through the corona and solar wind, accelerating ambient material. Studies of [4] found that large complex active regions can give rise to both types, whereas simple and magnetically weak regions are preferentially linked to one type. An 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 (^{3}He). Solar particle isotopic composition varies greatly from event to event, apparently due to mass fractionation during particle acceleration and/or transport.

The relationship between solar and geomagnetic activity parameters has been investigated [5-7]. The results indicated that the geomagnetic activity had two discrete components attributed to solar flare and corotating solar wind streams. Furthermore, the geomagnetic activity index Kp is correlated well with the $B_S \; V^2$, where B_S is the southward component of the interplanetary magnetic field and V is the solar wind velocity. Also, the yearly averages of the ring current geomagnetic activity index Dst correlated with $B_S \, V$ during the solar cycle 20.

Our work is focused on the comparison of the temporal variations in the interplanetary and geomagnetic parameters of the most largest SEP events occurred during the maximum solar-cycle years. We compare the three largest high-energy peak flux events (19-20 Oct. ’89, 14 Jul. 2000, and 9 Nov. 2000) that are characterized by a quite difference in the particle intensity-time profiles. Two of them (14 Jul. 2000 and 9 Nov. 2000) are temporally close and took place in a period of about 4 months. The intensity-rise of 19 Oct. ’89 was more gradual. The associated solar flare of the 19 Oct. ’89 was extremely large and its location near central meridian was optimum for protons from solar neutron decay to be captured by the interplanetary magnetic field (IMF) lines connecting to the earth [8].

By comparison of the time profiles of SEP intensities observed at the three events, we discuss their implication to the mechanisms of particle propagation in the heliospheric magnetic fields. We have used the hourly solar energetic particle (SEP) and interplanetary and solar measurements (field magnitude B, solar wind ion density N, solar wind ion temperature T and solar wind speed *SWS*) taken near earth, which were provided by the National Space Science and Data Center [9]. Also, the hourly measurements of the ring current geomagnetic activity index Dst and the 3-hour range of Ap index for the considered events have been investigated. The relationship between the largest SEPs occurred throughout the period 1973-2001, the interplanetary (IP) and geomagnetic disturbances, has been examined. The selection of major SEPs has been discussed elsewhere [10, 11]. Detailed discussions of hourly IP and solar plasma observations according to interplanetary medium factors were given elsewhere [11-15]. The study of the considered events can play an important role in improving our understanding of the acceleration particle processes and the source of interplanetary disturbances.

Table 1 lists the major solar proton events observed by IMP-8. The peak intensity (based on 1-hour average) of >60 and 30 MeV protons for each event and the associated solar flare as the source of the solar particles are shown. Flares are classified by their X-ray flux; an X class flare is the strongest type of flare.

Table 1. Solar events giving rise to SEP events observed at earth

Date (d.m.y)	Doy	SEP Peak $(cm^2\ ster\ sec)^{-1}$		Solar flare	
		> 60 MeV	> 30 MeV	Location	Bright/Emiss
19.10.89	292	1790	1910	S27E10	4B/X13
14.07.00	196	1200	2570	N22W07	3B/X5.7
9.11.00	313	1110	2100	N10W77	3F/M7.4

Event of 19-20 October 1989

During the maximum of solar cycle 22 (1989-1991), there was an unprecedented sequence of 13 cosmic-ray ground level enhancements (GLEs) that were detected by the world-wide neutron monitor network. The 29 Sep.'89 event was the largest GLE in the space since 1956 although the 19 Oct. '89 included highly relativistic particles with the largest peaked-flux [16], and it is the first of three GLEs that were associated with the same solar active region [17]. The considered event was associated with a major flare located at heliographic coordinated 27°S, 10°E. In addition, the flare was notable for the extremely large 2.2 MeV gamma-ray emission observed by the spacecraft which is indicative of neutron production [8]. This solar flare accelerated protons up to energies greater than 4.5 GeV. This event had been identified by [8] as possibly beginning with protons resulting from the decay of solar neutrons. No CME was detected at the time of the solar event [18], while others [19] proposed that the CME occurred at the time of the flare as a result of the arrival of ejecta material to earth on 21 October '89.

The particle intensity enhancements are thought to be the result of two distinct processes; acceleration at the shock driven by a coronal mass ejection (CME) close to the sun for the so-called gradual events and flare-acceleration in the lower corona for impulsive events [20]. Figure 1 (a-d) shows the near-earth SEP fluxes and local interplanetary parameters (field magnitude *B*, solar wind speed *SWS*, and solar wind ion density *N*) taken from the National Space Science Data Center [9]. In plot 1a, we have added the hourly-count rates of cosmic ray CR (shown as a step line) detected by the south pole neutron monitor (SOP NM), corrected for pressure variations, for the whole of 19th and 22nd October. Also shown in the upper graph are the times of solar flare and the interplanetary (IP) shock occurrence, which are described by thin vertical arrow and dash line, respectively. The triangle indicates the time of the sudden commencement (SC) followed by a magnetic storm, at 0916 UT on 20 Oct. 2000. In fact, the proton intensities with 60 MeV and greater at the time of SEP event are the highest observed during the solar cycle 22 [10]. We notice a shock at 1650 UT on the 20th of Oct. '89 followed an extremely high flux (plot 1a). The solar flare accelerate particles to sufficiently high energies to produce a sharp increase in the counting rates of cosmic rays (polar ground-based detector). Then it decreases smoothly as a Forbush-decrease type. The SC of magnetic storms did not produce any significant change when the intensities of CR were already decreasing.

