Basic development of direction finding system for lightning discharge at small balloon

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1. Introduction
As for the observation of the upper atmosphere, new observation technique has been born with a technological change in history. Balloon observation is lower-cost than other upper atmospheric observation technique like rockets, and in the recent years various experiment is performed with large balloons of JAXA. In addition, in the recent years when the downsizing of microcontrollers and the sensors has been realized rapidly, the observing experiment using small weather balloons is currently becoming feasible for the university laboratory level [1,2].
In this study, we developed the basics of balloon borne type small thunder direction-finding payload system. At present, the Meteorological Agency thunder reporting are leading the thunder observation in Japan. General technique of the thunder observation includes ground station as well as satellites for weather observation. However, most of the observation via the altitude area that a thundercloud developed (approximately within 5km-10km) has not yet been performed. For that reason, here, we introduce a thunder observation system to be equipped on high-altitude small balloons for weather observation use, and it is thought that provided data by making in-site measurements might be useful scientifically. In this paper, we report a design and the experiment of the small discharge direction-finding system and a future view [3].
2. System development
We adopted an electromagnetic wave detection type system by using a small loop antenna with a simple structure for balloon deployment with the direction-finding technique aboard. The developed system consists of a SD memory card and a GPS receiver for the precise data acquisition, a pair of orthogonal loop antenna, pre-amplifier for signal amplification with bias circuit, and 2-channel A/D converters.
3. System evaluation experiment
We performed an experiment for confirming the electric discharge detectabilities by using a discharging tube as a microscopic thunder generator. Confirming if a small loop antenna of φ100 mm× 90 turns could detect the change of the magnetic field. The purpose of experiment was checking distance-dependency and declination-dependency of the loop antenna when changing the distance direction of the discharging tube as a electromagnetic wave source. The distances of 0.5 m, 0.7 m, 1.0 m and 1.2 m were used for confirming each electromagnetic wave strength.
In addition, for confirming declination-dependency of the crossed loop antennas, chopping angle of the loop antenna was charged from right to left to realize 0-90 degrees changes in the direction relations artificially.4. Experimental results and discussion
In the distance-dependency experiment, it was confirmed that a second multinomial relation between signal strength A and distance d. The reception signal was weak but it canbe said that we can detectthe electromagnetic waves from the discharging tube quantitatively. On the other hand, the direction finding was impossible due to the low characteristics of accepted sampling rate on the used micro-controller, signal delay between the both channels growing at a time of the A/D conversion with the mbed microcontroller.
5. Summary
The developed system perferms continuous data collection without any significant problems. Microscopic discharge experiment was used for simulating a thunderbolt in laboratory. However, we have never tried the outdoor setting of this system, thus the electro-magnetic wave detection

coming from nature a lightning was not yet confirmed. Downsizing of the system and performance experiment under the simulated environment of the upper atmosphere is necessary when we consider the real balloon deployment. There exist two kinds of electric discharge phenomena that the polarity of discharge is anode-related lightning and cathode-related one. Thus, it is necessary to build an additional dipole antenna for the real direction-finding.

Keywords: Thunder, Electromagnetic wave, Balloon

Development and evaluative flight experiment result of small high-altitude balloon system optimized for domestic operation

