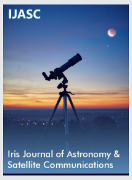

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Case Report

Plasmaspheric Dipolarization Driven Local Transport in The Heart of Van-Allen Radiation Belts Leading to Super Intense Third Radiation Belt

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Abstract

A recent study [1] concluded that local energization in the heart of Van-Allen radiation belts is a main cause of the relativistic electrons flux enhancement in the slot region of Earth's magnetosphere. This work reports a very contrasting event. It is found that local transport in the heart of Van-Allen radiation belts resulted in the formation of a super-intense third radiation belt in the slot region of Earth's magnetosphere. In super-intense third radiation belt peak cumulative fluxes of relativistic electrons were thousand times greater than those in the first study about third radiation belt formation [2]. Therefore, it is concluded that local energization in the heart of Van-Allen radiation belts can be dominated by local transport resulting from plasmaspheric dipolarization. This indicates that local energization is not always a sole and dominant source of flux enhancements in the slot region.

Keywords: Van-Allen radiation belts; super intense third radiation belt formation; plasmaspheric dipolarization; local transport; local energization

Introduction

Earth's magnetic field behaves as a natural magnetic mirror due to magnetic gradients and can trap energetic radiations. Early observations [3,4] discovered two radiation belts known as Van-Allen radiation belts. These are separated by a gape termed as slot region, where negligibly small fluxes of relativistic electrons have been predominantly observed [5]. Data from twin radiation belt storm probes revolutionized the situation by an unexpected discovery of a temporary third radiation belt in the slot region [2]. A recent study emphasized that the local energization by very low frequency waves is a main source of flux enhancement in the slot region [1]. During 2013-2019 many studies [6-26] have explained the relativistic electrons flux enhancements in slot region but before this work there is no study about the role of plasmaspheric dipolarization in the super intense third radiation belt formation. Dipolarization is a phenomenon when Earth's magnetosphere recovers from a stretched elongated configuration to dipole like structure. Earlier studies observed dipolarization of geomagnetic field near geosynchronous orbit at L = 6.6 [27,28]. The large inductive electric fields due to dipolarization [29], leads to earthward injection of particles [30,31]. Very recently Magnetospheric Multiscale (MMS) spacecraft observed dipolarization at L = 3.8 inside plasmasphere [32]. This work provides evidence that plasmaspheric dipolarization driven local transport can dominate the local energization in the heart of Van-Allen radiation belts. The paper is organized as follows. The section 2 deals with data and methods. The section 3 presents results based on the observations of RBSP-A in slot region (L = 3- 3.5). The results are explained and discussed in section 4. The section 5 is devoted to the summary and conclusions.

Data and Methods

This study uses the multi-satellites OMNI solar wind data at 1 AU and 2 MeV 45 degrees pitch angle relativistic electrons flux data based on the measurements of relativistic electron proton telescope (REPT), onboard radiation storm probe A (RBSP-A). The RBSP-A electric field and wave instrument (EFW) provided ultra-low-frequency waves and dipolarization electric fields data. The amplitudes data for HF band (10- 487 kHz) are from electric and magnetic field instrument suit (EMFISIS). We have selected the March 2015 intense storm. It is found that a super intense (thousand times greater cumulative peak fluxes of relativistic electrons in slot region) third radiation belt was formed during storm. Intense storm means one with a main phase Dst dip < -100 nT. The third radiation belt formation is studied. The event in [2] is considered as standard for detection of third radiation belt in slot region. That work had reported third belt for the first time. For that event, we found that 2 MeV 45 degrees pitch angle electrons cumulative flux attained a threshold value 105. When cumulative flux in region L = 3-3.5 is less than threshold (105) the third belt is considered to be absent. Based on the intensity of peak cumulative flux in region L = 3-3.5 during March 2015, we report a super intense third radiation belt (when cumulative flux peak attains 108) formation. The electron cumulative fluxes in this work are in units of cm-2 s-1 sr -1 MeV-1. The L is McIlwain L-shell, and shows geocentric distance to geomagnetic equatorial crossing point of Earth's magnetic line of force [33].