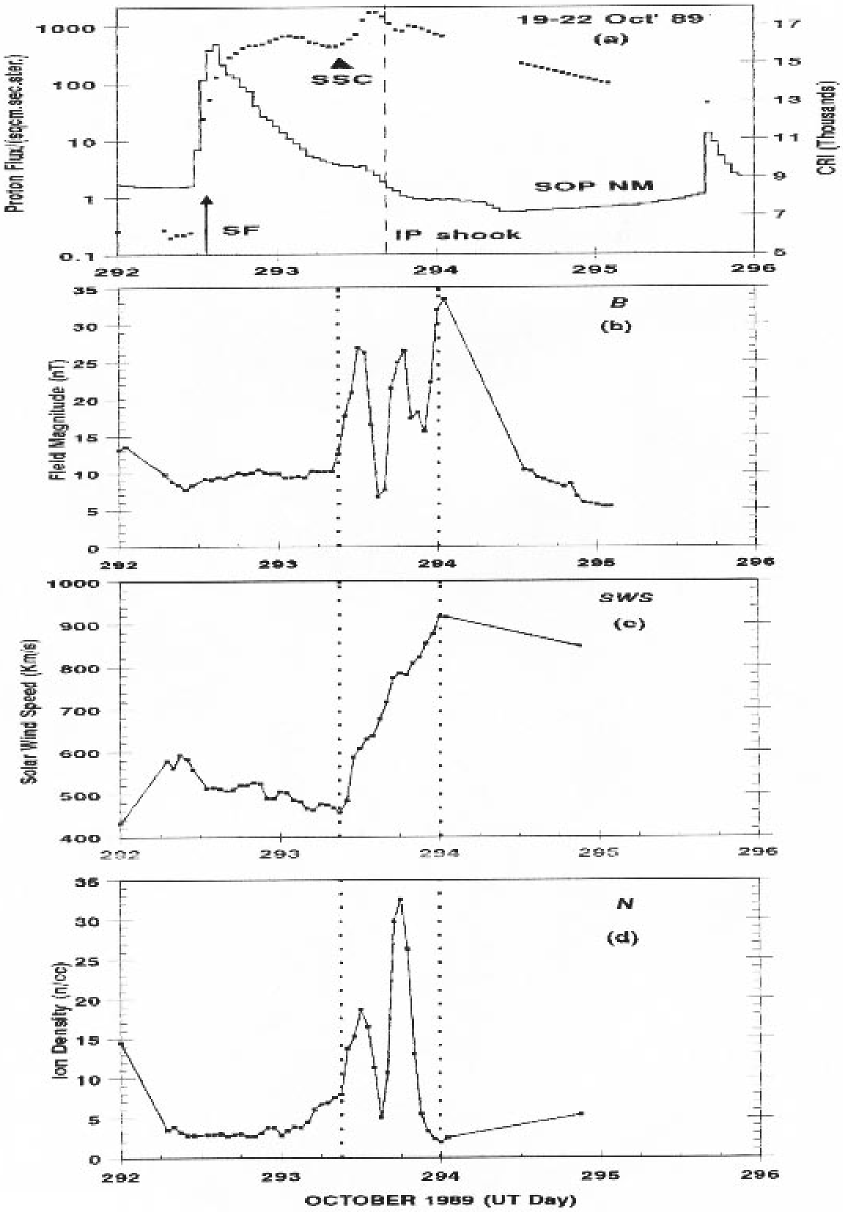

Fig. 1. Observations for the 19-22 October, 1989 SEP event. From the top: ≥ 60 MeV proton intensities together with the cosmic ray intensities (CRI) observed at south pole neutron monitor (SOP NM); magnetic field magnitude; solar wind speed and solar wind ion density. Arrow and dashed lines identify the arrival of solar flare and IP shock. The triangle marks the sudden commencement followed by the magnetic storm. The dotted lines mark the onsets of shock region.

The *SW* magnetic field and plasma observations are available during the time of the event 19-20 Oct. ’89. The observations show large changes throughout the considered event. We notice that the appearance of the SC of geomagnetic storms was associated with a strong disturbances in the interplanetary parameters. There are two *SW* features of interest around the time of event. The first is the region of enhanced magnetic field and plasma density, bounded by a forward and reverse shock pair (marked by the dotted vertical lines in plots 1b, 1c and 1d) which lies at the leading edge of the high-speed streams (at 0900 UT and 2400 UT on 20 Oct. ’89). This bound is based on the presence of stream interface midway between the IP shock [21]. The second noteworthy feature is that, there are no remarkable changes in *B*, *SWS* and *N* just a few hours around the flare occurrence, at the beginning of the event. No significant changes in solar and IP parameters are observed as a reference of the flare occurrence. Plot 1b shows that the field magnitude reflected a triple-peaked structure. At the forward-edge of the shock (0900 UT on 20 Oct. ’89), the *B* started to increase (from ~10 to 25 nT) in 3 hrs, and then decreased to a lower value (5 nT at 1500 UT). The *B* magnitude increased again forming a second peak at 1900 UT. The latter and the largest peak (~ 33 nT) was at the beginning of 21st day of Oct. ’89. The behavior of *B* during the range of IP shock wave shows consistent variations of 6-7 hours length.

