Further fine time resolution analysis of the Bastille Day 2000 GLE

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Abstract

Duldig [3] reported the results of fine time resolution analysis of the 14 July 2000 Ground Level Enhancement (Bastille Day GLE) at the 27th International Cosmic Ray Conference, Hamburg. Since then further neutron monitor data have become available as well as spacecraft observations of lower energy proton fluxes and the IMF. These data have now been incorporated into the study of the flux, spectrum and pitch angle distribution of the event for each five minute interval from the onset at around 10:30 UT until 20:00 UT. The results of this analysis are presented and their interpretation is discussed.

1. Introduction

The GLE of 14 July 2000 is associated with an X5.8 solar flare (importance 3B) from active region 9077 that commenced at 10:03 UT, reached its peak at 10:24 UT and ended at 10:43 UT. The largest neutron monitor responses were observed at South Pole and Sanae with respective maxima of 58.3% and 54.5% above the pre-increase level in 1-minute data. A very small increase was observed at Lomnicky Stit which has a vertical cutoff of ~ 4 GV. The technique for modelling the GLE response by neutron monitors has been developed over many years [8, 5] and is described in detail in [2]. The Tsyganenko geomagnetic field model [9] with IGRF 2000 parameters and adjustment for Kp was employed to determine the asymptotic viewing directions of ground-based instruments [4]. A least-squares fitting technique minimizing the difference between the computed and measured response for each neutron monitor was used to determine the apparent particle arrival axis of symmetry, pitch angle distribution and rigidity spectrum. Five minute averaged data from 30 neutron monitors were modelled (earlier, Duldig [3] used 25 monitors) for all intervals between 10:30 and 20:00 UT. Power law spectra were fitted and an exponential form was used for the pitch angle distribution. The observed increases were corrected to standard sea-level atmospheric

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pressure using the two attenuation length method [7]. An attenuation length of 110 g cm^{-2} was derived from a comparison of Mt. Wellington, Hobart and Kingston monitors. Sanae had the largest corrected response and was thus used as the normalization station for the analyses.

2. Results

Fig. 1 shows the observed increases at Thule (best fit) and Yakutsk (worst fit). The solid lines show the 5-minute observations between 10:30 UT and 20:00 UT on 14 July 2000. The dots are the model fits to those observations.

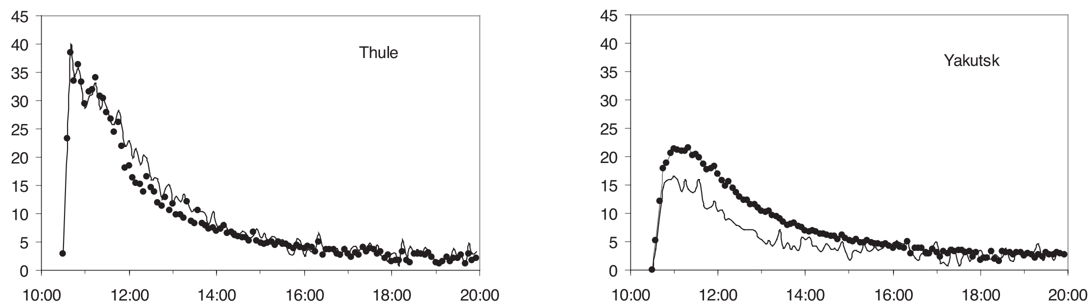

Fig. 1. Observations and fit for 14 July 2000 GLE between 10:30 and 20:00 UT.

The quality of fits were similar to the earlier analysis [3] although there were some minor changes to the derived parameters resulting from the greater coverage afforded by the larger data set. Power laws were fitted as in the previous analysis [3]. The spectral slope during the rising phase was typically between -5 and -7. In the declining phase the spectrum softened and remained between -7 and -8 until 20:00 UT. Example pitch angle distributions during the GLE are presented in Fig. 2. The earliest particle arrival (10:30-10:35 UT) was highly anisotropic and remained so throughout the rising phase until about 11:00 UT.

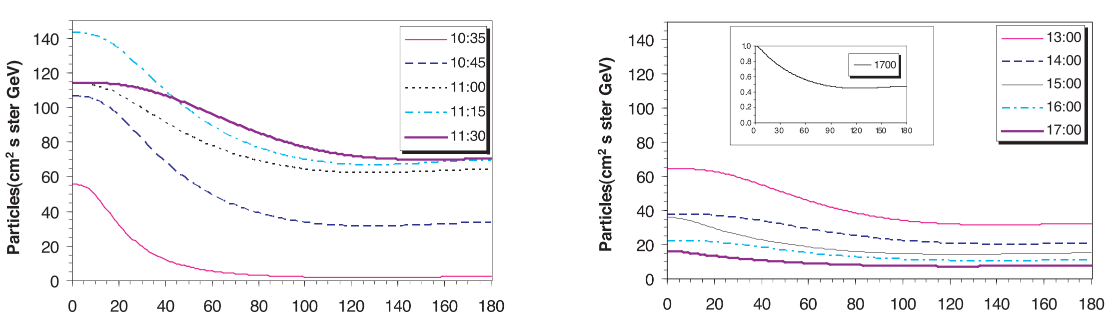

Fig. 2. Particle pitch angle distributions between 10:30 and 17:00 UT.

