Characteristics of acoustic mode gravity waves on the ground and their effect in the ionosphere

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Short period waves from lower atmosphere generate small-scale field-aligned currents through ionospheric dynamo. The magnetic fluctuations with amplitude about 1 nT and spatial scale about 100 −200 km generated by the small-scale field-aligned currents were named as “magnetic ripples”. The most plausible source of the atmospheric waves is the cumulus convection. Although the global distribution and its local time or seasonal variation of the amplitude of magnetic ripples strongly suggest the cumulus convection as the main origin, we need to clarify what mode of atmospheric waves contributes to the magnetic ripples and what meteorological condition correspond them. For those purposes, we analyze ground based magnetic and micro-barometric variations. We try to make quantitative estimation of the contribution from both acoustic and internal mode of gravity waves, acoustic resonance, etc.

The followings are our tentative results:

・Averaged PSD (power spectral density) increases to longer period (at least to 30 minute).

・PSD of pressure has a bulge in a range of acoustic gravity mode waves (100 −400 sec)

・The amplitude of the bulge is highly variable around vertical resonance period.

・PSD is larger on dayside.

・Average location of PSD peaks show slight shift depending on the latitude and season.

Keywords: micro-barometric variation, acoustic mode gravity waves, ionospheric current, vertical acoustic resonance

Relationship between magnetic ripples observed by the Swarm satellites and lower atmospheric disturbances

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The Swarm satellites, which are the low Earth, polar orbiting satellites, observed small-amplitude (0.1–5 nT) magnetic fluctuations, so-called magnetic ripples (MRs), with period around a few tens of seconds along the satellite orbit in the topside ionosphere at middle and low latitudes. A possible generation mechanism of the MRs is as follows. (1) The atmospheric waves generated by the lower atmospheric disturbance propagate to the ionospheric layer. (2) The neutral wind perturbations caused by the atmospheric wave drive the ionospheric layer dynamo, so that Hall and Pedersen currents flow in the ionosphere. (3) Because the dynamo region is limited, directions of the dynamo electric fields in the two adjoining dynamo regions with the spatial scales of the neutral wind perturbation apart are opposite. Therefore the ionospheric currents diverge to flow along the geomagnetic field-line with much higher conductivity. (4) As an Alfvén wave with polarized electric field, the front of the current circuit propagates along the geomagnetic field-line to the conjugate point on the ionosphere. (5) The currents are closed to make an electric current circuit which is made up of the currents in the ionosphere and field-aligned currents (FACs). The MRs are the spatial structure of small-scale FACs, and we confirmed with the Swarm observations their basic characteristics to be almost the same with those obtained by the CHAMP satellite. That is, the global distribution of the averaged MR amplitudes has clear geographical, seasonal and local time dependence highly correlated with the ionospheric conductivities. We found that the averaged amplitudes of the MRs derived from the Swarm-B satellite which flies about 50 km higher altitude are slightly smaller than those of the Swarm-A and -C, suggesting that the location of origin of the MRs is below ~470 km altitude, i.e., not in the magnetosphere. From the global distribution and its characteristics, the source of the MRs has been expected to be the atmospheric waves generated by lower atmospheric disturbances including the effects of earthquakes or volcanic eruptions. The fact that the MRs appear almost always suggests that some typical meteorological phenomena are the main source of MRs. To confirm the suggestion, we tried to find the connection between the MRs and typhoons as the first step. To show the evidence which correlates the MRs with typhoons, we performed an event and a statistical analyses with track data of typhoons. The data of 54 typhoons during the period from 26 November 2013 to 31 July 2016 are used for the statistical analysis. The results show that the averaged amplitudes of the MRs during typhoon activity are, in general, except for the day side local time sector, larger than those during non-typhoon condition. The event analyses indicate amplitudes enhancement of the MRs around the typhoons, and the latitude of the enhancement moved with the typhoon. These analyses indicate that typhoons are one of the source meteorological phenomena of the MRs. From the comparison with the infrared brightness temperature data the convection activity include typhoon seems to affect the amplitude of MRs. These results indicate that the MRs are generated by the lower atmospheric waves through the ionospheric dynamo.

