

Properties of the extreme solar particle events of the cycles 22 and 23

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Abstract. Ground level enhancements (GLEs) are short and sharp increases in the counting rates of cosmic ray intensity measured by neutron monitors. Studying these extreme solar particle events is of particular importance, since they are involved in a vast range of scientific applications. Such a case is the real time GLE alert system functioning in Athens neutron monitor station. In this work an effort to obtain and connect the main characteristics of the thirty one GLEs occurring during the last two solar cycles 22 and 23, is realized via statistical analysis. Despite the uniqueness of these events, characterized by specific solar and interplanetary conditions during the time period they took place, possible similarities of the GLE characteristics between different event cases may be evidence for the existence of common physical mechanisms. This analysis includes the calculation of the onset time and the determination of longitudinal and latitudinal distributions. One-minute and five-minute cosmic ray data provided from the worldwide network of neutron monitors as well as from the NMDB database (<http://www.nmdb.eu>) was used. The main properties of the analysed cases of GLEs are classified and some preliminary results are presented. The possibility to use them in space weather applications is discussed.

Keywords: Cosmic rays, neutron monitors, solar energetic particles

I. INTRODUCTION

Solar Energetic Particles (SEPs) are highly energetic particles that seem to be associated either with solar flares or with coronal mass ejections (CMEs). Particle flux with energy from 10KeV to some GeV per nucleon can pose threat to space missions or even to telecommunications. SEPs with energy greater than 500MeV can be recorded by ground-based detectors, resulting in ground level enhancements (GLEs). Since they are used in a vast range of scientific applications the study of GLEs has been occurring for a long period, while several techniques including the analysis and modelling of some of their characteristics have been developed. [1], [2], [3], [4], [5] and [6] are some worth mentioned works. Some applications are the prediction of harmful for the satellite systems and the telecommunications particle fluxes [7],

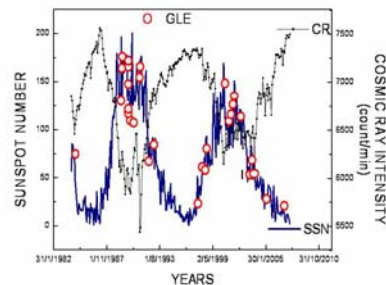


Fig. 1: Sunspot numbers (continuous line) together with cosmic ray intensity (from Apatity station, dashed line) and GLE occurrence (cycle points) during the 22nd and the 23rd solar cycles

[8], the analysis of the interplanetary conditions [9] and the prediction of strong geomagnetic storms [10]. To this direction a general GLE-alert system has been recently developed in Athens neutron monitor station [7], [11]. Using real-time data from 23 ground-based neutron monitors, this alert system is of major significance since it can provide the earliest alert possible for the onset of a SEP event. A general GLE-alert is declared when at least three stations are in alert mode. The system tries to detect a GLE at an early stage, while at the same time minimizes the possibility of a false alarm (see <http://cosray.phys.uoa.gr> for further information). During cycles 22 and 23, thirty one GLEs were recorded by the worldwide neutron monitor network. The very intense event of January 20, 2005, also known as GLE69 was among these events. Despite the fact that the majority of the fifteen GLEs of cycle 22 were recorded near the cycle's maximum phase, in solar cycle 23 extreme solar particle events occurred also near the maximum as well as in the inclining and declining phase of the cycle. The sunspot number, the cosmic ray intensity and the GLE occurrence in the time period from 1982 to 2007 are presented in Fig. 1. In this work the properties of the GLEs occurred in the cycles 22 and 23 are discussed through a statistical analysis and comparison among the events. This work is the continuation of a previous

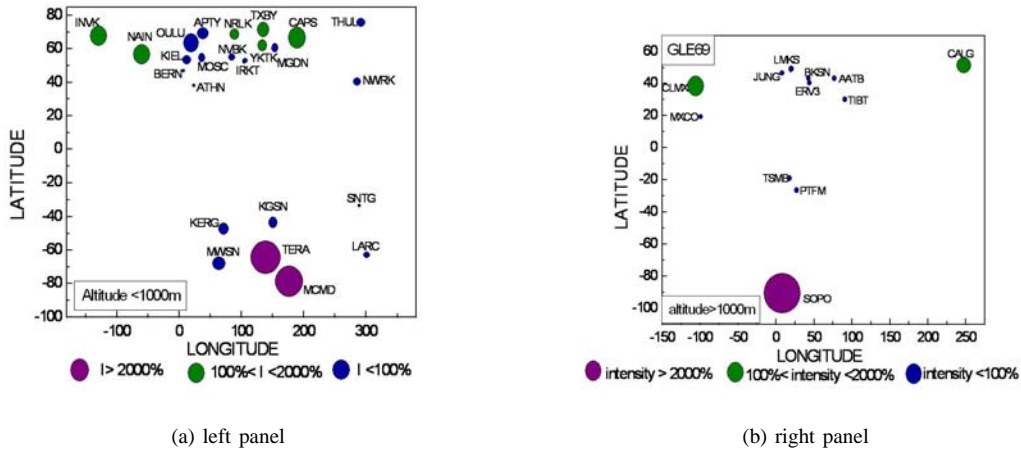


Fig. 2: Latitudinal-longitudinal distribution of GLE69 in different NM stations with altitude <1000m (left panel) and altitude >1000m (right panel)

work [12] that includes either additional or improved calculations of some important GLE parameters. Some of them include the calculation of the onset time of the events using 1-minute data, when this was possible and the determination of the asymptotic directions of viewing for several neutron monitor stations.

