Cosmic ray variations and anisotropy near Earth during the July 16, 2005 Forbush decrease: Results from ANMODAP CENTER

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35-words abstract

During July 2005 intense solar activity resulted an intense Forbush effect that was followed by a sharp enhancement of cosmic rays with a duration of less than 24 hours. The ANMODAP Center determined that it was neither a ground level enhancement nor a geomagnetic disturbance.

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INTRODUCTION

Whenever an intense or/and unusual decrease or increase in cosmic rays is recorded, it is essential to analyse the background of the event regarding solar and geomagnetic activity as well as cosmic ray activity and anisotropy [1]. It is clear that solar blasting events, such as solar flares (SF) and coronal mass ejections (CMEs), produce significant variations in cosmic ray (CR) intensity. Over the years a lot of attempts [2], [3], [4] have been made in order to establish specific criteria on the impact of these phenomena to CR modulation. As a result, it is commonly pointed out that, solar extreme events influence CR in a dynamic way.

An analysis of the solar and interplanetary background has been made for the mid-July events of 2005. It is characteristic that through one week's time (11^{th} to 18^{th} of July) solar activity ranged from low to very active. Thereafter, the number of sunspots decreased until a blank Sun was observed on the 17th of July. The blank Sun remained for a number of days until the 22^{nd} of July. In that interval of time, a significant number of solar events took place. In a total 35 C-class, 13 M-class and 1 X-class SF, as well as five Halo CMEs were produced from a single active region (NOAA AR 786), highlighted by the events of the 14^{th} of July where two SFs of importance X1.2 and M9.1 and even Halo CMEs occurred. It is noticeable that on the 18^{th} of July the Sun was spotless at the Earth side but had a good sized sunspot at the far side. This sunspot traced from the 14^{th} of the month and had a significant role in the development of interplanetary conditions. As a result, the Earth's magnetic field was impacted, and the shock arrived at the Earth on the 16^{th} to 17^{th} of July.

Despite the fact that the main flares occurred on the western portion of disk, the interplanetary space near Earth was not strongly disturbed. Solar wind velocity was limited to ~500 km/s and the Interplanetary Magnetic Field (IMF) intensity ranged within 15 nT. Geomagnetic activity was also relatively quiet, the Kp index did not exceed the value 5 while the lowest Dst index was ~-70, and there was no strong shock (Sudden Storm Commencement - SSC).

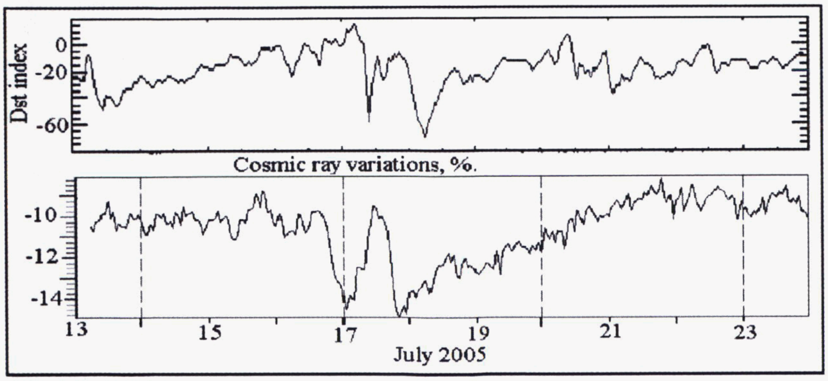

Figure 1: Dst variations and cosmic ray counting rate from Athens neutron monitor station.

Nevertheless, the event was also characterized by unusually high anisotropy of cosmic rays (~7-8%), especially of the equatorial component, with a direction to the western source of this anisotropy.

From all available neutron monitor and satellite data, an effort has been made to acknowledge the possible causes that triggered those events that never before have been revealed in the history of CR. In addition, a detailed analysis of these events was carried out, from the onset process, by the Athens Neutron Monitor Data Processing Center (ANMODAP).

ANMODAP CENTER

Galactic CR density started to fail from the 10th of July and by the 16th of July had a decrease ~2%, after a series of relatively weak Forbush effects. Most dramatic events occurred on 16th of the month, when FD reached 8% in several stations, only in a few hours. The CR intensity recovered rapidly up to the starting level, but in the mid of the next day a sharp decrease started again and reached the same 8% at many stations, followed by the classical FE profile. At the 16th of July the ANMODAP Center [5], [6] recorded a Forbush decrease from 23 neutron monitors in real time around the globe (6% variation in Athens). The decrease was the result of the solar and geomagnetic activity that has already been described and had a significant signature at almost all stations despite their geographical position.

