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COSMIC RAY EVENTS RELATED TO SOLAR ACTIVITY RECORDED AT THE ATHENS NEUTRON MONITOR STATION FOR THE PERIOD 2000–2003

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In this work a complete study of 359 solar flares, 111 Halo coronal mass ejections (Halo CMEs) and 45 Partial Halo events occurred from November 2000 to November 2003, is considered. This time period characterized by an unexpected activity of the Sun, was divided into 27-day intervals starting from Bartels Rotation No. 2284 (14.10.2000) to No. 2324 (25.11.2003), generating diagrams of the cosmic ray intensity data recorded at the Athens Neutron Monitor Station. On these qualitative data presented for the first time, a mapping of all available solar and interplanetary events, such as solar flares with importance C, M and X, coronal mass ejections (Halo and Partial) was done. The existence of a connection between solar flares with CMEs and the respective connection to the Forbush effects on yearly and monthly basis are discussed. The role of extreme solar events occurred in March-April 2001 and in October-November 2003 is also considered.

Keywords: Cosmic Ray Intensity; Space Weather Forecasting; Forbush decrease; Coronal Mass Ejections; Solar Flares

1. Introduction

As the sun is the driver of Space weather, solar events such as solar flares and coronal mass ejections are closely related to the Forbush effects recorded at the Neutron Monitor Stations. Forbush effect (FE) is a heliospheric phenomenon which is caused in the cosmic rays (CRs) by solar wind disturbances. The main sources of FE are Solar Flares (SFs) and Coronal Mass Ejections (CMEs) which are energetically the most important transient phenomena on the Sun. This paper is a comprehensive study of the relation between solar flares, coronal mass ejections and Forbush Decreases (FDs) recorded at the Athens Neutron Monitor station within the time period 2000 to 2003.

2. Data analysis

As it is known, Neutron Monitors (NMs) provide continuous ground based recording of the hadronic component in the atmospheric secondary radiation, which is related to primary cosmic rays. Our project is based on data in the form of countings taken from the Athens Neutron Monitor (cut-off rigidity 8.53 GV, super 6NM-64). Cosmic ray measurements in

Athens, initiated in November 2000 and are provided in real time to the internet (URL: <http://cosmicray.phys.uoa.gr>).[1,2] The resolution of the measurements reaches as much as one second – which is uniquely worldwide. Recently a new Neutron Monitor Network in real time, useful for space weather prediction has been established in this station. In this work a mapping of all available solar and cosmic ray data has been performed. The three-year time period, from 2000 to 2003, has been divided into 27-day intervals starting from Bartels Rotation (BR) 2284 to BR 2324. All information about these events, such as the time of first observation, the date of the event occurrence and its co-ordinates are presented (Fig. 1).

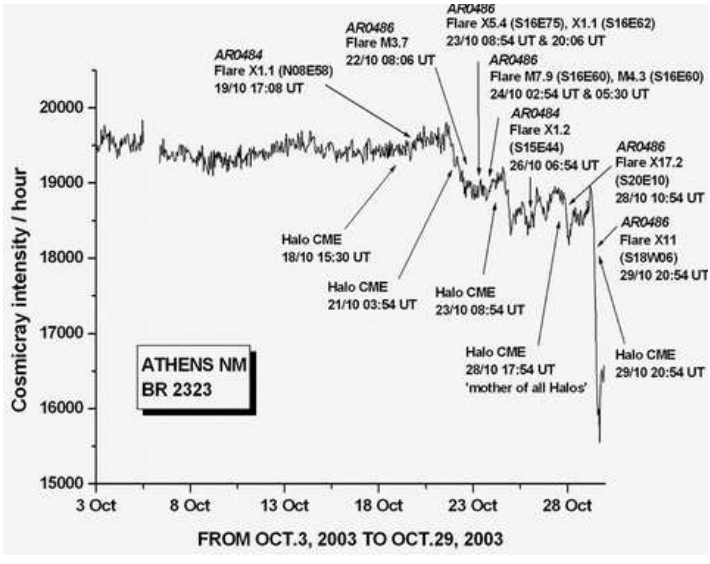

Fig. 1. An example of the mapping diagrams for BR 2323 (3 to 29 October, 2003).

3. Statistical analysis

A detailed statistical analysis of our data creating histograms of Halo CMEs, Forbush decreases and flares with importance less or/and greater than M is performed. As can be obtained by Refs. 3, 4 and 5 a number of papers in the field indicates a strong possible connection. At this point we are almost at the end of the 23rd solar cycle. Unexpected unique phenomena took place from March to April 2001 and October to November 2003 (BR 2289, 2323, 2324) when intense activity was recorded. The expected peaks indicated in the histograms (Fig. 2) for the periods mentioned above, represent the extreme events of the discussed periods. The analysis made clear that there is – at least a statistical – correlation between SFs and Halo CMEs (49 per cent). Furthermore the occurrence rate between Forbush decreases and Halo CMEs showed that a significant percentage of 55 per cent indicates the correlation.

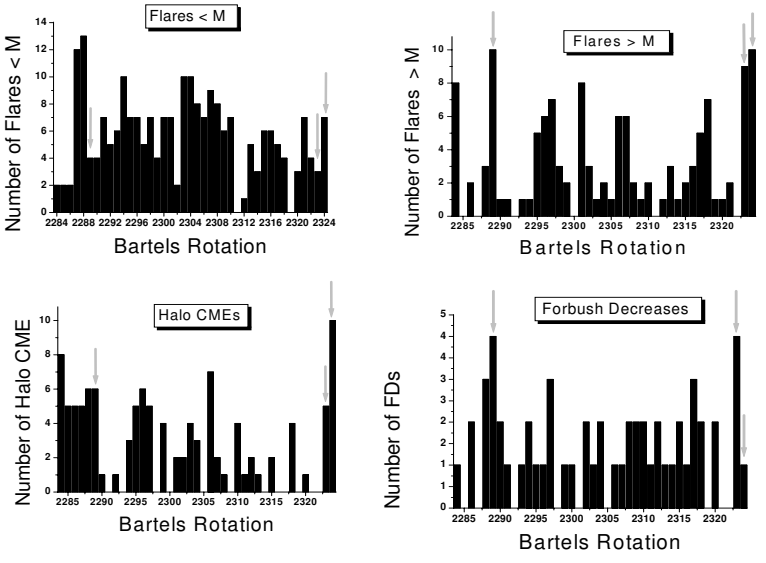

Fig. 2. Histograms of Solar and Heliospheric events for the period 2000–2003.

4. Conclusions

The following results can be extracted: (i) A number of 359 flares and 111 Halo CMEs occurred within the studied period, caused 56 Forbush decreases of the cosmic ray intensity on the ground based NMs. (ii) During this period two extreme bursts of solar activity in March–April 2001 and October–November 2003 were recorded. (iii) Outstanding events distinguished by their magnitude and unusual peculiarities were observed. In particular, one of the most astonishing Halo CMEs took place on the 28th of October 2003 and it was actually called "Mother of all Halos". It provoked a major Ground Level Event (GLE) called "Greek Effect" and a series of Forbush decreases. Three GLEs recorded in one week at the end of October 2003. Aurora was visible even from lower latitudes and it was very clear at Athens on the 20th of November 2003. Our results will be useful for better understanding of Space Weather phenomena.

Acknowledgements

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