Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PEM27-01 Room:A01 Time:May 25 17:15-17:30

Development of wideband impedance probe system for observation of the ionosphric ion composition

KUMAMOTO, Atsushi[1*]

[1]Tohoku University

Concept and design of new wideband impedance probe system for observation of the ionospheric ion composition have been investigated. Impedance probe system for measurement of the electron number density, which is called NEI, were developed by Oya [1966], and successfully utilized for numerous sounding rockets and spacecraft such as Denpa, Taiyo, Jikiken, Hinotori, Ohzora, and Akebono [e.g. Wakabayashi et al., 2013]. NEI measures the equivalent capacitance of the probe immersed in the magnetized plasma. By applying RF signal to the probe, we can identify the minimum of equivalent capacitance due to upper hybrid resonance (UHR). The frequency of RF signal is swept from 100 kHz to 25 MHz, in order to cover the UHR frequency range in the Earth's ionosphere. The equivalent capacitance of the probe in the magnetized plasma shows minimum not only at UHR frequency but also at another resonance frequency: Lower hybrid resonance (LHR). If we can measure LHR frequency with UHR frequency and electron cyclotron frequency, we can derive effective mass of ionospheric plasma and determine the ionospheric ion compositions. Because LHR frequency is about several kHz in the ionosphere, we have to extend the lower limit frequency of the current impedance probe system to 100 Hz. We changed the design of NEI as follows: (a) Coupling capacitor between the circuits is changed in order to pass the low-frequency AC signals. (b) Because long time is needed for frequency sweep in a low frequency range, high-frequency signal with short sweep period and low-frequency signal with long sweep period are combined and impressed to the probe in order to keep the high time resolution in the measurement of UHR frequency. We have performed the chamber experiment with bread-board model (BBM) of wideband impedance probe system in 2014. We confirmed that the new impedance probe system could measure (1) UHR in high frequency range as well as the current NEI could, and (2) equivalent capacitance profile from 100 Hz to 100 kHz, which indicates sheath capacitance of 120 pF and sheath resistance of 30 kohm. Unfortunately, LHR could not be identified in the chamber experiment because of high collision frequency in the chamber. The detectability of LHR with the wideband impedance probe system have to be verified through the future sounding rocket experiments in the ionosphere, where the collision frequency is enough low.

Keywords: Impedance probe, Ion composition, Sounding rocket, Chamber experiment, Lower hybrid resonance (LHR), Electron number density

Japan Geoscience Union Meeting 2015
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PEM27-02 Room:A01 Time:May 25 17:30-17:45

Study of the ionospheric plasma density structure observed by topside sounder on board the EXOS-D (Akebono) satellite

HOSHI, Yasuto[1*] ; KATOH, Yuto[1] ; KUMAMOTO, Atsushi[1]

[1]Dept. Geophys., Grad. Sch. Sci., Tohoku Univ.

The electron number density, electron and ion temperature of the ionospheric trough in the polar ionosphere has been investigated based on the analysis of data obtained by Plasma Wave detectors and Sounder (PWS) system onboard the EXOS-D (Akebono) satellite.

Stimulated Plasma Wave experiments (SPW), one of the subsystems of PWS, enables us to conduct topside sounding of the ionosphere and to measure the excitation of plasma resonances in the surrounding plasma [Oya et al., 1990]. In operation of SPW in H-band normal sweep mode, RF pulse is transmitted with a swept frequency ranging from 0.3 MHz to 11.4 MHz within 32 sec. We measure the frequency and delay time of each echo found in the ionograms. We then divide the topside ionosphere into multiple plasma layers, and determine group velocities in them, which are to be consistent with measured frequency and delay. Finally, we can obtain the plasma density distribution of the topside ionosphere.

First, we analyze ionograms obtained by SPW in the region nearby European Incoherent Scatter (EISCAT) radar at (69.58 N, 19.23 E) (Tromso, Norway). We identified two events of ionospheric trough, in which the plasma density is depleted. One is found at (65 N, 15 E) on Feb. 28, 1995 (hereafter called ”Event 1”), and the other is found at (70 N, 35 E) on Mar. 1, 1995 (hereafter called ”Event 2”). We also analyze simultaneous EISCAT UHF radar data with EXOS-D observations and find no density depletion in the radar data.

Next, we derive the vertical profile of the scale height inside and outside the inospheric trough from the vertical profile of the electron number density. The derived scale height at 500 km altitude inside the ionospheric trough of these 2 events is 20 % less than that outside the ionospheric trough. Assuming that the distribution of electrons and ions can be explained by the diffusive equilibrium of the bipolar diffusion, we estimate the sum of electron and ion temperature from the scale height. The estimated temperatures are 3730 K inside the trough and 5070 K outside the trough found in Event 1, and 3290 K outside the trough and 2940 K inside the trough in Event 2. These results indicate that the plasma temperature in the identified plasma depletion region is lower than that in the surrounding region. Based on the explanation that the frictional heating increase the plasma temperature, and cause the plasma density depletion by the enhanced dissociative recombination, the plasma temperature in the trough have to be higher than that outside the trough. The results do not agree with the expectation. However, in Event 1, the estimated plasma temperature in the trough is higher than the plasma temperature (about 3000 K) obtained from IRI-2012 model at the observed local time. So we can consider also that the plasma temperatures both inside and outside the trough was higher than normal background ionospheric temperature. We also discuss the dependence of the temperature inside the trough on other control factor such as composition of ionospheric plasma, and unsteady control factor such as the geomagnetic activities.

Keywords: ionosphere, topside sounder, trough

Japan Geoscience Union Meeting 2015
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PEM27-03 Room:A01 Time:May 25 17:45-18:00

A study of equatorial plasma bubbles by 630-nm airglow imaging observations from the International Space Station

YAMADA, Takanori[1*] ; OTSUKA, Yuichi[1] ; SAKANOI, Takeshi[2] ; YAMAZAKI, Atsushi[3] ; KUBOTA, Minoru[4] ; JIN, Hidekatsu[4] ; SAITO, Akinori[5] ; AKIYA, Yusuke[5] ; HOZUMI, Yuta[5]

[1]Solar-Terrestrial Environmental Laboratory, Nagoya University, [2]Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University, [3]Institute of Space and Astronautical Science / Japan Aerospace Exploration Agency, [4]National Institute of Information and Communications Technology, [5]Department of Geophysics, Graduate School of Science, Kyoto University

In order to disclose global distribution of the upper atmosphere, Ionosphere, Mesosphere, upper Atmosphere, and Plasmasphere mapping mission (IMAP) on the International Space Station (ISS) started on October 2012. In this study, we analyzed 630-nm airglow images observed during a period from September 5, 2012 to August 28, 2013 by VISI (Visible and Infrared Spectral Imager), mounted on ISS to reveal the longitudinal characteristics of the equatorial ionosphere disturbances. We examined the seasonal and longitudinal characteristics of the occurrence of the plasma bubbles, and found occurrence rate of the plasma bubbles is high in spring and autumn equinoxes, especially at African longitudinal sector. This result is consistent with previous studies. Furthermore, we measured zonal interval between the plasma bubbles and examined its longitudinal characteristics. We found that plasma bubble intervals depend on longitude and that most of intervals are 100-200 km at 0-90o longitudinal sector and 200-300 km at 225-360o longitudinal sector. In this study, we also compare the observed 630-nm airglow intensity with that simulated by GAIA(Ground-to-topside model of Atmosphere and Ionosphere for Aeronomy) model to discuss day-to-day and longitudinal variations of equatorial ionization anomaly.

Keywords: plasma bubbles, ISS-IMAP

Japan Geoscience Union Meeting 2015
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PEM27-04 Room:A01 Time:May 26 09:00-09:15

Comparison of neutral temperature with ion temperature in the polar lower thermosphere

TAKITA, Shintaro[1*] ; NOZAWA, Satonori[1] ; OGAWA, Yasunobu[2] ; KAWAHARA, Takuya[3] ; TSUDA, Takuo[4] ; SAITO, Norihito[5] ; WADA, Satoshi[5] ; TAKAHASHI, Toru[1] ; FUJIWARA, Hitoshi[6] ; HALL, Chris[7] ; BREKKE, Asgeir[8]

[1]Solar-Terrestrial Environment Laboratory, Nagoya University, [2]National Institute of Polar Research, [3]Faculty of Engineering, Shinshu University, [4]The University of Electro-Communications, [5]Advanced Photonics Technology Development Group, RIKEN, [6]Faculty of Science and Technology, Seikei University, [7]Tromsoe Geophysical Observatory, The Arctic University of Tromsoe, [8]Faculty of Science, The Arctic University of Tromsoe

We will present results of comparison between the neutral temperature and the ion temperature at 100-110 km height above Tromsoe (69.6^{o}N, 19.2^{o}E), Norway. We have conducted observations of the neutral temperature and the sodium density between about 80 and 110 km with the sodium LIDAR at Tromsoe since October 2010. We have also obtained wind data by making five directional observations since October 2012. To date, we have obtained temperature and sodium density data for about 2800 hours in total and about 1800 hours of wind data. For five winter observational seasons between 2010 and 2015, simultaneous observations of the sodium LIDAR and the EISCAT UHF radar were conducted at altitudes between 100 and 110 km for 43 nights (about 250 hours).

Below 150 km in altitude at middle latitudes, due to collisions between the two species as well as absence of external heat sources, the ion temperature is thought to be almost the same as the neutral temperature. This is not the case in the polar lower thermosphere because of the energy input from the magnetosphere. Major heat sources are Joule heating, auroral particle heating, and the electron-ion heat exchange. Among them, Joule heating is the strongest component in the lower thermosphere. To evaluate contributions of these heat sources, as the first step, we have compared the neutral temperature obtained by the sodium LIDAR with the ion temperature by the EISCAT UHF radar at altitudes between 100 and 110 km. In general, at and below about 105 km there seems to be a reasonable agreement between the temperatures, and the ion temperature tends to be higher than the neutral temperature with increasing height above 105 km. We will present the comparison results and also discuss the effect of the Joule heating.

Keywords: sodium lidar, EISCAT radar, joule heating, atmosphere temperature, polar lower thermosphere

Japan Geoscience Union Meeting 2015
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PEM27-05 Room:A01 Time:May 26 09:15-09:30

A case study on generation mechanisms of a sporadic sodium layer during a night of high auroral activity

TAKAHASHI, Toru[1*] ; NOZAWA, Satonori[1] ; TSUDA, Takuo[2] ; OGAWA, Yasunobu[3] ; SAITO, Norihito[4] ; HIDEMORI, Takehiro[1] ; KAWAHARA, Takuya[5] ; HALL, Chris[6] ; FUJIWARA, Hitoshi[7] ; BREKKE, Asgeir[8] ; TSUTSUMI, Masaki[3] ; WADA, Satoshi[4] ; KAWABATA, Tetsuya[1] ; OYAMA, Shin-ichiro[1] ; FUJII, Ryoichi[1]

[1]Solar-Terrestrial Environment Laboratory, Nagoya University, [2]The University of Electro-Communications, [3]National Institute of Polar Research, [4]RIKEN Center for Advanced Photonics, RIKEN, [5]Faculty of Engineering, Shinshu University, [6]Tromso Geophysical Observatory, The Arctic University of Tromso,, [7]Faculty of Science and Technology, Seikei University, [8]Faculty of Science, The Arctic University of Tromso, Tromso, Norway

Generation mechanisms of sporadic sodium layers (SSLs) have been discussed for more than three decade. Proposed mechanisms are as follows: *Es* layer, chemical reaction enhancement due to a background temperature variation, gravity waves, meteor deposition, and aurora particle spattering. However there are few studies that evaluate these mechanisms quantitatively based on observational data. In this study, we have quantitatively evaluated generation mechanisms of a SSL based on observational data obtained by multiple instruments at a high latitude station: Ramfjordmoen, Tromso, Norway (69.6^{o}N, 19.2^{o}E).

The sodium LIDAR observed an SSL at 2118 UT on 22 January 2012. The SSL was observed for 18 min with a maximum sodium density of about 1.9x10^{10} m^{-3} at 93 km with a 1.1 km thickness. The EISCAT UHF radar observed a sporadic *E* layer (*Es* layer) above 90 km from 2000 to 2300 UT. After 2000 UT, the Es layer gradually descended and reached 94 km at 2118 UT when the SSL appeared at the same altitude. In this event, considering the abundance of sodium ions (10% or less), the Es layer could provide only about 21% or less of the sodium atoms to the SSL. We have investigated a temporal development of the normal sodium ion layer with consideration of chemical reactions and the effect of the (south-westward) electric field using observational values of the neutral temperature, electron density, horizontal neutral wind, and electric field. This calculation has shown that those processes, including contributions of the *Es* layer, would provide about 88% sodium atoms of the SSL. Effects of meteor absorption and auroral particle spattering appear to be less important. Therefore, we have concluded that the major source of the SSL was sodium ions in a normal sodium ion layer. Two processes-namely the downward transportation of sodium ions from a normal sodium ion layer due to the electric field, and the additional supply of sodium ions from the *Es* layer under relatively high electron density conditions (i.e., in the *Es* layer)-played a major role in generating the SSL in this event. Furthermore, we have found that the SSL was located in a lower temperature region, and that the temperature inside the SSL did not show any remarkable temperature enhancements.