Keywords: Magnetic ripple, Magnetic fluctuation, Field-aligned current, Ionospheric dynamo, Acoustic gravity wave, Swarm

Ionospheric disturbances associated with volcanic eruptions observed by GPS-TEC and HF Doppler sounding

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It is reported that ionospheric disturbances are caused not only by solar-terrestrial conditions but the phenomena below the ionosphere such as earthquakes, typhoons and volcanic eruptions. Compared with ionospheric disturbances caused by earthquakes, there are very few studies examining the ionospheric disturbances associated with volcanic eruptions.
In this study, we have examined ionospheric disturbances associated with volcanic eruptions using GPS-TEC and HF Doppler sounding. We detected ionospheric disturbances associated with Mt. Asama eruption at 11:02 UT on Sep., 1st, 2004. In HF Doppler sounding observation, the spiky disturbances whose frequency is about 7 - 16 mHz was observed firstly. Following this disturbances, longer-period disturbance was appeared, whose frequency is about 3 - 5 mHz. The former disturbance was also observed by GPS-TEC,
whose ionospheric pierce points were located near the Mt. Asama. From the propagation time of this disturbance, it is possible that the eruption generated shock waves which propagated to the higher ionosphere. In terms of the frequency, the latter disturbances observed by HFD sounding shows the resonance of the atmospheric wave between the lower ionosphere and the ground.

Keywords: Ionosphere, GPS-TEC, HF Doppler

Long-term variation of geomagnetic Sq filed and its cause

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Long-term variation of geomagnetic Sq field was used to study that of neutral pressure difference of the thermosphere (PD), considering high correlation between Ampere force by geomagnetic Sq currents and PD. It was shown that long term variation of PD can be explained almost only solar activity variation. Other factors such as eletric conductivity and geomagnetic main filed will be considered in the presentation.

Keywords: geomagnetic daily variation, long term variation, solar activity, pressure difference in the thermosphere, electric conductivity, geomagnetic main field strength

Bimodal electron energy distribution observed by sounding rocket in the Sq current focus

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“S-310-44” sounding rocket experiment was conducted on January 15, 2016 to investigate electron heating and anomalous phenomena occurring in the Sq current focus. A total of 5 instruments to measure electron energy distribution, electric field, magnetic field, and plasma wave were installed on this rocket to observe key parameters for elucidating the physical process responsible for the electron heating. We reported last year that the electron temperature was observed to be about 200 K larger than the background temperature at 100-110 km altitude in the Sq current focus. In this presentation, we will talk about a result of our recent analysis on the electron energy distribution obtained during the rocket flight. Fast Langmuir Probe (FLP), which is one of the onboard instruments, is capable of measuring electron energy distribution with a cylindrical probe based on Druyvesteyn method. In this measurement, it is possible to estimate electron energy distribution from the second derivative of the probe current with respect to the applied voltage once the space potential can be determined on the rocket. The space potential corresponds to the voltage where the second derivative of the probe current has a sharp minimum.

The FLP Data obtained in the region below 100 km altitude show ordinary energy distribution of ionospheric electrons by which the electron temperature and density are calculated from the gradient in the electron deceleration region and the space potential. In contrast, it becomes difficult to determine a position of the space potential in the altitude range between 100 and 110 km. Moreover, bimodal peaks in the second derivative are found to exist in the higher energy from the space potential above 110 km altitude. A possible cause of such bimodal energy distribution will be 1) Bi-Maxwellian energy distribution with two different temperatures, 2) Electron temperature anisotropy, and 3) Two distributions consisting of stational ionospheric electrons and higher energy electrons coming from different altitude. In addition, another characteristics of the observed energy distribution is that the peak height of the second derivative has a periodic variation according to the phase of rocket spin, which may be related to the cause of such a distribution. We also need to discuss a causal relationship between the high electron temperature in 100 –110 km altitudes and these higher-energy electrons. In this talk, we will present the latest result of our analysis of the electron energy distribution.

