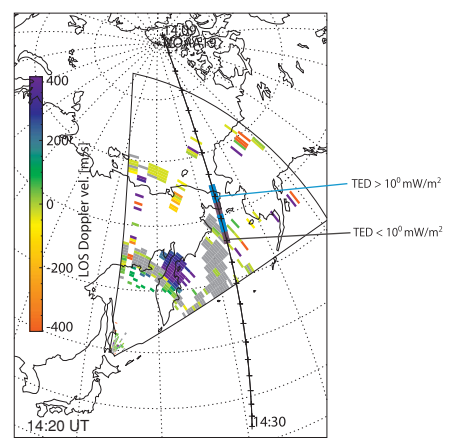
Earth, Planets and Space

Coupling of the High and Mid Latitude Ionosphere and Its Relation to Geospace Dynamics



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Journal Scope

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Yours sincerely,

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Earth, Planets and Space

Nishitani *et al. Earth, Planets and Space* (2016) 68:168
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PREFACE

Open Access

Special issue "Coupling of the high and mid latitude ionosphere and its relation to geospace dynamics"

Nozomu Nishitani[1*], Tsutomu Nagatsuma[2], Akira Sessai Yukimatu[3], Hongqiao Hu[4] and Takeshi Sakanoi[5]

The EPS special issue, *Coupling of the High and Mid Latitude Ionosphere and Its Relation to Geospace Dynamics,* originated from a session held during the Asia Oceania Geosciences Society (AOGS) 2014 meeting in Sapporo (Japan). In addition to the papers presented at the conference, others of common scientific interest have been included. In the end, 12 papers have been published, covering a wide variety of scientific topics.

The focus of this special issue is on the coupling of the high and mid latitude ionosphere, which plays an important role in geospace dynamics. Recently, the coverage offered by ground-based observation networks, such as magnetometers, high-frequency (HF) radars, Global Positioning System (GPS) receivers and others, has increased dramatically, improving our understanding of the coupling between the high and mid latitude ionosphere. In addition, several satellites in geospace provide essential in situ data, yielding numerous new findings, as well as posing new questions. The papers in this issue contribute to our understanding of the high/mid (and low/equatorial) latitude ionosphere and geospace coupling, as well as geospace dynamics.

Sudden changes in the dynamic pressure of solar wind, known as sudden impulses (SI), have a major influence on the magnetosphere and ionosphere. Specifically, the SI have a significant effect on ionospheric convection at high and mid latitudes, as observed by the Super Dual Auroral Radar Network (SuperDARN) HF radars (Hori et al. 2015), as well as on auroral emissions (Liu et al. 2015). In addition, the interaction between solar wind and the magnetosphere leads to substorms, which are manifestations of the explosive energy release processes. The inductive effects of the magnetosphere during the course of a substorm have been studied by Mishin et al. (2015).

Magnetosphere–ionosphere interaction, equatorward of the auroral emission region (subauroral latitudes), often generates subauroral polarization streams (SAPS). Nagano et al. (2015) have identified the slowest speed limit of SAPS and have suggested that the ionospheric feedback mechanism does not play a significant role in the slower part of the SAPS.

The ionosphere is formed as a result of solar emission, magnetosphere–ionosphere coupling, and ionosphere–thermosphere coupling processes. It is important to know the distribution of ionospheric plasma densities in order to understand the formation processes of the ionosphere. The characteristics of the distribution of ionospheric plasma density were studied by employing FORMOSAT-3/COSMIC satellite data (Chang et al. 2015), GPS TEC data (Kumar et al. 2015), and SuperDARN HF radar data (Oinats et al. 2016a). The results of the analysis of the observation data were compared with HWM93 simulation or International Reference Ionosphere (IRI)-2012 model.

Additionally, the ionosphere is disturbed by ionospheric plasma instability processes and ionospheric–thermosphere coupling processes. The characteristics of traveling ionospheric disturbances of various origins were studied by employing SuperDARN HF radar data (Oinats et al. 2016b). Tsunami-driven traveling ionospheric disturbances were studied by employing GPS TEC data (Tang et al. 2015). Seif et al. (2015) have studied the detailed characteristics of daytime ionospheric scintillation near the magnetic equator and have discussed the role of gradient-drift instability in generating ionospheric plasma irregularities.

