

Correlation between Substorm Onset Ground and Space Observations: Implication for Kinetic Ballooning Instability

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The observations of substorm onset phenomena in the magnetosphere and ionosphere are examined to study their correlation and understand the substorm onset mechanism. In particular, we examine the Pi2 wave structure, propagation, frequency and growth rate in the magnetosphere observed by the THEMIS satellites and the structure and dynamics of the substorm auroral onset arcs. We show the correlation between the substorm onset arcs and the Pi2 pulsations in terms of wave structure, propagation, and the exponential growth of arc intensity and Pi2 wave amplitude. The correlation between the ground and space phenomena strongly supports the kinetic ballooning instability (KBI) as the cause of substorms. We demonstrate that KBI is most unstable in the strong cross-tail current region magnetic field lines and the KBI parallel electric field accelerates electrons along the magnetic field lines into the ionosphere to produce the substorm onset arc.

Keywords: substorm, kinetic ballooning instability, magnetospheric dynamics, magnetospheric structure

Investigation of the Triggering Mechanism of Magnetospheric Substorm by means of 2-1/2D Full-Particle Simulation

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The triggering mechanism of substorm in the Earth's Magnetotail is thought to be closely related to the magnetic reconnection and the tearing mode instability. Recently we proposed a new scheme of the substorm onset called "Catapult Current Sheet Relaxation Model (CCSR Model)" to physically understand the results from statistical analyses of GEOTAIL and THIMIS data. In the results, it can be seen that the local maximum region of the northward magnetic field around $X \sim -17R_E$ are created a few minutes before substorm onset, and the magnetic reconnection occurs at the tailward edge of the enhancement at the time of substorm onset. We investigate a stability of the current sheet by means of particle simulation in order to physically verify the results of the statistical analyses.

We have given a magnetic field structure which is akin to the Earth's dipole magnetic field together with a stretched magnetic field by thin current sheet as a basic initial condition of our simulation. We have started the simulation with such initial condition. In an early stage, the fluctuation of magnetic field which seems to be produced by tearing mode instability has been found at the location tailward of the boundary between dipole-field and current sheet with a distance about one wave length of the tearing mode with a maximum growth rate. Further, we have investigated variations in the development of the instability by adding the local enhancement of the northward magnetic field to the initial current sheet. It was found that such local enhancement of the northward magnetic field enhances the instability in the current sheet. By shifting initial location of the local enhancement, we found that the most rapid development of tearing mode occurred when the tailward edge of the local enhancement and the location of the original tearing mode overlap with each other.

The obtained results suggest that the results of the statistical analyses of the satellite data reflect the tearing mode instability occurring in the thin current sheet with the effect of the convective electric field at the time of substorm onset.

Keywords: Substorm, Tearing instability, Magnetic reconnection

Investigation of the characteristics of the dipolarization region with THEMIS data (II)

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Taking an advantage of THEMIS/All-Sky Imager (ASI) observations with high time resolution (typically 3 sec), we performed the superposed epoch analysis on the evolution of the Earth's magnetotail with THEMIS probe data. In this study, we focus on the progress of the dipolarization and low frequency electromagnetic turbulence closely associated with the current disruption. Practically, the standard deviations of the magnetic field data with the time window of 1 min were obtained.

By investigating the location and timing of the enhancements of standard deviations for three components of the magnetic field, we found that the first variation occurs at $X \sim -10$ Re. Interestingly, the enhancement starts near the lobe-side boundary of the near-Earth plasma sheet, and it rapidly propagates earthward. It was also found that the earthward flows start simultaneously with the enhancement of the magnetic field variations about 20 sec before the substorm onset that was determined by auroral breakup with ASI data. The tailward flows whose velocities are less than those of the earthward flows start at the same time. The region of flow enhancement expands in an earthward direction synchronized with the enhancement of magnetic field variations.

Prior to these variations, convective earthward flows reach the very thin plasma sheet at $X \sim -12$ Re, and further proceed earthward. The convective flows originally accompany large magnetic field variations, but they seem to trigger the occurrence of considerable enhancement of the magnetic field fluctuations associated with the current disruption. Those statistical features support the outside-in model for substorm triggering.