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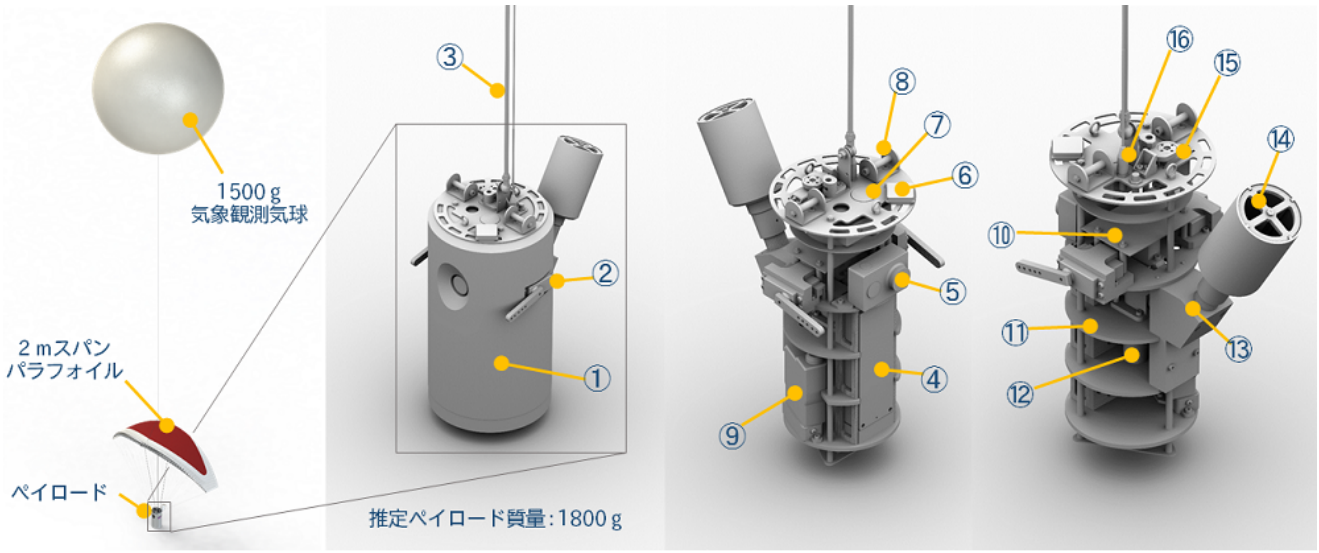
1.Introduction: Special high-altitude airplanes, sounding rockets and high-altitude balloons are used for observation technique in high-altitude area. High-altitude balloons have an advantage of making easy to product simple-structure payloads in comparison, therefore it has also an advantage of the cost per experiment when physical loads on the payload are small. In addition, high-altitude balloons are able to be launched slowly upward with a velocity of several m/s and do not use chemical reactions to provide lift-off, thus an advantageous technique in scientific observation. Applying these kind of advantages, the application of using weather balloons in high-altitude balloon experiment increased recently. Weather balloons are made of rubber that approximately 3 m in diameter, mounting payload weight is approximately 5 kg per balloon or less. In comparison with other observation techniques the small scale and low cost high-altitude balloon experiment may show the effectiveness in future when the weight of payload is not so heavy. Based on these backgrounds, the importance of the high-altitude balloon is greatly considered to escalate the role in high-altitude observation drastically depending on a way of the utilization. However, the observation technique using the small high-altitude balloons has not been spread in Japan rather than the continental countries mainly because ensuring safety of operation and recovery of the payload is difficult by geographical limitation in Japan. In this study, we are focusing on constructing operative system aboard the small high-altitude balloons that the development and inspection were possible at university laboratory level. We developed the controlled-descent-style payload technique using a small parafoil with automatic servocontrol to overcome the problem, and examined the validity of the developed system and utility through a performance evaluation experiments.
2. Developed airframe and low altitude flight experiment: We designed an examination airframe as is shown in figure to offer for various flight tests and conducted low altitude flight experiments by throwing down from a tower wagon an altitude of approximately 20 m, being controlled by remote console on ground.
3. Results of the experiment: The ratio of the gliding distance to the falling altitude was approximately 2 which we calculated from GPS position and barometer data recorded with a SD memory card. Long period flight is necessary for the evaluation with the stable gliding altitude of the parafoil, however, due to the short term evaluation period, obtaining the precise gliding ratio was difficult. Analizing the relationship between the heading orientation of the flight and the right and left servocontrol angles, it was confirmed that the state of airframe heading direction was changed from the east to the south when turning the servo controlled rudder with pulling down the right side arm.
4. Summary: Design validity of the developed airframe with the servocontrolled parafoil was confirmed by low altitude flight experiments. As for the future problem, it is necessary to evaluate with a flight from higher altitude, and to test it to confirm the ratio of the gliding distance to the falling altitude in the long-range flight. Assuming the more realistic large scale flight experiment in near future, we will develop a reliable bus apparatus and the balloon communication system to the ground stations. In addition, for the future mission, we have to confirm the design of mission and bus apparatus for the small balloon payload.

