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Cosmic ray events in the beginning of 2012

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Abstract. The beginning of 2012 is characterized by a burst in solar activity, which is especially obvious, in the first half of March. During these days a series of considerable solar flares was observed – among which six of great significance – together with several powerful emissions of solar substance (coronal mass ejections – CMEs) which resulted in large solar wind disturbances. As a result, several magnetic storms ranging from minor to severe were registered at the Earth. The splash in solar activity was also revealed in cosmic rays. Specifically, on January 27th and on March 7th, 13 significant proton increases (solar energetic particle – SEP) at several spacecrafts and instruments which probably were accompanied by very small ground level enhancements (GLEs) were observed. Furthermore, a series of Forbush decreases is recorded in the same time (i.e. March 2012). It is worth noting that the Forbush decrease on March, 7th became the greatest (up to now) event of its kind in the new cycle of solar activity. All of the aforementioned cosmic rays phenomena are investigated in the given work on the basis of the data from the worldwide network of neutron monitors.

1. Introduction

After the extended solar minimum of the previous solar cycle 23, the present solar cycle 24 is characterized by a burst in solar activity. A powerful solar flare (SF) with X1.7 importance was marked at GOES X-ray measurements on January 27th at 17:37 UT [1]. This was an extreme solar event that was spotted on the west limb of the Sun (N29W29) and was followed by a coronal mass ejection (CMEs). As a result a well connected – given the location of both solar events – SPE was recorded by GOES-13 and was most prevalent at higher energies (100MeV) (Fig. 1). Although, this was an isolated event, the burst of solar activity continued thirty eight days afterwards, when a series of X-ray SFs accompanied by a series of CMEs took place in the first half of March 2012 starting from March 5, 2012 and lasting for almost a week (Fig. 2). It is worth noting that on March 5, 2012 twenty SFs ranging from C to X importance were detected, originating from AR 11429 [1]. The aftermath of the strong CME that was recorded by SOHO/LASCO on March 5, 2012 at 03:24 UT [2,3] and on March 7, 2012 at 01:30 UT, modulated the galactic cosmic ray flux and resulted in a Forbush decrease (FD) of ~14% at Oulu Neutron Monitor (NM) (0.8 GV), ~12% for Moscow NM (2.43 GV) and ~ 7.5% for Athens NM (8.53 GV) [4]. The geomagnetic impact of the plasma eruption

was marked at Kp index which exceeded value 6 at the beginning of the FD, while it was also elevated to 8+ latter on, during the minimum phase of the FD (Fig. 3).

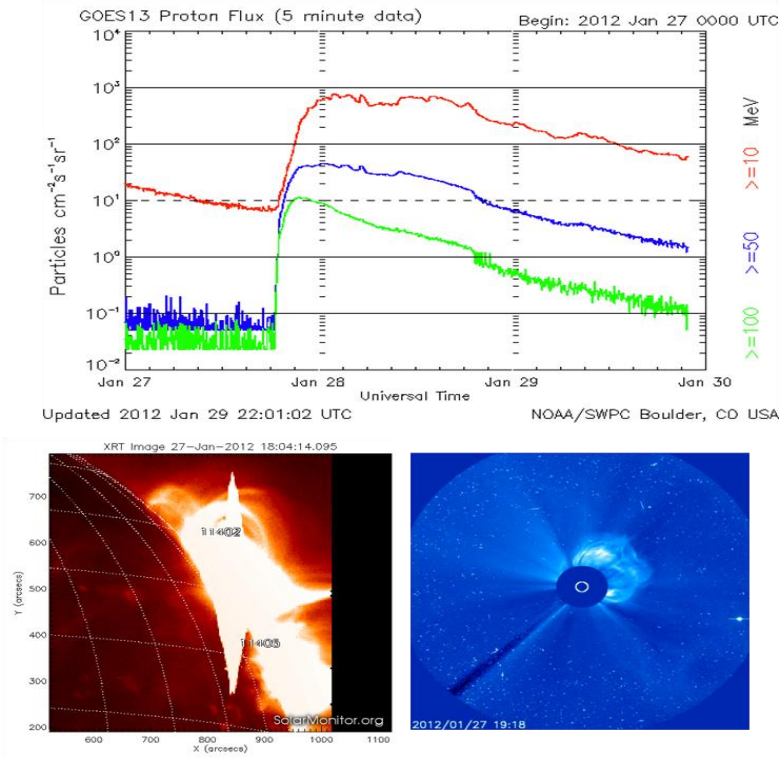

Figure 1. The SPE on 27.01.2012 as it was registered by GOES-13 satellite (upper panel) [5] and the triggering SF X1.7 (lower left panel) and its corresponding CME (lower right panel) [6]