With the passage of IP shock, the solar wind speed increased from 500 km/s to 900 km/s. The *SW* observations gradually increased, reaching a maximum of ≈ 900 km/s at 2400 UT on 20 Oct. ’89. Such high speed streams tend the interplanetary magnetic field lines to move closer to the sun-earth line. This means that these increases resulted from particles acceleration at the shock front and persisted inside the IP shock region. Therefore, the particle-intensity increases that observed around the time of the shock passage (plot 1a) 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. Furthermore, we can see that the variation in ion density (plot 1d) formed a double-peaked (at 1200 and 1800 UT). The *N* measurements showed less pronounced at the passage of the forward-region of the shock. Then, *N* increased rapidly from 5 to 32 n/cc in 3 hrs just at the shock onset, forming N-wave of 6-7-hour length each. Both *B* and *N* reached a high value at 1200 UT and a minimum one at 1500 UT on 20 Oct. ’89, when the high proton intensities reached to a maximum fluxes. The accompanying energetic particle event showed a rather unique signature: relativistic protons started shortly to increase (with the CRI) after the solar flare occurrence (at 1258 UT on 19 Oct. ’89). High energy particles appeared gradually later and followed by a remarkable pulse of particles, particularly prominent at E > 60 MeV that is roughly bounded by the times of the 4B flare and the shock at 1650 UT. The particle event originated in a flare at E 10°. As the active region (or flare location) rotates to the western limb, it continues to produce large flares and SEPs that lead to higher maximum fluxes. This highly SEP flux persisted few hours. The subsequent maximum occurs at or slightly before the IP shock arrival. The gradual increases of particle intensities are consistent with diffusive transport, and it also indicates that there was a direct magnetic connection between earth and the CME shock.

In addition, we find that the arrival of the IP shock did not produce a local variation in the count rates of cosmic rays. The peaked energetic particles enhancement at 1500 UT on 20 Oct. coincided with the simulations decrease in B and N observations.

So, we can say that SEPs typically have a slow rate of rise to maximum intensity and a slow decay. Around the flare onset, the event of 19 Oct. ’89 was not associated with significant changes in the interplanetary parameters in comparison with the IP shock onset. The passage of IP shock region reflected strong interplanetary disturbances in space. The intensity-time profiles of the SEP event had two distinct features, the shock’s efficiency for accelerating particles and the transport implications (or mechanism of particles propagation) inside the shock region. 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. 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 when the intensities of CR were already decreasing. Furthermore, variations of 6-7 hrs are seen in the observations of field magnitude and solar wind plasma density. 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 heliospheric current sheet during the negative IMF polarity period [15].

Event of 14 July 2000

The GLE of 14 July 2000 (sometimes named Bastille Day) was caused by the parent flare 3B/X5.7 with optical coordinates N22 W07. The flare really occupied an extended area along the solar equator and the associated activity involved the whole central area of the sun. The start of type II radioburst, which roughly corresponds to the time of relativistic proton acceleration [22], happened at 1012 UT with maximum values between 1020 UT to 1025 UT, and ended at 1043 UT. According to X5.7-ray data, the flare lasted from 1003 UT through 1043 UT with a peak at 1024 UT. This flare was the second biggest flare in the current solar cycle (the 23rd) until April 2001, and the third largest proton event above 10 MeV since 1976 [23]. On the other hand, the deepest Forbush decreases in the 23rd solar cycle were registered during 13–17 Jul. 2000 [24, 25], implying a high activity level on the sun. However, the solar CRs emitted were not high enough to register by NMs of high rigidities. This decrease was caused by the CME associated with the Bastille Day. The coronal mass ejection associated to this flare was even more outstanding than the flare itself. Numerous evidences of large scale eruption on the sun happened [23].

The Bastille Day event had the highest flux recorded since the October 1989 event. The time-profile of density distribution of solar particles causing 14 Jul. 2000 GLE has various information about the dynamic structures of the interplanetary magnetic field in the heliosphere. Figure 2a shows the proton fluxes and the CR