Keywords: small high-altitude balloon, parafoil, guidance control



① 保護外装（発泡スチロール）
② RC サーボモーター
③ パラフォイル固定ロッド
④ Li-Poバッテリー（耐衝撃外装）
7.4 V / 7500 mAh
⑤ 水平方向カメラ
⑥ 外部GPSアンテナ
⑦ 垂直方向カメラ
⑧ パラフォイル締結金具
⑨ 430 MHz帯アマチュア無線機
⑩ Main Control Unit (MCU)
⑪ 内部構造板（MDF材）
⑫ 緊急パラシュート射出ボンベ
⑬ 空圧シリンダー
⑭ パラシュート格納容器
⑮ 気球切り離し機構
⑯ UHF帯アンテナ

Water vapor estimation using digital terrestrial broadcasting waves - Results using reflected waves -

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We, National Institute of Information and Communications Technology (NICT), are developing a water vapor measurement system using digital terrestrial broadcasting wave. One of our goals is to develop a 2D water vapor monitoring system with distributed many small receivers. Horizontal distribution of water vapor mopnitoring will be contribute to increase the precision of weather forecast with data assimilations. Very precise measurements (at least several tens of pico-second order) are needed for the effective observations. 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. Each TV station has their own local oscillators. Out system is improved and it can measure phase fluctuations of radio waves from whatever TV station stably for a long time. We are planning a proving test for synchronization of local oscillators at different sites.
In this presentation we report a method and results of water vapor measurment without synchronization of local oscillators. We observe phase variations of digital terrestrial broadcasting waves at cartain site. If there is a reflector at the opposite side from the radio tower, we can observe direct waves and reflected waves simultaneously. Measurement is conducted using single local oscillator at the observing point. So we can measure a round trip propagation delay between the observing point and reflector without synchronization of local oscillators. NICT is located at about 29 km westward from the Skytree. A building is located at about 1 km westward from NICT. Both direct and reflected waves can be observed at NICT. We have a groundbase meteorological observatory equipment at NICT. Provagation delay can be calculated using these data on the assumption that these data are representative of the meteorological condition around there (within 1 km). Observed time vriations of propagation delay using digital terrestrial broadcasting waves correspond to the calculation.

Keywords: digital terrestrial broadcasting wave, water vapor

Global occurrence distributions and rates of lightning and TLEs and their LT dependences

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Transient Luminous Events (TLEs) are the instantaneous discharge phenomena excited by intense cloud-to-ground (CG) discharges. Using the optical data obtained by the FORMOSAT-2/ISUAL data, global occurrence distributions and rates of TLEs were estimated. However, due to the sun-synchronous polar orbit of the FORMOSAT-2 satellite, the local time (LT) dependences of the global occurrence rates of TLEs has not been estimated. In this study, we analyzed optical data obtained by the JEM-GLIMS (Global Lightning and Sprite Measurements on JEM-EF) instruments onboard the ISS (International Space Station) for the period from December 2012 to November 2014. Since the orbital inclination of the ISS is 51°, we can estimate more accurate global occurrence distributions and rates of lightning and TLEs and their LT dependences. From our data analyses, it is found that the estimated occurrence distributions of lightning and TLEs are mainly centered over the Africa, Southeast Asia, and Central America. It is also found that the LT dependences of lightning and TLEs occurrence rates showed small peak at 20LT and gradual increase from 00LT to 03LT. At the presentation, we will show the results derived from our data analyses more in detail and will discuss the possible reasons for the estimated LT dependences of lightning and TLEs occurrence rates.

Keywords: TLEs

Study of atmospheric gravity waves of orographic origin by airglow imaging

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Excitation and propagation processes of atmospheric gravity waves (AGWs) have been widely studied by both an observation and modeling schemes to understand energy and momentum balance in the middle atmosphere. Major sources of AGWs are known to be an interaction between winds and topography like mountains, inhomogeneous thermal absorption due to lands and sea distribution, active convections in troposphere, and wind shears etc. In particular, AGWs with orographic origin is thought as one of the important factors for a seasonal variation in mesospheric circulation, since the source is fixed to the ground. An airglow imaging system for OH7-3 band is newly developed and installed in Kawasaki, Japan (35.6°N, 139.5°E) in Nov 2015 to investigate propagation and excitation mechanisms of mountain waves over the Kanto plain. Since Kanto Plain is sandwiched by mountain rich area including Mt. Fuji and the Pacific Ocean, identification of AGWs from orographic origin is expected to be easy. For example, continuous easterly wind in a surface level would excite mountain waves with zero ground phase speed over the Kanto plain. In addition, a simple shape of cross section (i.e. Model-like shape) of the source (Mt. Fuji) would make comparison with modeling studies easy. In this talk, details of the airglow imaging system and prompt results from early observations are presented.