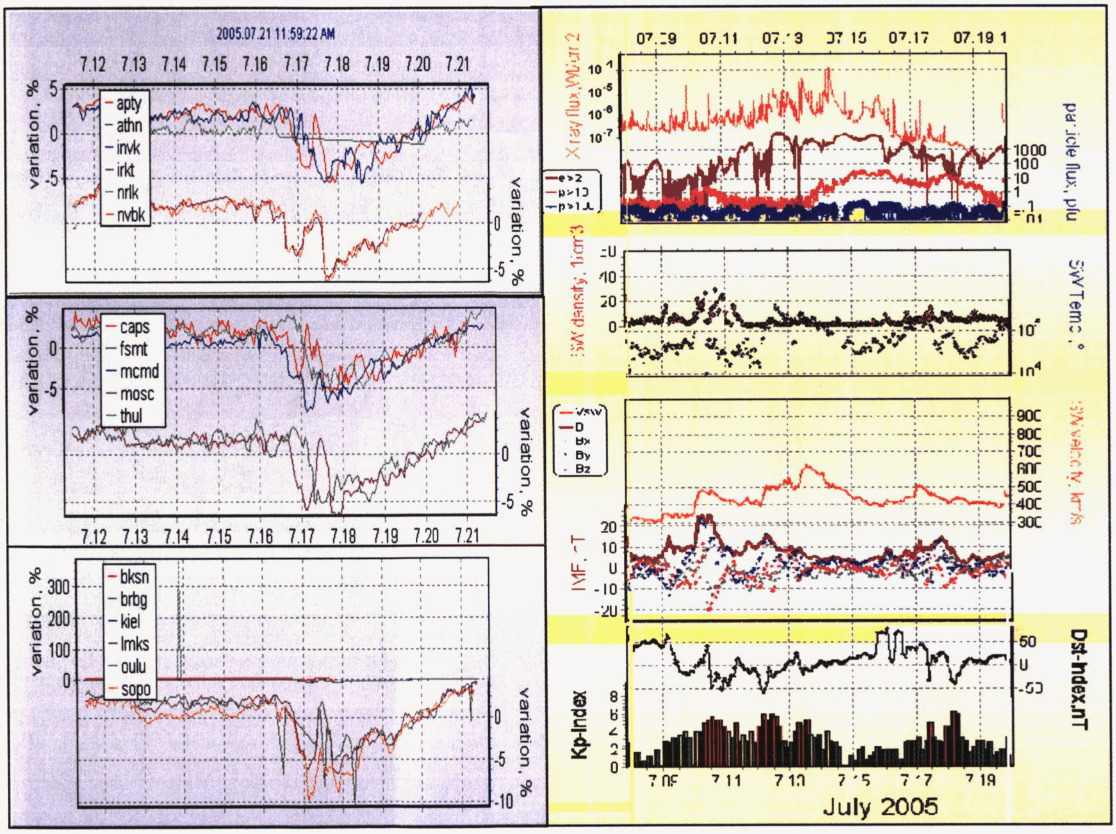

Figure 2: Neutron monitor data from all real time stations (left panel) and satellite data from GOES and ACE (right panel) are presented for the time interval 12 to 21 of July 2005. (URL: http://cosray.phys.uoa.gr)

The Onset program of ANMODAP Center can determine whether or not the enhancement, which was recorded on the 17th of July was a Ground Level event (GLE) or a geomagnetic disturbance [7], [8]. The outcome of the Onset process showed that it was neither a GLE nor a geomagnetic disturbance. This algorithm makes use of hourly cosmic ray data and although it spotted the sudden enhancement it responded that this was more gradual, in no case sudden and without an increase in the X-ray or particle channels from GOES. The geomagnetic activity remained in low levels and as a result, the enhancement did not present typical characteristics of a GLE.

ANISOTROPY

The structure evolution of interplanetary disturbances is dominated by anisotropy in a rather complicated way then flux. The use of the first order anisotropy extends the capabilities to diagnose solar wind structure, although often this is not enough to reach to a conclusion about the structure of a disturbance and predict its development. In order to obtain the variations in the flux and the first harmonic of anisotropy for 10GV cosmic rays, data from as many stations as possible from the entire world network of neutron monitors (40 – 45 stations, with their own properties: coupling coefficients and yield functions) can be used. The calculation of the anisotropy components is being performed by the Global Survey Method (GSM). Figure 3 illustrates the north-south component of the anisotropy Az as a series of vertical lines originating from the plot of CR flux as a function of time. The equatorial component of the anisotropy: $A_E = sqr\,(A^2_x + A^2y)$ is presented by a series of head to tail vectors. Thin lines establish time correspondence of the vector and CR density diagram [8].