In addition, in order to study ionospheric characteristics, it is important to develop techniques to enhance the

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precision of analyzing observational data. Ponomarenko et al. (2015) have developed an algorithm for calibrating the elevation angle parameter of the SuperDARN radars, which is important in identifying echo locations. Furthermore, it is important to model the ionospheric parameters to extract the main characteristics of ionospheric disturbances. Mandrikova et al. (2015) have developed an algorithm for modeling ionospheric parameter FoF2 and extracting the main characteristics of ionospheric perturbations during different seasons and geomagnetic activities.

With the advance of observational techniques and the expansion of the field of view of the existing observation network, as well as the development of modeling/numerical simulation algorithms, we hope to enhance the understanding of the ionosphere, ranging from the high to mid/low latitude, and its relation to the dynamics of the geospace and upper atmosphere.

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Kumar S, Tan EL, Murti DS (2015) Impacts of solar activity on performance of the IRI-2012 model predictions from low to mid latitudes. Earth Planets Space 67:42

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FRONTIER LETTER Open Access

IMF-By dependence of transient ionospheric flow perturbation associated with sudden impulses: SuperDARN observations

Tomoaki Hori*, Atsuki Shinbori, Shigeru Fujita and Nozomu Nishitani

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Abstract

A statistical study using a large dataset of Super Dual Auroral Radar Network (SuperDARN) observations is conducted for transient ionospheric plasma flows associated with sudden impulses (SI) recorded on ground magnetic field. The global structure of twin vortex-like ionospheric flows is found to be consistent with the twin vortices of ionospheric Hall current deduced by the past geomagnetic field observations. An interesting feature, which is focused on in this study, is that the flow structures show a dawn-dusk asymmetry depending on the combination of the polarity of SI and interplanetary magnetic field (IMF)-By. Detailed statistics of the SuperDARN observations reveal that the dawn-dusk asymmetry of flow vortices due to IMF-By appears during negative SIs, while such asymmetric characteristics are not seen during positive SIs. On the basis of the upstream observations, we suggest that this particular dawn-dusk asymmetry is caused by the interaction between the pre-existing round convection cell and a pair of the transient convection vortices associated with SIs.

Keywords: Sudden impulse; Ionospheric plasma convection; SuperDARN

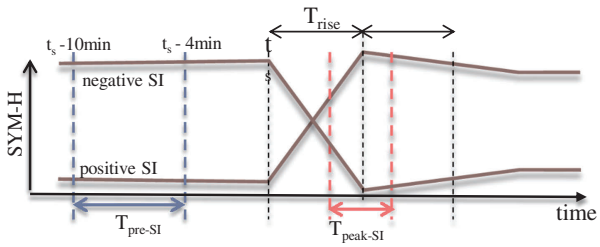

Figure 1

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FULL PAPER Open Access

Impacts of solar activity on performance of the IRI-2012 model predictions from low to mid latitudes

Sanjay Kumar*, Eng Leong Tan and Dhimas Sentanu Murti

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Abstract

This study investigates the impacts of solar activity on the performance of the latest release of International Reference Ionosphere (IRI) model version 2012 (IRI-2012) predictions during the ascending phase of solar activity from 2009 to 2013. The study is based on the data of total electron content (TEC) retrieved from the Global Positioning System (GPS) at Singapore (NTUS) (geographic latitude 01.34°N, longitude 103.67°E, geomagnetic latitude 8.4°S), Thailand (CUSV) (geographic latitude 13.73°N, longitude 100.54°E, geomagnetic latitude 3.96°N), China (KUNM) (geographic latitude 25.02°N, longitude 102.79°E, geomagnetic latitude 15.15°N), Mongolia (ULAB) (geographic latitude 47.67°N, longitude 107.05°E, geomagnetic latitude 37.73°S), and Russia (IRKM) (geographic latitude 52.21°N, 104.31°E, geomagnetic latitude 42.28°S). The GPS-TEC has been compared with the IRI-2012 model TEC for three different options, namely, IRI-NeQ, IRI01-corr, and IRI-2001, for topside Ne over all the above five stations lying at different latitudes from equatorial-equatorial ionization anomaly (EIA) to mid-latitude regions but at around the same longitude line (104° ± 3°E). The study showed that the IRI model predictions for different topside options are different and significant in low-latitude region but insignificant in mid-latitude regions (except during winter season of high solar activity year 2012). During the period from 2009 to 2013, upon moving from low to high solar activity, the prediction nature (overestimation/underestimation) of IRI-2012 model changes significantly at EIA station KUNM of low-latitude region. The discrepancy in IRI-2012 model TEC as compared to GPS-TEC in low-latitude region is found to be larger and significant than in mid-latitude region (Mongolia and Russia). The discrepancy in the IRI-2012 model TEC with IRI-2001 topside is found to be maximum at equatorial station CUSV (RMSD 99%) during the solar minimum year 2009 and decreases moving towards high solar activity year. This suggests that significant improvements to the IRI-2012 model (hmF2 model) are required particularly in the equatorial regions taking the impacts of solar minimum year into account.

