Intense cosmic ray effects recorded by the super 6NM64 Neutron Monitor of the Athens University during March-April 2001

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Abstract

A series of big Forbush effects in cosmic ray data was recorded by the Athens Neutron Monitor (NM) station from the second part of March to the end of April 2001. These effects are caused by an unusually extremely high solar activity during the last forty years. In this report the altitude and latitude dependence of these events in comparison with other stations of the Worldwide Neutron Monitor Network are studied. Especially, two strong Ground Level Enhancements (GLEs) in April 15 and 18, 2001 associated with great proton events such as those of the years 1956 and 1989 and registered in Neutron Monitor stations with low cut-off rigidities are mainly analyzed. In this case the high latitude stations, as the Athens one, would be very useful in order to evaluate the upper limit of energy of accelerated particles during these events.

1 Introduction

It is known that big Forbush effects give important information on the moving from the Sun magnetic structures and strong interplanetary shock waves connected with great solar flares and coronal mass ejections (Cane, 2000). Charged particles accelerated to high speeds by solar flares can be detected on the Earth at Neutron monitor stations referred as GLE. On the basis of Neutron Monitor (NM) data from the world wide NM Network characterized by different cut-off rigidities and altitudes we can determine the energy spectrum of primary cosmic ray variations (Belov et al., 2001). Athens Neutron Monitor station is important for estimation solar cosmic ray spectra since cut-off rigidity is closed to the upper energy limit of particles during the great proton flares. Frequently the upper energy of the particles accelerated at the sun is ranged within 5-10GeV that is very close to minimal energy of particles recorded in Athens. In this work using 1-min and hourly corrected for pressure data from 15 Neutron Monitor stations of high and middle latitude from the Worldwide network the spectrum of cosmic ray variations over a wide range of energy 0-9GV for the GLEs of April 15 and April 18, 2001 is derived conducting latitude surveys

2 Neutron Monitors and Solar Observations

Two strong ground-level events on April 15 at 14.00 UT and April 18 at 2.15 UT were registered at Neutron Monitor energies. They took place after a strong Forbush decrease, implying significantly disturbed interplanetary and geomagnetic conditions. A class X14.4/2B flare with heliocoordinates S20 W85 on April 15, 2001 (Easter effect) at 13:50 UT in active region 9415, together with an accompanying coronal mass ejection (CME) were followed by a large solar energetic particle event recorded by the Lion Instrument on SOHO and large ground level events starting at 14:00UT which were observed by neutron monitors worldwide. The start of the type II radioburst was recorded at 13.48 UT. An interplanetary shockwave reached at earth at 00:48UT on April 18, stimulating a high value of Kp index. The particle signatures exhibited a fresh injection from the same active region starting at 02:15UT on April 18 (a C2 flare and a CME). These events were followed by a further smaller GLE from 02:42UT. Time profiles of the GLE of April 15, 2001 using 1-min cosmic ray intensity values for a number of high latitude Neutron Monitors (Apatity 0.55 GV, Oulu 0.77 GV, Moscow 2.30 GV and Athens 8.53 GV) are presented in Fig.1. The event obviously has a short rise time and exponential decay. It started at about 14.00UT that means at least 12min after the type II radioburst took place. The maximal enhancement at the neutron monitors was reached quickly and time profile was simple enough and hot extended. A remarkable difference in the profiles at the two closely located stations of Apatity and Oulu was attributed to some magnetospheric effect under disturbed conditions in the 14 MLT dayside sector where Oulu station was located during the event, allowing a more easier penetration of solar protons into the inner magnetosphere and to the ground than expected from commonly magnetospheric models using statistical averages of the magnetic field. A similar feature was appeared in the GLEs of July 14, 2000 and May 2, 1998 (Koslovsky and Kanzas, 2001;Vashenyuk et al, 2001). The rigidity spectrum and time-profile of intensity distribution of solar particles causing GLE has various information about the dynamic structure of the interplanetary magnetic field in the heliosphere (El- Borie and S.S. Al-Thoyaib, 2001; Paizis et al, 2001). The cosmic ray intensity variations for the time interval 14-17 April 2001 including the two GLEs recorded at seven NM stations with different cut-off rigidities are illustrated in Fig 2. The hourly values are normalized to the mean cosmic ray intensity of 9-10 April, 2001. The first event is very sharp with a maximum increase of about 68 percent from the 13-14 UT level at Thule NM station, while the second one is small (about 13 percent from 01-02 UT level) (Cordaro et al, 2001). In this case thus we can say about acceleration up to 6.32 GeV at least. Data from many stations at once indicate that first particles came to the Earth at 14.00-14.01 UT and we can not exclude that small amount came even earlier. Charged particle of several GeV energy needs no less than 11 min to come in from the Sun. The analysis of previous proton events at Earth (Vashenyuk, 2001) shows that GLE onset is always delayed relatively to radio II radio emission by no less than 14 min. This indicates the most amount of arrived at Earth hard particles to be accelerated before maximum of the soft X-ray emission measured by GOES or nearly this time. The percentage cosmic ray intensity variation recorded in different NM stations for the considered GLEs with respect to the geomagnetic vertical cut-off rigidity is given in Fig. 3. It noteworthy that the rigidity spectrum of these events is exponetial and does not show the existence of a broad maximum around 1-2 GV, as in the case of Forbush decreases (Paizis et al, 2001). In the second GLE of April 18 the maximum enhancement is appeared in Apatity station and not in Thule station, due to the asymptotic cones. It is characteristic that solar protons have accelerated up to 6-7 GeV at least.