Keywords: Sporadic sodium layer, sodium lidar, polar region, aurora, MLT

Japan Geoscience Union Meeting 2015
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PEM27-06 Room:A01 Time:May 26 09:30-09:45

Derivation of the stratospheric temperature with the sodium lidar

HIBINO, Tatsuya[1*] ; NOZAWA, Satonori[1] ; TSUDA, Takuo[2] ; KAWAHARA, Takuya[3] ; SAITO, Norihito[4] ; WADA, Satoshi[4] ; TAKAHASHI, Toru[1] ; FUJIWARA, Hitoshi[5] ; HALL, Chris[6]

[1]Solar-Terrestrial Environment Laboratory, Nagoya University, [2]The University of Electro-Communications, [3]Faculty of Engineering, Shinshu University, [4]The RIKEN Center forAdvanced Photonics Technology Development Group, RIKEN, [5]Faculty of Science and Technology, Seikei University, [6]Tromso Geophysical Observatory, The Arctic University of Tromso, Tromso, Norway

We have derived the temperature in the upper stratosphere between 30 and 50 km by using Rayleigh scatter data obtained by the sodium LIDAR at Tromsoe (69.6N, 19.2E), Norway. We have carried out observations of the neutral temperature and sodium density between 80 and 110 km in the polar upper mesosphere and lower thermosphere for five winter seasons (October-March) starting in October 2010 by using the sodium LIDAR. To date, about 2800 hours of data are obtained. Together with datasets obtained by EISCAT radars, MF radar and meteor radar operated at the same observational field, we have studied the vertical coupling of the atmosphere as well as the magnetosphere-ionosphere-thermosphere coupling. To facilitate these activities, a millimeter wave receiver for measuring minor constituent in the stratosphere/mesosphere/lower thermosphere will be installed at the same observational field in the near future. In this talk, we will present results of the derivation of the neutral temperature in the upper stratosphere (30-50 km) by using the sodium LIDAR.

A sodium LIDAR observations use the resonance scattering from sodium atoms in the sodium layer between 80 and 110 km. We also successfully receive Rayleigh scattering light from the atmosphere between about 30 and 60 km. The upper height depends on the background noise level, while the lower height limit is determined by contamination of Mie scatter light. We calculated the temperatures between November 2011 and February 2012 with a 1 km resolution and compared them with the calculated atmospheric temperatures with the ECMWF (The European Centre for Medium-Range Weather Forecasts) data. The comparison shows a reasonable agreement.

This new addition of the datasets will make it possible to investigate the correlation of the temperature variation between the upper stratosphere (30-50 km) and the upper mesosphere/lower thermosphere (80-110 km). Furthermore, the observed stratospheric temperature will improve the accuracy of the millimeter wave observations.

Keywords: Sodium Lidar, Rayleigh scattering

Japan Geoscience Union Meeting 2015
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PEM27-07 Room:A01 Time:May 26 09:45-10:00

Statistical study of probability of instabilities in the polar upper mesosphere/lower thermosphere

ASATO, Saki[1*] ; NOZAWA, Satonori[1] ; FUJIWARA, Hitoshi[2] ; KAWAHARA, Takuya[3] ; TSUDA, Takuo[4] ; TSUTUMI, Masaki[5] ; SAITO, Norihito[6] ; WADA, Satoshi[6] ; KAWABATA, Tetsuya[1] ; TAKAHASHI, Toru[1] ; HALL, Chris[7] ; BREKKE, Asgeir[8]

[1]STEL, Nagoya University, [2]Faculty of Science and Technology, Seikei University, [3]Faculty of Engineering, Shinshu University, [4]The University of Electro-Communications, [5]National Institute of Polar Research, [6]Advanced Photonics Technology Development Group, RIKEN, [7]Tromsoe Geophysical Observatory, The Arctic University of Tromsoe, [8]Faculty of Science, The Arctic University of Tromsoe

The aim of this study is to clarify probabilities of convective and dynamical instabilities and their variations in altitude/time in the polar upper mesosphere and lower thermosphere (80-110 km). In this study, we have used temperature data obtained with the sodium LIDAR operated at the EISCAT Tromsoe (69.6N, 19.2E) site. Between October 2010 and January 2015, there are 287 nights when their temporal data lengths are equal to or longer than 4 hours on a night. Based on the temperature data, we have calculated square of Brunt-Vaisala frequency (N^2). The time and height resolution of the temperature data used are 10 min and 1 km, respectively. Together with wind data obtained by the sodium LIDAR (after October 2012) or the co-located meteor radar (before March 2012), we have also calculated Richardson numbers (R_i) for the 287 nights. The instability probability on one night is calculated as the percentage of the number of points whose N^2 is negative for convective instability, and whose Ri falls in the range of $0 < R_i < 0.25$ for dynamical instability to the total data set over the height region for the entire night.

Studies of probabilities of instabilities around the mesopause region were made at middle/low latitudes. Zhao et al. (JASTP, 65, 219-232, 2003) analyzed 32 nights (195 hours) of data sets over 1 year between June 1998 and May 1999 obtained at Starfire Optical Range, near Albuquerque, NM (35N, 106.5W) and showed that the probabilities of static and dynamic instabilities were maximum in mid-winter. Li et al. (JGR, 110, 2004JD005097, 2005) analyzed 19 nights of data sets obtained between January 2002 and November 2003 at Maui, Hawaii (20.7N, 156.3W), and pointed out that at any given time the probability that an unstable condition was found at some altitudes in the 85-100 km range was about 90%. To the best of our knowledge, no such a study has been made for the polar upper mesosphere/lower thermosphere.

We will show probabilities of instabilities in the polar upper mesosphere and lower thermosphere, and difference of the probabilities in terms of year, month, and altitude. Furthermore, we will discuss correlations between the probabilities and amplitudes of tides/gravity waves and between the probabilities and auroral activity.

Keywords: polar upper mesosphere and lower thermosphere, convective instability, dynamical instability, sodium LIDAR, Tromsoe

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PEM27-08 Room:A01 Time:May 26 10:00-10:15

Comparison of horizontal phase velocity distributions of gravity waves observed by ANGWIN, using a 3D spectral technique

MATSUDA, Takashi S.[1*] ; NAKAMURA, Takuji[2] ; EJIRI, Mitsumu K.[2] ; TSUTSUMI, Masaki[2] ; TAYLOR, Michael J.[3] ; ZHAO, Yucheng[3] ; PAUTET, P.-dominique[3] ; MURPHY, Damian[4] ; MOFFAT-GRIFFIN, Tracy[5]

[1]SOKENDAI (The Graduate University for Advanced Studies), [2]National Institute of Polar Research, [3]Utah State University, [4]Australian Antarctic Division, [5]British Antarctic Survey

Atmospheric gravity waves (AGWs), which are generated in the lower atmosphere, transport significant amount of energy and momentum into the mesosphere and lower thermosphere and cause the mean wind accelerations in the mesosphere. This momentum deposit drives the general circulation and affects the temperature structure. Among many parameters to characterize AGWs, horizontal phase velocity is very important to discuss their vertical propagation. Airglow imaging is a useful technique for investigating the horizontal structures of AGWs around mesopause. An international airglow imager (and other instruments) network in the Antarctic, named ANGWIN (Antarctic Gravity Wave Imaging/Instrument Network) was started in 2011. Its purpose is to understand characteristics of mesospheric gravity waves and their impacts on the Mesosphere and Lower Thermosphere (MLT) environment over Antarctica.

In this study, we compared distributions of horizontal phase velocities of gravity waves at around 90 km altitude over different locations using our new statistical analysis method based on 3-D Fourier transform, developed by Matsuda et al. (2014). The comparison has been carried out for airglow imagers at four stations, that are, Syowa (69S, 40E), Halley (76S, 27W), Davis (69S, 78E) and McMurdo (78S, 156E), out of the ANGWIN imagers, for the observation period between April 6 and May 21 in 2013. Not only horizontal propagation characteristics, gravity wave energies can also be quantitatively compared, indicating a smaller GW activity in higher latitudes. The presentation will be focused on showing the performance of the new statistical technique for studying gravity waves.

Keywords: atmospheric gravity wave, airglow imaging

Japan Geoscience Union Meeting 2015
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PEM27-09 Room:A01 Time:May 26 10:15-10:30

A revisit to critical level blocking diagram

TOMIKAWA, Yoshihiro[1*]

[1]National Institute of Polar Research, [2]SOKENDAI

Matsuda et al. (2014) have proposed a new method to obtain a power spectral distribution of gravity waves in a horizontal phase velocity domain from airglow observations. The obtained power spectral distribution can be interpreted as a product of gravity wave source spectrum and wave transmissivity distributions under an assumption without wave dissipation/reflection and wave horizontal propagation. The gravity wave transmissivity depends on the existence of a critical level for the wave, which is determined by background horizontal wind distributions. Taylor et al. (1993) have proposed a critical level blocking diagram which represents a gravity wave transmissivity in a horizontal phase velocity domain. In this talk, the critical level blocking diagram proposed by Taylor et al. (1993) will be revisited, and its amendment will be discussed. In addition, examples of the critical level blocking diagram in some given background horizontal wind distributions will be shown.

Keywords: critical level, gravity wave, mountain wave

Japan Geoscience Union Meeting 2015
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PEM27-10 Room:A01 Time:May 26 10:30-10:45

Gravity Waves in the Martian Atmosphere detected by the Radio Science Experiment MaRS on Mars Express

TELLMANN, Silvia[1*] ; PATZOLD, Martin[1]

[1]University of Cologne, Germany

Gravity waves are a ubiquitous feature in all stably stratified planetary atmospheres. They are known to play a significant role in the energy and momentum budget of the Earth and they are assumed to be of importance for the redistribution of energy. This high vertical resolution of the radio occultation profiles from the MaRS experiment on Mars Express provides the unique opportunity to study small scale vertical wave structures in the Martian lower atmosphere. These small scale temperature perturbations are most probably caused by gravity waves (buoyancy waves) produced by the displacement of air masses flowing over elevated topographical features or other atmospheric sources like convection in the surface boundary layer or wind shear. A study of the global distribution of gravity waves provides insight into possible source mechanisms, local time dependencies, seasonal dependencies and/or topographical dependencies.

Keywords: Mars, Mars Express, Gravity Waves, Atmosphere, Radio Occultation Experiment, Radio Science

Japan Geoscience Union Meeting 2015
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PEM27-11 Room:A01 Time:May 26 11:00-11:15

Imaging of polar cap patches with small airglow cameras

HOSOKAWA, Keisuke[1*] ; OGAWA, Yasunobu[2] ; TAGUCHI, Satoshi[3]

[1]University of Electro-Communications, [2]National Institute of Polar Research, [3]Graduate School of Science, Kyoto University

In the last two decades, 630.0 nm airglow measurements with cooled CCD cameras have been widely used to observe various kinds of ionospheric phenomena such as plasma bubble and MSTID. Recently, similar airglow observations at high-latitudes have enabled us to visualize the dynamical behavior of polar cap patches, which are regions of high density plasma propagating in the central polar cap region. In this sense, now the all-sky airglow measurement is one of the essential tools for monitoring ionospheric phenomena at all the latitude regions. However, it is still very difficult to make a dense network of airglow imagers and capture the large-scale structure in the ionosphere because the system is relatively large and high cost.

In this paper, we have employed a cheap and small CCD camera (Watec Co.Ltd.: WAT-910HX) to observe airglow in the polar cap region and check if such a camera can be used for observations of polar cap patches. We prepared two sets of small airglow camera, one with a fish-eye lens and the other with a wide field-of-view lens. They are combined with an optical filter whose central wavelength is 632.0 nm, FWHM is 10 nm and transmittance is 85%. The two airglow cameras were installed in Longyearbyen (78.1N, 15.5E), Norway in October 2013 and operated continuously during the 2013/2014 winter season. In Longyearbyen, airglow measurements with an EMCCD all-sky airglow imager (ASI) and the auroral spectrograph (ASG) have been carried out; thus, we were able to compare the images from the small airglow cameras with those from the conventional airglow observation systems.

On the night of December 4, 2013, a series of polar cap patches was observed by the EMCCD all-sky imager in Longyearbyen. The optical intensity of the patches was as large as 500 R. At the same time, the small airglow cameras also detected regions of enhanced airglow intensity passing through their fields-of-view. The quality of the images was slightly lower than those from the EMCCD-ASI, but it was high enough for capturing the 2D structure of the patches. This indicates that the small CCD camera of Watec Co.Ltd. can be used for observations of ionospheric phenomena such as polar cap patches. However, there is some sort of difference in the optical intensity between the EMCCD-ASI and the small airglow camera. We suppose that this is due to the difference in the FWHM of the optical filters. In the presentation, we will discuss this difference in a quantitative manner by using airglow spectra from ASG.

