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Mapping of the cosmic ray events related to the solar activity for the period 2003-2005

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Abstract

The relationship between cosmic ray intensity decreases and solar events is still an open field of space research. In this work a complete study of solar events occurred from January 2003 to December 2005, is considered. This three-years time period characterized by an unexpected activity of the Sun was divided into 27-day intervals starting from Bartels Rotation 2313 (06.01.2003) to 2353 (21.12.2005), generating diagrams of the cosmic ray intensity data recorded at the Athens Neutron Monitor Station. This station is working at an altitude of 260m and cut-off rigidity 8.53GV provided to the Internet high-resolution data in real-time. A mapping of all available solar and interplanetary events, such as solar flares with importance M and X, coronal mass ejections (Halo and Partial) was done. As we are going down from the solar maximum to the declining phase of the 23rd solar cycle, a statistical overview of the corresponding relationship among these phenomena, the significant percentage of the connection of Halo CMEs and solar flares and the respective connection to Forbush decreases on yearly and monthly basis are discussed. The close association, as well as a probable quantitative analysis, between solar events is being denoted. The role of extreme solar events occurred in October / November 2003 and January 2005 are also discussed. Obtained results may be useful for predictions of transient solar events and space weather forecasting.

Introduction

As the sun is the driver of Space weather, solar events such as solar flares, coronal mass ejections etc. are close related to the Forbush effects recorded at the ground based Neutron Monitor Stations. There are numerous indications that natural solar variability-driven time variations of the Earth's magnetic field can be hazardous in relation to health and safety.

• A solar flare (SF) is defined as a sudden, rapid, and intense variation in brightness. It occurs when magnetic energy that has built up in the solar atmosphere is suddenly released.

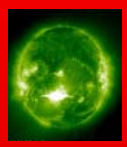


Figure 1: Solar Flare occurred at 28/10/2003

Figure 2: Typical CME

• Coronal Mass Ejections (CMEs) are plasma eruptions from the solar atmosphere involving previously closed regions which are expelled into the interplanetary medium.

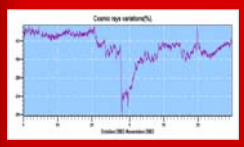


Figure 3: A consequence of great Forbush decreases occurred at Oct./Nov. 2003

• Forbush decrease (FD) is a heliospheric phenomenon which is caused in the cosmic rays (CR) by solar wind disturbances, which - in their turn – are caused by processes of the Sun

Athens Neutron Monitor Station

Cosmic ray measurements in Athens (37.58°N, 23.47°E) initiated in November 2000 with a standard 6NM-64 neutron monitor. The measurements of the station are being elaborated automatically in order to be compatible to other stations data because of the necessity to compare a number of high rigidity stations in a good quality data which is required for a detailed study of CR variations and space weather conditions. The resolution of the measurements reaches as far as one second – which is uniquely worldwide.

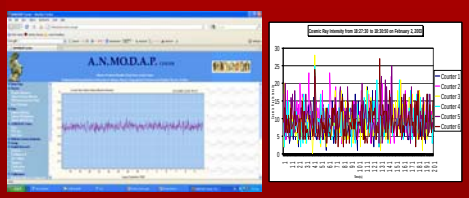


Figure 4: Extreme events recorded at the Athens Neutron Monitor Station - July/August 2004 - (upper panel) and 1-sec High Resolution Data (lower panel).

In this work a brief presentation of the relation between solar flares (SF), Coronal Mass Ejections (CMEs) and Forbush decreases (FD) recorded at the Athens Neutron Monitor Station for the time period 2003 to 2005 is outlined. This examined period covering forty Bartels Rotations, from BR2313 to BR2353 gives very interesting results on occurred extreme events.