II. DATA ANALYSIS

Using 1-minute and 5-minute data from stations of the worldwide network of neutron monitors, collected and processed from the IZMIRAN group, ftp://cr0.izmiran.rssi.ru/COSRAY!FTP_GLE/, as well as from the recently created real-time High resolution Neutron Monitor Database (NMDB), <http://www.nmdb.eu> [13], some important characteristics for the eleven most intense events of cycles 22 and 23 were determined. The events analysed in this study are presented in Table I. More specifically, the onset times for every station that observed a specific event using 1-min and 5-min data, when it was available, were calculated, the identification of the maximum intensity rate as well as the time it was reached and the calculation of the time difference between the time of the maximum and the onset time was realized, using 5-min data for each station and each GLE.

Moreover, both the latitudinal, longitudinal, latitudinal-longitudinal distribution of each GLE maximum, for various altitudes were determined. Results of this analysis for GLE69 are presented in Fig. 2. A more complete picture of an event, calculating the solar proton trajectories as they several neutron monitors enter the Earth's magnetosphere and then determining how the event was observed in several geographical regions in Earth, can be generally obtained. The asymptotic directions of viewing for stations, during GLE69 are given in Fig. 3. A more detailed GLE analysis, based on the definition of the neutron monitor

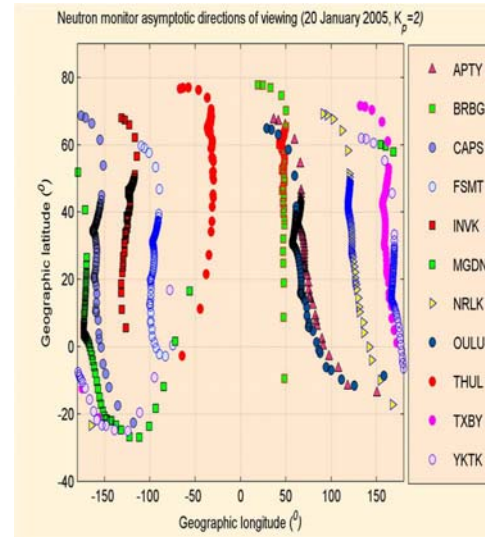


Fig. 3: Determination of asymptotic cones of acceptance of stations with latitude 60° to 90° for the case of the event of January 20, 2005

asymptotic directions of viewing is presented in [6] and [14].

The solar and geomagnetic activity during the period the events occurred was also examined. Onset time calculations using 1-min data was realized only for the events of the 23rd cycle since there was a limited number of available 1-min data for solar cycle 22. Therefore, the importance of the existence of a common database that includes a complete set of accurate data, such as the NMDB database is again revealed.

III. DISCUSSION -CONCLUSIONS

From the above analysis the following conclusions are derived:

Despite the fact that every single GLE event is a unique case characterized by its own properties, the joint

TABLE I: Results for some GLE characteristics

GLE event	NM by max ampl.	Ampl.(%) by 5min	Ton (UT) by 5min	Ton (UT) by 1min	Tmax (UT) by 5min	Tmax- Ton (min)
GLE42 29/09/1982	CALG	403.60	11:40	-	12:55	75
GLE43 19/10/1989	SOPO	91.80	13:05	-	16:35	210
GLE44 22/10/1989	MCMD	155.90	18:00	-	18:05	5
GLE45 24/10/1989	SOPO	202.90	18:35	-	20:35	120
GLE52 15/06/1991	SOPO	55.80	08:35	-	09:35	60
GLE59 14/07/2000	SOPO	57.80	10:35	10:34	11:25	50
GLE60 15/04/2001	SOPO	225.40	14:00	13:58	14:30	30
GLE65 28/10/2003	MCMD	44.70	11:10	11:16	11 :50	40
GLE66 29/10/2003	SOPO	34.00	20:35	20:32	22 :35	120
GLE69 20/01/2005	SOPO	4808.95	06:30	06:30	06:50	20
GLE70 13/12/2006	OULU	92.10	02:45	-	03:05	20

analysis of different events seems to give evidence in the existence of common characteristics. For instance, there seem to exist some preferable directions for the registration of the significant ground level enhancements.

An effort to determine these regions was made before in [12]. The altitude of the stations plays an important role as it concerns this classification.

Unfortunately, an exact determination of these regions cannot be made more accurately at present since in some geographical regions there was a lack of data and additionally not the same neutron monitor stations observed each GLE event. Some apparent differences in the intensity rates of the geographical regions among the events may be explained through the different asymptotic directions of viewing of a station for different events.

Furthermore, the use of 1-min data is necessary for a more accurate onset calculation that would lead to a more sensitive GLE-alert system [11]. Therefore data accuracy and upgrading the neutron monitor registration systems so that higher resolution data can be obtained are of major importance in order to study future events.

The work is to be continued and more detailed results will be presented in the near future. The results of this study could be proven useful for various space weather applications, provided that the desirable accuracy is achieved.

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