

磁気圏近尾部におけるサブストームの磁場双極子化開始前の低周波波動 Low-frequency waves in the near-Earth magnetotail before substorm dipolarization onsets

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磁気圏近尾部で発生する磁場双極子化は、サブストーム開始機構を理解する上で重要な現象である。本研究では、X=-10 Re 付近の磁場双極子化開始前の低周波波動について調べた。まず、Geotail 衛星による 43 例のサブストーム事例について解析を行ったところ、次のことがわかった。磁場双極子化開始の少なくとも 10 分以上前から、振幅は小さいながらも、周期が 1-2 分程度のアルフベン波とスローモードの磁気音波が存在する。それらは、磁場双極子化開始後に大きくなる。また、磁場双極子化前の波動の振幅は、赤道面から離れたプラズマシートからプラズマシート境界層にかけて大きく、赤道面とローブでは比較的小さい。これらの結果と THEMIS 衛星による多点同時観測データの解析結果をもとに、低周波波動と磁場双極子化、サブストーム開始との関連について議論する。

キーワード: サブストーム, 磁気圏尾部, 磁場双極子化, 低周波波動

Keywords: substorm, magnetotail, dipolarization, low-frequency waves

北海道-陸別 HF レーダー観測に基づく中低緯度電離圏 Pc5 波動の統計的性質の研究 Statistical properties of Pc5 waves in the mid-latitude ionosphere observed by the Super-DARN Hokkaido HF radar

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The Pc5 wave, which is one of ULF waves, is defined as the continuous pulsation in the frequency range between 1/600 and 1/150 Hz. It has been considered that the magnetospheric Pc5 waves are globally and directly generated either by solar wind dynamic pressure variations on the dayside or by Kelvin-Helmholtz surface waves on the dawn/dusk flank, and partially and indirectly on the nightside by wave-particle interactions. Pc5 waves can play an important role in the mass and energy transport in the inner magnetosphere. The radiation belt electrons in the inner magnetosphere can be significantly accelerated by the Pc5 waves, as suggested by previous studies. One of outstanding problems in Pc5 studies is to clarify its global distribution, generation mechanisms, and especially their dependence on the solar wind parameters.

We conducted a statistical analysis of data from the SuperDARN Hokkaido HF radar in mid-latitude ionosphere. The beams 5 and 14 data of the HF radar and the OMNI solar wind data for the period from January, 2007 to December, 2012 are used. We identified Pc5 wave events through an automatic Pc5 selection with criteria to extract coherent variation over a certain range of the magnetic latitude and by the visual inspection after the automatic selection. Out of the 60 events identified, and we examined 55 events during which the OMNI data are available. As a result, the Pc5 waves in the mid-latitude ionosphere are roughly categorized into two types, i.e., events under low-speed solar wind and high-speed solar wind conditions. The amplitude of the high-speed solar wind Pc5 events tends to increase with increasing solar wind velocity. This result is consistent with the idea that they are driven by the Kelvin-Helmholtz instability at the magnetopause. On the other hand, the amplitude of the low-speed solar wind Pc5 events has a positive correlation with the variances of the solar wind dynamic pressure. It is thus implied that the Pc5 events under the low-speed condition in the low-latitude are directly driven by the solar wind dynamic pressure variations.

キーワード: 内部磁気圏, ULF 波動, 北海道-陸別 HF レーダー, Pc5 波動

Keywords: inner magnetosphere, ULF wave, SuperDARN Hokkaido HF radar, Pc5 wave

AKR 偏波解析のためのかぐや WFC-H データの較正 Calibration of the KAGUYA/WFC data for AKR polarization analysis

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かぐや衛星では、地球の極域を起源とする AKR(auroral kilometric radiation:オーロラキロメートル電波) が頻繁に観測されている。AKR の偏波は、観測領域に依存することが知られている。かぐや衛星による観測では、月の掩蔽を利用して南北半球の偏波を独立に解析できると期待される。

WFC (Waveform Capture) は、かぐや衛星に搭載されたプラズマ波動受信器である。WFC のサブシステムである WFC-H は、観測期間中に渡って 1kHz ~ 1MHz のスペクトルと波の偏波を観測した。オンボード処理の過程において直交アンテナ X-Ych 間に時間ずれが生じており、観測データから偏波の解析を行なうためには、そのずれの較正が必要となる。本研究では、AKR 偏波を推定するためにデータの較正処理を行なった。