Keywords: Polar cap region, Polar cap patches, Airglow measurements

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PEM27-12 Room:A01 Time:May 26 11:15-11:30

Measurements of neutral wind and plasma drift with chemical release in the cusp region - preliminary results

KAKINAMI, Yoshihiro[1*] ; KIHARA, Daiki[1] ; WATANABE, Shigeto[2] ; YAMAMOTO, Masa-yuki[1] ; CONDE, Mark[3] ; LARSEN, Miguel[4]

[1]Kochi University of Technology, [2]Hokkaido Information University, [3]University of Alaska, Fairbanks, [4]Clemson University

A chemical release experiment was taken place on 24 November 2014 to measure neutral wind and plasma drift in the cusp region, which was named the Cusp Region Experiment (C-REX). We set up 2 cameras (one for neutral Barium (Ba) and the other for ionized Barium (Ba+)) at Longyerben and Ny-Alsund for each site. In addition, one video camera at Ny-Alsund and one camera with a grating at Longyerben were set up. The rocket was launched from Andoya at 08:05 UT and first chemical release was observed at 08:14:19 UT from Longyerben, Ny-Alsund and an airplane. Ten of 24 canisters were successfully ignited between 200 and 400 km altitude at about 600 km away from Svalbard islands. Each canister contains barium (Ba) and strontium (Sr). Evaporated gasses reflect sunshine and green and blue “space fireworks” were observed by digital cameras with filter and video as well as human eyes. The filters were developed to observe resonance scattering of neutral Ba (552.5 nm) and ionized Ba (454.5 nm), and evaluated with an integrating sphere in National Institute of Polar Research. We also observed space fireworks with a grating and successfully obtained spectrums. In this paper, we introduce our observation and show preliminary results of the experiment.

Keywords: cusp, neutral wind, plasma drift, space firework, chemical release exeprimet, neutral density anomaly

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PEM27-13 Room:A01 Time:May 26 11:30-11:45

Detecting mid-latitude Es by InSAR

SUZUKI, Takato[1*] ; MAEDA, Jun[1]

[1]Department of Natural History Sciences, Hokkaido University

Maeda and Heki. (2014) succeeded in capturing sporadic-E (Es) over Japan two-dimensionally, using the observation of Global Positioning System – Total Electron Content (GPS-TEC). While the GPS is originally used for the crustal deformation monitoring, Interferometric Synthetic Aperture Radar (InSAR) is another space geodetic technique that allows us to detect crustal movements. SAR transmits a microwave pulse and receives the reflected pulse while a target on the ground is in the beam by using an antenna on the platform like aircrafts and satellites, so that it can implement virtually a large aperture antenna and can create high-resolution images. InSAR can detect crustal deformation signals between the two acquisition dates as a two-dimensional image by taking the difference of the phase data of the SAR images. Like GPS carrier phases, ionospheric effect sometimes appears on the InSAR images. The lower the used microwave frequency, the more notably the ionospheric effect appears. Hence, a satellite using L-band microwave like Advanced Land Observing Satellite (ALOS) is advantageous to detect ionospheric phenomena. If Es can be detected by InSAR whose spatial resolution is higher than GPS, we can understand its spatial structure in more detail and help to clarify the generation mechanism of the Es. In this study, we aimed to detect Es over Japan by InSAR.

First, we chose the dates whose critical frequencies of Es (foEs) were more than 15MHz at ionosonde in Wakkanai, Kokubunji and Yamagawa in the morning in 2006 through 2010 from May to August. Second, we chose the data of ALOS/PALSAR whose observing areas and dates are as close as possible, and generated interferometric images. An interesting phase shift appeared on one of the images, the pair of March 28, 2009 (Master) and Jun 28, 2009 (Slave), and it had northeast direction slope. Although the entire shape could not be imaged due to the sea surface, we could observe four patches; the spatial scale of each patch is about 20km. Converting this phase shift into TEC variation (△TEC), it turns out that △TEC=0.44TECU, which is close to when Es appears. However, we could not identify the altitude in the InSAR image, and thus we used GPS-TEC. As a result, a similar signal was detected near the place where the phase shift appeared on the InSAR image. We could identify the altitude of the signals to be 100km. Therefore, it turns out that the phase shift on the InSAR image is caused by mid-latitude Es.

Keywords: InSAR, sporadic-E, GPS-TEC

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PEM27-14 Room:A01 Time:May 26 11:45-12:00

Tidal effect of the neutral atmosphere in the lower thermosphere on the movement of sporadic E at midlatitude

MAEDA, Jun[1*] ; HEKI, Kosuke[1]

[1]Hokkaido University

Introduction

Sporadic *E* is a highly ionized plasma patch unpredictably appears at an altitude of ˜100 km in the *E*-region of the ionosphere. At midlatitudes, occurrences maximize in local summer (Whitehead, 1989 and references there in), and in the Far East region including Japan (Wu et al., 2005; Arras et al., 2008). Ground-based radar observations and rocket experiments have been the two primary methods of sporadic *E* observations. Since their spatial and temporal resolutions are restricted, two-dimensional (2-D) and/or continuous observations of sporadic *E* plasma patches and their movements have been difficult. Maeda and Heki [2014] have performed 2-D observations of midlatitude sporadic *E* by using dual-frequency Global Navigation Satellite System (GNSS) satellites and a dense array of GNSS receivers in Japan (GEONET) composed of ˜1200 GNSS staions. Sporadic *E* can be observed as positive total electron content (TEC) anomaly in the GNSS-TEC observations. Mapping these anomalies revealed 2-D horizontal structure of sporadic *E* plasma patches and time sequences of TEC maps showed temporal evolution of the plasma structure, including their movements.

Analyses

In the present study, we use GNSS-TEC observations with GEONET receivers. We focus on the movement of sporadic *E* patches. Typically sporadic *E* plasma patches form frontal structure that elongates 50-500 km in the east-west (E-W) direction [Maeda and Heki, 2014]. Since the movements in the E-W direction cannot be distinguished from the development of elongation, here we only study movements in the N-S directions. 5 min TEC maps are generated to study temporal evolution of plasma patches. Direction and speed of movements are manually read by 20-30 min interval. In total, 27 cases of sporadic *E* movements over Kanto region are analyzed.

Results and Discussion

We counted the number of northward and southward movements, respectively, and plotted in the local time (LT) order. The histogram shows LT dependence of N-S movements, i.e., northward and southward movements concentrates in the 10-12 LT and 18 LT, respectively. In between the two peaks, there is a silent period, i.e., the minimum of the number of movements at 15 LT. These results are consistent with those reported by Tanaka [1979] who conducted backscatter radar observations in Kanto region (the same study area as ours). Tanaka [1979] showed that the westward movement peaks around 15 LT. Since we ignored the E-W movements, the silent period in the N-S movements can be interpreted as the results of rotation of movement directions of plasma patches possibly governed by atmospheric tide. Thus, GNSS-TEC observations of sporadic *E* plasma patches may be useful to infer the dynamics of the neutral atmosphere in the lower thermosphere.

Keywords: sporadic-E, GPS, TEC, atmospheric tide

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PEM27-15 Room:A01 Time:May 26 12:00-12:15

Imaging observation of spatial structure of sporadic E layer by Magnesium Ion Imager on the sounding rocket S-520-29

KURIHARA, Junichi[1*] ; IWAGAMI, Naomoto[2] ; KOIZUMI-KURIHARA, Yoshiko[3] ; TANAKA, Makoto[4] ; TAKAHASHI, Takao[4] ; ABE, Takumi[3]

[1]Faculty of Science, Hokkaido University, [2]Graduate School of Science, The University of Tokyo, [3]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, [4]ICT Education Center, Tokai University

To study the spatial structure of midlatitude sporadic E (Es) layers, the vacuum ultraviolet resonant scattering by magnesium ions (Mg^+) in an Es layer was observed with the Magnesium Ion Imager (MII) on the sounding rocket S-520-29. Since the Es layers is formed by the convergence of metallic ions that have slow ion-electron recombination rates, the distribution of Mg^+, which is one of the dominant species among the metallic ions, is thought to reflect the spatial structure of the Es layer. It is suggested that the spatial structure of the Es layer is closely related to various ionospheric phenomena such as the field aligned irregularity and the E-F coupling. Therefore, it is expected that imaging observations of the Mg^+ distribution will provide new knowledge in the spatial structure of the Es layer.

The sounding rocket S-310-38 was launched from the Uchinoura Space Center in Kagoshima, Japan, on 6 February 2008 for the same purpose and the two-dimensional horizontal structure of Mg^+ in an Es layer was observed for the first time. While this result demonstrates the usefulness of Mg^+ imaging for understanding the spatial structure of Es layers, the attitude of the sounding rocket, especially the zenith angle of the rocket axis was unusually tilted and the area of meaningful observation was limited.

In the sounding rocket S-520-29 experiment conducted on 17 August 2014, the MII was improved since the S-310-38 experiment and an attitude control system by gas jet was implemented. Unfortunately, the attitude control did not work as expected, but the Mg^+ distribution was successfully observed and important information on the spatial structure of the Es layer was obtained.

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PEM27-16 Room:A01 Time:May 26 12:15-12:30

Ampere force exerted by geomagnetic Sq currents and thermospheric pressure difference

TAKEDA, Masahiko[1*]

[1]Data Analysis Center for Geomagnetism and Space Magnetism., Kyoto Univ.

Relationship between Ampere force exerted by geomagnetic Sq currents and neutral pressure was examined. It was shown that the Ampere force around the Sq current vortex center is almost equal to the pressure difference between its maximum and minimum, and this balance is kept through the solar cycle. The lowest height of the pressure integration for best fit is 120km, which is reasonable considering the height profile. There was a seasonal variation that the pressure difference is smaller and larger in local summer and winter, respectively. This is consistent with the effects of magnetic field by inter-hemispheric field-aligned currents on geomagnetic Sq field.

Keywords: geomagnetic daily variation, total current, Ampere force, thermospheric pressure difference, solar acivity

Japan Geoscience Union Meeting 2015
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PEM27-17 Room:A01 Time:May 26 12:30-12:45

Study of ionospheric disturbances using the remote HF wave receiver of the SuperDARN Hokkaido East radar

NISHITANI, Nozomu[1*] ; KIGAWA, Ryusuke[1] ; HORI, Tomoaki[1] ; HAMAGUCHI, Yoshiyuki[1]

[1]Solar-Terrestrial Environment Laboratory, Nagoya University

We have been operating the remote HF wave receiver of the SuperDARN Hokkaido East radar in Nagoya and Rikubetsu (in the vicinity of the HF radar) since 2014 to monitor the ionospheric disturbances. Using the remote receiver data it is possible to monitor the upward / downward motion of the ionosphere at the ionospheric reflection point of the HF radar backlobe beams emitted torward Nagoya areas. Initital result of the observation of ionospheric perturbations using the remote HF wave receiver of the SuperDARN Hokkaido East radar will be presented.

Keywords: SuperDARN, remote HF wave receiver, ionospheric disturbance

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PEM27-18 Room:A01 Time:May 26 14:15-14:30

Seismo-traveling ionospheric disturbance observed by HF Doppler sounding system

CHOU, Min-yang[1*] ; TSAI, Ho-fang[1] ; LIU, Jann-yenq[2] ; LIN, Charles[1]

[1]National Cheng-Kung University, [2]2Institute of Space Science, National Central University,

In this paper, networks and concurrent/co-located measurements of seismometers (BATS, K-net, KiK-net), HF Doppler Sounding Systems in Taiwan and Japan are used to study Seismo-traveling ionospheric disturbance (STIDs). It's shown that these infrasound wave packets triggered by seismic surface waves that was generated by strong earthquake. The infrasound wave packets were detected in the ionosphere at heights ˜200 km about 9 min after the detection of corresponding wave packets on the ground. The individual wave packets recorded on the HF Doppler have different observed horizontal velocities and correspond to different type of seismic waves.

The Hilbert-Huang Transform (HHT) is applied to analyze Doppler frequency shifts (DFSs) detecting STIDs and estimated the amplification factor in vertical displacement of the ionosphere relative to the ground surface motion, while the time delay, circle, ray-tracing, and beam-forming methods are used to compute the origin of the detected STIDs.

Keywords: STIDs, Ionosphere

Japan Geoscience Union Meeting 2015
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PEM27-19 Room:A01 Time:May 26 14:30-14:45

Propagation Characteristics of Neutral Atmospheric Waves Associated with Earthquakes Using a Numerical Simulation

YOSHIKAWA, Kouhei[1*] ; SHIMIZU, Yuki[1] ; NAKATA, Hiroyuki[1] ; TAKANO, Toshiaki[1] ; MATSUMURA, Mitsuru[2]

[1]Graduate School of Engineering, Chiba University, [2]National Institute of Polar Research

By using HF Doppler and GPS ionospheric total electron content (TEC) observations, it is found that atmospheric waves excited by earthquakes cause ionospheric disturbances. In this study, we examined the relationship between seismic ground perturbations and ionospheric disturbances in order to mechanism of the propagations of atmospheric waves using a numerical simulation. In this simulation, we calculated temporal evolutions of neutral atmospheric waves by solving basic equations of neutral atmosphere.