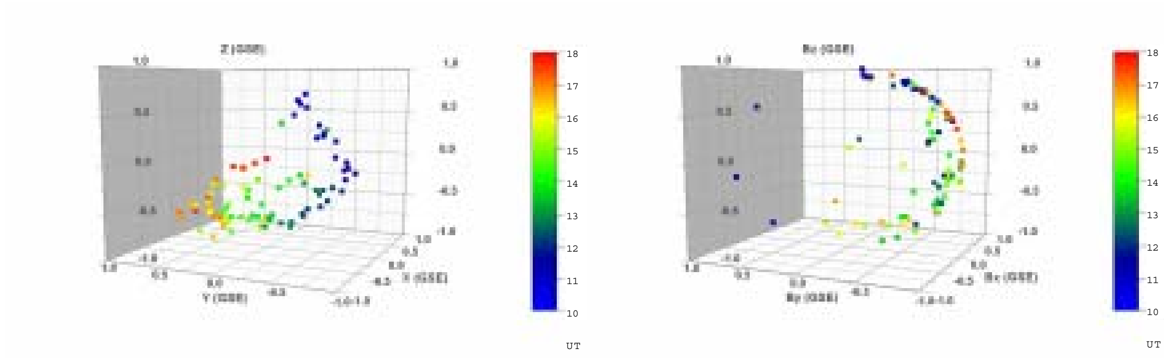

Fig. 3. Particle *arrival direction* (left panel) and IMF orientation (right panel) in GSE coordinates between 10:30 and 17:45 UT.

The subsequent particle arrival became increasingly isotropic. The initial axis of symmetry of the arriving particle distribution (hereafter referred to as the *arrival direction*) was east and north of the Sun-Earth line. It progressed relatively smoothly west and south remaining south for the rest of the event and returning to the east from ∼13:00 UT. The position of the *arrival direction* is plotted in Fig. 3 together with a similar plot of the orientation of the IMF measured at the Earth. The IMF became extremely turbulent with the passage of a magnetic storm at around 15:30 UT (see Fig. 4.). The *arrival direction* however did not show similar dramatic variations. It was also directed eastward, not consistent with the average local IMF.

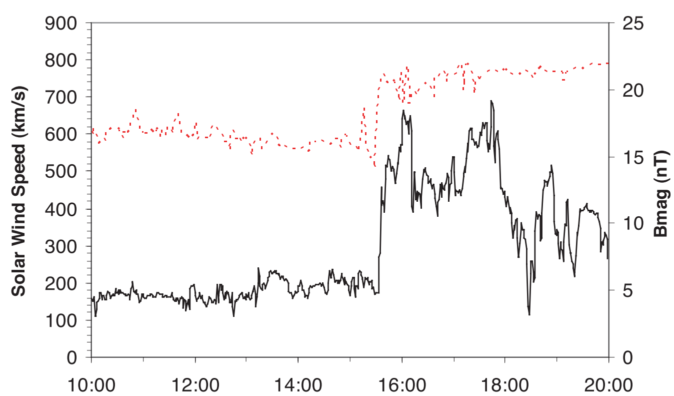

Fig. 4. Solar wind speed and IMF magnitude data from the WIND spacecraft.

3. Discussion

The passage of a magnetic storm past the Earth during this GLE could have been expected to substantially alter the *arrival direction* of the GLE particles. This analysis shows that little, if any, such effect was present. From the duration of the storm passage we estimate it to be ∼0.05 AU in extent, which represents roughly 10 gyroradii of a 2 GV particle in the average field magnitude of 10 nT. It is thus surprising that the particles were not more greatly affected by the storm. It is more difficult to explain the arrival direction east of the Sun-Earth line. This can only be explained by an atypical field arrangement perhaps even more distorted than that proposed by Bieber et al. [1]

The presence of >1 GV particles 8 hours after the onset implies that some form of continuous but weakening acceleration must have been involved. However the impulsive onset requires a sudden acceleration either from the flare or in the corona perhaps from magnetic reconnection [6].

The high degree of isotropy after the initial onset of the GLEs is in agreement with the results of Bieber et al. [1] and may represent scattering of particles back toward the Sun from beyond the Earth.

The analysis of spacecraft proton fluxes has not been included at this stage because the expected energy dispersion in arrival times is not observed. Rather, the higher energy channels from the GOES 8 and 10 spacecraft show onset times virtually identical to the neutron monitors. Thus it is both difficult to correct for dispersion in generating a spectrum and also it is difficult to understand why the arrival times are almost the same. Further work on this aspect of the study is being undertaken.

4. Acknowledgments

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5. References

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