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Advances in Space Research 35 (2005) 691–696
ADVANCES IN SPACE RESEARCH (a COSPAR publication)
www.elsevier.com/locate/asr

Unexpected burst of solar activity recorded by neutron monitors during October–November 2003

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Received 6 October 2004; received in revised form 24 November 2004; accepted 26 November 2004

Abstract

During the extreme burst of solar activity in October–November 2003, a series of outstanding events distinguished by their magnitude and peculiarities were recorded by the ground based neutron monitor network. The biggest and most productive in 23rd solar cycle active region 486 generated the most significant series of solar flares among of which the flare X28/3B on November 4, 2003 was the mostly powerful over the history of X-ray solar observations. The fastest arrival of the interplanetary disturbance from the Sun after the flare event in August 1972 and the highest solar wind velocity and IMF intensity were observed during these events. In one-week period three ground level enhancements (GLEs) of solar cosmic rays were recorded by neutron monitor network (28, 29 October and 2 November 2003). Maximum proton energy in these events seems to be ranged from 5 to 10 GeV. Joint analysis of data from ground level stations (neutron monitors) and satellite measurements allows the estimation of the particle path length, the onset time of the injection on the Sun and some other proton flux characteristics.

Keywords: Ground level enhancement; Solar cosmic rays; Neutron monitors

1. Introduction

Solar cosmic rays (SCR) can effectively be used for studying the processes of particle acceleration in the solar atmosphere and their propagation in interplanetary space, as well as for understanding the electromagnetic conditions at the Sun. On rare occasions a solar flare will accelerate protons to sufficiently high energies for these particles to propagate along the heliomagnetic field to the earth and be detected as a sharp increase in the counting rate of a ground based cosmic ray detector. Such events are known as ground level enhancements (GLEs). Since 1942 there have been recorded 67 GLEs by neutron and muon monitors.

An unusual burst of solar activity in October–November 2003 resulted in series of outstanding events recorded by ground based neutron monitor (NM) detectors. In a 6-days time period NM network recorded three GLEs of solar cosmic rays: on 28 October (GLE 65, also known as the "Greek effect"), on 29 October (GLE66) and on 2 November (GLE67). In the present work, we examine the time profiles of the observational variations of CR intensity at multiple sites, in a wide energy range, in order to allow the determination of the *amplitude*, the *onset time* and the *maximum energy* reached for each one of these three events. Data from several NM stations of the worldwide network (Fig. 1) are used. Moreover, for GLE 65 the onset time of the injection of the accelerated particles from the sun and

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0273-1177/$30 © 2004 Published by Elsevier Ltd on behalf of COSPAR.
doi:10.1016/j.asr.2004.11.023