The effects of the artificial viscosity used in the numerical simulation are evaluated. In compressible fluids, shock waves occur when advection velocity is faster than the sound velocity. Although shock waves correspond to discontinuous planes mathematically, they have the thickness of the mean free path of air molecules approximately. When we run the simulation without artificial viscosity, the simulation is diverged. Thus, we add Von-Neumann-type artificial viscosity. In adding the artificial viscosity, it is necessary to determine an adequate artificial viscosity coefficient. Therefore we compared the simulation results with the theoretical equations (*Chum et al*., 2012) obtained by subtracting attenuation from law of the conservation of energy flux. The simulation results were determined with the various artificial viscosities. As the artificial viscosity becomes larger, the amplitude of simulation results become small and the amplitude depend on the period of input disturbance as compared to the theoretical equations. This result means that the adequate artificial viscosity coefficient must be determined owing to the period of input disturbances. At the wave front, the waveform is elongated, the amplitude is larger than theoretical equation. We discussed temporal waveforms to find the cause of this waveform. It is found that the waveform includes the lower frequency component than input disturbance. The theoretical equation shows that the atmosphere works as low pass filter, and that the cut-off frequency become lower with the higher altitude because high frequency components are attenuated due to viscosity and heat conduction. Due to these characteristics, low-frequency component is dominant at higher altitude.

Keywords: Earthquake, Neutral atmospheric wave, Numerical simulation, Ionospheric disturbance

Japan Geoscience Union Meeting 2015
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PEM27-20 Room:A01 Time:May 26 14:45-15:00

Ca+ density perturbations observed by a resonance scattering lidar during MSTIDs

EJIRI, Mitsumu K.[1*] ; TSUDA, Takuo[2] ; NISHIYAMA, Takanori[1] ; ABO, Makoto[3] ; NISHIOKA, Michi[4] ; MARUYAMA, Takashi[4] ; SAITO, Akinori[5] ; NAKAMURA, Takuji[1]

[1]National Institute of Polar Research, [2]The University of Electro-Communications, [3]Graduate School of System Design, Tokyo Metropolitan University, [4]National Institute of Information and Communications Technology, [5]Department of Geophysics, Graduate School of Science, Kyoto University

In the mesosphere and lower thermosphere region, there are permanent layers of metal atoms and ions, the source of which is vaporization of cosmic dust and meteoroids during their entry into the Earth's atmosphere. Some metal atom layers e.g. Na, K, Ca, and Fe layers, and only Ca^+ (Calcium ion) can be observed by ground-based resonance scattering lidars. The National Institute of Polar Research (NIPR) is developing a new resonance scattering lidar system with a frequency-tunable laser. The lidar transmitter is based on injection-seeded, pulsed alexandrite laser for 768-788 nm and a second-harmonic generation (SHG) unit for 384-394 nm. The new lidar is able to measure density variations of minor constituents including Ca^+ (393 nm). As a part of the development, observation tests are carried out at NIPR (35.7N, 139.4E) since 2013, and we got the first light from Ca^+ on 21 August, 2014. The Ca+ density profiles were obtained for $\sim$5 hours (23:13 LT-28:28 LT) with time and height resolutions of 1 min and 15 m, respectively. At the same night, sporadic E (E_s) layer was observed with an ionosonde at Kokubunji by National Institute of Information and Communications Technology (NICT) (35.7N, 139.5E), also medium scale traveling ionospheric disturbances (MSTIDs) were observed with the dense GPS receiver network (GEONET). In this presentation, we compare these data in detail and discuss relationships between observed Ca^+ density perturbations, E_s layer and MSTIDs.

Keywords: resonance scattering lidar, Ca+, medium scale traveling ionospheric disturbances, GPS-TEC, sporadic E layer

Japan Geoscience Union Meeting 2015
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PEM27-21 Room:A01 Time:May 26 15:00-15:15

Characteristics of spatial gradient of ionospheric TEC assoicated with plasma bubbles and its impact on GNSS

SAITO, Susumu[1*] ; YOSHIHARA, Takayuki[1]

[1]Electronic Navigation Research Institute

The plasma bubble is a sharp depletion in the ionospheric plasma density. Spatial gradient of the ionospheric TEC (total electron content) associated with the sharp depletion of the plasma density makes it difficult for GNSS augmentation systems to work properly. To mitigate the ionospheric threats associated with the spatial TEC gradient, it is important to know the characteristics of the TEC gradient.

Data used are obtained in Ishigaki (24.3N, 124.2E) with five GNSS receivers with mutual distances from 86 to 1557 m. TEC differences and thus the gradients between a pair of GNSS receivers are precisely derived with the single-frequency carrier-based and code-aided (SF-CBCA) technique. Directions of the TEC gradients are estimated with the TEC gradients between three of the five stations. The derived TEC gradients are compared with those derived with the dual-frequency TEC estimation with the assumption that the TEC gradient in quiet time would be zero. The velocity and propagation directions of the gradients are estimated with the correlation analysis of TEC variation of three of the five stations.

Associated with the plasma bubble events on 3 April 2008, the TEC gradients derived with the SF-CBCA method was amounted to be 3.2 TECU/km, which is equivalent to the gradients in the ionospheric delay at L1 frequency of 518 mm/km. It exceeds the upper bound of the ionospheric threat space (maximum assumed values in the safety design) of ground-based augmentation system (GBAS). The result is proved to be realistic with the dual frequency measurements, though there seems to be cycle-slip effects in TEC estimation. The velocity was estimated to be 118 m/s, and the propagation direction was estimated to be 75 degrees. The propagation direction is consistent with the direction of the TEC gradient of 74 degrees (clockwise from the North). The spatial scale of the TEC gradient is estimated to be 7 km.

These parameters derived in this study are all relevant to the ionospheric threat space of GBAS, and the threat space is shown to be modified so that this extreme TEC gradient is bounded. Thus, studying the characteristics of the TEC gradient with the parameters shown above are very important to the safety design of GNSS augmentation systems, and have to be investigated extensively. Further analysis of the data obtained in the periods of higher solar activity than that of the event analyzed here is necessary and is now going on.

Keywords: plasma bubble, ionospheric irregularity, TEC gradient, irregularity velocity, irregularity scale size, GNSS augmentation system

Japan Geoscience Union Meeting 2015
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PEM27-P01 Room:Convention Hall Time:May 26 18:15-19:30

Water vapor estimation using digital terrestrial broadcasting wave

KAWAMURA, Seiji[1*] ; OHTA, Hiroki[1] ; HANADO, Hiroshi[1] ; YAMAMOTO, Masayuki[1] ; SHIGA, Nobuyasu[1] ; KIDO, Kouta[1] ; YASUDA, Satoshi[1] ; GOTOH, Tadahiro[1] ; ICHIKAWA, Ryuuichi[1] ; AMAGAI, Jun[1] ; IMAMURA, Kuniyasu[1] ; FUJIEDA, Miho[1] ; ISHIZU, Kentaro[1] ; IWAI, Hironori[1] ; SUGITANI, Shigeo[1]

[1]National Institute of Information and Communications Technology

We, National Institute of Information and Communications Technology (NICT), are developing a water vapor measurement system using digital terrestrial broadcasting wave. Radio waves are delayed due to water vapor through propagation. Water vapor can be retrieved by measuring this time delay. If the humidity increases by 1 %, radio waves delay by about 17 ps during propagating 5 km distance. Very precise measurements (at least several tens of pico-second order) are needed for the effective observations. Radio waves used for digital terrestrial broadcasting are modulated with OFDM, and known signals (SP signals) are embedded. Complex delay profiles are calculated using these known signals. Using the phase of delay profile, we can measure propagation delay with precise accuracy (pico-second order). When we consider the accuracy with order of sub-nano seconds, phase fluctuations of local oscillators at radio tower and receivers are essential error factors. So we measure the propagation delay at two receiving points on the same line including the radio tower. Each result includes phase fluctuations of local oscillators at radio tower and receivers. Phase fluctuation of local oscillator at radio tower will be canceled out by taking the difference. We can estimate water vapor between two receiving points by synchronization between their local oscillators.

We are developing a real-time delay (phase of delay profiles) measurement system with software-defined radio technique. We have improved this system and maximum number of channels which can be processed in real-time has expanded to 5. Measurement accuracy of this system is evaluated, and the time resolution of measured delay time is found to about 50 ps. We plan to use CATV to synchronize the local oscillators at different sites. Signals pass-through in the CATV network are the same RF signals as that transmitted from the radio tower, and they can be also processed with the system mentioned above. Phase fluctuations of local oscillators at both sites are canceled out using the signals pass-through in CATV as references. Each signal pass-through in CATV has its own delay due to the difference of network path. We have developed the method to correct it. The precision of synchronization is less than 100 ps, and in-house test is going on to improve it. We are planning demonstration experiments to estimate water vapor using two receiving stations in next summer. We will use optical fiber synchronization method, which is already established by NICT, to evaluate CATV synchronization. We investigate miniaturization of measurement system using DSP board for the multi-point measurement in the future.

Keywords: water vapor, radio wave, propagation delay, digital terrestrial broadcasting

Japan Geoscience Union Meeting 2015
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PEM27-P02 Room:Convention Hall Time:May 26 18:15-19:30

Dual frequency observation of subionospheric perturbations associated with Hokuriku winter lightning

MORINAGA, Yosuke[1*] ; TSUCHIYA, Fuminori[1] ; OBARA, Takahiro[1] ; MISAWA, Hiroaki[1] ; HONMA, Yasunori[2]

[1]Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University, [2]Tohoku Electric Power Company

Intense electromagnetic pulses (EMP) radiated from lightning discharge could cause heating and ionization and alter the conductivity in the ionospheric D-region. The purpose of this study is to reveal influence of the lightning on the lower ionosphere and its dependence on properties of lighting discharges. For this purpose, two LF radio observation systems were installed in Takine (Fukushima) and Sasaguri (Fukuoka). Radio signals from two JJY transmitters at Haganeyama (Fukuoka, 60kHz) and Otakadoyayama (Fukushima, 40kHz) are simultaneously measured at Takine and Sasaguri, respectively. Radio propagation paths of both transmitter ? receiver pairs are almost overlapped and the midpoints of both paths are located over the coast of Hokuriku area. These enable us to investigate the lightning effect on the lower ionosphere at different height because it is expected that reflection height of radio wave depends on radio frequency.

The LF signature of subionospheric perturbations associated with winter lightning in the Sea of Japan (around Hokuriku) has been observed from December 13, 2014. Signatures of subionospheric perturbation (early event) which occur immediately after the causative lightning were detected. While modeling studies (E. D. Schmitter. 2014) show that change of ionization state in the lower ionosphere depends on intensity of EMP, there is no clear observation evidence that shows quantitative relationship between them. We analyze the data derived from these observations using peak current of causative lightning and difference in frequency of two JJY.

Acknowledgement: We would like to thank A. Yoshikawa, T. Uozumi and S. Abe, Kyushu University, Fukuoka and T. Ohno, Hoshinomura astronomical observatory, Fukushima, for cooperating LF radio observation.

Keywords: lightning discharge, subionospheric perturbation, dual frequency observation

Japan Geoscience Union Meeting 2015
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PEM27-P03 Room:Convention Hall Time:May 26 18:15-19:30

Spectral analysis of ionospheric and atmospheric perturbations associated with typhoons using HFD and microbarometer

HIRABAYASHI, Shinichiro[1*] ; NAKATA, Hiroyuki[1] ; TAKANO, Toshiaki[1] ; TOMIZAWA, Ichiro[2]

[1]Graduate School of Engineering, Chiba University, [2]Center for Space Science and Radio Engineering

It is reported that ionospheric perturbations are observed by extreme weather conditions such as tornadoes and typhoons, and they cause ionospheric disturbances. However, the features and propagation characteristics of atmospheric waves is still unclear. We examined atmospheric waves caused by typhoons, using HF doppler (HFD), which is maintained by The University of Electro-Communications, and microbarometer located at Mineyama, Kyoto prefecture. In this study, HFD receiver data for 5006 kHz observed at Sugadaira is used. Because of unstable ionosphere in the nighttime, we examined HFD data from 7:00 to 18:00. Details of typhoons, path, barometric pressure, and wind speed, are provided by Digital Typhoon, managed by National Institute of Informatics. Here, we give a brief description of Typhoon No.26 in 2013. This typhoon passed Japan in 2013/10/15 ˜10/17. It was closest to the Sugadaira observation point on 10/16. From dynamic spectrum of HFD data, it is found that perturbations of spectral intensity at the frequency under 5 mHz were observed in these 3 days even though Typhoon No.26 didn't get closed to Japan. On the other hand, spectral intensity of perturbations were enhanced at the frequency from 5 mHz up to 40mHz when Typhoon No.26 got closed to Japan. Simultaneously, a perturbation of doppler shift was observed whose amplitude is 0.2 Hz. Spectral intensity on microbarometer data also tended to be strong at the frequency from 5 mHz up to 50 mHz. Then we also examined temporal variations of spectral intensity at 4 mHz and 30 mHz, comparing them with the distance between Sugadaira observation point and the center of Typhoon No.26, and with wind velocity at Chichibu, which is the nearest observatory to the reflection point. Data of wind velocity was provided by AMeDAS, maintained by Japan Meteorological Agency. As a result, when Typhoon No.26 was approaching Japan, the spectral intensity of the perturbations at 30 mHz was clearly enhanced, but not at 4mHz. Therefore, it is clear that typhoons seem to affect spectral intensity at frequency higher than 5mHz. The spectral intensity reaches its maximum when the distance between Sugadaira and the center of Typhoon No.26 became the shortest. At this moment the wind velocity at Chichibu became the strongest.