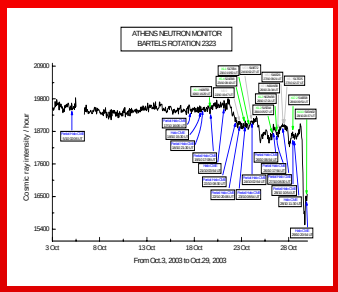
Data Sources

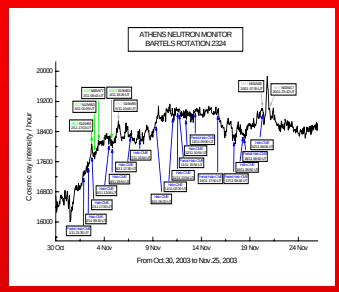
Athens NM data are available in the on-line database at: http://cosray.phys.uoa.gr.

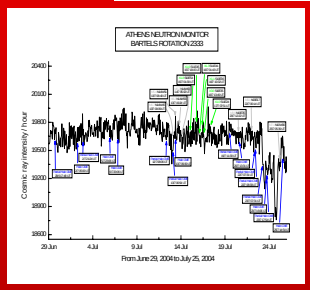
CME Lists of the U.S. Naval Research Laboratory (NRL) on the Large Angle and Spectrometric Coronagraph (LASCO) are used. These lists represent a subset of the final LASCO dataset and can be accessed through the web at the site: http://cdaw.gsfc.nasa.gov/CME_list. Data for solar flares were taken from: http://www.ngdc.noaa.gov/stp/SOLAR/ftpsolarflares.html.

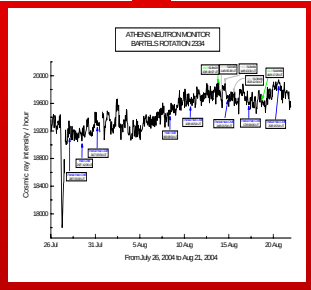
Mapping of Solar Activity on CR data

On the constructed diagrams all available data, such as: time of first observation, date the event occurred and its co-ordinates are recorded. In this way an overall statistical picture of the relation between CMEs, Flares and Forbush decreases (FD) is appeared.









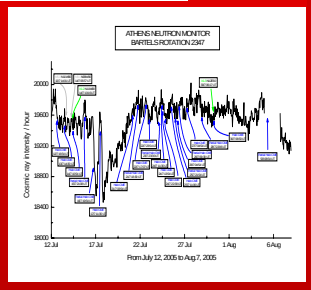


Figure 5: Cosmic Ray Intensity as recorded from Athens Neutron Monitor for the extraordinary periods of 3Oct. to 29Oct. (BR 2323), 30Oct. to 25Nov. (BR 2324), 29Jun. to 25Jul. 2004 (BR 2333), 26Jul. to 21Aug. 2004 (BR 2334) and 12Jul. to 7Aug. 2005 (BR 2347) .

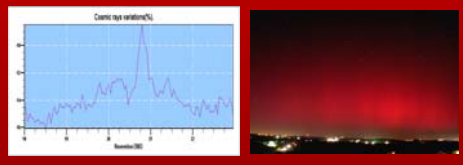


Figure 6: The big magnetic storm and the aurora in Athens on November 20, 2003 .

Results

The detailed analysis of the CR data of the Athens Neutron Monitor Station during the characterized time period 2003 – 2005 in relation to the solar events leads us to the following results:

➔ During this period three extreme bursts of solar activity in October-November 2003, July-August 2004 and July 2005 were recorded. Outstanding events distinguished by their magnitude and unusual peculiarities were observed. In particular :

- Three Ground Level Events in one week at the end of October 2003
- Aurora was visible even from lower latitudes. It was very clear at Greece on the 20th of November. (See Figure 6)
- 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 provided a major GLE called 'Greek Effect' and Forbush decreases of 21% as recorded at Athens NM (See Figure 5)
- The irregular Forbush effect of July 17, 2005 was clearly registered.

➔ It is noteworthy that all of the forth mentioned events was also connected to intense solar events, though some evolved in the background of quiet geomagnetic conditions.

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