Keywords: magnetosphere, aurora, substorm, current disruption, THEMIS

Poleward expansion of high-altitude acceleration region at substorm

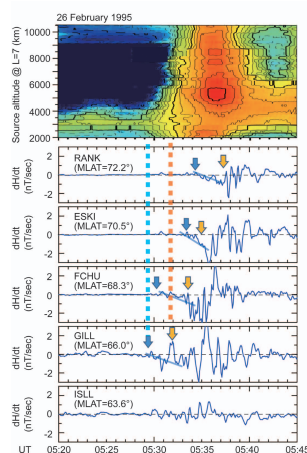
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It is well established, since the first phenomenological study of auroral substorm by Akasofu [1964], that auroral bulge expands poleward after breakup. Fujii et al. [1994] showed that the poleward edge of the auroral bulge is characterized by dense upward FAC and intense electron precipitation. On the other hand, the behavior of field-aligned acceleration during the bulge development has not been well understood. In this paper we examine the evolution of field-aligned acceleration during the substorm expansion phase invoking spatial development of high latitude Pi pulsations.

Figure shows that the start time of the negative excursion of DC-ULF at GILL (blue arrow) corresponds to that of the low-altitude AKR enhancement (vertical blue line), and the commencement of large amplitude Pi 2 (yellow arrow) corresponds to that of the high-altitude AKR breakout (vertical yellow line). This means that GILL station was almost the foot print of the magnetospheric substorm onset. Wave forms of Pi 2 at higher latitudes indicated the poleward motion of bulge front, and high-altitude AKR (manifestation of high- altitude acceleration) was active during the poleward motion of the bulge front. This indicates an important consequence that the bulge front accompanied the high-altitude acceleration throughout the poleward expansion, resulting in the continuous emanation of active high- altitude AKR.

Keywords: field-aligned acceleration, high-altitude acceleration region, poleward expansion, substorm



Contribution of wave activity observed around the X-line to the reconnection energy dissipation

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In JpGU 2012, we have reported plasma wave activity observed in one of the best event on May 15, 2003 of the near Earth magnetotail reconnection. Our conclusion was that the Geotail observation is consistent with the collisionless reconnection model as shown in recent kinetic simulation results. Recently, Zenitani et al. (2012) successfully estimated the energy dissipation rate of the same reconnection event. Their result is also consistent with our interpretation that the observed wave activity cannot be a major player of the reconnection dissipation. To confirm our present conclusion more, we have examined plasma wave activity observed in some more reconnection events where Geotail possibly encountered with the electron diffusion. As a result, we commonly found that the wave intensity right in the center of the electron current layer, that is a possible X-line, is much weaker than that in its surrounding region. These Geotail observations suggest that the magnetic diffusion region of the near Earth magnetotail reconnection site is mainly controlled by the physics of the collisionless reconnection process, rather than the anomalous resistivity due to turbulence.

Keywords: magnetic reconnection, energy dissipation

Particle and field near the equatorial region in the magnetosphere at the onset of pulsating aurora

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Fundamental characteristics of pulsating auroras, such as modulation region, modulation mechanism, and their shapes are still open question. Simultaneous observation onboard satellite and on the ground are important method to examine such fundamental characteristics of pulsating aurora. In this study we examined some selected pulsating auroral events, which obtained onboard Cluster spacecraft and ground-based all-sky camera at Syowa-Iceland conjugate-pair and also onboard THEMIS satellites and the THEMIS ground-based all-sky camera network. Both of Cluster and THEMIS satellites were located near the equatorial plane in the magnetosphere. The particle and field signatures in the magnetosphere during pulsating aurora are; 1) All pulsating aurora associate with high-energy (>10 keV) electron flux enhancement, 2) Not all pulsating aurora associate with ELF/VLF wave enhancement, 3) It is difficult to identify a quasi-periodic modulation of high-energy electron flux, which may be corresponding to pulsating aurora patch. We will discuss modulation region and possible mechanism of pulsating aurora.

Keywords: aurora, pulsating aurora, high energy electron, plasma wave, magnetosphere, ionosphere

THEMIS observations of electromagnetic ion cyclotron emissions in the inner magnetosphere

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Electromagnetic ion cyclotron (EMIC) triggered emissions were first reported by Pickett et al. [2010]. These were observed by the Cluster spacecraft close to the plasmopause in the equatorial region of the magnetosphere, which have rising tone spectra similar to those of whistler-mode chorus emissions. These phenomena have received much attention because of the possibility of their strong interaction with particles in the inner magnetosphere pointed out by Shoji et al. [2011] and Omura and Zhao [2012], regardless of their few observations.

