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The Cosmic Ray Ground Level Enhancement during the Forbush Decrease in January 2005

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The cosmic ray ground level enhancement (GLE) on January 20, 2005 is ranked among the largest in years, with neutron monitor count rates increased by factors of more than 50. From the data of the Swiss cosmic ray detectors and of the worldwide network of neutron monitors, we evaluated characteristics of the solar particle flux near Earth. The analysis includes solar wind and geomagnetic data, and it is based on simulations with recently developed Geant4 codes. Special emphasis is given to the peculiarities in the intensity-time profiles (e.g. pre-increase of GLE). In the paper we discuss the analysis method and present first results.

1. Introduction

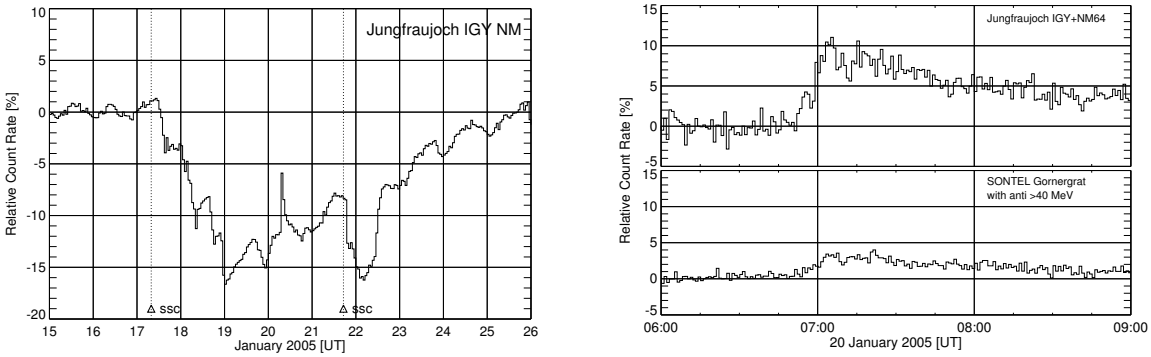
In association with major solar activity in January 2005 the worldwide network of neutron monitors recorded several pronounced variations in the ground-level cosmic ray intensity. After a sudden storm commencement (ssc) on January 17, 2005, at 0748 UT the worldwide network of neutron monitors (NM) recorded a significant decrease in the counting rate. The IGY neutron monitor at Jungfraujoch, Switzerland (geogr. latitude: 46.55°N, geogr. longitude: 7.98°E; altitude: 3570 m asl; effective vertical cutoff rigidity R_c = 4.5 GV), observed a Forbush decrease (Fd) with onset around noon GMT, and with a maximum amplitude of about -15% as can be seen from Figure 1 (a). The Fd was associated with strongly enhanced geomagnetic activity. Three days later, on January 20, 2005, while the Fd at Earth was in its recovery phase, the active region NOAA AR 10720 near the west limb produced an X7.1 solar burst with onset time at 0636 UT and peak time at 0952 UT. This solar flare created a very intense burst of energetic particles that was observed by the worldwide network of NMs. This solar cosmic ray ground level enhancement (GLE) reached a maximum amplitude of >5000% at the South Pole neutron monitor station in the 1-minute recordings.

The January 2005 GLE has a certain similarity with the GLEs on May 7, 1978, on October 24, 1989, on July 14, 2000, and on April 15, 2001. All these events occurred during a Forbush decrease.

2. Measurements

Figure 1 (b) shows the relative counting rates of both Jungfraujoch NMs combined (IGY + NM64) and of the neutron channel >40 MeV of the Solar Neutron Telescope (SONTEL) at Gornergrat, Switzerland, [1, 2] during the GLE on January 20, 2005.