Keywords: Ionosphere; GPS; IRI model; Solar activity

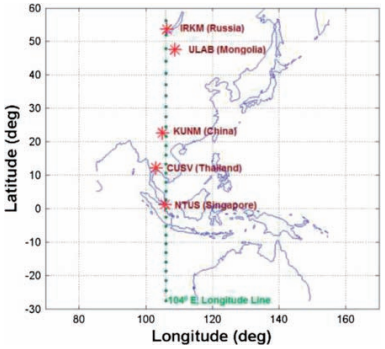

Figure 1

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FULL PAPER Open Access

Observation of ionospheric disturbances induced by the 2011 Tohoku tsunami using far-field GPS data in Hawaii

Long Tang, Xiaohong Zhang* and Zhe Li

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Abstract

In this study, we employ far-field GPS total electron content (TEC) observed in Hawaii to detect the ionospheric disturbances induced by the 2011 Tohoku tsunami. We observed tsunami-driven traveling ionospheric disturbances (TIDs) at two different times: at about 12:40 UT, there were TIDs in the disturbance series propagating at approximately 260 m/s in an outward direction from the tsunami's source, and then, the signals began to weaken and gradually disappeared after 14:00 UT; however, at about 17:30 UT, the TIDs appeared again in the disturbance series with similar propagation characteristics. According to the observation times, the former TIDs can be attributed to the straight tsunami from the mainshock, while the latter TIDs are most likely driven by tsunami from aftershocks. Furthermore, we also observed tsunami-like TIDs at about 11:50 UT with similar horizontal velocity and direction compared to tsunami waves. However, the arrival time of the TIDs was about 1.5 earlier than tsunami waves in the sea level and should be induced by other sources.

Keywords: GPS; Total electron content; Traveling ionospheric disturbances; Tsunami

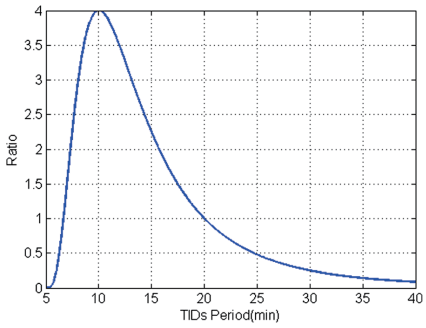

Figure 1

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Simultaneous ground-based optical and SuperDARN observations of the shock aurora at MLT noon

Jianjun Liu*, Hongqiao Hu, Desheng Han, Huigen Yang and Mark Lester

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Abstract

Using ground-based high temporal and spatial optical aurora observations, we investigated one fortuitous event to illustrate the direct responses of the fine structure auroral emission to interplanetary shock on 7 January 2005. During the shock impact to the magnetosphere, the Chinese Arctic Yellow River Station (YRS) equipped with all-sky imagers (ASIs) was situated at the magnetic local noon region (~1210 MLT) in the Northern Hemisphere, while the SuperDARN CUTLASS Finland HF radar covering the field of view (FOV) of the ASIs at YRS had fine ionospheric plasma convection measurement. We observed that an intensified red aurora manifesting as a discrete emission band at a higher latitude responds to the shock impact gradually, which results in a distinct broadening of the dayside auroral oval due to the equatorward shifting of its lower latitude boundary after the shock arrival. In contrast, the green diffuse aurora, manifesting as a relatively uniform luminosity structure, reacts immediately to the shock compression, displaying prompt appearance in the southern edge of the FOV and subsequent poleward propagation of its higher latitude boundary. Simultaneously, the CUTLASS Finland radar monitored enhanced backscatter echo power and increased echo number, which coincided with intensified discrete aurora in approximately the same latitudinal region. Doppler velocity measurement showed moving ionospheric irregularities with generally enhanced line-of-sight (LOS) speed, but with prominent sunward flow in the polar cap and antisunward flow in both the eastern and western regions. The SuperDARN global ionospheric convection pattern clearly presented a large-scale plasma flow divided in four circulation cells, with two reversed flow cells nested in the noon sector of the polar cap. These direct observations strongly suggest that the prompt shock compression intensified the wave-particle interaction in the inner magnetosphere and enhanced the lobe magnetic reconnection rate at magnetospheric high latitude.