This study reports the presence of various EMIC triggered emissions found in the flux gate magnetometer (FGM) data onboard the THEMIS probes during the interval from 2007 to 2011. They are Pc1-2 emissions with narrow-band frequency and sporadic frequency variation with the timescale of tens of second. We can find them over a broad area between the magnetopause and the plasmopause, mainly in the dayside of 6-10Re. We recognize various type of emissions which have typical rising-tone spectra, have falling-tone spectra analogous to whistler-mode falling-tone discrete emissions, and are excited simultaneously in the different frequency bands bounded by the cyclotron frequencies of ions.

Omura et al. [2010] have developed the nonlinear wave growth theory which explains the generation of the EMIC triggered emissions. We compared some events observed with their theory, and found that the obtained relation between the magnetic amplitudes of the emissions and variations in frequencies are well explained by the theory. In addition, there are rising-tone emissions with right-hand polarization and the lower limits in frequency corresponding to the equatorial crossover frequency. We consider that they are the L-mode emissions generated by nonlinear growth and suffered the mode change through the propagation process. According to the nonlinear growth theory, a rising-tone emission is initially generated with a continuous frequency waves in the generation region, normally equatorial plane. This belongs to two different branches in dispersion relation of EMIC wave with a boundary at the crossover frequency around half of the gyrofrequency at the source region. These two branches propagate from the source region through different processes, and it is expected that the branch with upper frequencies can propagate over a relatively high latitude than the lower branch. This result is important as these emissions generated in the equator as L-mode waves.

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Comparison study of particle acceleration in the Earth's magnetotail and solar corona

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One of the most famous rapid energy conversion mechanisms in space is a magnetic reconnection. The general concept of a magnetic reconnection is that the rapid energy conversion from magnetic field energy to thermal energy, kinetic energy or non-thermal particle energy. The understanding of rapid energy conversion rates from magnetic field energy to other energy is the fundamental and essential problem in the space physics. One of the important goals for studying magnetic reconnection is to answer what plasma condition/parameter controls the energy conversion rates. Earth's magnetotail has been paid much attention to discuss a magnetic reconnection, because we can discuss magnetic reconnection characteristics in detail with direct in-situ observation. Recently, solar atmosphere has been focused as a space laboratory for magnetic reconnection because of its variety in plasma condition. So far considerable effort has been devoted toward understanding the energy conversion rates of magnetic reconnection, and various typical features associated with magnetic reconnection have been observed in the Earth's magnetotail and the solar corona.

In this talk, we first introduce the variety of plasma condition/parameter in solar corona and Earth's magnetotail. Later, we discuss what plasma condition/parameter controls the energy conversion from magnetic field to especially non-thermal particle. To compare non-thermal electron and ion acceleration in magnetic reconnection, we used Hard X-ray (electron) /Neutron monitor (ion) for solar corona and Geotail in-situ measurement (electron and ion) for magnetotail. We found both of electron and ion accelerations are roughly controlled by reconnection electric field (reconnection rate). However, some detail point is different in ion and electron acceleration. Further, we will discuss what is the major difference between solar corona and Earth's magnetotail for particle acceleration.

Keywords: flare, substorm, particle acceleration, comparison study

Coupling between the ULF waves and the ring current in the inner magnetosphere based on the GEMSIS-RC model

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Understanding of acceleration mechanisms of electrons to cause drastic variation of the Earth's outer radiation belt is one of outstanding issues of the geospace researches. While the radial diffusion of the electrons driven by ULF waves has been considered as one of the candidate mechanisms, efficiency of the mechanism under realistic ULF characteristics and distribution is far from understood. GEMSIS (Geospace Environment Modeling System for Integrated Studies) of STEL, Nagoya University, is the observation-based modeling project for understanding energy and mass transportation from the Sun to the Earth in the geospace environment. Aiming at understanding the dynamics of the inner magnetosphere during the geospace storms, the GEMSIS-Magnetosphere working team has developed a new physics-based model for the global dynamics of the ring current (GEMSIS-RC model). The GEMSIS-RC model is a self-consistent and kinetic numerical simulation code solving the five-dimensional collisionless drift-kinetic equation for the ring-current ions in the inner-magnetosphere coupled with Maxwell equations.