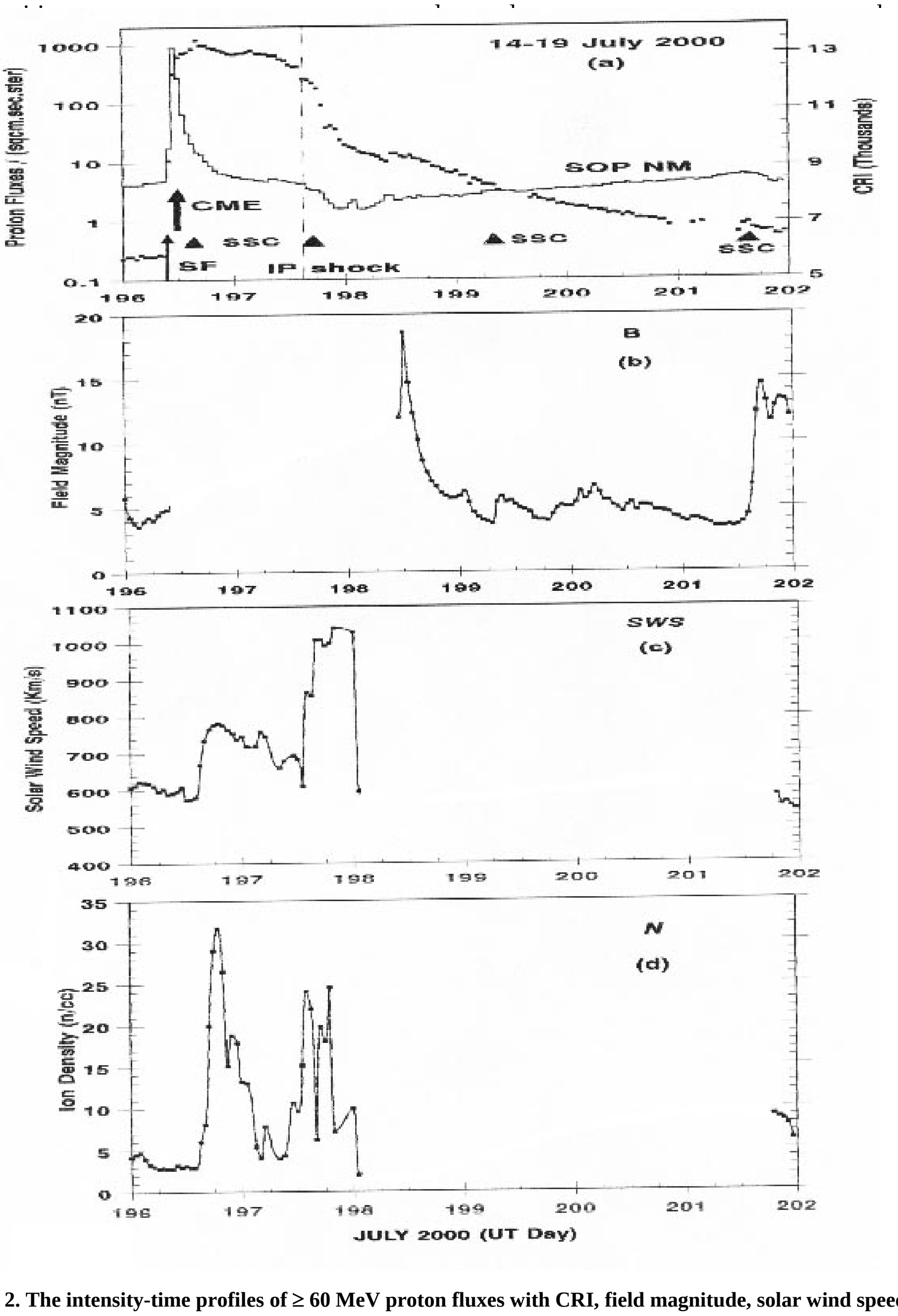

Fig. 2. The intensity-time profiles of ≥ 60 MeV proton fluxes with CRI, field magnitude, solar wind speed and ion density during the period 14-19 July 2000. Dark arrow marks the arrival time of the CME. Solar flare, SSC and IP shock are clearly shown.

SOP NM (step line). The dark arrow represents the CME arrival time at 1054 UT [26], while the triangles mark the times of sudden commencements (SSC). The IP shock (dashed line) reached the earth orbit at 1415 UT, 15 July 2000. The transient speed of the shock is of order 1500 km/s. The maximal enhancement at the neutron monitor was reached quickly, and its time profiles were simple enough and not extended. This indicates the most amount of arrivals at earth were hard particles, to be accelerated before maximum of the soft X-ray emission (at 1024 UT). Note that the distributions of arriving particles were anisotropic and of short duration during the onset-event; then it tended to become isotropic during the declining phase of the event, when only low energy protons remained [27]. On the other hand, SEP fluxes immediately started after the parent flare SF. During the rising phase, about a few minutes after the event onset, a CME and the SSC passed 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 and stayed constant. The increase of SEP nearly persisted constant or continue to roughly decrease at high energies for 20 hrs, forming a plateau of fluxes. Particles acceleration could be observed up to some hundreds MeV/nucleon. With the passage of the shock (of high order of speed) at 1415 UT on 15 Jul. 2000, the proton fluxes decreased fast for the next 12 hrs. In fact, we do not observe shape changes after the shock. At the beginning of the 16th day, intensities smoothly decreased (linearly) to the end of the period. Therefore, we can say that the particles are not locally accelerated at the shock. Thus, the time profile of the second largest event is not similar to that of October 1989. It is not a function of the shock's efficiency for accelerating particles. The acceleration seems probably to be occurred in the lowest part of the solar corona. Enhancements of energetic particles were immediately observed at the earth, their onset times consistent with the velocity dispersion due to the streaming of particles along magnetic field lines from the CME shock in the corona to the earth. Others [28] proposed that during the 14 Jul. 2000 GLE, the increase effect on the ground was caused by imposing of two components of relativistic solar protons, fast and delayed one originated probably from various sources on the sun.

Figure 2 (b-d) displays the magnetic field and *SW* parameters throughout the period 14-19 July 2000. 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 and 780 km/s, and decreased until mid of the next day. It started again to increase with the passage of shock. Following the IP shock, the measurements of *SW* registered 1050 km/s. In plot 2a, we observed a sudden commencement at 1438 UT, 15 July 2000, when a mean velocity of the shock was ≈ 1500 km/s. The *SWS* was ≈ 1000 km/s at 1500 UT, 15 July 2000, 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. Thus, the timing of GLE and other characteristics of this event lead to a conclusion that the majority of relativistic particles suppose to be accelerated before the 1029 UT, during the first 10 minutes after the type II radio bust started. The complex structure of the magnetic field that formed in the front of the shock was acting as a barrier to energetic particles which were unable to escape from the upstream region of shock. The *SWS* averages were not quantitatively similar on either side of the solar flare or IP shock.

On the other hand, the plasma densities (plot 2d) started to rise very rapidly after 4 hrs of the flare onset on that day. Strong increase in densities is observed (from 4 to 32 n/cc). The density fads back to pre-increase state within 7 hrs. During the plateau of the particle fluxes, both particle density and speed showed two significant peaks (for example, 32 n/cc and 24 n/cc in *N).* The latter peak nearly coincides with the IP shock passage. In general, there are large interplanetary disturbances following the solar flare and IP shock passage. The solar plasma are highly dense (6-8 times) and fast as a reference of solar flare and shock arrivals.

