J. Astrophys. Astr. (2008) **29,** 313–317

Energy Dependence of Near-relativistic Electron Spectrum at Geostationary Orbit during the SEP Events of 2005

A. Chandrasekhar Reddy[1], Jatin Rathod[1], Girija Rajaram[1], Radharani Alyana[1], D. S. Misra[1], C. G. Patil[2], M. Y. S. Prasad[3] & A. G. Ananth[4]
[1]*CSRE, Indian Institute of Technology, Bombay, Powai, Mumbai 400 076, India.*
[2]*MCF-Indian Space Research Organisation, PB No. 66, Hassan, Karnataka 573 201, India.*
[3]*SITAA-SAC, Indian Space Research Organisation, Ahmedabad, Gujarat 380 015, India.*
[4]*Indian Space Research Organisation, Headquarters, Bangalore, Karnataka, India.*

Abstract. In view of the renewed interest in the study of energetic particles in the outer radiation belt of the earth, we feel it will be helpful in looking for the energy dependence of the electron energy spectrum at geostationary orbit. This may give us some insight into how we can safeguard geostationary satellites from functional anomalies of the deep dielectric charging type, which are caused by charge accumulation and subsequent discharge of relativistic electrons. In this study we examine whether there is any energy dependence in relativistic electron enhancements at geosynchronous altitudes during solar energetic proton events of 2005.

Key words. SEP events—shocks—geostationary orbit—REDs—REEs.

1. Introduction

The study of charged particle distributions in the earth's radiation belts encompasses as many unknown features as known. One enigmatic area concerns the energetic particles which cause problems in instruments onboard satellites in space; in particular, the Relativistic Electron Dropouts (REDs) and the Relativistic Electron Enhancements (REEs) observed at the geosynchronous altitudes. The sudden drop in the relativistic electron flux often by two orders of magnitude is called RED which is usually preceded by the gradual enhancement in the relativistic electron fluxes, REEs. Certain operational problems on geostationary satellites were attributed to enhanced relativistic electron flux at geostationary altitudes (Baker *et al.* 1987, 1994). The processes which are responsible for electron acceleration in the outer magnetosphere are still not completely known (Rostoker *et al.* 1998; Liu *et al.* 1999). Onsager *et al.* (2002), have discussed the radiation belt electron drop outs with respect to their local time, radial and particle-energy dependence. In this paper we present the energy dependence of REDs and REEs at geostationary orbit for electrons at energies 2 MeV, 0.9 MeV, 0.6 MeV with respect to the solar wind and Interplanetary Magnetic Field (IMF) conditions during the proton events of 2005.

Table 1. List of SEPs observed by both ACE and GEOS-10 during 2005, when the GEOS-10 also observed the relativistic electron drop outs and enhancements at geosynchronous orbit.

Month/year of SEP	Start date	End date
January 2005	15 January	24 January
May 2005	5 May	8 May
May 2005	13 May	16 May
June 2005	16 June	19 June
July 2005	13 July	19 July
July–August 2005	25 July	2 August
August 2005	21 August	26 August
September 2005	7 September	17 September

2. Data presentation

In order to identify the Solar Energetic Particle (SEP) events, we analyzed the fluxes of $E > 10\,\mathrm{MeV}$ and $E > 30\,\mathrm{MeV}$ proton fluxes at both Lagrangian point 1 (L1) and geosynchronous orbit measured by the Advanced Composition Explorer (ACE) and Geosynchronous Earth Observation Satellite-10 (GEOS-10) satellite respectively. These proton fluxes measured by ACE are taken from CDA (Coordinated Data Analysis) web service (http://cdaweb.gsfc.nasa.gov) and those measured by GEOS-10 are taken from Space Physics Interactive Data Resource (http://spidr.ngdc.noaa.gov). To identify the REE at geosynchronous orbit, we analyzed the data of $E > 0.6\,\mathrm{MeV}$ and $E > 2\,\mathrm{MeV}$ electron fluxes measured by GEOS-10 satellite and differential electron fluxes centered at 0.9 MeV measured by the SOPA instrument on board the LANL 1994, 084 satellite. These electron fluxes are taken from CDA web service (http://cdaweb.gsfc.nasa.gov). We are able to identify 8 such events when we see an REE during the SEPs, which are listed in Table 1.

In order to investigate the characteristic solar wind and IMF associated with these events under consideration, we collect hourly solar wind parameters of solar wind number density (Nsw), solar wind speed (Vsw), solar wind pressure (Psw), average component of IMF (Bav) and z-component of IMF (Bz) measured by ACE Satellite. These data are taken form CDA web service (http://cdaweb.gsfc.nasa.gov).