Keywords: Interplanetary shock; Sudden impulse; Optical aurora; SuperDARN; Sunward flow

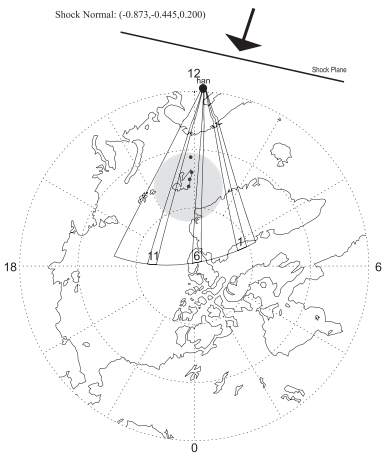

Figure 1

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Method for modeling of the components of ionospheric parameter time variations and detection of anomalies in the ionosphere

Oksana V. Mandrikova*, Nadejda V. Fetisova, Yuri A. Polozov, Igor S. Solovev and Mikhail S. Kupriyanov

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Abstract

In this study, a new multicomponent model (MCM) to determine the time variation of ionospheric parameters is suggested. The model was based on the combination of wavelets with autoregressive-integrated moving average model classes and allowed the study of the seasonal and diurnal variations of ionospheric parameters and the determination of anomalies occurring during ionospheric disturbances. To investigate in detail anomalous changes in the ionosphere, new computational solutions to detect anomalies of different scales and estimate their parameters (e.g., time of occurrence, duration, scale, and intensity) were developed based on a continuous wavelet transform. The MCM construction for different seasons and periods of solar activity was described using ionosphere critical frequency f_0F2 data from Kamchatka (Paratunka Station, 52° 58′ N, 158° 15′ E, Institute of Cosmophysical Research and Radio Wave Propagation FEB RAS). A comparison of the MCM with the empiric International Reference Ionosphere (IRI) model and the moving median method for the analyzed region showed that the suggested method was promising for future research, since it had the advantage of providing quantitative estimates for the occurrence time, duration, and intensity of the anomalies, characterizing the ionospheric state and disturbance degree with a higher accuracy. Geomagnetic storms from 17 March and 2 October 2013 were analyzed using the suggested method, and it was shown that the ionospheric disturbances were at maximum during the strongest geomagnetic disturbances. An increase in the electron concentration in comparison with the background level, under calm or weakly disturbed geomagnetic field conditions, was identified before the analyzed magnetic storms.

Keywords: Wavelet transform; Autoregressive-integrated moving average model; Ionosphere critical frequency; Ionospheric disturbances

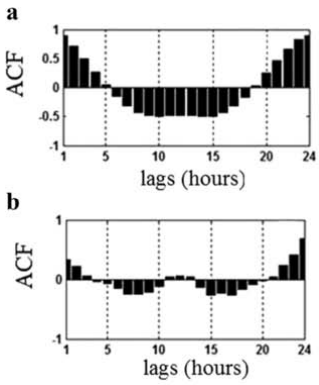

Figure 1

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Application of ground scatter returns for calibration of HF interferometry data

Pavlo Ponomarenko*, Nozomu Nishitani, Alexey V. Oinats, Taishi Tsuya and Jean-Pierre St.-Maurice

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Abstract

Information on the vertical angle of arrival (elevation) is crucial in determining propagation modes of high-frequency (HF, 3–30 MHz) radio waves travelling through the ionosphere. The most advanced network of ionospheric HF radars, SuperDARN (Super Dual Auroral Radar Network), relies on interferometry to measure elevation, but this information is rarely used due to intrinsic difficulties with phase calibration as well as with the physical interpretation of the measured elevation patterns. In this work, we propose an empirical method of calibration for SuperDARN interferometry. The method utilises a well-defined dependence of elevation on range of ground scatter returns. "Fine tuning" of the phase is achieved based on a detailed analysis of phase fluctuation effects at very low elevation angles. The proposed technique has been successfully applied to data from the mid-latitude Hokkaido East SuperDARN radar. It can also be used at any other installation that utilises HF interferometry.

