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Major Forbush Decrease recorded by Lead Free-Neutron Monitor

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A strong Forbush decrease was observed by the ground-based lead free Gulmarg Neutron Monitor (GNM) at High Altitude Research Laboratory - Gulmarg in response to the burst of solar eruptions on the sun at the end of October 2003. The GNM also records bunches of neutrons detected in pre-determined small time intervals of 50 milli-seconds duration each, in groups of 1 to 9. The hourly integrated neutron intensity decreased to about 16% and the percentage decrease in neutron bunch recording channels varied from about 9% in bunch-1 to about 50% in bunch-5. This paper presents the results using the data recorded by this neutron monitor.

1. Introduction

Highly energetic solar eruptions were produced on the sun at the end of October and the beginning of November 2003. This interval had everything: very large sunspot regions; intense solar flares; particle events; and geomagnetic disturbance. A wide range of effects were felt around the world due this remarkable solar activity. Two active regions (NOAA regions 0486 & 0488) located close to the centre of the visible solar disk produced these eruptions causing a series of very intense geophysical, interplanetary and other magnetospheric effects. Ground based worldwide network of conventional neutron monitors have recorded the Forbush decrease following the major solar flare that occurred on the sun on 28th of October and had X-ray importance of 17.2 and heliographics co-ordinates as S18-E08 [1, 2, 3]. The inspection of the 3 minute resolution neutron count recorded with three independent channels of the GNM reveal a strong Forbush decrease in overall integrated count and also in the neutron bunches, coinciding with the decrease registered by several worldwide neutron monitors and muon telescopes. This solar burst also resulted in decreased geomagnetic index Dst upto -300 nT at High Altitude Research Laboratory - Gulmarg indicating a large geomagnetic storm.

2. Gulmarg Neutron Monitor

Gulmarg is a high rigidity (11.6 GV), mid latitude (34.07° N), high altitude (2743 m.a.s.l) station with geographic longitude of 74.42° E. The neutron monitor at Gulmarg was previously operated as an IGY type instrument for more than two decades and provided many significant results during this period [4, 5, 6]. The present system is a modified version of the original IGY type cosmic ray neutron monitor optimized to record the 2.45 MeV fusion neutrons supposed to be produced in the atmospheric lightning discharges and simultaneously function as a low energy cosmic ray neutron detector. Three major modifications were made in the original GNM to suite these requirements [7, 8, 9, 10, 11, 12]. These include the complete removal of the producer lead and inner paraffin moderator from the system and the reduction in the thickness of the upper paraffin from 28 cms to 8 cms. This lead free neutron monitor consists of 21 enriched BF_3 counters, each 90 cms long and 3.8 cm in diameter spread in the form of a pile over 28 cms thick paraffin slabs covering a total surface area of $3x10^4$ cm^2. The counters are covered with 8 cms paraffin wax slabs from above to sufficiently thermalize the 2.45 MeV D-D fusion neutrons and allow there detection with an overall efficiency of 3%. The average efficiency was found experimentally using a Pu-Be neutron Source. The thick paraffin base helps render the monitor essentially opaque to low energy background neutrons entering it from below as it sets an energy threshold of $>$ 50 MeV for Neutrons and $>$ 180 MeV for protons that can enter the monitor from below due to interaction of high energy cosmic rays with the ground. It also serves as a reflector of neutrons that enter the pile from above. The count rate of about $3.6x10^4$ per hour of the neutron monitor is considerably lower than that of the IGY monitor because of the absence of lead and the presence of just half the mass of paraffin compared to an IGY type neutron monitor. The monitor is divided into three separate channels each comprising of seven counters. The counters are segmented into three sections to prevent any chance of disturbance in the counters or electronics being recorded as a count due to neutrons. Each channel is connected via the electronic chain comprising of specific preamplifiers, amplifiers and discriminators to the registration node, which consists of a PC/AT and an RS-232C data acquisition interface. The registration node also collects the atmospheric pressure from a BCD multiplexed and interfaced bus of a digital barometer, which houses a Motorola semiconductors MPX4115A pressure sensor [13]. The registration node in the counting room is connected to a remote analysis node in the data analysis room via an ethernet interface to allow monitoring of the individual channel data without disturbing the registration node and its data acquisition system. This gives an opportunity for checking the quality of data, comparing directly with stations having their data displayed on the internet in realtime, and correction for the meteorological effects. From the analysis node we can check the three minute interval data of all channels separately and together. The pressure coefficient of the monitor was determined by using data on 14 major atmospheric pressure troughs recorded at the site of observatory as well as uninterrupted data of 120 days of neutron count rate and atmospheric pressure. Based on this data a regression analysis of the atmospheric pressure and neutron count rate reveals a barometric pressure coefficient of -0.845% per mbar, in close agreement with reported values [14].