We applied the GEMSIS-RC model for simulation of global distribution of ULF waves to test its capability of describing fast time scale phenomena like SCs and ULF waves. Comparison between runs with/without ring current ions show that the existence of hot ring current ions can deform and amplify the original sinusoidal waveforms. The deformation causes the energy cascade to higher frequency range (Pc4 and Pc3 ranges). The cascade is more pronounced in the high beta case. It is also shown that the existence of plasmopause strengthens ULFs outside the plasmopause and widens the MLT region where the E_r (toroidal) component is excited from initially-given E_θ (poloidal) component. We report how the amplification and reflection of the ULF waves depend on the ring current parameters such as its density and temperature.

Keywords: inner magnetosphere, ring current, radiation belt, ULF wave, Pc5, drift resonance

Study on current generation mechanism in Earth's magnetosphere

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A study on perpendicular and parallel current generation mechanism in the magnetosphere is important problems in interaction between the solar wind and earth's magnetosphere-ionosphere. As the solar wind and IMF becomes abnormal conditions, plasma turbulence are strongly excited near boundary layers in the magnetosphere. In the plasma sheet magnetic reconnection occurs in patchy and intermittent manner to produce streamer-like structure. At the magnetopause, more regular vortex train is formed for northward IMF.

Dayside reconnection occurs in patchy and intermittent manner to give seeds of plasma turbulence. As the results, complicated and strong vortex turbulence appears in flank magnetopause. We will demonstrate those phenomena from 3-dimensional visualization method of simulation results to discuss relationship between the currents and vortices in boundary layers. In particularly we will stress relationship among parallel and perpendicular components of vorticity and current, and also compressibility in order to understand the fundamental picture of magnetospheric physics.

Keywords: MHD Simulation, current generation mechanism, Vorticity and compressibility, Magnetic Reconnection, Magnetospheric Dynamics, Boundary Layer Instabilities

THEMIS observations of plasma transport induced by eddy turbulence

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We provide an event study of THEMIS observations of the low-latitude boundary layer in the noon-dawn sector of the magnetosphere on 2008-12-05. Simultaneous multipoint observations show that the magnetosheath-like plasma is transferred earthward from the magnetopause. This earthward transport is accompanied by decrease in the density and fluctuating bulk flow, indicating that the transport is not due to convection. We calculate the eddy diffusion coefficients from the observed velocity data and found that the numbers are in good quantitative agreement with the spatial and time scales of the observed earthward transport signatures. Our study suggests that the observed transport is due to diffusive transport via turbulent eddy motions as is the case of an ordinary (Navier-Stokes) fluid.

Keywords: plasma transport, diffusion, turbulence, THEMIS

Statistical Study on Jovian Magnetospheric Response to Solar Wind Dynamic Pressure

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Structures and dynamics of planetary magnetospheres depend on magnitude of their planetary magnetic field, inner plasma source, and plasma wind from stars, and hence magnetospheres show a wide variety. Past observations have revealed the typical structures/dynamics of the Jovian magnetosphere, which represents distinctive plasma environments compared to the Earth's magnetosphere. However, the magnetospheric response to the variable solar wind is still unclear, due to the absence of the solar wind monitor at the Jovian orbit. I approach this issue by using the calculated solar wind parameters via MHD equations whose input parameters are based on the observation at the Earth's orbit. Referring the propagated solar wind parameters, I investigate the variability of the Jovian magnetotail. Through statistical analyses using data obtained from Jovian orbiter Galileo, I find the tendency that the structure of nightside current sheet changes, magnetic field north-south component is disturbed, and the energetic particle fluxes enhance, responding to the increase of the solar wind dynamic pressure. On the other hand, energetic particle beams were often observed even when solar wind dynamic pressure is low. Furthermore, when energetic particle beams are absent, north-south magnetic field disturbances and energetic particle enhancements were not significant. Assuming that such beams are generated by transient magnetic reconnection in Jovian magnetotail, I argue that (1) Jovian tail reconnection can occur without solar wind dynamic pressure increase, whereas (2) tail reconnection is not a sufficient but a necessary condition for large north-south magnetic field disturbance and energetic particle enhancement at the location of Galileo.