Keywords: Typhoons, ionosphere, atmosphere, microbarometer, HFD

Japan Geoscience Union Meeting 2015
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PEM27-P04 Room:Convention Hall Time:May 26 18:15-19:30

Origin of small-scale field-aligned currents as observed by SWARM above the ionosphere in middle and low latitudes

AOYAMA, Tadashi[1*] ; IYEMORI, Toshihiko[2] ; NAKANISHI, Kunihito[1]

[1]Graduate School of Science, Kyoto University, [2]Data Analysis Center for Geomagnetism and Space Magnetism, Graduate School of Science, Kyoto Univers

We analyzed magnetic field data obtained by the Swarm satellites launched on 22 November 2013, and confirmed that the short-period(10˜40 s) and small-amplitude scaled(0.1˜5 nT) magnetic fluctuations observed in middle and low latitudes are the manifestation of small-scale field-aligned current structure (Iyemori et al., GRL, 2015). Because of the characteristics of geographical and seasonal dependence of their amplitude obtained by analysis of the CHAMP satellite magnetic field data (Nakanishi et al., EPS, 2014), we interpret these results as the indication of field-aligned currents generated by dynamo action in the ionospheric E-layer. We assume that the dynamos are caused by the acoustic waves generated by the lower atmospheric disturbances. In this presentation, we show the evidence of the above interpretation by comparing the meteorological data with the magnetic fluctuations, and estimate in which hemisphere, i.e., in north or south hemisphere, the origin of the dynamo exists from a comparison of spectral indices of the small magnetic fluctuations above typhoons in 2014.

Keywords: field-aligned current, ionospheric dynamo, atmospheric gravity wave, acoustic gravity wave, swarm satellite, typhoon

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PEM27-P05 Room:Convention Hall Time:May 26 18:15-19:30

The verification of the small spatial structure of field aligned currents over the Brazilian Anomaly

NAKANISHI, Kunihito[1*] ; IYEMORI, Toshihiko[1] ; AOYAMA, Tadashi[1]

[1]Department of Geophysics, Graduate School of Science, Kyoto University

Nakanishi et al. (2014), using the magnetic data observed by the CHAMP satellite through high-pass filter with cutoff period around 40 seconds, show the ubiquitous existence of small scale (1-5 nT) magnetic fluctuations with period around a few tens seconds along the satellite orbit in middle and low latitudes. The results of analysis show the difference in the dependence of the amplitude and period on latitude between the magnetic fluctuations over the Brazilian Anomaly and the other region. That is, as the satellite approaches the dip equator, the period and amplitude get longer and smaller, respectively over the other region; on the other hand, over the Brazilian Anomaly, the period doesn't get longer and the amplitude doesn't get smaller or rather gets larger respectively. Another characteristics of the magnetic fluctuations over the Brazilian Anomaly are similar to those over other regions. That is, the magnetic fluctuations are perpendicular to the geomagnetic field; the amplitude on the dayside is much larger than that on the nightside, which shows high correlation between the amplitude and the ionospheric conductivities in E-layer with respect to local time; the amplitude has the geomagnetic conjugacy in general; almost no dependence on both geomagnetic activity and the solar wind parameters is found; the global distribution of the amplitude has clear seasonal dependence with the geographical characteristics.

They, putting importance on the dependence of the amplitude and period on latitude seen over the other region, suggest that the above characteristics can be interpreted as the spatial structure of small scale (200 ? 300 km) field-aligned currents generated by the ionospheric dynamo driven by atmospheric gravity waves (acoustic mode or inertial mode) propagating from the lower atmosphere. The dependence of the amplitude and period on latitude can be explained in the following way. With use of dipole model, the spatial scale of the field aligned current is traced to the satellite altitude along the main magnetic field. The scale at the satellite altitude gets larger as latitude decreases to the dip equator. Over the dip equator, the scale gets larger than a scale corresponding to the cutoff period and the amplitude gets attenuated.

This time we verify that the magnetic fluctuations over the Brazilian Anomaly have the same generation mechanism with those over the different region and especially show the possibility that the different characteristic can be explained by the above model. That is, as the geomagnetic field leans to the East-West direction over the Brazilian Anomaly, by trace along the magnetic field, the latitudinal scale doesn't get larger than the scale corresponding to the cutoff period comparatively even over dip equator, therefore, the amplitude doesn't get smaller comparatively.

The possibility shows that we can study the objective magnetic fluctuations over all the regions in middle and low latitudes including the Brazilian Anomaly.

Keywords: spatial structure of field aligned currents, middle and low latitudes, the CHAMP satellite, the SWARM satellite, atmospheric gravity wave, the Brazilian Anomaly

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PEM27-P06 Room:Convention Hall Time:May 26 18:15-19:30

The relationship between ionospheric disturbances detected by HFD and ground perturbations associated with earthquakes

TAKABOSHI, Kazuto[1*] ; NAKATA, Hiroyuki[1] ; TAKANO, Toshiaki[1] ; TOMIZAWA, Ichiro[2] ; NAGAO, Hiromichi[3]

[1]Graduate shool of Engineering, Chiba University, [2]Center for Space Science and Radio Engineering, [3]Earthquake Research Institute, The University of Tokyo

Many studies have reported that ionospheric disturbances occur after giant earthquakes. One of the causes is the acoustic wave excited by surface waves propagated on the ground from the epicenter. In this study, we compared the ionospheric vertical drift velocity calculated from HF Doppler (HFD) observation and vertical ground motions recorded at seismometer directly beneath the reflection point of the HFD radiowave in order to elucidate relationships between them. The HF Doppler observation is enable to detect ionospheric disturbances since this can observe ionospheric vertical drift from Doppler shift of HF radiowaves transmitted from the Chofu campus of The Univercity of Electro-Communications. In this study, using Doppler shift data for 5006 kHz, ionospheric disturbances associated with earthquakes are detected. To obtain accurate vertical drifts, we determined reflection altitudes of radiowave from ionogram data (Kokubunji) using POLAN (ionospheric density profile calculation software) . For seismometer data, we used 2 types of seismic networks installed by NIED, Storong-motion Seismograph Networks (K-NET,KiK-net) and Broadband Seismograph Network (F-net) .

We examined the correlation of the maximum values of ionospheric vertical drift velocity and vertical velocity of ground motion for 30 events (M≥6, 2003˜2013) . HFD observatories are Sugadaira, Oarai, and Iitate. The closest seismomete from each reflection points were selected.

As for Sugadaira observatory (20 events) , ionospheric velocity tends to increase in proportion to the square root of the ground velocity regardless of types of seismometers. In the other two observatories (Oarai, Iitate), ionospheric velocities are not proportional to square root of the ground perturbations. This is because sufficient events are not supplied (6˜12 events) in these observatories. However, the ionospheric vertical velocity increases with the ground velocity. If the numbers of the events are larger, the correlations of these observatories would be the same as the result of Sugadaira.

Keywords: ionosphere, HFD, earthquake, acoustic wave, seismometer, ground perturbations

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PEM27-P07 Room:Convention Hall Time:May 26 18:15-19:30

Simulation Results for the Ionospheric Density Disturbances Triggered by Earthquake Rayleigh Waves

CHEN, Chia-hung[1*] ; MATSUMURA, Mitsuru[2] ; LIN, Charles[1] ; SAITO, Akinori[3] ; LIU, Jann-yenq[4]

[1]Department of Earth Sciences, National Cheng Kung University, Taiwan, [2]National Institute of Polar Research, [3]Department of Geophysics, Graduate School of Science, Kyoto University, [4]Institute of Space Science, National Central University, Taiwan

During the great earthquake event of M9.0 Tohoku earthquake on 11 March 2011 in Japan, previous studies detected the horizontal wave structure of ionospheric total electron content (TEC) disturbances by a dense ground-based GPS receiver network. These results suggested that the ionospheric TEC disturbances could be caused by the earthquake-triggered seismic surface, acoustic-gravity, and tsunami waves, which are distinguished by the different propagation velocities, durations, and periods. In order to further investigate the vertical coupling effect for the ionospheric plasma density disturbances, this study employed a three-dimensional, non-linear, compressible numerical model. This model simulated the disturbances of neutral mass densities from the surface to lower, upper atmosphere and the ionosphere, by specifying the surface displacement triggered by the earthquake, such as the rayleigh waves, at the model lower boundary. The results show that the TEC disturbances have two types of the propagation waves, first horizontal waves and slow co-centric waves. These might be caused by the neutral wind dynamo effect and the ion-neutral collision along the magnetic field.

Keywords: Earthquake, Rayleigh wave, Ionosphere, Plasma density disturbance

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Comparison between the ionospheric holes between inland earthquakes and subduction earthquakes with tsunami.

KANAYA, Tatsuya[1*] ; KAMOGAWA, Masashi[1]

[1]Dpt. of Phys., Tokyo Gakugei Univ.

We investigate the ionospheric holes generated by two inland earthquake and two subduction earthquakes with tsunami of which magnitudes are similar, using data of GPS total electron content. For the comparison, the ionospheric hole clearly appeared only in the subduction earthquakes. From our interpretation, this is due to the difference of the initial conditions to excite the acoustic waves.

Keywords: Ionospheric hole, Inland earthquake, Tsunami

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OBSERVATION OF METEOR SHOWERS IN 2014 - 2015 BY 5CH HRO-IF AND EVALUATION OF SYSTEMS AT KOCHI UNIVERSITY OF TECHNOLOGY

MIZUMOTO, Satoshi[1*]

[1]Kochi Tech of Univ.

Introduction: Ham-band Radio meteor Observation (HRO) has an advantage of 24-hour continuous data-detection. In Kochi University of Technology (KUT), 5 channel HRO-interferometer (HRO-IF) was developed in 2009 and has been observing the meteor appearance position of every meteor echo. We operated an automatic meteor observation system that automatically shows observational results on Web in quasi-real time for about two years until 2011 (Noguchi, 2009). In addition, we have developed a system of meteor trajectory measurement by multiple-sites observation with GPS time keeping and the 5ch HRO-IF (Yamasaki, 2012). In 2012, an HRO observation with a calibrating system which could regularly observe the absolute strength of the meteor echo was developed, thus the plasma density of each meteor echo was precisely determined (Yamato, 2013). We will report observation facilities, equipments, the future prospects and latest observation result.

Meteor observation by 5ch HRO-IF: In KUT, we started 6 direction HRO in 2003. We performed the basic development of the 3ch HRO-IF from 2005 to three years (Horiuchi, 2005; Okamoto, 2005) and obtained an arrival angle of each meteor echo from the phase difference of three antennas, calculating the approximate meteor appearance position (Hamaguchi, 2006; Noguchi, 2007). The 3ch HRO-IF is limited in positional accuracy for the angle of arrival obtained from the phase difference. In order to solve this problem, we developed the 5ch HRO-IF as the improved version in 2009, realizing the automatic meteor observation for two years in KUT (Noguchi, 2009). Since high time resolution is needed for interferometer, we calculate phase difference at every 0.1 s, synchronizing the 5 channel input signal to an AD board with 1 PPS (Pulse Per Second) signal provided by a GPS receiver every 1 s. We observed Camelopardalis meteor shower (May, 2014) and Daytime Arietids meteor shower (June, 2014) by using these equipments.

Meteor shower observation result in 2014 - 2015: We observed meteor showers of Camelopardalis, Daytime Arietids and Leonids 2014 by the KUT 5ch HRO-IF. We tried calculate trajectory vector of each meteor echo by a multisite observation of Geminids 2014 and Quadrantids 2015 meteor showers. The multisite observation system was developed with the other two HRO sits in addition to the KUT 5ch-IF. Preliminary result of the multisite observation was obtained and the system performance was evaluated with trouble shooting process.

Summary: We performed the KUT 5ch HRO-IF as a forward scattering meteor radar system continuously with some verifications of accuracy that is important to reveal meteor showers structures (e.g. Geminids). However, it is necessary to realize calculation of meteor trajectory information by the multiple-sites observation to obtain precise parameters of the meteor showers such as the suddenly observed Camelopardalid 2014 meteor shower. Therefore, we will have to develop an improved version of the HRO-IF observation system as a permanent automatic data transmission with acquiring observation data from multiple sites. We tried multisite observation of Geminids 2014 and Quadrantids 2015 meteor showers with evaluating the system performance and trouble shooting process. In this paper, we will report the current status of the KUT 5ch HRO-IF system with recent observational results in 2014 - 2015 and outlook for the future.

Keywords: Meteor radio observations, Radio interferometer, Multisite observations

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Large-scale structure and continuation of intense Es around the Kyusyu-Okinawa by VHF long-distance propagation

YANAGISAWA, Shinya[1*] ; TOMIZAWA, Ichiro[1] ; YAMAMOTO, Atsushi[2]

[1]Center for Space Science and Radio Engineering, [2]Maritime Science and Technology, Japan Coast Guard Academy

We have been observing VHF long-distance propagations reflected by intense sporadic-E (Es) both at Kure and at Chofu [1]. It has shown that intense Es may have a very long and thin structure [2]. In this report, we describe the large structure and the moving characteristic of three intense Es observed around the Kyushu-Okinawa area on May 11, 2014 and September 14, 2013 and July 1, 2014. Since these three events were observed in the same area, it's suitable to compare the structure and characteristics.