Keywords: Ionospheric radio wave propagation; High-frequency radars; Interferometry

Figure 1

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FULL PAPER Open Access

Three-dimensional electron density along the WSA and MSNA latitudes probed by FORMOSAT-3/COSMIC

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Earth, Planets and Space 2015, **67**:156 DOI: 10.1186/s40623-015-0326-8
Received: 8 December 2014, Accepted: 7 September 2015, Published: 21 September 2015

Abstract

In this paper, we employ electron density profiles derived by the GPS radio occultation experiment aboard the FORMOSAT-3/COSMIC (F3/C) satellites to examine the electron density on geographic latitudes of 40° to 80° in the Southern hemisphere and 30° to 60° in the Northern hemisphere at various global fixed local times from February 2009 to January 2010. The results reveal that an eastward shift of a single-peak plasma density feature occurs along the Weddell Sea Anomaly (WSA) latitudes, while a double-peak plasma density feature appears along the northern Mid-latitude Summer Nighttime Anomaly (MSNA) latitudes. A cross-comparison between three-dimensional F3/C electron density and HWM93 simulation confirms that the magnetic meridional effect and vertical effect caused by neutral winds exhibit the eastward shifts. Furthermore, we find that the eastward shift of the peaks when viewed as a function of local time suggests that they could be interpreted as being comprised of different tidal components with distinct zonal phase velocities in local time.

Keywords: FORMOSAT-3/COSMIC; WSA; MSNA; Neutral wind effect

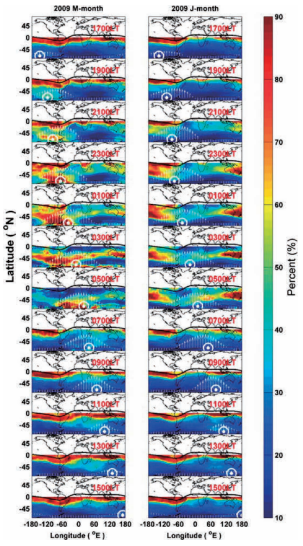

Figure 1

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FULL PAPER Open Access

Daytime gigahertz scintillations near magnetic equator: relationship to blanketing sporadic E and gradient-drift instability

Aramesh Seif*, Roland T. Tsunoda, Mardina Abdullah and Alina Marie Hasbi

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Abstract

Observations made in non-equatorial regions appear to support the hypothesis that the daytime scintillation of radio signals at gigahertz (GHz) frequencies is produced by the gradient-drift instability (GDI) in the presence of a blanketing sporadic E (E_{sb}) layer. However, the only evidence offered, thus far, to validate this notion, has been some observations of E_{sb} in the vicinity of GHz scintillations. A more comprehensive evaluation requires information about electric field, together with the presence of a steep gradient, which is presumed to be that of E_{sb}. In this regard, the region in the vicinity of the equatorial electrojet (EEJ) appears to be an ideal "laboratory" to conduct such experiments. The dominant driver of electron drift there is the same as that of the EEJ, the vertical polarization electric field, and indications are that the presence of E_{sb} in that vicinity is controlled by a balance in horizontal transport of E_{sb}, between the EEJ electric field and the neutral wind, as described in a model by Tsunoda (On blanketing sporadic E and polarization effects near the equatorial electrojet, 2008). In this paper, we present, for the first time, results from a comprehensive study of daytime GHz scintillations near the magnetic equator. The properties, derived from measurements, are shown, for the first time, to be consistent with a scenario in which E_{sb} presence is dictated by the Tsunoda model, and the plasma-density irregularities responsible for GHz scintillations appear to be produced by the GDI.