A neutron bunch detector is incorporated with the neutron monitor to record rates of neutron pulses of upto 9 detected neutrons in a predetermined small time interval of 50 milli-seconds each. Thus the monitor is capable of providing us rates on the detection of neutrons coming in groups of 1 to 9 in predetermined time interval. The detector receives neutron pulses from 21 BF_3 counters of the monitor, which appear as a train of neutron pulses. This is accomplished by opening a time gate initiated by first neutron count and adding the subsequent counts that occur during the gate length. The total number of counts in each event determines the bunch level.

3. Data analysis and results

The low energy GNM recorded the Forbush decrease on october 29th with 0951 Hours UT as the onset time as a consequence of X17.2/4B class solar flare on October 28th, 2003.The identification of the onset time has been made from the three-minute resolution data available from the monitor. The pressure corrected hourly integrated intensity from the GNM for the period October 26 to November 5 has all the features of the Forbush decrease as recorded by other worldwide conventional neutron monitors. The decrease in the integrated counts recorded by the GNM is about 16% following the onset of the event. We present in figure. 1. pressure corrected hourly neutron count rate (%) for the period October 26 to November 5. The 100% countrate is taken as average of 72 hours of counts occurring before the onset time of major decrease on 29th of October 2003. It is clearly seen that with onset time of 0951 Hours UT, the sudden amplitude decrease of 16% is followed by slow recovery. Also presented in figure. 2. are the variations observed in neutron bunch data from bunch 1 to bunch 5. The decrease in neutron bunches coincides with the decrease registered by the individual channels of the neutron monitor. It is seen from the figure. 1. and figure. 2. that the the onset time and profile of Forbush decrease as observed in integrated neutron count and bunch data is similar. However, the rates recorded in bunches 6 to 9 are very low and scanty and are not presented here. The decrease similar to that observed in figure. 1. is also seen in figure. 2. (plots b,c,d,e,f). In figure. 2. (plot a) we present bunch no. Vs the % decrease. It is observed that percent decrease increases from about 9% in bunch-1 to about 50% in bunch-5. The percentage error increases as one moves from lower bunches to higher bunches.