Event of 9 November 2000

This event was associated with a parent flare 3F/M7. The flare occurred at 2304 UT behind the west lime with optical coordinates N10 W77 and was accompanied by a fast CME at 2306 UT (the velocity was ≈ 2035 km/s). It is the second largest major SEP ever occurred in 2000's (the event of 14 July is the first one). Plot 3a displays the time development of SEP and CR intensities during 8-13 Nov. 2000. No significant effect in CR count rates has been observed. High GLE was not necessarily a sequence of major SEP event and it was not a condition for creating major SEP fluxes [10, 15, 29].

The SEP intensities 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. 2000). Generally, the shape of the decay phase may be affected by interplanetary disturbances.

The field magnitude *B* (plot 3b) started to decrease pre-flare and CME onsets. The decrease was extremely gradual. The depression in *B* started 13 hours before the solar flare onset. Maximum depression (from 19 to 1 nT) happened during 4 hrs before the onset. The behavior of *B* shows that there is a reduction in the interplanetary magnetic field connection. After sufficient fluxes have been achieved around the beginning of the CME and flare, the fields magnitude can be seen to increase steadily in a weak manner. Unfortunately, the *B* observations are mist until the earlier hours of 11 Nov. 2000. During the period 11-13 Nov. 2000, there is a small enhancement in *B* and it decreases roughly in comparison with the fluxes behavior.

The measurements of *SWS* and *N* (plots 3c-d) were not registered at the flare commencement. In the period between the late hrs of the 9th day and 11 Nov. 2000 , the *SWS* increases to 900 km/s and then decreased to the late hours of 10 Nov.. At the earlier hours of 11 Nov., a small change in *SWS* is observed (from 800 km/s to 920 km/s) and it smoothly decreased to the end of our considered period. In contrast, the measurements of N started around 10 n/cc. It increased to 20 n/cc in two hrs. From the mid-day of 10 Nov. the particle density remained low ~ 2 n/cc.

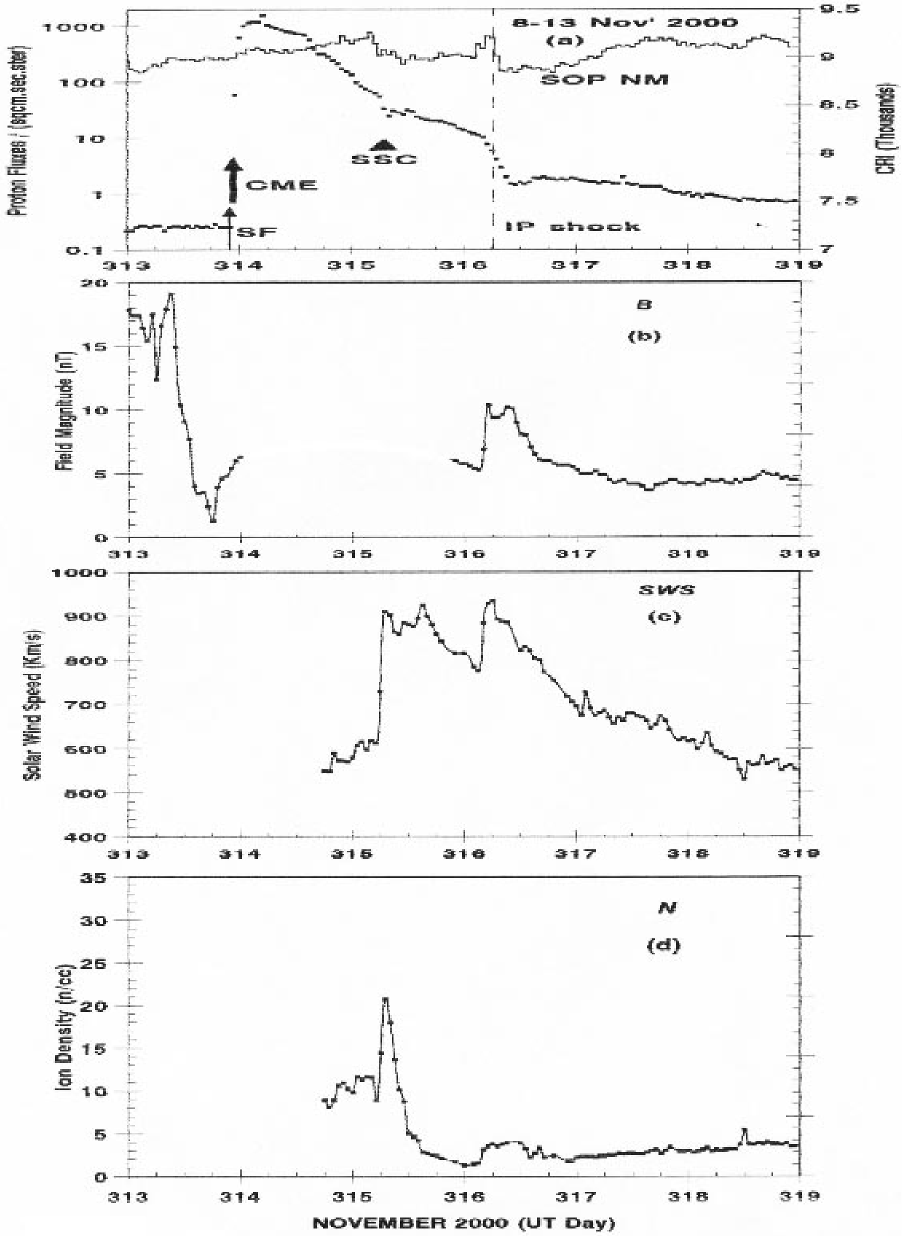

Fig. 3. The observations for 8-13 November 2000.