X-Ych 間の時間ずれは、WFC-H 内部の PDC (Programmable Down Converter) と呼ばれる IC が同期していないことによって発生している。PDC が X-Ych それぞれのデジタル処理を担っている。PDC では、1kHz ~ 1MHz の広帯域の信号を 39kHz の 26 狭帯域に分割して処理している。これら 26 帯域に生じている X-Ych 間の時間ずれを推定するために、隣り合った 2 つ帯域でオーバーラップしている周波数帯のデータを利用した。隣接した 2 帯域に対して「X-Ych 間の位相差」の差を統計的に計算し、その頻度分布を求めた。その結果、X-Ych 間の時間ずれは周波数に対して線形であることがわかった。これは、X-Ych 間の時間ずれは、分割された各狭帯域に対して一定であることを意味しており、その傾きから時間ずれは 1.1 マイクロ秒であるといえる。さらに、PDC 内部の 3 つの LPF による位相の回転も考慮して、WFC-H の偏波データを較正した。

較正前は、偏波 (X-Ych 間の位相差) は周波数に依存しており、明らかにおかしい偏波となっていた。一方、較正後は、偏波は 2 時間周期で時間に変動をもつ結果が得られた。これは、衛星軌道における衛星の姿勢を考慮すると妥当であるといえる。

キーワード: かぐや衛星, AKR, キャリブレーション

Keywords: KAGUYA, AKR, calibration

Pi2の子午面内 Poloidal 成分 Poloidal component of Pi2 in the meridian planes

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オーロラ帯の特定の緯度で Pi2 の H 成分の位相が逆転する事と、また同時に偏波も逆転する事は良く知られているが、その原因に子午面内 Poloidal 成分の関与があることが指摘されている(*)。ここでは、

(1) 磁気圏内の東向き電流(反磁性電流)による Poloidal 成分の励起が地上磁場 H 成分の反転に現れる事を報告する。

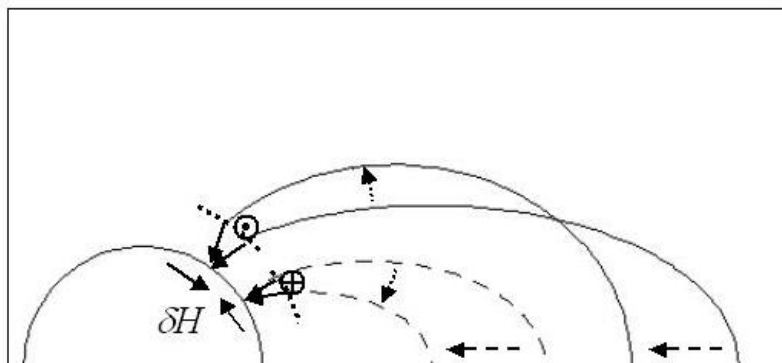
(2) オーロラとの同時観測から予測される Poleward expansion の Onset latitude と反磁性電流の位置関係について報告する。

References

* Saka, Hayashi, Koga, (JGR, 2012).

キーワード: Pi2 脈動, オーロラ ブレイクアップ, サブストーム, ポロイダル成分

Keywords: Pi2 pulsation, aurora breakup, substorm, poloidal component



Deformation of field lines in the meridian planes

脈動オーロラにおけるマルチスケールな時間変動特性: On-off 脈動と数 Hz 変調 Multi-scale temporal variations of pulsating auroras: on-off pulsation and a few-Hz modulation

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Pulsating aurora (PA) is characterized by the periodically changing emission amplitudes with on-off pulsations of less than 1 s to a few tens of seconds. PA is also well-known as its patchy structure with the horizontal size of 10-200 km. The energy of precipitating electrons ranges from one to a few tens of keV, which is thought to result from pitch angle scattering due to wave-particle interactions near the magnetic equator. Recently, Nishimura et al. [2010] found a one-to-one correspondence between the intensities of PA and amplitudes of whistler mode chorus near the equator. Similarly, electron cyclotron harmonics (ECH) were observed with on-phase of PA. ULF wave is expected to control the excitation of both the whistler mode chorus and ECH by the modulation of the local plasma density. However, an important problem, identifying which mechanism is the most dominant, remains unsolved. In addition, since PA has the distinctive properties in a variety of spatial and temporal scales, we should investigate such multi-scale properties statistically to further understandings of the generation mechanism of PA. The purpose in this study is to reveal the precise spatial-temporal properties and to establish a generation mechanism of PA using ground-based instruments. We developed an EMCCD camera with a wide field-of-view (FOV) and 100-Hz sampling, which is optimized to spatio-temporal properties such as the small-scale structures (< 10-30 km) and rapid temporal variations (3-Hz modulations) in a 2-D plane.