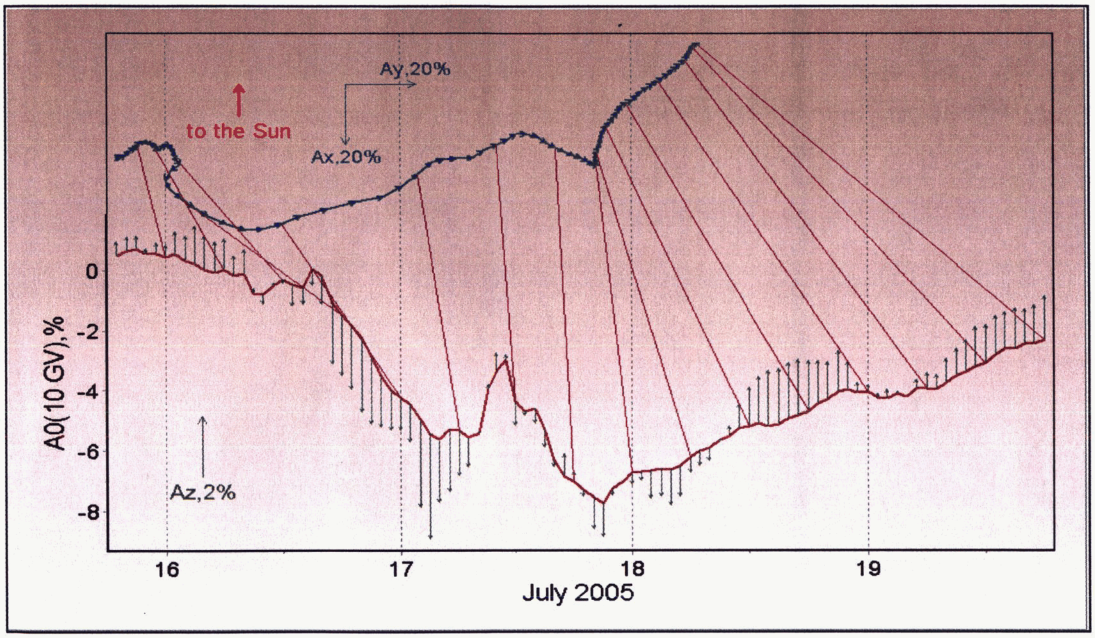

Figure 3: Variation of 10GV cosmic ray density and the equatorial first order anisotropy during the unique events of July 2005. The north-south anisotropy is presented by vertical arrows along density curve.

As can be obtained by this figure the anisotropy vector Az increases significantly within the declining phase of the FD on the 16th to 17th of July and changes its direction in the mid of 17th of July. This increase of the amplitude and the direction change are typical responses of the first order anisotropy to a shock. A_E is constantly changing its direction and increases, especially during the second FD which followed the sharp enhancement of the mid 17th of the month. Az changes sign from positive to negative throughout this disturbed period. The big equatorial component of CR anisotropy at this time is evidence of an intensive inflow of particle flux from the eastern direction that provided fast recovery of the FD.

All anisotropy components reveal sharp and big changes that occurred on the background of a more or less quiescent interplanetary and geomagnetic conditions [9], [10].

CONCLUSIONS

The above analysis of all neutron monitor and satellite data showed that solar activity, which preceded the extreme cosmic ray events on the 16^{th} and 17^{th} of July, could pr0duce the gigantic Forbush decrease of the 16^{th} of the month, although it can not justify the great amplitude of the decrease (~8 %). The geomagnetic and interplanetary activity near Earth was relatively quiescent. The geomagnetic field was disturbed essentially less then cosmic rays, although a minor magnetic storm evolved on the 17^{th} of July when Kp index exceeded the value 5. The big equatorial component of CR anisotropy observed at the same time is evidence of an east-opened structure which caused an intensive inflow of particle flux from the eastern direction that provided fast recovery of the FD just after the minimum. The sudden CR increase on the 17 July did not present the characteristics of a ground level enhancement or a geomagnetic effect confirmed by the onset program of ANMODAP centre. In a whole the CR behaviour on 16^{th} -17^{th} of July is the result of the crossing, by the Earth, of a complicated structure of the periphery area of the giant Forbush effect which developed in the western part of the inner heliosphere after the full halo CME release on 14^{th} of July.

This initial analysis implies intense events of possible great scientific interest. A more detailed analysis as well as the study of other similar events using ANMODAP and IZMIRAN databases will be followed in order to provide solid physical answers to this peculiarity.

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