In this paper we present a representative event of January 2005, for all the events under consideration. We discuss the common features observed in all the events. Figure 1 shows the proton fluxes observed by both ACE and GEOS-10 satellites, confirming the SEP during this period. In Fig. 2, we present the characteristic solar wind and IMF behaviour and the geosynchronous electron response. In Fig. 2 (from top to bottom) we present Vsw, Nsw, Psw, Bav, Bz, and electron fluxes of $> 2\,\mathrm{MeV}$, 0.9 MeV and $> 0.6\,\mathrm{MeV}$ respectively.

3. Summary of work

In this section we discuss the observations and our calculations. For the representative event from Fig. 1, we can say that there is SEP observed by both ACE at L1 point and GEOS-10 at geosynchronous orbit. From the bottom 3 panels of Fig. 2, it is evident that the REEs are observed by the GEOS-10 and LANL satellites. The scale is in terms of

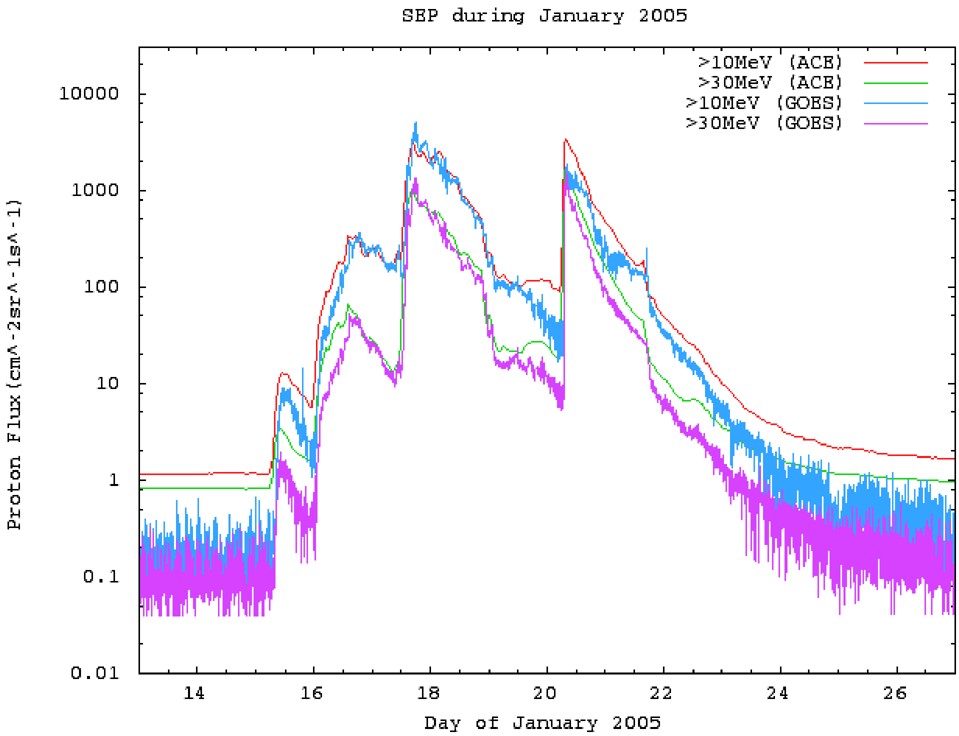

Figure 1. The SEP during January 2005 observed by both ACE at Lagrangian point 1 and GEOS-10 at geosynchronous orbit.

particle flux units. From both Figs. 1 and 2, it is clear that there are 2 REEs during this event. In both cases the amount of enhancements and drop outs in the electron fluxes at geosynchronous orbit is different. The drop out and enhancement during the late hours of 16 January is less intense than 21 January. This is because of the difference in the solar wind and IMF behaviour in both the events. Many of the previous workers (Williams 1966; Paulikas and Blake 1976; Li *et al.* 2001a, 2001b; Kim *et al.* 2006) who concentrated in the acceleration and loss mechanisms of relativistic electrons in the magnetosphere, showed how the solar wind and IMF controls the relativistic electron changes in the magnetosphere of earth. The solar wind and interplanetary drivers during the 17 January case are less pronounced than in the 21 January case. In particular Psw during 17 January is very less, which we believe is the main cause for the intense drop out and enhancement seen in the 21 January case. In this study we tried to look at the enhancements and drops of the electron fluxes during the SEPs.

We have calculated the amount of drop and amount of enhancements during the REDs and the REEs respectively. To calculate the amount of drop during the REDs we took the ratio of the maximum and minimum flux values before and after the occurrence of REDs. This represents the amount of drop in the electroflux during RED. Similarly, we have taken the ratio of maximum to minimum values of electron flux after and before the REEs respectively. This represents the amount of enhancement in the electron flux during REE. In the representative case we found that the amount of drop and enhancements of $> 2\,\text{MeV}$ electrons is $4.2e + 5$ and $4.6e + 4$ respectively.