The statistical study on the cross-scale properties was presented based on 53 events observed at Poker Flat Research Range during the period from December 1st, 2011 to March 1st, 2012. The observed modulation frequency ranged from 1.5 to 3.3 Hz. Any strong modulations were not seen in frequency range higher than about 3 Hz in our study, which may suggest that the TOF of electron makes the time-smoothing effect on the rapid variations higher than 3 Hz. Furthermore, the frequency of modulation showed relatively strong correlation to auroral intensity with the correlation coefficient of 0.52, and it can be explained with non linear wave growth theory suggesting that higher modulation frequency with larger wave amplitude of whistler mode chorus. In contrast, the on-off pulsations showed no significant correlations with any of other properties of PA. This result implies that the on-off periods may be determined by the balance of a variety of factor, such as a spatial size on the flux tube, a drift velocity of an energetic electron. Alternatively, long-term variations of the cold plasma density would control the condition for wave-particle interactions in the temporal scale of the on-off pulsation periods.

キーワード: オーロラ, 内部磁気圏, 波動粒子相互作用, 地上観測, ULF 波動

Keywords: Aurora, Inner magnetosphere, Wave-particle interactions, Ground-based observations, ULF waves

内部磁気圏ホイッスラーモード波動のIMF Bz依存性に関するシミュレーション Simulation on the IMF Bz control of the chorus wave excitation during the high-speed coronal hole streams

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Electron flux of the outer belt tends to increase when the high-speed solar wind interacts with the magnetosphere. The flux enhancement depends not only on the solar wind speed but also on the offset in the north-south component of the interplanetary magnetic field, i.e. the southward offset causes larger flux enhancement than the northward offset, although large-amplitude Alfvénic fluctuations always exist in the high-speed solar wind. If the acceleration process of the outer-belt electrons via the whistler-wave particle interaction is dominant, the populations of hot electrons, plasmasphere, and whistler waves enhance all together during the SBz stream, while they weaken all together during the NBz stream. We have observationally shown the north-south IMF dependence. In this study, we use the relativistic-RAM electron model to confirm the north-south IMF dependences of the key parameters. The data measured by LANL/MPA is used as a boundary condition at L=6.6. As a result, in the SBz stream, there are enhancements of hot electrons of ~30 keV and lower-band whistler mode waves around L=4 at dawn-side, while they are at L>5 in the NBz stream. It is found that, in our simulations, these differences are primarily originated from the magnetospheric convection. We further discuss an assessment of non-linear whistler wave growth based on the threshold of the non-linear growth and the optimum wave amplitude [Omura and Nunn, 2011]. The regions for the non-linear growth are different from that for the intense linear growth. The assessment of non-linear whistler wave growth is useful to identify when and where we can observe chorus waves.

キーワード: 内部磁気圏, ホイッスラーコーラス, シミュレーション, 太陽風磁気圏相互作用
Keywords: inner magnetosphere, whistler chorus, simulation, solar wind - magnetosphere coupling

磁場計測による磁気赤道と人工衛星の相対位置の推定

Use of magnetic field measurements as an indicator of spacecraft locations

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It is known that the configuration of the magnetosphere is more complicated than that of the intrinsic magnetic field only due to highly dynamical and time-dependent magnetospheric currents. There are empirical magnetospheric models derived from statistical analysis of large data sets. However, the models give us average states, which often results in deviation from instantaneous magnetospheric configurations. It is important to construct a technique to show where spacecraft is located in the magnetosphere, especially, how far from the magnetic equator spacecraft is when we interpret the observational results since the distance from the equator is a significant controlling factor for evolution of plasma temperature anisotropy and plasma wave intensities. In this study, using the data obtained by the THEMIS spacecraft, we show a simple method to estimate spacecraft location relative to the magnetic equator using local magnetic field measurements. The method uses the ratio of B_r to $|B|$, where B_r and $|B|$ is the radial component of the magnetic field vector and total magnetic field intensity, respectively. When we choose a simple dipole magnetic field as a reference, we can analytically estimate the magnetic latitude from the measured ratio $B_r/|B|$. Since rising tone chorus emissions are generated in the region close to the magnetic equator and propagate higher latitudes in both the Northern and Southern hemispheres, the method was tested by deriving the latitudinal distribution of propagation direction of rising tone chorus emissions measured by THEMIS. We analyzed 246 rising tone chorus events and statistically derived the latitudinal distribution referring to both the dipole magnetic latitude and the magnetic latitude estimated by $B_r/|B|$. The latitudinal distributions based on the dipole magnetic latitude and estimated magnetic latitude show that 77 % (190 events) and 98 % (241 events) of the events are observed to propagate from the equator to higher latitudes, respectively. It indicates that the magnetic latitude based on the magnetic field measurements is more reliable than the dipole magnetic latitude to show the spacecraft location relative to the magnetic equator. We will test and discuss the performance of our method by comparing the latitudinal distribution of propagation direction of chorus emissions based on the estimated magnetic latitude with that based on the empirical magnetospheric models. We will also discuss capabilities of the method and applications to magnetospheric studies, especially plasma wave phenomena.