Keywords: Daytime GHz scintillation; Blanketing sporadic E (E_{sb}); Magnetic dip equator; Equatorial electrojet (EEJ)

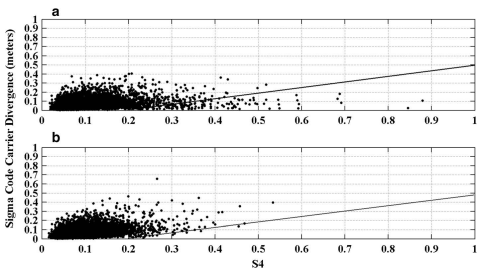

Figure 1

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LETTER Open Access

Occurrence characteristics and lowest speed limit of subauroral polarization stream (SAPS) observed by the SuperDARN Hokkaido East radar

Hiroki Nagano, Nozomu Nishitani* and Tomoaki Hori

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Abstract

We investigate the characteristics of the subauroral polarization stream (SAPS), with focus on the relationship between geomagnetic parameters and occurrence characteristics of SAPS. This study's observations were made using the Super Dual Auroral Radar Network (SuperDARN) Hokkaido East radar, which can observe the Far East region of Russia and has been in operation since 2006. In particular, we identify the lowest limit of SAPS speed, which has not been discussed in previous literature, in order to examine the lowest threshold of electric field able to generate SAPS as a result of magnetosphere-ionosphere (M-I) coupling. In order to conduct a comprehensive investigation of SAPS occurrence characteristics, we analyzed events with wider ranges of velocity and magnetic latitude (MLAT) than those in previous studies. As a result of quantitative estimation, we found two categories of westward flows that were reasonably separated using a speed threshold of 150–200 m/s. For the faster flows above the speed threshold, there is a clear correlation between MLAT and SYM-H geomagnetic index, whereas for the slower flows, there is no such correlation. The faster flows are considered to be SAPS, whereas the slower flows are probably associated with mid-latitude F-region ionospheric irregularities not directly related to storms or substorms. This slowest limit of SAPS gives us a minimum electric field of 7.5–10 mV/m that generates SAPS. However, this field strength is not strong enough to cause frictional heating, which is generally considered to be a crucial mechanism for generating SAPS. This result suggests that frictional heating is not always necessary to generate SAPS.

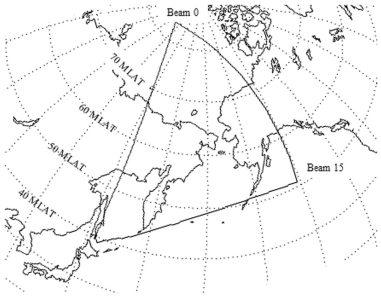

Figure 1

Keywords: SAPS; Subauroral polarization stream; SuperDARN; Hokkaido East radar

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LETTER Open Access

Strong induction effects during the substorm on 27 August 2001

V. V. Mishin*, V. M. Mishin, S. B. Lunyushkin, Z. Pu and C. Wang

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Abstract

We report on strong induction effects notably contributing to the cross polar cap potential drop and the energy balance during the growth and active phases of the substorm on 27 August 2001. The inductance of the magnetosphere is found to be crucial for the energy balance and electrical features of the magnetosphere in the course of the substorm. The inductive response to the switching on and off of the solar wind-magnetosphere generator exceeds the effect of the interplanetary magnetic field (IMF) variation. The induction effects are most apparent during the substorm expansion onset when the rapid growth of the ionospheric conductivity is accompanied by the fast release of the magnetic energy stored in the magnetotail during the growth phase. Using the magnetogram inversion technique, we estimated the magnetospheric inductance and effective ionospheric conductivity during the loading and unloading phases.

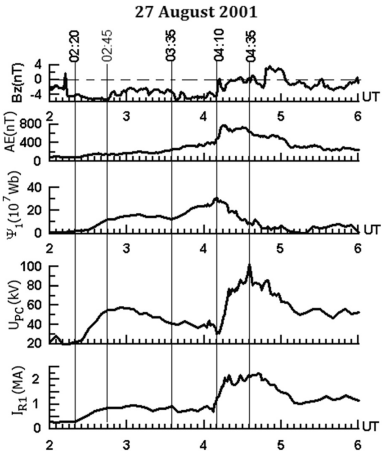

Figure 1

Keywords: Substorm loading and unloading phases; Electromagnetic induction; Polar cap magnetic flux