Results

Figure 1 shows the L-shell vs flux profiles for the super intense third radiation belt considered in this study. Panel (a) is for reference case and is for 23 January-23 February 2013 when third radiation belt was absent. The time intervals for other panels read as (b) 1-18 March (c) 19-25 March (d) 26-31 March (e) 1-6 April (f) 7-17 April (g) 17-26 April (h) 27 April-10 May (I) 11-26 May 2015. In panel (a) the third belt is absent as the flux between L = 3-3.5 is negligibly small as compared with peak flux in the vicinity of L = 5. But in panel (b) the flux has stronger bursts in slot region and super intense third belt is formed. The formed third belt existed during 18 march (as obvious in panel a) – 10 May 2015 (panel h). That gives an existence time of 53 days. These plots are using instantaneous values of flux and L-shell. The collective fluxes of electrons for this third belt in region L = 3-3.5 were 1000 times greater than collective fluxes in same region for the first reported third radiation belt [2]. The flux measurements are based on the relativistic electron proton telescope (REPT) onboard RBSP-A. L-shell represents the distance from center of Earth to the intersection point of equator and field line.

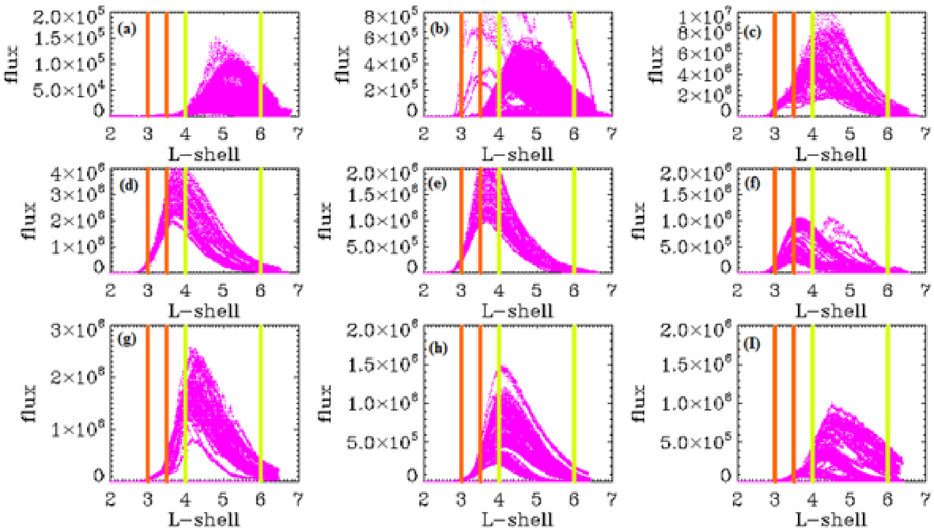

Figure 1: shows the distributions of relativistic electrons fluxes for super –intense third belt formed during 18 March 2015. The time intervals are discussed in text in section 3.

Figure 2a presents the L-shell distribution of magnetospheric east-west electric field (Ey). It shows very high electric fields in the heart of Van-Allen radiation belts. Such field can give same radial velocities as due to small wave fields outward of the outer radiation belt. Such fields can act as source of third radiation belt formation. The Figure 2b exhibits Ey fields for the absence of third belt during (23 Jan-23 Feb 2013). These were much smaller than those in Figure 2a.

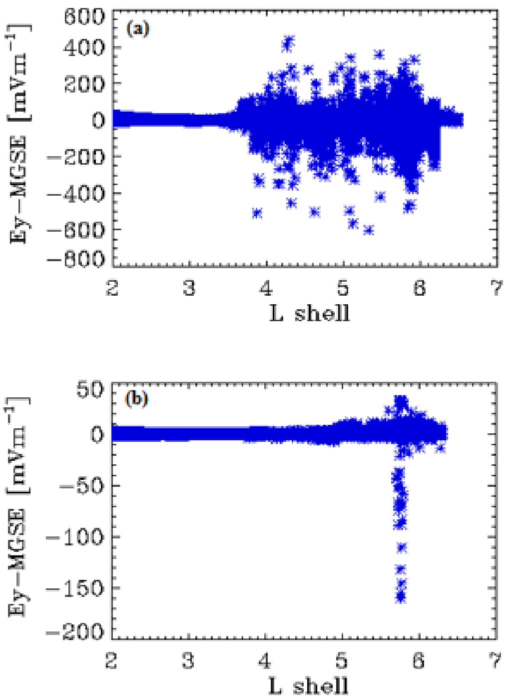

Figure 2: Exhibits extraordinary electric fields due to plasmaspheric dipolarization during the event of superintense third belt.
(a) Shows the scattered plot of the instantaneous values of EFW measured Ey electric field with L-shell for super intense third radiation belt formation.
(b) Shows the scattered plot of the instantaneous values of EFW measured Ey electric field with L-shell for the absence of third radiation belt.