太陽風と太陽紫外線による土星オーロラ電波の長期変動

Long-Term variations of Saturn's Auroral Radio Emissions by the Solar Ultraviolet Flux and Solar Wind

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The long-term variations of Saturn's auroral current system have been suggested to be controlled by the seasonal variations of the polar ionospheric conductivities and atmospheric conditions associated with the solar ultraviolet (UV) flux. However, that long-term variations are not investigated in terms of the other controlling factors such as the solar wind variations in the timescale of the solar cycle. This study investigated the long-term variations of Saturnian Kilometric Radiations (SKR) as a proxy of the auroral current, which were observed by Cassini's radio and plasma wave experiment mostly during the southern summer (DOY 001, 2004 to DOY 193, 2010). We deduced the height distribution of the SKR source region in the northern (winter) and southern (summer) hemispheres from the remote sensing of SKR spectra. It was found that on average the southern (summer) SKR was 7 dB greater than the north (winter) in the spectral density, and the altitude of the southern flux peak (0.7 Rs) was lower than the north (0.9 Rs). The southern and northern spectral densities became comparable with each other around the equinox in August, 2009. These results suggest the stronger field aligned acceleration during the summer than the winter by the seasonal UV effect as opposed to the terrestrial one. The long-term correlation analysis was performed for the SKR and solar wind parameters extrapolated from Earth's orbit by the MHD simulation focusing on variations at timescales beyond several weeks. We found the clear positive correlations between the solar wind parameters and peak flux density in both of the southern and northern hemispheres during the declining phase of the solar activities. It is concluded that the solar wind variations in the timescale of the solar cycle controls the SKR source region in addition to the seasonal solar UV effect. The variation of SKR activity over both seasonal and solar cycles are discussed comparatively to the terrestrial case.

キーワード: 土星, オーロラ, 電波, 磁気圏, 太陽活動

Keywords: Saturn, aurora, radio, magnetosphere, solar activity

地上磁場からの磁気圏密度推定における地下電導度効果の適切な除去の重要性 Importance of correctly removing the underground-conductivity effect in the gradient methods

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There are methods called the hodograph method and the amplitude-phase gradient method (APGM below) that are used to obtain the latitude dependence of the field-line-resonance (FLR) frequency by using data from two ground magnetometers latitudinally separated by ~100km. They both apply FFT to the two magnetometers' data, and calculate the amplitude ratio and the cross phase between the two stations' data as functions of the frequency. From there the two methods use different ways to estimate the latitude dependence of the FLR frequency; the hodograph method fits a circle to the obtained ratio (as a complex number including both the amplitude ratio and the cross phase) to separate out the non-FLR signal in the data, while APGM assume that the obtained amplitude ratio and phase difference include no non-FLR signal and obtains the FLR frequency (as a function of latitude) in an algebraic manner. In this paper we discuss the differences between the two methods by using example events, and show that the both methods need precise enough removal of the effects of the underground conductivity, superposed on the signal from space, in the magnetic field data before applying the method. More details will be presented at the meeting.

近地球磁気圏尾部領域におけるプラズマ高速流まわりのエネルギー変換と電子加速の特性

Characteristics of energy conversion and electron acceleration around the fast plasma flows in near-Earth magnetotail

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Fast earthward flows accompanied by large B_Z enhancement, are sometimes observed in the near-Earth magnetotail. Such B_Z enhancements are called "dipolarization front". In some cases, earthward flows are instantly followed by the tailward flows. We call such events as "flow reversal", where the earthward flow seems to reverse to the tailward flow. However, the energy conversion and electron acceleration mechanisms during the flow are not fully understood. In this study, the two types of events were analyzed using THEMIS spacecraft data from Dec., 2008 through Mar., 2009. The number of events is 25 for dipolarization front events [1] and 16 for flow reversal events. Based on the results of $\mathbf{j} \cdot \mathbf{E}$ and electron distribution function, we discuss energy conversion and electron acceleration mechanisms during the dipolarization front events or flow reversal events.

[1] A.Runov, V.Angelopoulos, X.-Z.Zhou, X.J.Zhang, S.Li, F.Plaschke and J.Bonnell, A THEMIS multiscale study of dipolarization fronts in the magnetotail plasma sheet, J. Geophys. Res., 116, A05216, 2011.

Keywords: energy conversion, fast plasma flow, electron distribution function