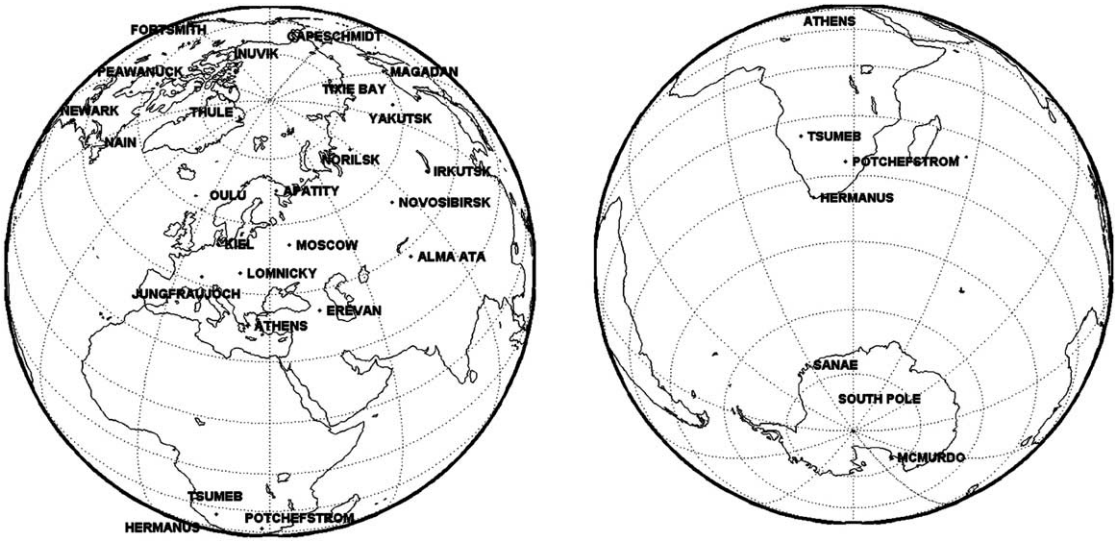

Fig. 1. Neutron Monitor stations of the worldwide network used in our analysis.

the length of their path in the interplanetary space is calculated.

2. Solar activity in October–November 2003

The sunspot number maximum of solar cycle 23 occurred in April 2000, while a secondary maximum was seen during the period September 2001–February 2002 (Coffey and Erwin, 2002). Therefore, year 2003 falls into the descending phase of the current solar cycle.

From mid-June until mid-October 2003 solar activity was relatively low: big or complicated active regions were absent. The situation changed in the second half of October with the appearance of sunspot group 484 on the eastern solar limb. On 19 October, this group started to generate big flares having already taken delta configuration of magnetic field. On 23 October another sunspot group (486), bigger and more dangerous (as it was located near the central meridian of the Sun), appeared on the visible part of the solar disk and started to generate series of great flares. The most important flares (>M4) generated by sunspot groups 484 and 486 in the period 19 October–5 November are presented in Table 1. It is clearly seen that sunspot group 486 generated 13 major flares (seven of them were very powerful, i.e. >X1), turning out to be the most productive sunspot group in the 23rd solar cycle. In the last days of October

Table 1
A list of the greatest flares (>M4) in October–November 2003 is given

Date	Sunspot group	T_1 (UT)	T_2 (UT)	T_3 (UT)	Location	Importance	Class
19/10/2003	484	16:29	17:04	16:50	N08 E58	1N	X1.1
22/10/2003	486	19:47	20:28	20:07			M9.9
23/10/2003	486	08:19	08:49	08:35	S21 E88	1B	X5.4
23/10/2003	486	19:50	20:14	20:04	S17 E84	1N	X1.1
24/10/2003	486	02:27	03:14	02:54	S19 E72	1N	M7.6
24/10/2003	486	05:04	05:16	05:10	S24 E74	1F	M4.2
26/10/2003	486	05:57	07:33	06:54	S15 E44	3B	X1.2
26/10/2003	484	17:21	19:21	18:19	N02W38	1N	X1.2
26/10/2003	484	21:34	21:48	21:40	N01W38	2N	M7.6
27/10/2003	486	09:21	09:32	09:27	S16 E26	SF	M5.0
27/10/2003	486	12:27	12:52	12:43	S17 E25	SF	M6.7
28/10/2003	**486**	**09:51**	**11:24**	**11:10**	**S16 E08**	**4B**	**X17.2**
29/10/2003	**486**	**20:37**	**21:01**	**20:49**	**S15W02**	**2B**	**X10.0**
2/11/2003	**486**	**17:03**	**17:39**	**17:25**	**S14W56**	**2B**	**X8.3**
3/11/2003	488	01:09	01:45	01:30	N10W83	2B	X2.7
3/11/2003	488	09:43	10:19	09:55	N08W77	2F	X3.9
4/11/2003	486	19:29	20:06	19:50	S19W83	3B	X28
5/11/2003	486	10:46	10:56	10:52	S16W90	SF	M5.3

T_1 is the time the detectors on GOES-10 started to record increase in the radiation flux, T_2 is the time the values of the radiation flux returned to the level preceding the event and T_3 is the time of maximum radiation flux. The time of emission of radiation (i.e., the real start time of the flare on the sun) is found by subtracting 8 min from T_1.