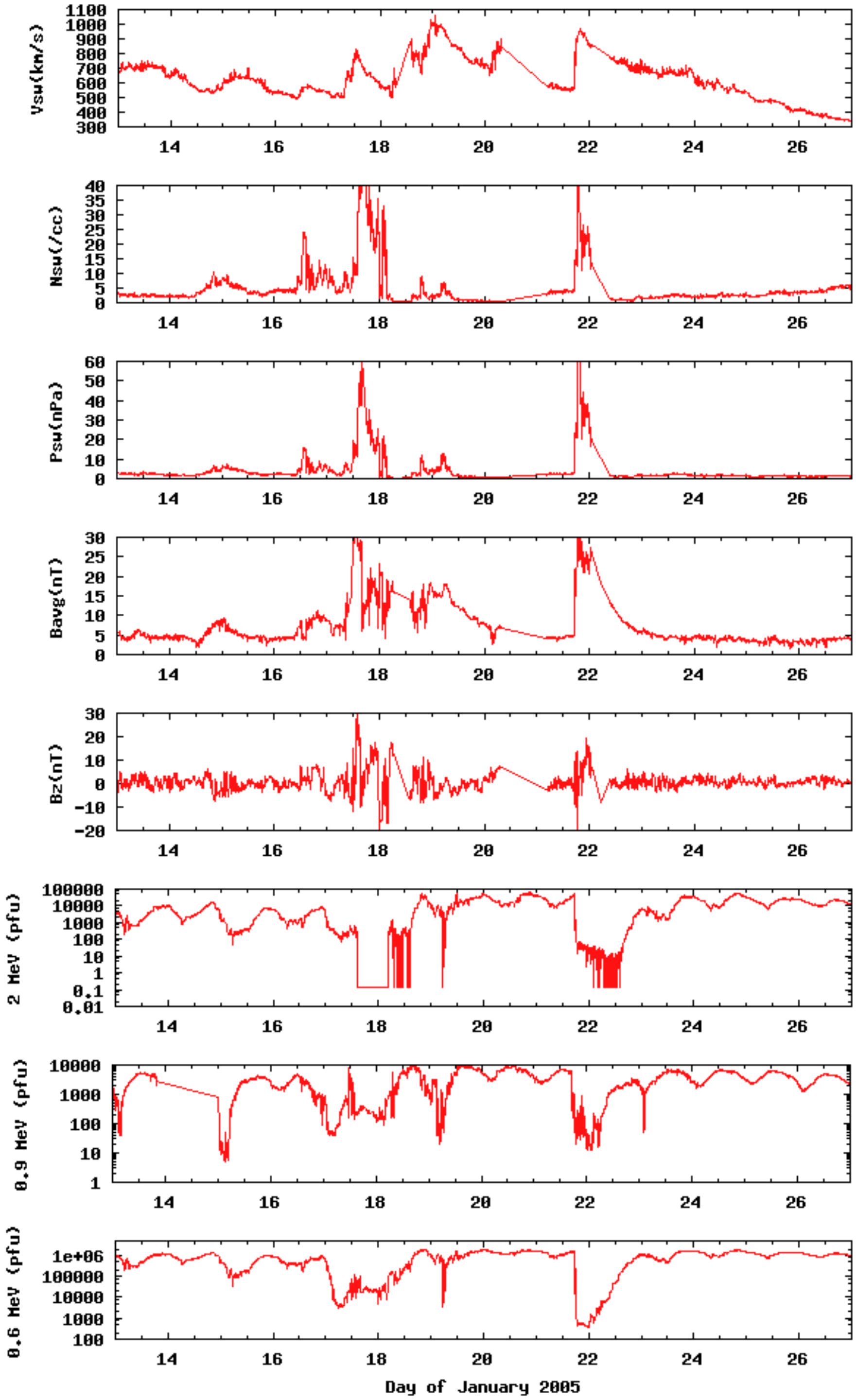

Figure 2. The solar wind and IMF behaviour is shown, alongwith the geosynchronous electron flux response. From top to bottom, Vsw, Nsw, Psw, Bav of IMF, Bz of IMF, 2 MeV electron flux, 0.9 MeV electron flux and 0.6 MeV electron flux respectively.

Similarly, the drop and enhancements observed by 0.9 MeV are 1e + 3 and 4.8e + 2 respectively and for > 0.6 MeV, it is 4e + 3 and 3e + 2 respectively. The amount of drop and enhancements are more for > 2 MeV electron than for > 0.6 MeV and 0.9 MeV electron fluxes. This kind of behaviour is observed in all the events under consideration.

4. Conclusions

The above-mentioned observations made us think that the solar and interplanetary disturbances which are responsible for the REEs at geosynchronous altitudes, may be driving different kinds of acceleration and loss mechanisms that are acting differently on electrons with different energies or these acceleration and loss mechanisms are acting predominantly on some energies than on the others. But from our observations we are convinced that there is some kind of energy dependence in the way the acceleration and loss processes at geosynchronous altitudes are working.

Acknowledgements

The authors are grateful to Indian Space Research Organisation, India for funding these studies and to CSRE, IIT Bombay, India for all logistic support towards the same.

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