Figure 2 shows the GLE on January 20, 2005, as observed by the NMs at South Pole, Inuvik, Barentsburg and Jungfraujoch. It illustrates clearly the complexity of this event. The station South Pole showed a dramatic sharp increase of more than 5000% after 0648 UT. The maximum count rate was reached in the interval 0653–0654 UT. The onset time at the NM stations Inuvik, Barentsburg, and Jungfraujoch was 6–9 minutes later than at South Pole. The onset times of the worldwide grid of NM stations are listed in Table 1. The Inuvik NM recorded the maximum increase at ∼0705 UT when the count rate of the South Pole NM was only at ∼20% of its maximum increase, but still over 1000% above the baseline of 0500–0600 UT. The NM at Barentsburg, Spitsbergen, showed a second peak around 0730 UT. Both NMs at Jungfraujoch as well as many other NM



(a) (b)

Figure 1. (a) Relative count rate of the IGY neutron monitor at Jungfraujoch for the time interval January 15–25, 2005. Hourly values. (b) Relative count rates of the neutron monitor stations Jungfraujoch (IGY + NM64) combined (above) and relative count rate of the neutron channel >40 MeV of the Solar Neutron Telescope (SONTEL) Gornergrat, Switzerland, (below) for January 20, 2005, 0600–0900 UT. 1-minute values.

Table 1. Onset times for the January 20, 2005, GLE as recorded by the worldwide network of NM stations

Time [UT]	NM Station
0648–0649	South Pole, McMurdo, Newark
0650–0654	Apatity, Climax, Fort Smith, Hermanus, Irkutsk, Jungfraujoch, Kiel, Kingston, Larc, Lomnický Štít, Mawson, Moscow, Nain, Norilsk, Oulu, Tixie Bay, Yakutsk
0655–0657	Barentsburg, Cape Schmidt, Inuvik, Magadan, Novosibirsk, Thule

stations (Forth Smith, Irkutsk, Lomnický Štít, Newark, Novosibirsk, and Sanae) showed a significant pre-increase before 0657 UT (Figure 3), coincident in time with the maximum increase at South Pole. The neutron channels of the SONTEL detector at Gornergrat however did not show an increase at this time (Figure 1b). Therefore the possibility that the pre-increase was due to solar neutrons can be excluded; moreover, the zenith angles of the position of the Sun at the stations with a pre-increase were $>75°$ at the time of the event.

3. Analysis

In a first analysis we tried to determine the GLE parameters during the initial phase of the event according to the method by Smart et al. [3] and Debrunner and Lockwood [4]. For the evaluation of the asymptotic directions and the cutoff rigidities for each NM location including effects of local time position and geomagnetic activity the GEANT4 program MAGNETOCOSMICS [5] was used. It can be assumed that the solar cosmic rays follow the interplanetary magnetic field (IMF) lines, therefore the apparent source position outside the Earth's magnetosphere is expected to be equal to the direction of the IMF near Earth. According to ACE [6] measurements the direction of the IMF during the initial phase of the GLE was in the region around 280°E and 75°S in the geographic coordinate system. However, it must be mentioned that the position of ACE is more than 200 Earth radii away from the Earth in the direction toward the Sun. First analysis results in a somewhat different apparent source position at around 320°E and 40°S during the main phase of the GLE. Figure 4 shows a world map with asymptotic directions of vertically incident cosmic ray particles at NM stations with high count rate increases in the time interval 0655–0657 UT. The apparent source position is also indicated and con-

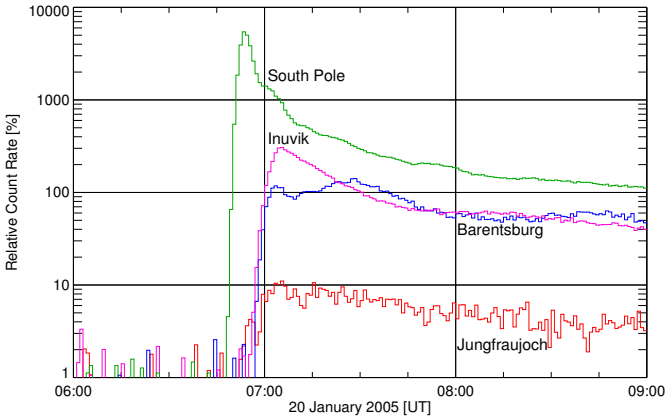


Figure 2. Relative neutron monitor count rates for January 20, 2005, 0600–0900 UT.