Keywords: Atmospheric gravity wave, Middle atmosphere, Mountain wave

Investigation on Na layer response to geomagnetic activities using resonance scatter measurement by Odin/OSIRIS

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The Na layer is normally distributed from 80 to 110 km, and the height range is corresponding to the ionospheric D and E region. In the polar region, the energetic particles precipitating from the magnetosphere can often penetrate into the E region and even into the D region. Thus, the influence of the energetic particles to the Na layer is one of interests in the aspect of the atmospheric composition change accompanied with the auroral activity.
There are several previous studies in this issue. For example, recently, we have reported an initial result on a clear relationship between the electron density increase (due to the energetic particles) and the Na density decrease from observational data sets obtained by Na lidar, EISCAT VHF radar, and optical instruments at Tromsoe, Norway on 24-25 January 2012. However, all of the previous studies had been carried out based on case studies by ground-based lidar observations.
In this study, we have performed, for the first time, statistical analysis using Na density data from 2004 to 2009 obtained with the Optical Spectrograph and InfraRed Imager System (OSIRIS) onboard Odin satellite. In the presentation, we will show relationship between the Na density and geomagnetic activities, and its latitudinal variation. Based on these results, the Na layer response to the energetic particles will be discussed.

Keywords: Na layer, energetic particle, Odin/OSIRIS

Performance evaluation of low-cost airglow camera for mesospheric gravity wave measurements -Part 3: Image processing

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Atmospheric gravity waves significantly contribute to the wind/thermal balances in the mesosphere and lower thermosphere (MLT) through their vertical transport of horizontal momentum. It has been reported that the gravity wave momentum flux preferentially associated with the scale of the waves; the momentum fluxes of the waves with a horizontal scale of 10-100 km are particularly significant. Airglow imaging is a useful technique to observe two-dimensional structure of small-scale (<100 km) gravity waves in the MLT region and has been used to investigate global behavior of the waves. Recent studies with simultaneous/multiple airglow cameras have derived spatial extent of the MLT waves. Such network imaging observations are advantageous to ever better understanding of coupling between the lower and upper atmosphere via gravity waves. In this study, we newly developed low-cost airglow cameras to enlarge the airglow imaging network. Each of the cameras has a fish-eye lens with a 185-deg field-of-view and equipped with a CCD video camera (WATEC WAT-910HX) ; the camera is small (W35.5 x H36.0 x D63.5 mm) and inexpensive, much more than the airglow camera used for the existing ground-based network (Optical Mesosphere Thermosphere Imagers (OMTI) operated by Solar-Terrestrial Environmental Laboratory, Nagoya University), and has a CCD sensor with 768 x 494 pixels that is highly sensitive enough to detect the mesospheric OH airglow emission perturbations. In this presentation, we will report some results of performance evaluation using the data obtained during test observations made at Shigaraki, Japan, in 2014.

A numerical study on decrease of electron temperature inside the sporadic E layer

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The sporadic E (Es) layer has been studied for a long time. Wind-shear theory is generally accepted about its generation mechanism. This theory explains an accumulation process of the electron density, but hardly gives information on thermal energy budget inside the layer.Although the electron temperature is the parameter for discussing the thermal energy budget inthe ionosphere, there were few data of reliable electron temperature in the Es layer in the past.Thus, few information on the electron temperature are only available, and there were very few discussions about the thermal energy budget inside the Es layer.The sounding rocket "S-520-29" was launched from Uchinoura Space Center at 19:10 JST on August 17, 2014. The purpose of this experiment is to elucidate spatial structure of the Es layer in the lower ionosphere.Langmuir probe installed on this rocket is capable of making high-speed sampling of probe current, and thereby it is possible to estimate the electron temperature and density more than 10 samples per second. In addition, it becomes possible to obtain the temperature and density in shorter time interval by adopting a new method of interpolation for obtained current -voltage relationship. Data calculated by using such an interpolation based on Langmuir probe measurements suggest that the electron temperature significantly decreased inside the Es layer with respect to the background temperature. Furthermore, the detailed trend of the electron temperature from its boundary toward the center of Es layer was revealed due to the interpolation.In this study, we will discuss a physical implication of the observed high electron temperaturefor energy budget inside the Es layer by conducting numerical calculation in which we consider electrons, ions, and neutrals in the vertical 1-D direction. The electron temperature distribution is estimated for various conditions of electron density using electron energy equation.The photoelectron heating and Joule heating are included in the calculation as a heating process, and the electrons' interaction with the neutrals and the ions is considered as a cooling process. It was found that the electron temperature tends to decrease inside the Es layer when the electron density becomes significantly larger as in the Es layer. Furthermore, we tried to find an important process dominant for the electron temperature increase by examining adependence of various parameters such as ion density and the electric field. We will present a result from this numerical consideration.