It is interesting to note that the event was not associated with a GLE. Also, the particles acceleration did not make by the IP shock. The IP shock was decelerated strongly in its path to the earth. It moved in the interplanetary space with slowing speed. To the best of our knowledge the reasons may be: (a) the suppression effect of the proton intensities from the sun by the strong variation of solar magnetic fields, (b) the deterioration of the proton acceleration efficiency during the sectorization-phase of IMF, or (c) escaping particles in the inner heliosphere. However, this might be a result of deterioration magnetic connection between earth and flare site, in contrast we observed a different conditions in the Oct. ’89 event. Although the 9 Nov. 2000 event was not a GLE, its fluxes were extremely high. Furthermore, the passage of IP shock were not associated with large disturbances in interplanetary parameters.

The Geomagnetic Data During the Considered Events

The appearance of sudden commencements (SC) of geomagnetic storms is a result of the interaction of the earth’s magnetosphere with the interplanetary shock waves and discontinuities flowing over it. Some studies [5, 10, 15, 30] 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 part of the 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 4 shows the variations of Dst ring current (left plots; 4a-c) and the Ap index of geomagnetic activity (right plots; 4d-f), during 19-22 October 1989, 14-19 July 2000, and 8-13 November 2000. 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 4a-c show that the observations of Dst index correlate well with the SC of geomagnetic storm onsets, while there are no significant changes around the flare occurrence. 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 the other events. Also, the Dst values during 8-13 Nov. 2000 show clearly that the IP shock wave has no significant role.

On the other hand, plots 4d-f displayed nearly similar behaviors. The rate of change in Ap index during the Bastille Day was about six times larger than observed in 8-13 Nov. 2000 event and two times stronger than the event of 19-22 Oct. ’89. In general, the Bastille Day event had the stronger geomagnetic disturbances than the other studied events.

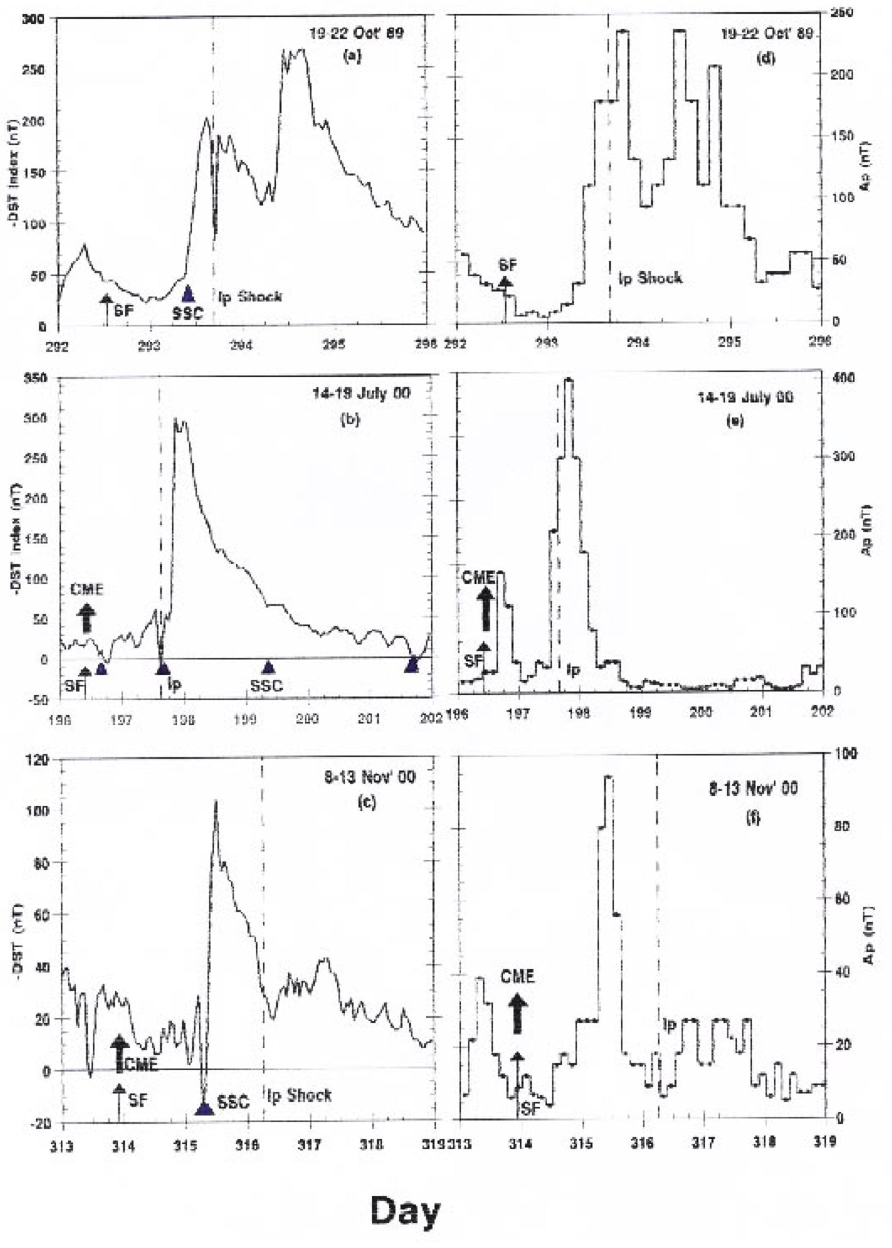

Fig. 4. The variations of the Dst ring current (left plots; 4a-c), and the Ap index of the geomagnetic activity (right plots, 4d-f) during the events of 19 October 1989, 14 July 2000, and 9 November 2000.