(1) The speed of Es by VOR around 17:00 JST on September 14, 2013 was about 40 m/s and the length of the intense Es observed was about 300 km moving in southeast. The width of the Es was 7˜20 km which was much smaller than the length, but the west-portion became expand to 120 km, and the moving speed and the direction were different from the east-portion. Therefore, the whole structures were presumed to be during the observation period bending around the center. Additional the west-portion became thick with progress, but the east-portion did not showing change. Moreover, the duration times of the Es were more than 2 hours.

(2) The Es observed at around 19˜21:00 JST May 11, 2014, had two frontal structures moving in the same northwestward direction. But the two fronts had the moving speed of 50˜60 m/s, the length fronts of 300˜400 km, and the variable width of 5˜80 km, the duration time were about 1 hour.

(3) The Es observed at around 10˜11:00 JST July 1, 2014, had two frontal structures moving in the same northwestward direction. While moving 2 structures with speed different in about 50 m/s and about 150 m/s big as a point different from (2), and it intersected. The length of the structure was same as about 380 km and about 300 km mostly but different from 7˜35km and 55˜180 km in the width of the structure big like (2). Both of 2 were about 1 hour in duration.

These three intense Es observed in the same area had the structure length of 300˜400km equally, but the Es structure and moving speed were different. (1) was the southeast for the movement direction, but (2) and (3) were the reverse northwestward. Moreover (1) could continue high electronic density structure for about 2 hours, but only half of about 1 hour of (1) could continue (2) and (3). As these results, intense Es can be presumed that can move maintain the slender structure for about 1-2 hours.

In poster session, we will describe the comparative results, such as the moving characteristic of Es, the feature and structure, are reported in detail.

[1]Takuya Yamahata, Ichirou Tomizawa, Atsushi Yamamoto: Broader-based Es structure observation system development by VHF belt long distance propagation reception, SGEPSS, B005-P038, 2012.

[2]Ichirou Tomizawa, Koutarou Hujii : HF wave reflection propagation model by the shape of a wave face Es, JPGU, P-EM29-01, 2013.

Keywords: Ionosphere, Sporadic E layer, Large-scale structure

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Derivation of shape of cross-section of frontal sporadic E by the HF Doppler spectral analysis

OHTA, Hiroki[1*] ; TOMIZAWA, Ichiro[1]

[1]Center for Space Science and Radio Engineering ,UEC

As for shape of cross-section of frontal sporadic E(Es), it has been revealed that had a shape of thin cylindrical structure by a past study [1]. However, there are no observation data about the shape of cross-section along Es front concerning we have developed a new method of analysis HF Doppler spectrum multi-state network in Kanto with high resolution.

At first I observe shape of cross-section of frontal Es passing HFD middle reflection point of Kanto and demand three dimensions of details data of the electric field strength every Doppler shift frequency at the near midway point passage time. We are able to consider the change to be the incidence angle dependence of the equivalence of value dispersion cross section when an radio wave was incident on a slim Es shape of cross-section from the lower part in time for field strength that cut and brought down these data every constant frequency. Because the baseline halfway point between each transmission and reception points are different, We can estimate cross-section of frontal Es reflection surface finely. I find a movement direction and the speed of frontal Es by performing this analysis at the many observation point and derive the sectional structure of the reflection whole shape of cross-section of frontal Es in detail.

A change really demands an average change from the electric field strength graph which cut and brought down observation data in the frequency direction by a quadratic equation fitting by the least-squares method because it is difficult to greatly analyze it directly. We found width based on this average change at the biggest strength every the Doppler shift frequency and the time, 3 dB time width. We found the width of cross-section of frontal Es from the product of 3 dB time width and the horizontal mobility speed, and the irregularity of shape of cross-section from the biggest strength and the time.

I applied the above mentioned method of analysis and checked the frontal Es which occurred at 23:00 JST on July 23, 2009 in detail. Shape of cross-section of frontal Es which advanced in 102 m/s, the southwestern direction, and the width of shape of cross-section was found with approximately 12 km. This shape of cross-section of frontal Es knew that structure and the asymmetry structure that there were not only one simple mountain-formed sectional structure but also two mountains existed when I looked at the shape of cross-section of the Es in resolving power of Fresnel zone approximately 4 km.

From the above results, I knew that I could derive shape of cross-section of frontal Es on the scale of the Fresnel zone by checking HF Doppler spectrum in detail at each observation point. I derive a regularity of the structure of shape of cross-section of frontal Es by performing this analysis for more frontal Es and can expect that I understand deeply to an atmosphere change to be concerned with Es generation.

[1]Ichiro Tomizawa and Kotaro Fujii: HF propagation model reflected by frontal Es, JPGU 2013, PEM29-01, 2013.5.

Keywords: ionosphere, HF Doppler, Sporadic E

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Examination of the Es propagation model of ITU-R based on VOR long distance propagation and the observation of ionosonde

NITTA, Takuya[1*] ; TOMIZAWA, Ichiro[1] ; YAMAMOTO, Atsushi[2] ; SHINJI, Saitoh[3]

[1]Center for Space Science and Radio Engineering ,UEC, [2]Japan Coast Guard Academy, [3]Electronic Navigation Research Institute

The University of Electro-Communications observe Very High Frequency Electric wave Reflected in Sporadic E layer in Chofu and Kure. It is necessary to check electron density structure in a wide area to examine it whether a long-distance propagation wave by a strong Es reflection pro-VHF propagation (GBAS-VDB) is not beyond interference permissible level. In the Es propagation model of ITU-R based on the observation until

the 1970s, expression of relations of the Es reflection ionosphere reflection decrement quantity is guaranteed only to Electric wave Reflected in Sporadic E layer to 80MHz. In this lecture, I express the result about whether it is possible to apply data of the ionosphere reflection decrement quantity observed from VOR observation of frequency around 110MHz and NICT verticality critical point frequency foEs data of the middle reflection point neighborhood to Es propagation model type of ITU-R.

In from May 1, 2014 to September 30, I observed an electric wave of the VOR transmission station of Yoron Island (27.044N, 128.398) and Yonagunijima (24.457N, 122.998E) which the distance with Yamagawa (31.20N, 130.62E) and the VOR middle reflection point was close in Kure (34.246N, 132.528E). I demanded Yamagawa perpendicular critical frequency foEs and ionosphere reflection decrement quantity for the use frequency and, from data of provided VOR reception electricity, performed the comparison with the Es propagation model type of ITU-R. As a result, which is obtained from Kure VOR reception electricity is smaller than the Es propagation model of ITU-R and gives weaker value than real reception electricity. This goes down assuming the Es reflection model that is bigger than Fresnel zone in the Es propagation model of ITU-R, and it is thought that this is because it observes the Es in Fresnel zone domains by the VOR long distance propagation observation. The ionosphere reflection decrement quantity between Kure and Yoron Island interval of surface of the earth propagation distance 893km has a bigger bigger difference with the predicted value than Kure and Yonagunijima Island interval of surface of the earth propagation distance 1427km. In addition, it becomes the slow degree of leaning in the VOR when I pay attention to a degree of leaning of ionosphere reflection decrement quantity for foEs and shows that an index to express the frequency dependence of the Es propagation model of ITU-R is too big. As a result, it is necessary for the propagation model type of ITU-R in frequency around 110MHz to perform a review. I increase the number of the examination lines and am going to examine an Es propagation model type of ITU-R at around 110MHz in detail in future.

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[1] Takuya Yamahata, Ichiro Tomizawa, Atsushi Yamamoto: Wide area Es structure observation system development by the VHF Zone long distance propagation reception, SGEPSS, B005-P038, 2012.

[2] Shinji Saitou, Ichiro Tomizawa, Atsushi Yamamoto: Examination of the influence of the VOR long distance propagation by the sporadic E on GBAS-VDB, communication engineering technology research report, vol. 114, SANE2014-125, pp113-118, 2015.

[3] K. Miya and T. Sasaki: Characteristics of ionospheric Es propagation and calculation of Es signal strength, Radio Sci., vol.1, pp.99-108, 1966.

[4] ITU-R:Recommendation of ITU-R, Method for calculating sporadic-E field strength, Rec.ITU-R P.534-4,1999.

Keywords: ionosphere

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Estimation of spatial structure of sporadic E layer observed by S-310-40 rocket with 2-dimentional FDTD simulations

MIYAKE, Taketoshi[1*] ; INOUE, Hironori[1] ; ISHISAKA, Keigo[1]

[1]Toyama Prefectural University

We developed a 2-dimensional FDTD simulation code
which can treat wave propagations in magnetized plasma.
According to sounding rocket experiments,
we can only obtain altitude profile of wave intensity,
usually magnetic field intensity.
In this study, therefore, we are going to estimate spatial structure of sporadic E layer
in the lower ionosphere by analyzing the altitude profile of the magnetic field intensities.

We compared simulation results and observation results obtained by S-310-40 sounding rocket,
but were not able to identify spatial structure of the sporadic E layer.
This is because the scale of the spatial structure of the sporadic E layer
assumed in the simulation was inappropriate.
We are going to perform 2-dimensional FDTD simulations with different spatial scales of the sporadic E layer,
and investigate the influence that a scale of the space structure gives electric wave propagation.
Then, we will identify spatial structure of the sporadic E layer observed by S-310-40 sounding rocket
from the altitude profile of the magnetic field.

Keywords: Sporadic E layer, spatial structure, 2D FDTD simulation

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Improvement of an estimation method of the electron density profile in the lower ionosphere with time domain Full wave

MIYAKE, Taketoshi[1*] ; MORIYAMA, Hiroaki[1] ; ASHIHARA, Yuki[2] ; MURAYAMA, Yasuhiro[3] ; KAWAMURA, Seiji[3]

[1]Toyama Prefectural University, [2]Nara National College of Technology, [3]National Institute of Information and Communications Technology

We are going to simulate the observation process of the present MF radar system
with the time domain Full wave method,
and investigate the observation method with which
we can obtain the precise electron density profile in the lower ionosphere.
One of the general methods to estimate the electron density in the present MF radar system
is the differential absorption experiment (DAE) method.
The DAE method is a technique to estimate the electron density from
the differential amount between the left and the right polarized waves
reflected from the lower ionosphere.
We simulated the MF radar with time domain Full wave analysis and examined the DAE method.
We improved the DAE method by using appropriate parameters automatically,
and succeeded to estimate more accurate electron density profiles in the lower ionosphere.
In the present improved DAE method, however,
we can only find appropriate parameters in the case that
the electron density increases with increase of the altitude.
Therefore, we are going to improve the DAE method, which is available in any case.

Keywords: Ionospheric D region, MF Radar, Full-wave method, DAE method

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Analysis of Propagation Characteristics of Radio Wave by S-520-29 Sounding Rocket

ITAYA, Keita[1*] ; ISHISAKA, Keigo[1] ; ASHIHARA, Yuki[2] ; KUMAMOTO, Atsushi[3] ; ABE, Takumi[4] ; KURIHARA, Junichi[5]

[1]Toyama Prefectural University, [2]Department of Electrical Engineering, Nara National College of Technology, [3]Department of Geophysics, Graduate School of Science, Tohoku University, [4]Japan Aerospace Exploration Agency Institute of Space and Astronautical Science Department of Solar, [5]Graduate School of Science, Hokkaido University

S-520-29 sounding rocket experiments was carried out in Uchinoura Space Center on August 17, 2014. The purpose of this sounding rocket experiments is observation of sporadic E layer that appears in the lower ionosphere at near 100km. Therefore, the experiments was carried out using three methods. The first method is an optical method that observe light of metal ion emitted by the resonance scattering in sporadic E layer using the imager. The second is a method of using radio waves that receive the LF/MF band radio waves transmitted from the ground to rocket. The third is a method that measuring the electron density in the vicinity of sounding rocket using the fast Langmuir probe and the impedance probe. In this presentation, we explain the preliminary report of radio waves observations and radio waves propagation characteristics using frequency analysis of S-520-29 sounding rocket experiment. This rocket was equipped with LF/MF band radio receiver for observation of characteristics of LF/MF band radio waves propagation, and observe the LF/MF band radio waves in rocket flight. Antenna of LF/MF band radio receiver is composed of three axis loop antenna. LF/MF band radio receiver receives three radio waves of 873kHz (JOGB), 666kHz (JOBK), 60kHz (JJY) from the ground. 873kHz and 60kHz radio waves are coming from north side of the rocket, 666kHz radio waves are coming from the east side to the trajectory of the rocket. It is possible to estimates the position and size of the high electron density region in the sporadic E layer by analysis radio waves propagation characteristics using radio waves come from different directions. In the sounding rocket experiment, LMR was working properly. We have completed the observation of radio wave intensity. We analyze the observation results using a Doppler shift calculations by frequency analysis. Radio waves received by the sounding rocket undergoes a Doppler shift by polarization and direction of rocket spin and magnetic field of the earth. Radio waves received by the sounding rocket was separated into characteristics waves using frequency analysis. Then we calculate the Doppler shift from the separated data. Finally, this study estimate the electron density by using Doppler shift and the equation of booker. As a result, 873kHz, 666kHz radio waves are reflected by the ionosphere. 60kHz radio wave was propagated to maximum altitude of sounding rocket after it converted into whistler mode. Then, this study was able to estimate the altitude distribution of electron density by using the Doppler shift. In this study, we explain the reports of LMR observations and characteristics of radio waves propagation by frequency analysis by S-520-29 sounding rocket experiment.