Keywords: Sounding rocket, sporadic E layer

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

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The surface of the frontal sporadic E (Es) was not same cylindrical shape, but was found that had the structure that varied according to the arrival place on the cross-section surface [1] [2].
In this study, surface of cross-section of the frontal Es via the middle reflection point of HFD of Kanto is observed and three dimensions of details data of the electric field strength every the Doppler shift frequency of the neighborhood at the midway point passage time is demanded. the change is considered to be the incidence angle dependence of the equivalence of value dispersion cross section when an electric wave was incident on a surface of slim frontal Es from the lower part in time for field strength that cut and brought down these data every constant frequency. Because the baseline halfway houses between each transmission and reception points are different, the section of the reflection surface of the frontal Es is estimated finely. A movement direction and the speed of the frontal Es is found by performing this analysis at a plural observation point and the cross-section of the reflection surface of the whole surface of the frontal Es is derived in detail.
For this method, the result that investigated a cross-section structure of the shape of surface of the frontal Es lower part by analyzing HF Doppler spectral using four transmit frequencies in detail at multiple receiving points of the Kanto HFD observation network was showed. 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. Based on this average change, the max field intensity, the time and 3 dB time width every the Doppler shift frequency are found. The surface of cross-section width of the surface of the frontal Es undersurface is found from the product of width and the horizontal mobility speed with the irregularity of the surface of cross-section is estimated at 3 dB time width from the max field intensity and the time.
The above-mentioned method of analysis was applied, found it about a sectional structure of surface of the frontal Es observed in 21 JST(UT+9) of January 16, 2013 and 19th in detail. The surface of the frontal Es of January 16 was 205 m/s and move to the 279° direction, January 19 was 151 m/s and move to the 205° direction. The both of frontal Es were high speed and have small cross-section width. The high speed frontal Es has few changes at peak field intensity for time, and has the structure that was cylindrical or near. In addition, as for the surface of the frontal Es of January 16, section width of high frequency becomes about the same with Fresnel zone diameter (4.1km); center of circle structure becoming higher leading electron density in this at the midway point passage time of the Es at each frequency was different, and center sectional structure knew that there was a degree of leaning.
By the lecture, I am going to argue about the sectional structure by applying this analytical method for the different surface of the water-formed Es of the Doppler shift change curve.

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Keywords: ionosphere, sporadic E, HF Doppler shift observation

Possible shear instability in the daytime midlatitude sporadic-E observed with InSAR and GPS-TEC

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Small-scale horizontal structures of daytime midlatitude sporadic E are studied by interferometric synthetic aperture radar (InSAR) and GPS total electron content (TEC) observations over Japan. With GPS-TEC observations, sporadic E with foEs higher than 16 MHz can be detected [Maeda and Heki, 2014]. A dense array of GPS receiving stations in Japan (GEONET) enables us to image horizontal shapes of sporadic E by plotting vertical TEC anomalies on a map. Such TEC maps revealed that sporadic E over Japan has a common shape which is elongated in the east-west (E-W) direction with typical length and width of ~200 km and ~20 km, respectively, regardless of occurrence latitudes [Maeda and Heki, 2014; 2015]. In this study, we observed smaller-scale structures by InSAR as well as GPS-TEC observations. The spatial resolution is ~300 m for InSAR and ~2 km for GPS-TEC (by analyzing raw slant TEC time series).
The results show that small-scale plasma patches are embedded in large scale frontal structures and such small patches are quasi-periodically located both in zonal and meridional directions.
There are two major candidates for the generation mechanism of daytime sporadic E structure, i.e, namely, atmospheric gravity waves, and the Kelvin-Helmholtz (K-H) instability. We speculate that the K-H instability in the neutral atmosphere under the presence of vertical shear of zonal winds would create billow structures elongated in the zonal direction. On the other hand, secondary instability, such as secondary turbulance in the neutral atmosphere or gradient-drift instability are the two major possible drivers for the patch structuring in the meridional direction.