Conclusion

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. We have used the hourly solar energetic particles (SEP), cosmic ray intensities observed at south pole, the interplanetary measurements (field magnitude *B*, solar wind ion density *N*, solar wind ion temperature *T* and solar wind speed *SWS*), and the geomagnetic indices (the ring current geomagnetic activity index Dst and the 3-hour range of Ap). These measurements provided by the National Space Science and Data Center (NASA) and the Bartol Research Institute, University of Delaware, USA.

The 19-20 Oct. ’89 event had the largest (≥ 60 MeV) proton intensities. The arrival of major flare at 1258 UT on 19 Oct. ’89 was not associated with significant changes in solar and IP measurements. Strong changes in *B*, *SWS*, *T* and *N* have been observed as a result of the arrival of IP shock wave. The SEP increases resulted from particles acceleration at the shock front and persisted inside the IP shock region. 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.

The event of 14 July 2000 is the third-largest proton fluxes (above 60 MeV) since 1973, and it has the highest flux since the first event in Oct. ’89. The event was produced by very fast CME. The time profile of 14 July 2000 fluxes was not similar to that observed in 19-20 Oct. ’89. The acceleration of fluxes was not a function of the IP shock’s efficiency. The velocity of IP shock has been decelerated in its path in the inner heliosphere. The acceleration of the particles seems probably to have happened in the lower part of the solar corona. The rate of geomagnetic disturbances during the 14-19 July 2000 was stronger than the other events and included high changes. The third studied event of 9 November 2000 was accompanied by a fast CME. The event was not produced a GLE. Fast rise and long decay in particle intensities which may be originated from different sources on the sun. The IP shock was hardly deteriorated in its path to the earth. However, the results indicate that there is a quite difference in IP and geomagnetic disturbances and in turn the mechanism of particle accelerations between the three events. The three events were not having similar pattern or behavior in SEP fluxes and the interplanetary disturbances and the mechanisms of particle propagation in heliosphere were quite different.

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References

[1] Reames, D.V. "Particle Acceleration at the Sun and in the Heliosphere." *Space Science Rev.*, 90 (1999), 413-419.

[2] Reames, D.V. "Particle Acceleration by CME-driven Shock Waves." *AIP Confer. Proc.*, 516 (2000), 289-300.

[3] Reames, D.V. "Solar Energetic Particles: A Paradigm Shift." *Revs. Geophys.*, 33 (1995), 585-592.

[4] Nitta, N.V., Cliver, E.W., Tylka, A.J. and Smit, P. "Source Regions of Major Solar Energetic Particle Events." *28 International Cosmic Ray Conference*, 6 (2003), 3363-3366.

[5] Venkatesan, D., Ananath, A.G., Graumann, H. and Suresh, P. "Relationship between Solar and Geomagnetic Activity." *J. Geophys. Res.*, 96 (1991), 9811-9813.

[6] Crooker, N.U. and Gringauz, K.I. "On the Low Correlation between Long-term Averages of Solar Wind Speed and Geomagnetic Activity After 1976." *J. Geophys. Res.*, 98 (1993), 59-62.

[7] El-Borie, M.A. and Al-Thoyaib, S.S. "The Observational Aspects of the Three Largest Solar-energetic Particle Fluxes: 19-20/10/1989, 14/7/2000 and 9/11/2000." *28th International Cosmic Ray Conference*, 6 (2003), 3507-3510.

[8] Shea, M.A., Smart, D.F., Wilson, M.D. and Fluckiger, E.O. "Measurements of Solar Neutron Decay Protons During the 19 October 1989." *Geophys. Res. Lett.*, 18 (1991), 829-833.

[9] Web, Omniweb, http://nssdc.gsfc.nasa.gov/omniweb/form/, (2002).

[10] El-Borie, M.A. "Major Solar-energetic Particle Fluxes: I. Comparison with the Associated Ground Level Enhancements of Cosmic Rays." *Astroparticle Phys.*, 19 (2003), 549-558.

[11] El-Borie, M.A. "Correlation Studies of the Inclinations of the Heliospheric Current Sheet: II. 27 Day and 13.5 Day Waves of the Cosmic Ray Intensity." *Astroparticle Phys.*, 16 (2001), 181-191.

[12] El-Borie, M.A., Sabbah, S.S. and Bishara, A.A. "Diurnal Variations of Cosmic Rays During a Solar Magnetic Cycle." *Astron. Nachr.*, 317 (1996), 267-271.

[13] El-Borie, M.A., Duldig, M.L. and Humble, J.E. "Interplanetary Plasma and Magnetic Field Observations at 1 AU." *25th International Cosmic Ray Conference*, 1 (1997), 317-320.

[14] El-Borie, M.A., Duldig, M.L. and Humble, J.E. "Galactic Cosmic Ray Modulation and the Passage of the Heliospheric Current Sheet at Earth." *Planet. Space Sci.*, 46 (1998), 439-448.

[15] El-Borie, M.A. "North-south Asymmetry of Interplanetary Plasma and Solar Parameters." *Il Nuovo Cimento*, 24C (2001), 843-857.