Keywords: Sq current system, Electron energy distribution, Souding rocket, Electron heating

Variations in the D-region heights during the total solar eclipse of 9 March 2016 in Insonesia using AVON data

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We report increase in the reflection heights of LF transmitter signals during a total solar eclipse in Indonesia on 9 March, 2016, using AVON (Asia VLF Observation Network) data. The transmitter signals of JJY-Fukushima (FKS, 40 kHz), JJY-Saga (SAG, 60 kHz), and BPC (China, 68.5 kHz) were received at Pontianak (PTK), Indonesia, where the maximum magnitude of the solar eclipse was 0.929 at 00:25 UT. The magnitude of the solar eclipse at the transmitter sites was about 0.2. The all paths did not cross the eclipse path. During the solar eclipse (00:00 –01:30 UT), the average changes of the phase delay of the SAG-PTK and BPC-PTK paths were 40º and 42º, respectively. Assuming a usual daytime height for the LF waves to be 70 km, the phase delays on both the SAG-PTK and BPC-PTK paths correspond to the increase in the reflection heights of about 1.5 km based on the Earth-ionosphere waveguide mode theory. The LF intensity of the FKS-PTK path during the solar eclipse was slightly larger by about 6.5 dB than that before and after the eclipse time. The increase in the LF reflection heights suggests the decrease in the D-region electron density during the solar eclipse.

Modeling of Na airglow emission and first results on the nocturnal variation at midlatitude

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The ablation of meteors at the mesopause region results in the formation of sodium layer. Due to the fact that it has a large scattering cross section and also that it acts as a tracer for the thermal and dynamical states of the atmosphere in the mesosphere region, the mesospheric sodium has been studied extensively among the meteoric metals. A model for sodium airglow emission is developed by incorporating all the known reaction mechanisms. The neutral, ionic and photochemical mechanisms are successfully implemented into this model. The values of reaction rate coefficients are based upon the theoretical calculations as well from experimental observations. The densities of major species are calculated using the continuity equations, whereas for the minor, intermediating and short lived species steady state approximation method is used. The modeled results are validated with the rocket, lidar and photometer based observations for a branching ratio of 0.04. The inputs have been obtained from other physics-based models and ground- and satellite-based observations to give the combined volume emission rate (VER) of Na airglow between 80 and 110 km altitude. In the present study, the model is used to understand the nocturnal variation of Na VER during the solstice conditions. The model results suggest a variation of peak emission layer between 85 and 90 km during summer solstice condition, indicating a lower value of peak emission rate during summer solstice. The emission rates bear a strong correlation with the O_3 density during summer solstice, whereas the magnitude of VER follows the Na density during winter solstice. The altitude of peak VER shows an upward shift of 5 km during the winter solstice.

Keywords: mesospheric sodium, meteor ablation, ozone, modeling of atmosphere, mesospheric chemistry

Improvement of 3D analysis of ionospheric plasma density over Japan

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Real-time monitoring of the ionospheric plasma distribution is important for the correction of the measurement errors of satellite navigation. We developed three-dimensional ionosphere tomographic analysis with GEONET data, and have started the real-time analysis since April 1, 2016. The purpose of this study is to improve this 3D tomography analysis. There are two points to be improved in this system. The first point is analysis of the whole GOENET data. The data before April 1, 2016 is not analyzed yet. We will analyze the archived GEONET data by using the supercomputer KDK at Kyoto University. Then the analysis results will be open to the public from a web page. The other point is improvement of graphic display of the tomography results. We now have four limited methods to show analysis results. To show distribution of the plasma density at different angles, we developed the vertical display along any azimuthal direction designated by a pair of horizontal locations (longitude and latitude). We plan to improve the web data service including these points.