2. The solar energetic particle event of 07.03.2012

On 07.03.2012 active region AR 11429 with strong magnetic structure beta-gamma delta located in the eastern side of the Sun (N17E27) produced a long-duration flare starting at 00:02UT which maximized at 00:024UT with importance X5.4. After almost 1 hour at 01:05UT during the decay of the X5.4 X-Ray flare, the nearest active region AR11430 produced a second great flare with X1.3 importance (Fig. 2). The associated CME which is visible on the LASCO C2 images is registered at 00:36:06UT. The CME was wide enough and the activity now more centrally located so that high energy particles were more able to reach the Earth in significant quantities. The highest energy (>100 MeV) protons increased significantly after 02:00 UT on the morning of the 07.03.2012 and ultimately rose to a peak of 69.3 particles/cm^2/s (pfu) (over 3 orders of magnitude above the background level) at 15:25 UT. Significant 'snow' on the LASCO C2 images caused by high energy particle impacts on the detector can be seen at 04:00UTC due to this flux increase. The >10 MeV SPE began on 07.03.2012 at 05:10 UT following the X5.4 as well as X1.3 flare early on the same day. The peak flux at > 10 MeV was 6530 pfu at 08.03.2012/11:15 UT. As it can be seen from Figure 2 it is a gradual SPE with an extended maximum and long lasting decay phase. This SPE event falls into the ascending phase of solar cycle 24, which approaching to its maximum is characterized according NOAA classification as a strong (S3 scale) particle event.

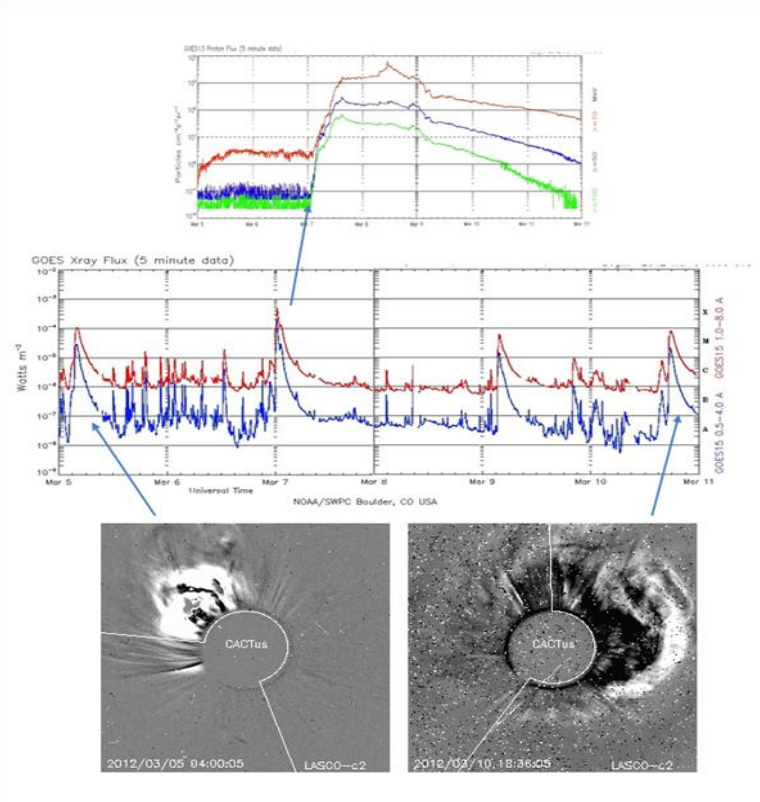

Figure 2. Time profile of the SPE on 07.03.2012 (upper panel), the solar activity evolution as it is registered from GOES satellite for the time interval 5 until 11 March 2012 (middle panel). The lines of the figure represent the following parameters: X-Ray flux in the wavelength 1- 8 Å X-rays in Watts/m2 and 0.5 - 3 Å X-rays upper and lower line S respectively.[5]. Frames of the most significant CMEs as recorded by LASCO C2 coronagraph and reported by Cactus on 5 and 10 March respectively (lower panel*)* [2]