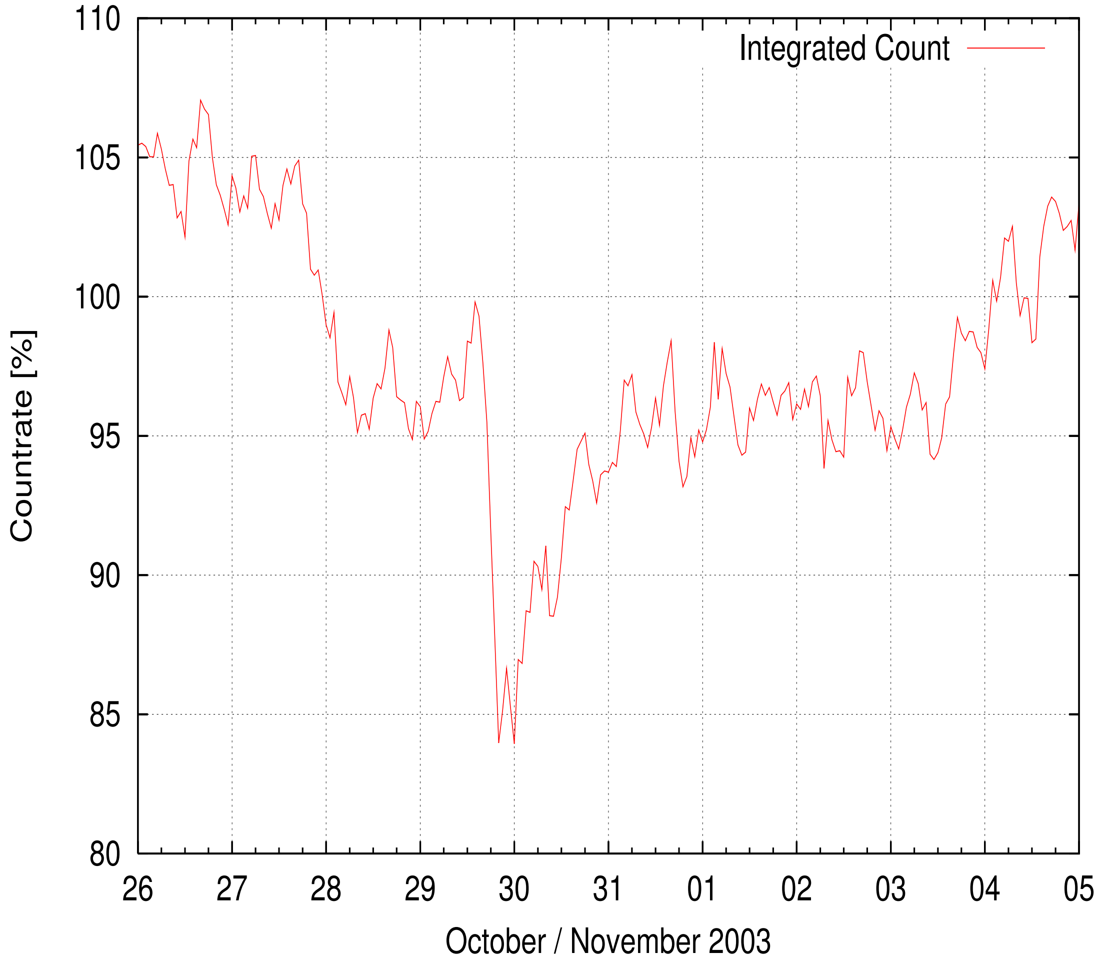

Figure 1. Pressure corrected hourly neutron count rate [%] of the GNM from October 26 to November 5, 2003 overlapping the occurrence of a X17.2/4B class Solar flare with onset at 9:51 Hrs UT on 28 October.

4. Discussion

We presented experimental evidence of recording a major Forbush decrease as a result of the extremely high activity on the Sun and in the heliosphere that took place in October-November 2003 during the declining phase of the 23rd solar cycle. During this period complex plasma and magnetic disturbances were formed as a result of the gushing solar wind. The coronal mass ejection initiated by this flare was emitted at a very high speed and was directed towards the earth. It passed the Earth after less than a day and was followed by a region, depleted of cosmic rays and possibly resulting in a Forbush decrease of about 16% in the hourly integrated and the bunch counting rates of the ground based GNM. The results indicate effectiveness of observing the solar modulation effects like Forbush decrease with the help of a lead-free neutron monitor.

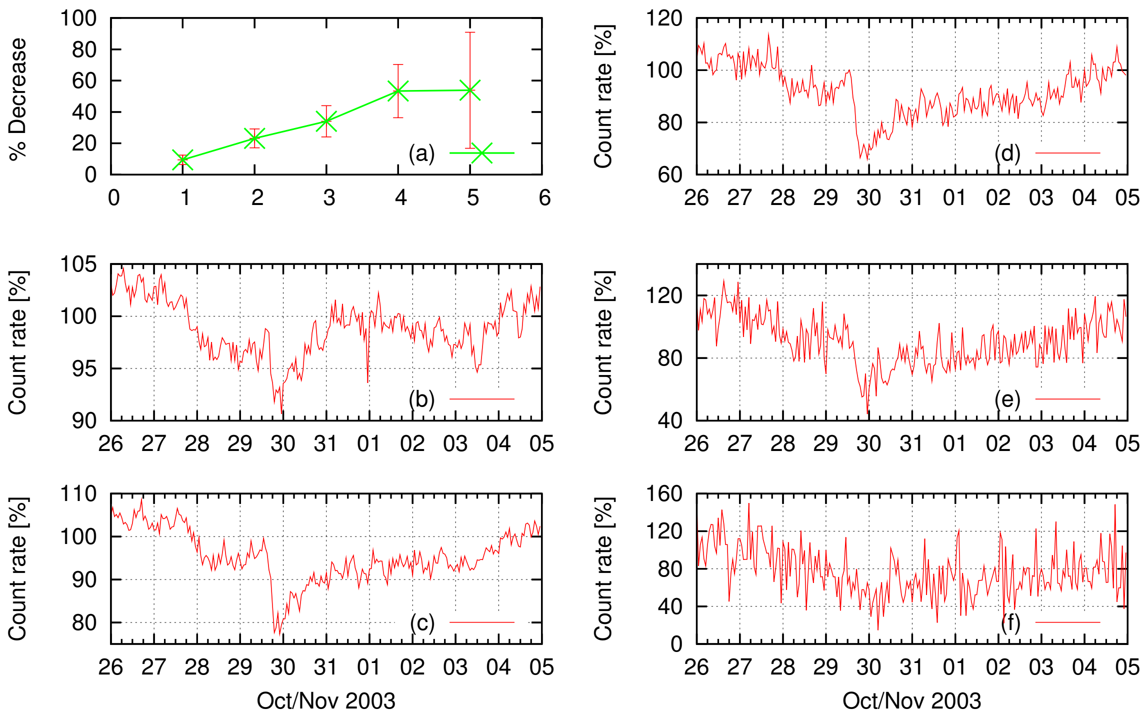

Figure 2. (a) % Decrease in neutron bunches as one moves from bunch-1 to bunch-5. Plots (b,c,d,e,f) show variation in the neutron Bunch countrate from October 26 to November 5 overlapping the occurrence of a X17/4B class Solar flare with onset at 9:51 Hrs UT on 28 October.

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