Preliminary results of the ionospheric observation by new ionosondes, VIPIR2

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National Institute of Information and Communications Technology (NICT) has been observing ionosphere by ionosondes for over 60 years in Japan. At present, four ionosondes at Wakkanai (Sarobetsu), Kokubunji, Yamagawa, Okinawa (Ogimi) are automatically operated and controlled from Tokyo. Ionospheric parameters such as foF2 and foEs are automatically scaled from the ionograms. The scaled parameters are provided through our web site (http://wdc.nict.go.jp/IONO/) and used for monitoring ionospheric disturbances. Currently we are replacing the current 10C type ionosondes with Vertical Incidence Pulsed Ionospheric Radar 2 (VIPIR2) ionosondes. VIPIR2 ionosonde can separate the O- and X-modes of ionospheric echoes automatically using an antenna array, which would make it easy and successful to scale the ionogram automatically. As of 2016, hardware of VIPIR2 ionosonde are installed at the four stations and its observation has started. Arrival directions of ionospheric echo were also estimated with the phase measurements of the antenna array. In the presentation, preliminary results of the VIPIR2 observation will be shown and possible collaborations will be discussed.

Keywords: ionosonde, VIPIR2, HF radar

Study of equatorward-extending structures of ionospheric irregularity using GPS-TEC in Northern America

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There are about 2700 dual-frequency GPS receivers in Northern America. The GPS receivers provide the data of carrier phase and pseudo-range measurements at two frequencies every 30 seconds. Phase and group velocities of the GPS signals are advanced and delayed, respectively, by electrons in the ionosphere. So the Total Electron Content (TEC) along the entire line-of sight (LOS) between receiver and satellite can be derived by analyzing the GPS data.
We used the Rate of TEC change Index (ROTI) to detect the ionospheric irregularities. ROTI is the standard deviation of Rate of TEC change (ROT) in 5 minutes, and ROT is the changes of TEC in 30 seconds. The two dimensional maps of ROTI can be obtained from all available GPS data in North America. For projecting ROTI on the two dimensional map, we assume that there is the ionized single layer at altitude of 300 km. The spatial resolution is 0.75 °×0.75 °in latitude and longitude.
A magnetic storm occurred on 17 March 2015. It started at 05 UT, and Dst index reached a minimum of -223 nT at 23 UT. Enhancement of ROTI were seen at 09:00-11:00 UT and 21:00-24:00 UT. The ROTI enhancement region observed at 09-11 UT was consistent with auroral region observed from DMSP satellites. At 21-24 UT, Storm Enhanced Density (SED) was seen from absolute TEC map, and ROTI enhancement was observed in SED and poleward region of SED.
Equatorward-extending structures of ROTI enhancement region were seen at 09:00-10:30 UT and 13:00-15:30 UT in equatorward of auroral region, northern latitude of 40-50 degrees. The scale of the Equatorward-extending structures were about 150 km in the parallel direction. We calculated the drift velocity of plasma in east-west and north-south direction from data of HF radar at Christmas valley (43.27 °N, -120.36 °E) using least squares method. The enhancement of eastward drift velocity were seen at 09-11 UT and 12-14 UT and the drift velocity were about 500m/s. In this study, we examine the relationship between the fine structures of ROTI enhancements and plasma drift.

Keywords: Ionosphere, TEC, GPS, ROTI

Observations of ionospheric scintillation and total electron content using Global Navigation Satellite System (GNSS) receivers in Tromsø, Norway