Keywords: sounding rocket, radio wave propagations, Doppler shift, sporadic E layer

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Velocity distribution of electrons generating plasma waves around the wake of an ionospheric sounding rocket

ENDO, Ken[1*] ; KUMAMOTO, Atsushi[1] ; KATOH, Yuto[1]

[1]Department of Geophysics, Graduate School of Science, Tohoku University

When a body moves in plasma at supersonic velocities, a rarefied plasma region called 'plasma wake' is formed behind the body. Wakes can develop behind a solar system body immersed in solar-wind plasma as well as behind spacecraft such as satellites and ionospheric sounding rockets.

Plasma waves around the rocket wake have been suggested by the observational results from previous rocket experiments, while there are also several studies which reported plasma waves around the wakes of a satellite and of the moon. In the S-520-26 rocket experiment (apex: 298 km), carried out in Japan at dawn of January 12, 2012, three kinds of plasma waves were identified (hereafter denoted Group-A,B, and C). We concluded that they are electrostatic electron cyclotron harmonic (ESCH) waves or upper hybrid resonance (UHR) mode waves (Group-A waves), and whistler mode waves (Group-B and Group-C waves). They have spin-phase dependence in characteristic manners.

Meanwhile, it was found that Group-A waves were also observed in the S-520-23 rocket experiment (apex: 279 km), which was performed in Japan at dusk of September 2, 2007, and that their spin-phase dependence is nearly the same with that of the Group-A waves observed in the S-520-26 rocket experiment.

We performed numerical calculations of plasma dispersion relations by assuming anisotropic velocity distribution functions such as electron beam and temperature anisotropy. As a result, positive linear growth rates have been obtained in the wave number and frequency ranges of UHR mode waves and ESCH waves in addition to electrostatic whistler mode waves. Accordingly, there have to be electrons with some anisotropic velocity distribution functions which are equivalent to those we assumed in the calculations. However, we have to clarify what kind of velocity distribution can be generated around the actual wake through the interaction between a sounding rocket and ionopsheric plasma.

Singh et al. (1987) performed a one-dimensional simulation of plasma entering a void region from the two sides using a Vlasov-Poisson code. They found counterstreaming electron beams in the very near wake. However, their study concentrates on electrons on the wake axis and does not indicate distribution functions in other areas. Besides, temperature anisotropy could not be treated in their simulation because it was performed in one dimension in velocity space.

In order to investigate inhomogeneity of electron distribution functions around the rocket wake, we are developing a Vlasov-Poisson code with one-dimensional space and two-dimensional velocity space, which is redesigned from the simulation code used in Singh et al. (1987). In this simulation, we deal with cases that electrons and ions are filling in a void space. The time evolution can be understood as spatial distribution along the wake axis. The direction of one-dimensional space is along the geomagnetic fields, along which electrons and ions can move easily. The size of space is 10 m, which is divided into 1024 grids in the calculation.

In this presentation, we clarify the frequency range and spatial distribution of the plasma waves around the wake based on the analyses of S-520-26 and S-520-23 rocket experiment data. We also discuss the velocity distribution of the electrons which can generate the plasma waves as observed. In addition, we report the results of our simulation for investigating the velocity distribution of electrons around the wake.

Keywords: wake, plasma wave, sounding rocket, ionosphere

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Characteristic feature of plasma irregularity obtained in ICI sounding rocket campaign

ABE, Takumi[1*] ; MOEN, Joran[2]

[1]Japan Aerospace Exploration Agency, [2]University of Oslo

ICI-3 (Investigation of Cusp Irregularities) campaign was conducted in December 2011, to study a better description of plasma instabilities and wave phenomena related to Reversed Flow Events (RFEs) in the cusp ionosphere. In this campaign, sounding rocket was launched at Ny-Alesund in Svalbard, and intercepted the dayside cusp aurora region as expected. Among science instruments onboard, a purpose of Fixed Bias Probe (FBP) is to measure electron current incident to its spherical probe with high time resolution for investigating plasma irregularity with a spatial scale from 1 m to 100 m. The FBP successively identified existence of the small-scale electron density irregularity during the flight.

Power spectrum analysis was applied to the incident electron current, which is basically proportional to the electron density, with an interest in understanding characteristic feature of the spatial scale in the irregularity. In fact, the data obtained in this campaign are appropriate to investigate altitudinal variation of the frequency characteristics because the rocket was staying almost in the irregularity region through its flight.

As a result of spectrum analysis of the electron density variation, it is clearly found that spectral power with 10 meter scale increases with altitude. However, it should be noted that spectral power tends to increase with the background density if the irregularity is contained at a constant rate in the background density. Therefore, spectral amplitude normalized by the background density was used to investigate the altitudinal dependence. Our analysis indicates that normalized amplitude of the density irregularity with 1-10 m scale is most significant at altitudes between 100 and 150 km, while the one with 100 m scale is almost constant independently of altitude. In particular, it is noticeable that the amplitude of electron density irregularity has a small local maximum in the frequency of 100-200 Hz (corresponds to decameter spatial scale) at 100 km altitude. Such feature is not found at other altitudes. The electron density irregularity with such a scale can be a target of HF backscatter radar echoes.

We will discuss altitudinal variation of the density irregularity in more detail.

Keywords: Sounding rocket, plasma irregularity, ionosphere, Cusp, electron density

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Space structure of Es layer observed by Langmuir probe and a new analysis method

SAKAMOTO, Yumika[1*] ; ABE, Takumi[2] ; MIYAKE, Wataru[1]

[1]Department of Aeronautics and Astronautics Graduate School of engineering, Tokai University, [2]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency

The sporadic E layer has been studied for a long time, and wind-shear theory is generally accepted about its generation mechanism. The theory explains an accumulation process of the electron density, but hardly gives information on thermal energy budget inside the layer. A great number of observations have been reported about the electron density structure in the sporadic E layer, but few information on the electron temperature are available, and therefore the accurate measurement is expected to conduct on the sounding rocket. In general, since a velocity of the sounding rocket is very high, it is difficult to get high special resolution data on the density structure of the sporadic E layer in the vertical direction. Therefore, it is necessary to find a new idea to estimate electron temperature and electron density in high-time resolution to understand the small scale structure of the sporadic E layer.

The sounding rocket ”S-520-29” was launched from Uchinoura Space Center at 19:10 on August 17, 2014. The purpose of this experiment is to elucidate spatial structure of sporadic E layer in the lower ionosphere. Langmuir probe was installed as one of the probes for direct measurements. In some current-voltage characteristics obtained by the Langmuir probe during this experiment, it was noted that the current variation with the bias voltage showed unusual behavior which suggests significant gradient in the electron density inside the sporadic E layer. In such a case, it is not possible to estimate electron density and electron temperature by using the conventional method.

In this study, we suggest a new analysis method to enable accurate estimation of the electron temperature and density, even when electron density is rapidly changed. It becomes possible to estimate the temperature and density in a time interval shorter than a period of the voltage sweep, because the probe current are interpolated by using adjacent data.

In this presentation, we report the small scale density structure and vertical thickness of the sporadic E layer estimated by adopting the new method, and validity of the current interpolation.

Keywords: E layer, Langmuir probe, sounding rocket

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Analysis of DC electric field in ionosphere by S-520-26 sounding rocket

ISHISAKA, Keigo[1*] ; YAMAMOTO, Mamoru[2] ; YOKOYAMA, Tatsuhiro[3] ; ABE, Takumi[4] ; WATANABE, Shigeto[5]

[1]Toyama Prefectural University, [2]RISH, Kyoto University, [3]NICT, [4]ISAS, [5]Hokkaido Univeristy

S-520-26 sounding rocket experiment was carried out at Uchinoura Space Center (USC) in Japan at 5:51 JST on 12 January, 2012. The purpose of this experiment is the investigation of the bonding process between the atmospheres and the plasma in the thermosphere. S-520-26 sounding rocket reached to an altitude of 298 km 278 seconds after a launch. The S-520-26 payload was equipped with Electric Field Detector (EFD) with a two set of orthogonal double probes to measure both DC and AC less than 200 Hz electric fields in the spin plane of the payload by using the double probe method. One of the probes is the inflatable tube structure antenna, called the ITA, with a length of 5 m (tip-to-tip). And ITA is very lightweight (12.5g per one boom). The ITA extended and worked without any problems. It was the first successful use of an inflatable structure as a flight antenna. Another one is the ribbon antenna with a length of 2 m (tip-to-tip). The electrodes of two double probe antennas were used to gather the potentials which were detected with high impedance pre-amplifier using the floating (unbiased) double probe technique. The potential differences on the two main orthogonal axes were digitized using 16-bit analog-digital converter, sampled at 800 samples/sec with low pass filter at cut-off frequency of 200 Hz.

Results of measurements of DC electric fields by the EFD have the large sine waves that result from the payload rotation at the spin period. The largest contribution to the electric field measurements by double probes moving through the ionosphere at mid-latitudes is that due to the v X B fields created by their motion across the ambient magnetic field, where v is the rocket velocity in the Earth-fixed reference frame and B is the ambient magnetic field. The sum of the squares of the two components represents the magnitude of the DC electric field in the spin plane of the payload. These data reveal abrupt, large-scale variations which can immediately be attributed to changes in the geophysical electric field since the v X B fields are slowly varying. The sum of the squares data also reveals contributions at the spin frequency and its harmonics. These contributions result primarily from distortions of the waveforms in the raw data. Then we obtained three components of natural DC electric fields by subtracting the v X B fields from raw data. As a result, the magnitude of DC electric field on a rocket orbit during the ascent was about 1mV/m, and the direction was for north-east.

Keywords: DC electric field, ionosphere, rocket experiment

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PEM27-P20 Room:Convention Hall Time:May 26 18:15-19:30

Inter-annual variations of Nitric Oxide in the polar mesosphere observed by a millimeter-wave radiometer at Syowa

UEMURA, Miku[1] ; ISONO, Yasuko[2] ; NAGAHAMA, Tomoo[1*] ; MIZUNO, Akira[1] ; EJIRI, Mitsumu K.[2] ; TSUTSUMI, Masaki[2] ; NAKAMURA, Takuji[2] ; MIYOSHI, Yoshizumi[1]

[1]Solar-Terrestrial Environment Laboratory, Nagoya University, [2]National Institute of Polar Research

Recent observations revealed that the nitrogen oxides (NO,NO2) are increased in the lower thermosphere and the mesosphere and the upper stratosphere, when energetic particle precipitations associated with solar proton events or magnetic storms occurred (e.g. Lopez-Puertas et al. 2005),. To detect such the enhancement, we installed a millimeter-wave spectroscopic radiometer at Syowa Station in Antarctica, and observation of the NO spectrum has been conducted since January 2012. The NO column density derived from this observation shows a seasonal variation that the NO column density increases in winter. In winter, the observed NO column density of 2014 is lower than 2012 and 2013.

To study reliability of millimeter wave spectral radiometer, we compared the NO column amount with the SOFIE sensor on board AIM satellite. We picked observed data in the same magnetic latitude zone as the Syowa Station, and calculate an NO column density. The NO column density observed at Syowa Station and SOFIE shows a same tendency. Further, we compared month averaged NO column density, and found a good correlation. From this, the millimeter-wave spectral radiometer do uniform observations, and decreasing of the NO column density in 2014 winter season is reliably phenomenon.

Next, we study about impact of variations of relativistic electron flux to NO column density in winter. We used the electron flux data observed from POES satellites and calculated monthly integrated amount of the electron flux. The electron flux in the 2014 is less than those of 2012 and 2013. In particular, this tendency is significant in a period between April and August in 2014. From this, a lower amount of NO column density of 2014 winter may be caused by a low amount of relativistic electron flux.

Keywords: microwave spectroscopy, Nitric Oxide, MLT region, Energetic Particle Precipitation

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An observation of sodium twilight airglow using a Fabry-Perot imager

SUZUKI, Hidehiko[1*] ; TAKAHASHI, Hideyuki[2] ; TAGUCHI, Makoto[2]

[1]Meiji university, [2]Rikkyo university

The mesosphere and lower thermosphere (MLT) region is thought as a key region to solve a mechanism of the global change in the Earth's atmospheric system. Atomic metal layers which are maintained by ablation of meteors in the MLT region are known as a precious tracer to investigate chemistry and dynamics of the upper atmosphere [Williams, 2002]. For example, resonance scatter lidars tuned for wavelengths of various metal species are widely used to infer the winds and temperature in the MLT region [Plane, 2003]. However, there are still many ambiguities in knowledge about a horizontal structure and a seasonal variability of the metal layers. Therefore, a twilight airglow is focused on as a tracer to investigate horizontal structures of the metal layers in the MLT region in this study. The twilight airglow is luminous phenomenon which is caused by a resonance scattering of the metallic atoms in the MLT region illuminated by solar irradiance. This emission is effectively detectable in twilight time under a suitable geometric condition among the Sun, the metal layers, and a ground-based observer [e.g. Chamberlein, 1961]. Unlike a resonance scattering lidar, an emission from a metallic atom layer occurs simultaneously in a horizontally spread area, because a light source of the emission is solar irradiance in a case of twilight airglow. Thus, it is possible to deduce a horizontal distribution of metallic atoms from twilight airglow observations by using a sensitive and narrow band imaging device with a wide field of view. The Fabry-Perot interferometric imager (FPI) of the National Institute of Polar Research (NIPR) is one of instruments which satisfy these requirements. In this study results of a test observation of sodium twilight airglow, which is one of the strongest emissions in twilight, using the FPI at NIPR are presented, and future possibilities for study of a horizontal structure of metallic atom distribution in the MLT region using the FPI are discussed.

