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Dawn–dusk asymmetry and adiabatic dynamic of the radiation belt electrons during magnetic storm

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Abstract

The changes of the latitudinal profiles of outer belt energetic electrons during magnetic storms are mostly explained by the precipitation into the loss cone caused by VLF and EMIC waves or by the scattering into the magnetopause. In present work, energetic electron dynamics during magnetic storm of August 29–30, 2004 we attributed at most to the adiabatic transformation of the magnetic drift trajectories and Dst effect. This conclusion was based on the analysis of dawn–dusk asymmetry of the electron latitudinal profiles measured by low altitude polar orbiter SERVIS-1 and on the coincidence of pre-storm and after-storm profiles of radiation belt electrons and protons.

Keywords: Radiation belt; Magnetic storm; Latitudinal profiles

1. Introduction

The problem of energetic electron dynamics during magnetic storms is a subject of long lasting discussion by scientific community. Several types of particle losses and accelerations were proposed for the explanations of the radiation belt energetic electron decrease during the main storm phase and flux reappearance during the recovery phase.

One of the two popular mechanisms of outer belt energetic electron losses is based on the process of the electron precipitation to the atmosphere caused by the increased pitch-angle scattering on different types of the wave activity, which are always present during magnetic storms (Friedel et al., 2002; Millan and Thorne, 2007; Shprits et al., 2008a,b; Turner et al., 2012). It is assumed that the VLF emissions produced during the substorms are responsible for the electron precipitation at the outer L shells, while generated by storm current belt ion cyclotron (EMIC) waves cause scattering of a high-energy electrons at the inner drift shells.

The second mechanism of electron losses is the magnetopause shadowing (for example Ukhorskiy et al., 2006). Shadowing occurs when the magnetic field decreases in the inner magnetosphere and transfers electrons from previously closed magnetic drift orbits to the open orbits where they are scattered at the magnetopause.

Both of the two mechanisms are based on the assumption that the electrons are being lost at the main phase without conservation of the adiabatic invariants and after that at the recovery phase the electron population returns back due to the acceleration of the low energy particles.

Both mechanisms are well described in the referred papers, and does not needs more detailed description. It is clear that non-adiabatic transformation of energetic particle population of the radiation belts really took place during magnetic storms, but usually it is mixed with an adiabatic one. This mixture is different in different magnetic storms and there are storms when adiabatic processes are

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predominant. The aim of this paper is to present arguments in favor of the explanation based not on the loss-acceleration idea but on the energetic electron adiabatic transformation during one magnetic storm of August 29–30, 2004.

Adiabatic effects were described times ago by McIlwain (1966a, 1966b) and were investigated and renamed as "Dst-effect" (Kim and Chan, 1997; Kim et al., 2010).This effect was considered as the main factor of radiation belt transformation by Lemaire et al. (2013).

The adiabatic effect is based on the condition of the adiabatic invariants conservation, which is justified because characteristic times of all the three invariants are smaller than the time scale of a Dst transformation. Conservation of the third invariant means that if the magnetic flux inside the particle magnetic drift orbit is decreasing, outward shift of the orbit must follow. Then due to the increase of the length of the magnetic field lines, the mirror point shifts upward, as the second invariant conservation demands. As a consequence such shift will decrease magnetic field magnitude at the mirror point. Finally the conservation of the first adiabatic invariant leads to the decrease of the particle energy. All that will cause decrease of the particle intensities registered by low-altitude satellites. At the magnetic storm recovery phase, particle energy and spatial distribution will return adiabatically to the prestorm condition.

Another adiabatic effect may influence the interpretation of the measurements if used incorrect coordinates of magnetic drift trajectories. Magnetic field configuration during the magnetic storms differs essentially in different local latitudes and longitudes, for different magnetic storm phases and from storm to storm. Meanwhile in most of the studies L coordinates or L^* coordinates were used calculated for undisturbed magnetosphere or for averaged storm models which does not represent dynamics of the specific storm.

The main phase of the magnetic storms usually begins with a dawn–dusk asymmetry of the magnetic field configuration (Shi et al., 2006; Tsyganenko, 2002a,b) and of the energetic electron outer radiation belt population (Onsager et al., 2002; Lazutin, 2012). Asymmetries registered as the magnetic field and particle decrease at the evening sector were presumably caused by partial ring current. As a rule the morning side of radiation belt joins the particle decrease at the later stage. Particle dynamics during the asymmetry stage present interesting possibility to investigate particle behavior at the storm main phase in detail. We will do that using particle measurements during the magnetic storm of August 30, 2004, although similar features were seen during some other storms too. We will not include comparison with magnetic field models, which now seems obligatory, because it will **involve** unnecessary uncertainties caused by the differences between the model and our magnetic storm.

2. Measurements

Energetic electrons were measured by low altitude polar orbiter SERVIS-1 (Space Environment Reliability Verification Integrated System). SERVIS-1 was developed by the Institute for Unmanned Space Experiment Free Flyer (USEF), and described in (Kodaira et al., 2005). Satellite was launched from Russian Kosmodrome Plesetsk in October 30, 2003. Data were available until the middle on 2005. Satellite has an altitude of 1000 km and the inclination of 99.5°.

Light Particle Detector (LPD) is a charged particle spectrometer which combines 0.5 mm thick SSD and 24 mm thick plastic scintillator. Data were presented in 4 electron channels (0.3–100 MeV) and 6 proton channels (1.2–150 MeV). Spectrometer has 60° field of view and oriented in the anti solar direction. Satellite was sun-oriented with the orbits crossing radiation belt at the 4–6 and 16–19 local times. This allows us to investigate the dawn–dusk asymmetry of the outer electron radiation belt. The detailed description of the asymmetry effects was done in our previous paper (Lazutin, 2012). The present paper is to some extent an addition, but with the description of

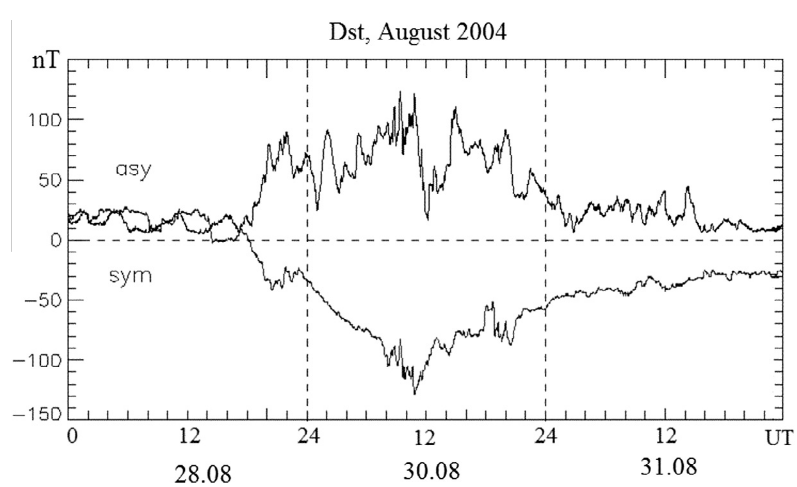

Fig. 1. Symmetric and asymmetric Dst plots (Kyoto WDC).