[16] El-Borie, M.A. and Al-Thoyaib, S.S. "An Extended Features of the Ground-level Cosmic-ray Event of 29 September 1989.", *27th International Cosmic Ray Conference*, 8 (2001), 3450-3453.

[17] Bavassano, B., Iucci, N., Lepping, R.P., Signorini, C., Smith, J. and Villoresi, G. "Galactic Cosmic Ray Modulation and Interplanetary Medium Perturbations Due to a Long-living Active Region During October 1989." *J. Geophys. Res*., 99 (1994), 4227-4234.

[18] Lario, D. and Decker, R.B." Re-examination of the October 20, 1989 ESP Event." *27th International Cosmic Ray Conference*, 9 (2001), 3485-3488.

[19] Cane, H.V. and Richardson, I.G. "Cosmic Ray Decreases and Solar Wind Disturbances During Late October 1989." *J. Geophys. Res.*, 100 (1995), 1755-1762.

[20] Reames, D.V., Barbier, L.M. and Ng, C.K. "The Spatial Distribution of Particles Accelerated by CME-Driven Shocks." *Astrophys. J.*, 466 (1996), 473-479.

[21] Cane, H.V. and Richardson, I.G. "What Caused the Large Geomagnetic Storm of November 1978." *J. Geophys. Res.*, 102 (1997), 17445-17449.

[22] Vashenyuk, E.V., Gvozdevsky, B.B., Pchelkin, V.V., Polar, V.V, Usoskin, I.G., Mursula, K. and Kovaltsov, G.A. "The Ground-level Enhancement of 14 July 2000: Explaining the Difference between Nearby Neutron Monitors at Apatity and Oulu." *27th International Cosmic Ray Conference*, 8 (2001), 3383-3386.

[23] Belov, A.V., Butikofer, R.B., Eroshenko, E.A., Fluckiger, E.O. and Yanki, V.G. "Analysis of the July 14, 2000 GLE." *27th International Cosmic Ray Conference*, 8, (2001), 3362-3362.

[24] Bieber, J.W., Droge, W., Evenson, P., Pyle, R., Ruffolo, D., Pinsook, U., Tooprakai, P., Rujiwarodom, M., Khumlumlert, T. and Krucker, S. "Relativistic Solar Protons on Bastille Day 2000", *27th International Cosmic Ray Conference,* 8 (2001), 3434-3434.

[25] Bieber, J.W., Droge, W., Evenson, P., Pyle, R., Ruffolo, D., Pinsook, U., Tooprakai, P., Rujiwarodom, M., Khumlumlert, T. and Krucker, S. "Energetic Particle Observations During the 2000 July 14 Solar

Event." *Astro. Phys. J.*, 567 (2002), 622-629.

[26] Reames, D.V., Ng, C.K. and Tylka, A.J. "Heavy Ions Abundance and Spectra and the Large Gradual Solar Energetic Particle Event of 2000 July 14." *Astrophys J. Lett.*, 548 (2001), 233-241.

[27] Duldig, M.L." Fine Time Resolution Analysis of the July 2000 GLE." *27th International Cosmic Ray Conference*, 8 (2001), 3363-3366.

[28] Pchelkin, V.V., Vashenyuk, E.V. and Gvozdevsky, B.B. "Relativistic Solar Proton Dynamic During the 14 July, 2000 GLE, Modeling Results." *27th International Cosmic Ray Conference*, 8 (2001), 3379-3382.

[29] El-Borie, M.A. "Correlation Studies of the Inclinations of the Heliospheric Current Sheet With: I. Cosmic Ray Intensity of Different Rigidities." *Astroparticle Phys.*, 16 (2001), 169-180.

[30] Makarov, G.A. " Sudden Commencements of Geomagnetic Storms and the Conditions in Solar Wind." *Geomag. and Aernno.*, 34 (1994), 269-273.

دراسـة معاملات التغ ات الـشمسـية وا ال ا غناطيسي ب الكوك أثناء فيض ا سيمات عالية الطاقة الشمسية

سليمان الذييب

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(قدم للنشر في ١٤٢٥/١/٣هـ؛ وقبل للنشر في ١٤٢٥/٨/٤هـ)

ملخص البحث. تمت المقارنة بين قياسات طاقة الجسيمات الشمسية ومعاملات المجال المغناطيسي بين الكوكبي، وحددت الدراسة الاضطرابات المغناطيسية الشمسية التي تحدد خواص الجسيمات ذات الطاقات العليا. وتمت الدراسة أثناء أحداث محددة، ووجد أن الزيادة في شدة الجسيمات المقاسة عند زمن حدوث الصدمات المغناطيسية تتكون ليس فقط من الجسيمات المعجّلة في منطقة الصدمة بسبب التغيرات الكبيرة في المجال المغناطيسي ولكن أيضا من الجسيمات المعجّلة مسبقاً والتي بقيت حول الصدمات ولكن بميكانيكية مختلفة. ويلي حدوث تلك الصدمات ميل البلازما الشمسية إلى كونها أكثر كثافة وبرودة وأسرع منها في المناطق على حدود الصدمات. وكان معدّل التغيرات المغناطيسية خلال الفترة من ١٤ إلى ١٩ يوليو لعام ٢٠٠٠م أقوى من الفترات الأخرى. وبالعكس فإن الحدث الثالث يوم ٩ نوفمبر عام ٢٠٠٠م لم يفرز زيادة كبيرة ملحوظة عند مستوى الأرض. ولهذا فإن الارتفاع السريع والانحلال الطويل في شدة الجسيمات ربما تكون صادرة من مصادر مغناطيسية مختلفة من الشمس.