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In the terrestrial ionosphere, electron density irregularities may cause variations of signal strength and/or carrier phase in trans-ionospheric satellite transmission signals received on the ground, which are commonly called ionospheric scintillations. Scintillations are categorized into amplitude scintillations and phase scintillations. Amplitude scintillations are observed as fluctuations of the signal strength, which are caused by interference between signals diffracted by irregularities. The amplitude scintillations are normally quantified by S_4 index, which is standard deviation of the received power normalized by its mean value. Phase scintillations are detected as high frequency fluctuations in the carrier phase, which are caused by variations in the refractive index due to spatial and temporal variations in electron density. The phase scintillations are normally quantified by σ_ϕ index, which is the standard deviation of the carrier phase. Phase scintillations occur both in equatorial and polar regions. In contrast, it is known that the amplitude scintillations in the equator are larger than those in the polar region.
In this study, GPS scintillations at high latitude were compared and analyzed using dual frequency (L1 : 1575.42 MHz and L2 : 1227.60 MHz) Global Navigation Satellite System(GNSS) receivers in Tromsø, Norway. This measures the amplitude and phase of the received signals at a sampling frequency of 50Hz for each satellite and calculates scintillation indices. In the present study, phase scintillations are monitored by estimating ROTI (Rate of TEC change Index). ROTI is the standard deviation of ROT (Rate of TEC change), where ROT is differential of the TEC time-series. In previous studies, amplitude scintillations are remarkable in high latitude, however we observed weak amplitude scintillations at high latitude by using low noise receivers in this study. We researched seasonal variations of S_4 and ROTI from the measurement data for the last three years, from January 2013 to December 2015. Both S_4 and ROTI have larger values at night mainly in spring and summer, and their occurrence rates depend on the season and local time. These features indicate that, at night in winter in the polar region, irregularities exist in the polar cap patches from the dayside area across the central polar cap, while electron density becomes uniform due to ionizations by solar radiation in summer. However, the S_4 increases do not always coincide with the ROTI increases. Therefore, we compared increases of S_4 and ROTI on daily basis. In this study, we classified the S_4 and ROTI data into three cases and compared them: simultaneous increase of S_4 and ROTI, increase of only S_4 and increase of only ROTI. The simultaneous increase occurs mainly in the morning and daytime. the increase of either S_4 or ROTI is mainly in the nighttime. Duration of S_4 increases tends to be longer than that of ROTI. Moreover, only ROTI increase in the daytime of summer. In this work, we considered generation mechanisms of the ionospheric irregularities which result in scintillations in the polar region.

Keywords: GPS scintillation, ROTI, Ionospheric irregularities

Study of thermospheric wind variations at substorm onsets using a Fabry-Perot interferometer at Tromsoe, Norway

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We studied the thermospheric wind variations at the onsets of isolated substorms by using a Fabry-Perot interferometer (FPI) at Tromsoe, Norway. The wind variations were measured from the Doppler shift of both red line (630.0 nm, altitudes: 200-300 km) and green line (557.7 nm, altitudes: 90-100 km) emissions with a time resolution of ~13 min. The wind data were obtained for 7 years from 2009 to 2015. We first identified the onset times of local isolated substorms by using ground-based magnetometer data of Tromsoe and Bear Island stations, and then checked the wind variations before and after these onset times. Totally, we obtained 8 events from red line data and 10 events from green line data located at different local times. By checking the all-sky images at Tromsoe, we found that most wind observations were made at the equatorward of substorm onset arcs at the onset times. For half of the events, the observation location kept at the south of the auroral arcs from -30 min to +90 min of the event times. Then, we calculated the differences of wind velocities at the onset time and at 30-min (1-hour) after the onset time using winds averaged over ±15 min (±30 min) of the epoch time. For red line events, except for few notable decreases at dawnside, eastward wind tends to increase from the onset time to both 30-min and 1-hour after the onset time at all nightside local times. This result is opposite to the tendency expected from thermospheric tidal wind variations, and suggest a particular eastward drive of thermospheric wind during substorms. With some exceptions, northward wind tends to decrease at local times before 2 LT and increase after that, which is consistent with the expectation from thermospheric tides. For green line events, eastward components have a tendency of increase at all local times with some notable decreases at duskside. Northward components show some increases at pre-midnight sector, and significant decreases at duskside, post-midnight sector and dawnside. All the observed wind changes after the substorm onsets were less than 76 m/s for red line events, and 51 m/s for green line events. These wind changes are much smaller than the typical plasma convection speed, indicating that the plasma motion caused by thermospheric wind through ion-neutral collision is a minor effect as the driver of high-latitude plasma convection and as the triggering of substorm onset. Since the movement of onset arcs could inevitably affect the local wind field, we will consider this factor when discussing the wind variations in the presentation.

Keywords: Thermospheric wind, Substorm, Fabry-Perot interferometer