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LETTER Open Access

Statistical characteristics of medium-scale traveling ionospheric disturbances revealed from the Hokkaido East and Ekaterinburg HF radar data

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Abstract

We present a statistical study of medium-scale traveling ionospheric disturbances (MSTIDs) using the Hokkaido East (43.53° N, 143.61° E) and Ekaterinburg (56.42° N, 58.53° E) high-frequency (HF) radar data. Radar datasets are available from 2007 to 2014 for the Hokkaido and from 2013 to 2014 for the Ekaterinburg radar. In the case of the Hokkaido East radar, we have utilized the elevation angle information to study the MSTIDs propagating at the heights of the E and F ionospheric regions separately. We have analyzed the diurnal and seasonal behavior of the following medium-scale traveling ionospheric disturbance (MSTID) parameters: propagation direction, apparent horizontal velocity and wavelength, period, and relative amplitude. The F region MSTID azimuthal patterns were observed to be quite similar by the two radars. The E region northwestward MSTIDs (from 280° to 320°) were typical of summer daytime. Comparison with the horizontal wind model (HWM07) has showed that the dominant MSTID propagation directions match the anti-wind direction well, at least during sunlight hours. We have also found that the wavelength and period tend to decrease with an increase in solar activity. On the contrary, the relative amplitude increases with an increase in solar activity. Moreover, the relative amplitude tends to increase with increasing auroral electrojet (AE) index, as do the wavelength and velocity.

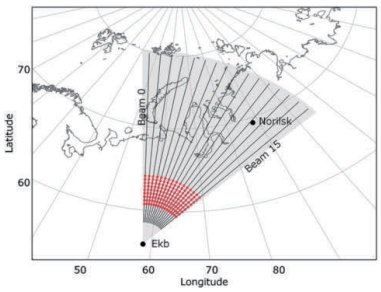

Figure 1

Keywords: Medium-scale traveling ionospheric disturbances; Atmospheric gravity waves; High-frequency radar; Hokkaido East SuperDARN radar; Ekaterinburg HF radar

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LETTER Open Access

Diurnal and seasonal behavior of the Hokkaido East SuperDARN ground backscatter: simulation and observation

Alexey V. Oinats*, Nozomu Nishitani, Pavlo Ponomarenko and Konstantin G. Ratovsky

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Abstract

We studied regular diurnal and seasonal behaviors of ground backscatter propagation characteristics corresponding to the Hokkaido East Super Dual Auroral Radar Network (SuperDARN) (43.53° N, 143.61° E). Firstly, we simulated key propagation characteristics using a high frequency (HF) calculation technique based on the waveguide approach and International Reference Ionosphere (IRI)-2012 model as background ionosphere. The minimum slant range, skip distance, corresponding elevation angle, and true reflection height were considered in this study. The behaviors of these characteristics were well explained by diurnal and seasonal variations in the critical frequency and maximum height of corresponding ionosphere layer in HF reflection point. We estimated the accuracy of the standard SuperDARN mapping technique and proposed a means for its improvement. Secondly, we constructed an algorithm for mass data processing and extracted diurnal dependencies of the minimum slant range, corresponding elevation angle, and effective reflection height from the Hokkaido East SuperDARN dataset for a period from 2007 to 2014. The algorithm uses the simulated characteristics for distinguishing regular ground backscatter echoes propagating in the E and F2 HF channels. Observed monthly mean and simulated values of the characteristics were compared, and the result showed that the accuracy of IRI-2012 significantly depends on solar activity level and orientation of HF propagation path. In general, the difference between observed and simulated values decreased with increases in solar activity and azimuth. We also analyzed the occurrence of echoes originating behind the radar and found that they most frequently appear in winter and equinoxes before sunrise in beam #0 and after sunset in beam #15. The probability of their observation for a specific local time could reach up to 35 %.

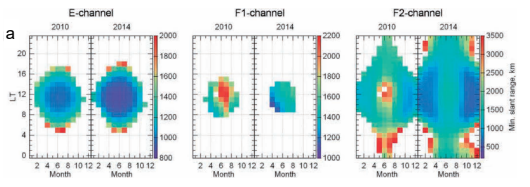

Figure 1

Keywords: High-frequency wave ionospheric propagation; International reference ionosphere; Hokkaido East SuperDARN radar

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