3 Conclusions

A preliminary analysis of GLEs on 15 and 18 April, 2001 observed by the worldwide neutron monitor network was carried out. The biggest flare in current solar cycle (X 14.4/2B) accompanying with a coronal mass ejection gave two strong GLEs. The first one is the largest proton event above 10 MeV since 1976. The two events were superimposed on a disturbed interplanetary background, where a strong Forbush decrease was in progress when the GLEs took place. A complex analysis of many relevant data suppose the particle acceleration up to relativistic energies to be occurred on the early phase of the flare and the proton enhancement had a relatively soft energy spectrum. However it contained high -energy particles up to 6-7 GeV at least. Timing of GLE of 15 April, 2001 and other characteristics of the event

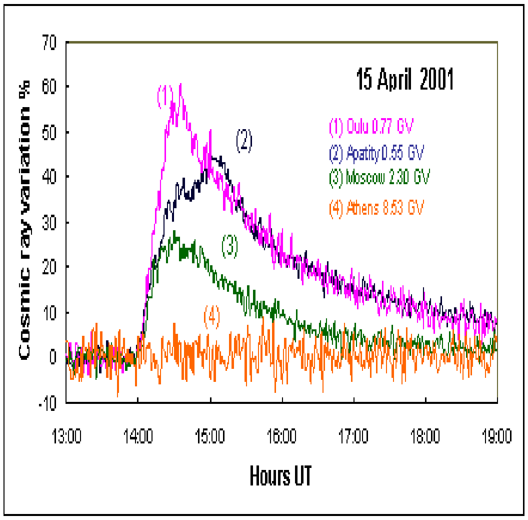

Figure 1: Intensity/Time profiles of the GLE of April 15, 2001 with 1-min cosmic ray intensity data for a number of high latitude Neutron Monitors (Apatity 0.55 GV, Oulu 0.77 GV, Moscow 2.30 GV and Athens 8.53 GV

lead to conclusion that relativistic particles suppose to be accelerated during the first 12 min after the type II radio burst started. Summarizing we can say that the renewed with all the modern requirements of data presentation Athens NM station makes an essential contribution to the Worldwide NM network. The study of Ground Level Proton Events and the selection of Solar Neutron Events is possible with this station, as it has the advantage of a high geomagnetic cut-off station which are not so many in the Worldwide Network. These stations are very useful to the Solar Terrestrial and Space Weather studies.

Acknowledgments

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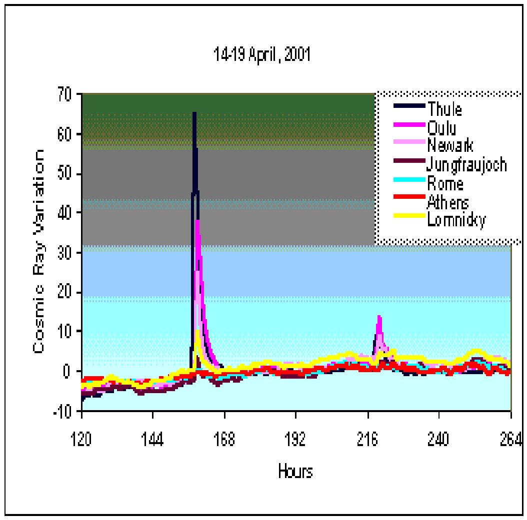

Figure 2: Hourly normalised cosmic ray intensity for the time period 14-17 April 2001 at multiple sites ranged in rigidity up to 9 GV.

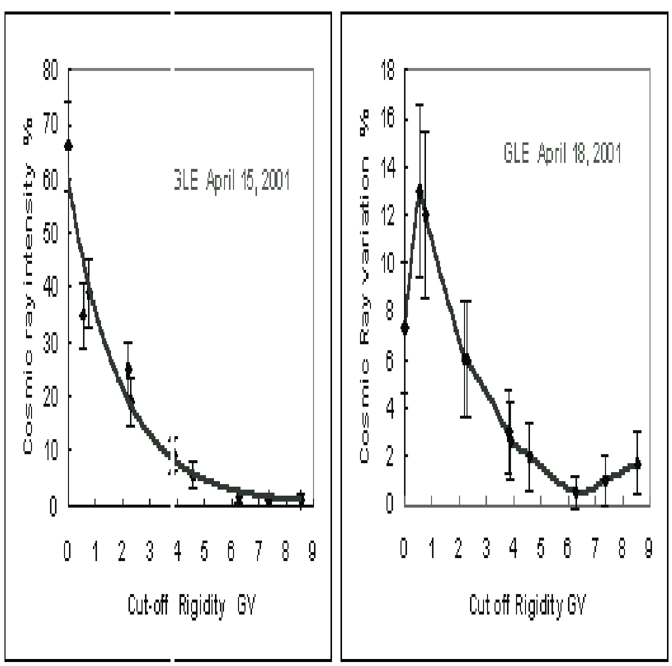

Figure 3: Rigidity spectrum for the two GLEs