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Given the interplanetary magnetic field (IMF) connection between AR 1429 and the Earth, very energetic solar protons have begun to saturate the Ionosphere. A more delayed effect may result with the CME that was produced with this X class flare. Since the radial propagation speed was expected to be < 1000km/s the arrival of the associated CME was on the next day, the high solar wind speed accompanying the shock, plus high plasma densities with a strong southward IMF resulted into a sudden storm commencement (SSC). These geomagnetic storms usually produce large magnetic disturbances due to ring current enhancements. The CME encountered Earth's magnetic field on 08.03.2012 ~11:00UT. It had a weaker impact than expected [7], causing a mild (Kp=5+) geomagnetic storm. The geomagnetic field was expected to be active, initially on 08.03.2012, but increased to major storm levels with isolated severe storm levels after the arrival of the CME from 07.03.2012.

3. Cosmic ray activity

The most characteristic feature of the FD was its profile: a sharp decrease of cosmic rays is marked by NM detectors all over the world [3] (Fig. 3), which lasts almost 1.5 days. The minimum of the decrease is spotted on March 10th and the recovery phase starts on the same day. Two days later, on March 12th, the recovery is interrupted by the arrival of further disturbance and a second decrease is

marked, which reaches its minimum almost immediately. After this, the galactic cosmic rays started to fill near-Earth space and the recovery of the FD begun and fulfilled with no other interruptions. This case is similar to the September 2005 events [8] when a series of strong X-ray flares and the accompanying CMEs modulated cosmic rays in such way that the resulted FD sustained at its minimum for a prolonged period of several days.

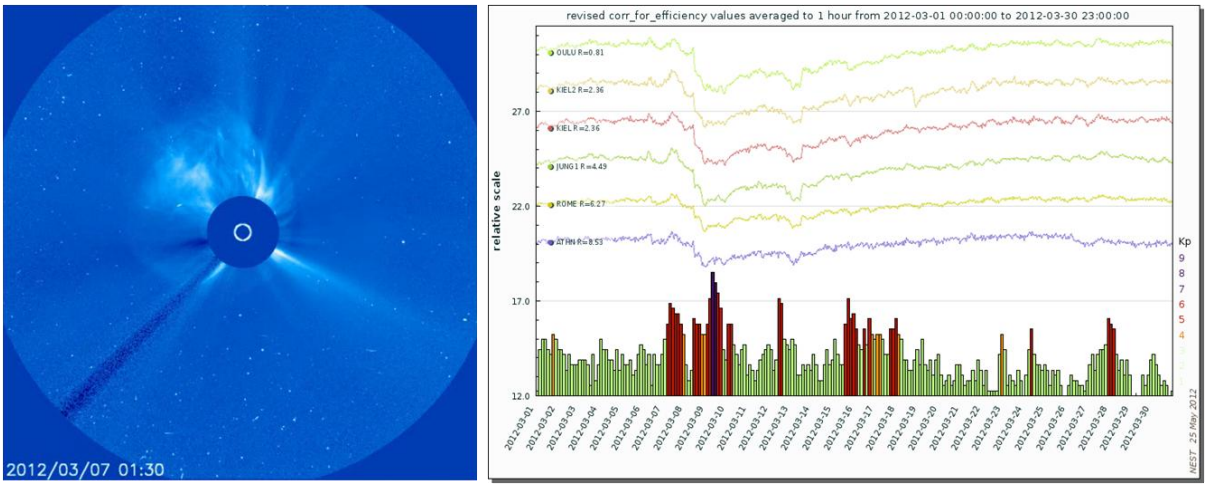

Figure 3. From the left to the right panel : A significant CME as recorded by LASCO C3 coronagraph [6] and recordings of ground based NM detectors around the world as well as the correspond geomagnetic index Kp recordings [4]

4. Conclusions

The cosmic ray events in the beginning of 2012 were of significant importance and resulted in major modulation of cosmic rays. Both SPEs on 27.01.2012 and on 07.03.2012 did not clearly extended to higher energies, but were prevalent at lower energies. The FD started on late 07.03.2012, possibly with the arrival of the CME on 05.03.2012 and got sustained by the arrival of the strong CME of 07.03.2012.

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