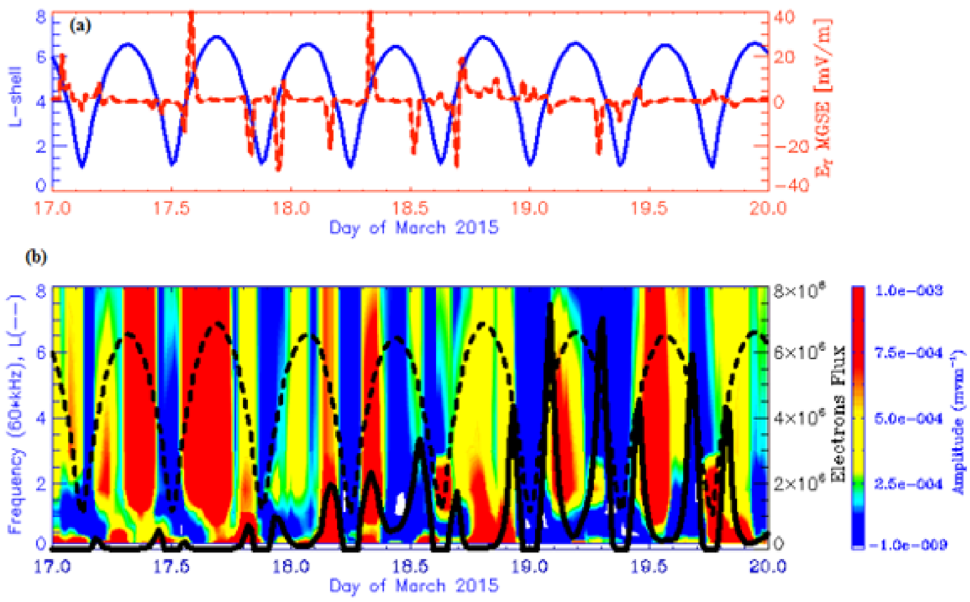

Figure 3: Exhibits relationships between electric fields and 2 MeV 45 degrees relativistic electrons flux for initial stage of first super-intense third radiation belt in slot.
(a) Shows twenty minutes averages of Ey (red curve) magnetospheric electric field and L-shell (distance from Earth's center to point where magnetic field line crosses magnetic equator) for the first event of superintense third radiation belt of this study.
(b) Shows the color coded amplitudes of HF band (10-487 kHz) of oscillations and 2 MeV 45 degrees pitch angle (over plotted in black) electrons flux.

Figure 3a shows L-shell vs temporal variations of Ey field. The eastward peaks (negative peaks) are followed by flux enhancements as shown in Figure 3b. The Figure 3b also shows the variations of high frequency (HF) band with time. The decay in the amplitude of HF band is followed by the flux enhancement in slot region. This indicates that one cannot ignore the role of HF band. However, dipolarization fields (Figure 2a) were several orders of magnitude greater than electric fields in HF band.

Discussion of results

This section compares the roles of high frequency (HF) wave band (which includes very low frequency waves and high frequency oscillations) and plasmaspheric dipolarization generated electric fields. The peaks of twenty minute averages of HF band electric fields were several orders of magnitude smaller than peaks of dipolarization electric fields in the heart (locations with $L < 4$) of Van-Allen radiation belts. Therefore, dipolarization played a critical role in the generation of super intense third radiation belt.

Summary and Conclusions

During March 2015 intense storm event occurred and a super intense third radiation belt formed in the slot region of Earth's magnetosphere. It is found that HF band amplitude decay was directly followed by relativistic electrons flux enhancement in the slot region. But the peak powers of waves in HF band were several orders of magnitude smaller than highest power of plasmaspheric dipolarization electric fields. Therefore, we conclude that plasmaspheric dipolarization generated electric fields played a primary role in the generation of super-intense third radiation belt. It also indicates that local transport dominated local energization in the heart of Van-Allen radiation belts.

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Data availability statement

The used data is available upon request at masifkf@gmail.com

Financial statement

There is no funding for this work.

Ethics declaration

Not applicable.

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