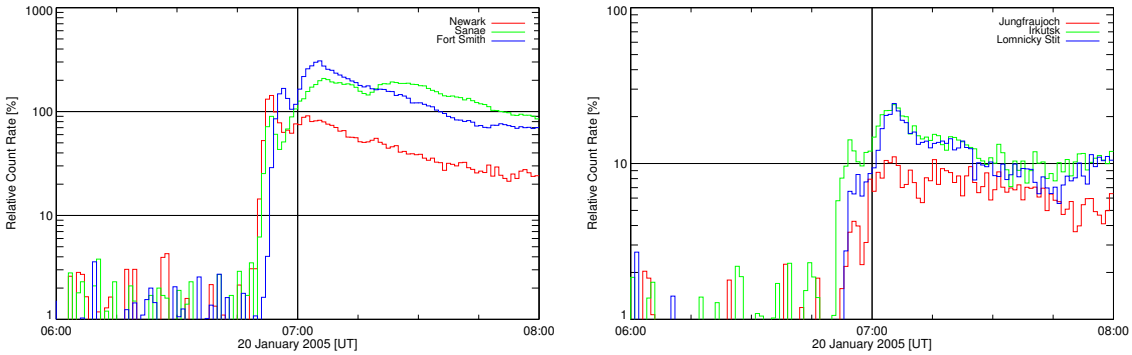


Figure 3. Pre-increase in the neutron monitor count rates on January 20, 2005, 0600–0800 UT.

tours are drawn for angular distances of 30°, 60°, and 90°. The fact that only the two NM stations McMurdo (2644%) and South Pole (3234%) have a much higher count rate increase than all the other stations of the NM worldwide network (Nain 312%, number three in the ranking of increase amplitude) during this time interval implies that the pitch angle in the forward direction must be very narrow. On the other hand the NM station Apatity with asymptotic directions at pitch angles >90° had a relative count rate increase of more than 100% in the time interval 0655–0657 UT, indicating that during the initial phase of this event a bi-directional flux near Earth must have already been present.

4. Conclusions

On January 20, 2005, almost at the end of the solar cycle 23, a giant solar cosmic ray ground level event was detected by the worldwide network of NMs. As for several previous major GLEs, this event occurred also during a Forbush decrease. Its intensity-time profile is extremely structured. The initial pulse appears to be a pencil beam of particles, although from the start of the event a bi-directional flux is also present. In Table 2 the preliminary GLE parameters are summarized. The analysis of this event is still in progress.

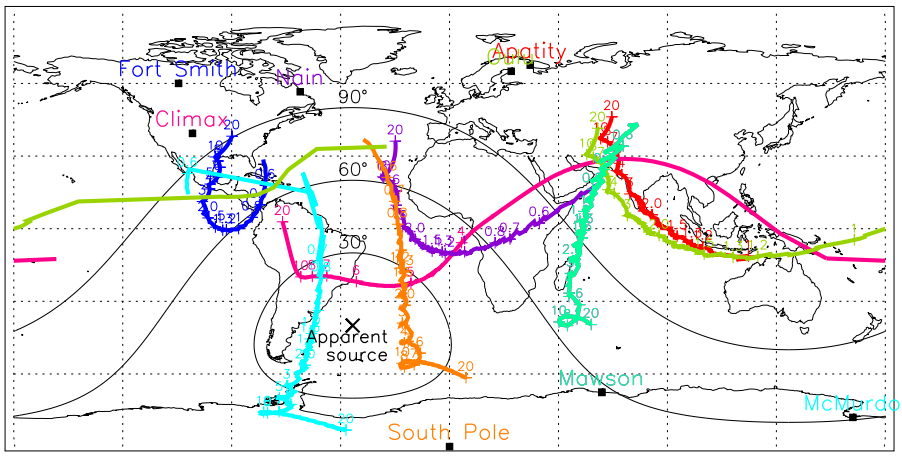


Figure 4. Asymptotic directions of NM stations with high count rate increases in the time interval 0655–0657 UT during the GLE on January 20, 2005. For further details see text.

Table 2. Parameters for the January 20, 2005, GLE (preliminary results)

Time	Spectral index	Apparent source	
		Latitude	Longitude
0653–0655	∼4.5	-40	310
0655–0657	∼7.0	-50	320
0657–0659	∼7.0	-40	320
0659–0701	∼6.5	-50	310

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