Keywords: twilight airglow, mesosphere, thermosphere, metallic layer, Fabry-Perot

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PEM27-P22 Room:Convention Hall Time:May 26 18:15-19:30

An estimation of three-dimensional structures of airglow emission discontinuities using images taken from ISS

SATO, Masato[1*] ; SAITO, Akinori[1] ; AKIYA, Yusuke[1] ; HOZUMI, Yuta[1]

[1]Graduate School of Science, Kyoto University

Three-dimensional structures of airglow emission discontinuities were revealed using images taken by astronauts from International Space Station (ISS). Airglow layers over the Earth's rim were captured by astronauts with a digital camera at night. Because these images were for the visible-light range, Na 589nm and OI 557.7nm emissions 90km altitude were expected to be dominant on these images. Two discontinuities on the airglow layers were observed on 16 October 2011 and 26 August 2014. They were observed from various viewing-angles during observing time 4m24s and 8m15s. Thus the three-dimensional structures of the discontinuities were estimated from these series of images. It was found that the structures would be caused by splitting of two emission layers, Na and OI. It is also found that they extended over 700km in the east-west direction. We estimated the altitude distributions of these emission layers' intensity and their RGB ratio by using Abel function. From the ground-based optical observation, mesospheric bore has been observed as an airglow discontinuity by terrestrial observation of airglow. The observed discontinuities and the bores have similarities and differences. In the presentation, the three-dimensional structures of the discontinuities will be reported, and their generation mechanism will be discussed in the comparison with the bore.

Keywords: airglow, mesospheric bore

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New analysis of gravity wave in middle atmosphere by Rayleigh/Raman lidar at Syowa station in Antarctica

KOGURE, Masaru[1*] ; NAKAMURA, Takuji[2] ; EJIRI, Mitsumu K.[2] ; NISHIYAMA, Takanori[2] ; TSUTSUMI, Masaki[2] ; TSUDA, Takuo[3]

[1]Department of Polar Science, The Graduate University for Advanced Studies, [2]National Institute of Polar Research, Japan, [3]The University of Electro- Communications

The gravity waves are generated in lower atmosphere, propagate upward and transfer momentum to the middle atmosphere. It has been found that the gravity waves induce large scale meridional circulation and drive the middle atmosphere away from radiative equilibrium [Lindzen, 1981; Holton, 1982; Matsuno, 1982]. However, we has not completely known the quantification of gravity wave roles in the middle atmospheric circulation. In particular, it has not been found that the quantification of gravity waves generated from convection (e.g. polar night jet). A Rayleigh/Raman lidar was installed in January 2011 at Syowa station, Antarctica (69S, 40E). It has measured temperature profiled between approximately 8 and 70 km for more than 850 nights (before the end of October in 2014).

We have analyzed the lidar data based on Duck et al. (2001) and Alexander et al. (2011). However, their analysis has a problem. They estimated gravity waves' temperature amplitude to be the value (T') that is difference between background temperature and atmospheric temperature. Their analysis may underestimate the potential energy (Ep) due to not consider the phase. To solve the above problem, we calculated the value (T_h') delaying 90 degree from T' phase to perform Hilbert transformation on T′ weighted by the square root of density, and defined gravity waves' temperature amplitude as $((T')^2+(T_h')^2)^{1/2}$. In this presentation, our analysis will be explained in detail.

Keywords: Stratsphere, Mesosphere, Middle atmosphere, gravity wave, Antarctica, Lidar

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Measurements of Fe and Ca+ temperatures using by a frequency-tunable lidar

TSUDA, Takuo[1*] ; EJIRI, Mitsumu K.[2] ; NISHIYAMA, Takanori[2] ; ABO, Makoto[3] ; KAWAHARA, Takuya[4] ; NAKAMURA, Takuji[2]

[1]The University of Electro-Communications, [2]National Institute of Polar Research, [3]Tokyo Metropolitan University, [4]Shinshu University

We are developing a new resonance scattering lidar system to be installed at Syowa Station (69S, 39E) in Antarctica. For the new lidar system, we have employed a tunable alexandrite laser covering the resonance scattering lines of two neutral species, which are atomic potassium (K, 770 nm) and atomic iron (Fe, 386 nm), and two ion species, which are calcium ion (Ca^+, 393 nm) and aurorally excited nitrogen ion ($N2^+$, 390 nm, 391 nm). Thus the new lidar system will provide information on the mesosphere and lower thermosphere as well as the ionosphere. Using the new resonance scattering lidar together with colocated other instruments, we will conduct a comprehensive ground-based observation of the low, middle, and upper atmosphere above Syowa Station. This unique observation is expected to make important contribution to studies on the atmospheric vertical coupling process and the neutral and charged particle interaction.

In this presentation, we will report current status on test observations of the iron atom layer at National Institute of Polar Research (NIPR) at Tachikawa, Japan (36N, 139E). In order to obtain the iron resonance line at 386 nm, we operate the fundamental laser (i.e. the tuneable alexandrite laser) at 772 nm, which is shifted by 2 nm from the potassium resonance line at 770 nm, and then obtain the pulsed 386 nm laser using nonlinear crystal based on the second harmonic generation (SHG) technique. On 14 August 2013, we successfully detected first signals from the iron atom layer, with one-frequency mode for Fe number density measurement. The observed iron number density would be fairly comparable to that from the previous observations at Illinois (40N, 88W). After that, we have prepared three-frequency mode for Doppler temperature measurements. Based on a theoretical calculation, we have determined good combination of the three laser frequencies to minimize the temperature error, and then performed operations of the three-frequency mode on 5 and 18 Augsut 2014. The obtained temperature data will be compared with those from NRLMSISE-00 model and satellite observations. Furthermore, we will show a challenge of observing Ca^+ temperature.

Keywords: Resonance scattering lidar, Mesosphere/Lower thermosphere, Ionospheric D/E region, Neutral temperature, Ion temperature

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Report of the STEL optical observation at the Tromsoe EISCAT radar site by March 2015

OYAMA, Shin-ichiro[1*] ; NOZAWA, Satonori[1] ; SHIOKAWA, Kazuo[1] ; OTSUKA, Yuichi[1] ; TSUDA, Takuo[2] ; TAKAHASHI, Toru[1] ; FUJII, Ryoichi[1]

[1]Solar-Terrestrial Environment Laboratory, [2]Department of Information and Communication Engineering, University of Electro-Communications

Solar-Terrestrial Environment Laboratory (STEL) has been operating various kinds of optical instruments for more than 10 years at the Tromsϕ EISCAT (European Incoherent Scatter) radar site in Norway (69.6^{o}N, 19.2^{o}E), which is one of the state-of-art observatories at high latitudes. Five instruments are now in automatic operation regularly from October to March: (1) three-wavelength photometer (427.8 nm, 630.0 nm, and 557.7 nm), which is fixed to look along the magnetic field line, (2) digital camera for monitoring weather and aurora, (3) proton all-sky camera (486.1 nm), (4) multi-wavelength all-sky camera (557.7 nm, 630.0 nm, OH band, 589.3 nm, 572.5 nm, and 732.0 nm), and (5) Fabry-Perot interferometer (557.7 nm, 630.0 nm, and 732.0 nm). The quick looks are available on the web at www.stelab.nagoya-u.ac.jp/~eiscat/data/EISCAT.html. These instruments are programmatically operated, and they have contributed to many campaign observations with the EISCAT radars, rockets, satellites, and other ground-based instruments by adjusting the observation mode.

Keywords: aurora, air glow, optical instrument, ionosphere, thermosphere, polar region

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Observation of GNSS scintillation in Tromso

UWASHITOMI, Kodai[1*] ; OTSUKA, Yuichi[1] ; OGAWA, Yasunobu[2] ; HOSOKAWA, Keisuke[3]

[1]Solar-Terrestrial Environment Laboratory, Nagoya University, [2]National Institute of Polar Research, [3]Department of Communication Engineering and Informatics, University of Electro-Communications

Ionospheric scintillation is a phenomenon that received radio wave fluctuates in phase and amplitude. It has been known that amplitude scintillation frequently occurs at equatorial regions, and that phase scintillation frequently occurs at high latitudes. We have been operating dual-frequency GNSS (Global Navigation Satellite System) receivers at Tromsoe, Norway. The receivers are controlled by PC and record carrier phase and signal-to-noise ratio of the received signal from GPS satellites. We have calculated S4 and $\sigma\phi$ indices. S4 is defined as a ratio of standard deviation of the signal intensity to the average signal intensity in each 1 minute. $\sigma\phi$is defined as the standard deviation of the phase of the received signal. During November and December 2013, in 12 days, we observed amplitude scintillation events in which S4 exceeds 0.3.In 7 days out of 5 days, magnetic activity was high. In this study, we will compare the amplitude scintillation with phase scintillation and total electron content (TEC) obtained from the GNSS receivers to discuss generation mechanisms of ionospheric irregularities causing the amplitude scintillations.

Keywords: scintillation, ionosphere, GPS, GNSS, geomagnetic disturbance, TEC

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Statistical analysis of Medium-Scale Traveling Ionospheric Disturbances using a GPS network at high-latitudes

MIZOGUCHI, Takuya[1*] ; OTSUKA, Yuichi[1] ; SHIOKAWA, Kazuo[1] ; TSUGAWA, Takuya[2] ; NISHIOKA, Michi[2]

[1]Solar-Terrestrial Environment Laboratory, Nagoya University, [2]National Institute of Information and Communications

In our previous study, using global positioning system (GPS) data taken from more than 100 GPS receivers in Alaska in 2012, we investigated two-dimensional maps of total electron content (TEC) perturbations with a time resolution of 30s and a spatial resolution of 0.15○×0.15○ in longitude and latitude to examine statistical characteristics of Medium-Scale Traveling Ionospheric Disturbances (MSTIDs) for the first time. From the statistical analysis of the TEC maps obtained in 2012, we have revealed some of the characteristics of MSTIDs in Alaska. MSTIDs over Alaska frequently occur in winter from 8 to 20 LT. Maximum occurrence rate of the MSTIDs in monthly and hourly bins exceeds 50%. Propagation direction of MSTIDs is dominantly southward or southeastward from 8 to 14 LT and southwestward from 14 to 20 LT.

In this study, we focus on the statistical result of propagation direction. Southward or southeastward propagating MSTIDs is consistent with that of MSTIDs at mid-latitudes and could be caused by atmospheric gravity waves (AGW) in the thermosphere. The southwestward propagating MSTIDs have been observed with all-sky airglow imager in Alaska, and are considered to be attributed to AGW generated by auroral activity. The present study shows that the southwestward propagating MSTIDs appear before sunset when the airglow observations can be carried out.

In this presentation, we show that statistical characteristics of parameters of MSTIDs, such as period, horizontal wave length, and propagation velocity, and discuss possibility of TEC perturbation caused by AGW propagation excited by auroral activity. Also, we investigate propagation direction of MSTIDs more detail using GPS data taken from GPS receiver networks in northern Europe in 2008 and discuss whether southwestward propagating MSTID is common phenomenon at high-latitudes.

Keywords: Medium-Scale Traveling Ionospheric Disturbances, GPS, auroral activity

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Statistical study of longitude dependencies of MSTIDs observed with GPS networks

YAMAWAKI, Keita[1*] ; OTSUKA, Yuichi[1] ; SHIOKAWA, Kazuo[1] ; TSUGAWA, Takuya[2] ; NISHIOKA, Michi[2]

[1]Solar-Terrestrial Environment Laboratory, Nagoya University, [2]National Institute of Information and Communications Technology

We revealed statistical characteristics of medium-scale traveling ionospheric disturbance (MSTID) by using global positioning system (GPS) networks in North America and compared them with previous studies.

TEC (Total Electron Content) is obtained from delays of radio wave transmitted GPS satellites to the receivers. Using two-dimensional maps of TEC perturbations, for the first time, we statistically analyzed MSTID above North America in 2013. The observed characteristics can be summarized as follows:

1. The occurrence rate of MSTID above North America during daytime (0800LT-2000LT) is high in winter (November-March) and its propagation direction is predominantly south-eastward. This seasonal variation of daytime MSTID occurrence rate is consistent with that reported by earlier publications. The daytime MSTID could be caused by gravity waves.

2. The occurrence rate of MSTID during nighttime (2200LT-0600LT) is high in summer (May-August) and its propagation direction is predominantly south-westward. This feature is consistent with that reported in earlier studies. Perkins instability could play an important role in generating the nighttime MSTID.

3. The occurrence rate of morning MSTID is high throughout the year. Its propagation direction is predominantly eastward and the gravity waves generated by terminator could account for this type of MSTID.

4. The occurrence rate of MSTID above the west part of North America is 20 percent higher than that above the east part in summer (May-June).The pervious paper shows that occurrence rate of ES layer in west part of North America is higher than that in east part, on the basis of occultation observations using low orbit satellite. Our statistical result suggests that the coupling process between E and F regions could play an important role for generating MSTIDs.

Keywords: MSTID, GPS, sporadic E layer, longitude dependencies