Keywords: sporadic-E, InSAR, GPS-TEC

Estimation of electron density distribution of strong Es using VOR, AIS and Ionosonde and its application to the VHF interference model of long-distance propagation wave

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The University of Electro-Communications observe Very High Frequency Electric wave Reflected in Sporadic E layer in Chofu and Kure[1].It is necessary to check electronic density structure over a wide area to expect intervention of the VHF data transmission system (GBAS - VDB) long-distance propagating wave of GBAS by Strong Es[2]. Regional structure of sporadic E (Es) and transport property have become clear by Yanagisawa's study[3], but it isn't done clearly yet about the electron density distribution structure of Es. Es propagation model of ITU - R was guaranteed only to frequency 80 MHz by ionospheric reflection attenuation Γbased on a Es transmission observation in 1960 's and the correspondence system with ionosonde vertical critical frequency foEs around the middle specular point[4],[5]. But the distance between the middle specular point and ionosonde could confirm the correspondence with Es propagation model of ITU - R for the first time in case of about 400 km in the range in 2013-VOR long-distance transmission observation around the 110 MHz in 2015.Using this relation, result of presumption of electron density distribution structure from a lot of VOR reception electric power was compared with electron density distribution from AIS, Yamagawa, Okinawa ionosonde.
Yamagawa (31.20N, 130.62E) and Okinawa (26.68N, 128.15E) observed Es in the East China Sea, Okinawa and around the Kyushu south where the distance with ionosonde will be about 400 km in the range at 10-JST time 15:00 on June 15, 2014. It could be confirmed that Es has moved to about 330 deg direction by high 108 km and speed about 70 m/s. This Es showed that the electron density the strong Es territory where 1.0 x 10^13 el/m^3 appeared, and which can put electron density in Okinawa ionosonde is parallel with strong Es where 9.2 x 10^12 el/m^3 mostly in the Okinawa south and around the east around 10:10-11:30 in AIS. In case of this time’s Es, it was assumed that there was a possibility beyond the VOR reception electric power-98dBm that intervention with VOR and GBAS - VDB is worried about when Es propagation model of ITU - R was applied. An analysis sample by this way will be indicated in the lecture, and I report on a relation between the distribution of the electron density, the feature of the transport property and intervention occurrence of strong Es conversantly.
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Small-scale magnetic fluctuations of lower atmospheric origin as observed by low Earth orbit satellites ~ Identification of lower atmospheric phenomena ~

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We recently found small-scale (0.1~5 nT) magnetic fluctuations above the ionosphere in middle and low latitudes with period about 20-30 sec along the satellite orbit observed by the low Earth orbit satellites such as the CHAMP (2000~2009) or the SWARM (2013~) having precise magnetometer (resolution: 0.065 nT). We name these magnetic fluctuations the "Magnetic Ripples" (MRs). The magnetic fluctuations are perpendicular to geomagnetic main field. By comparing the magnetic fluctuations observed by two SWARM satellites at the same latitude, we could confirm that they are the manifestation of the spatial structure of small scale field-aligned currents along the satellite orbit. The amplitude of the MRs have local time, geographical and seasonal dependence, therefore we suppose that localized field-aligned currents are generated by the ionospheric E-layer dynamo driven by the atmospheric gravity waves propagated from lower atmosphere. Typhoons and volcanic eruptions are known to generate gravity waves, and we report the characteristic of the MRs probably generated by a volcanic eruption, typhoons, rain fronts etc.. We try to identify the lower atmospheric phenomena which cause the MRs.

Keywords: ionospheric dynamo, field-aligned current, acoustic resonance, SWARM, CHAMP, magnetic ripple

Ionospheric Hole made by the Kwangmyongsong-4 Rocket Launched from Norh Korea on Feb. 7, 2016, and Increase of Thrust of its Second Stage Engine

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Exhaust gas from ascending rockets and ballistic missiles bring large amount of water molecule to the ionosphere. Such water molecules receive positive electric charges from atmospheric ions, and their dissociative recombination with ionospheric electrons causes the formation of ionospheric holes (region of low electron density). Ionospheric total electron content (TEC) can be measured by comparing the carrier phases of the two L-band signals from Global Navigation Satellite System (GNSS) satellites, and such GNSS-TEC technique is useful in studying such ionospheric holes (Furuya & Heki, 2008). By analyzing the GNSS data from the dense network of GNSS receivers in Japan (GEONET), Ozeki & Heki (2010) compared ionospheric signatures by the two ballistic missiles launched from eastern North Korea, i.e. the 1998 Taepodong-1 and the 2009 Taepodong-2, and inferred their difference in thrusts. In 2012 December, a rocket, Unha-3, was launched southward from a launch pad in northwestern part of North Korea, and Nakashima & Heki (2014) studied the ionospheric hole made above the Yellow Sea/the South China Sea by the second/third stage engine of the rocket using a GLONASS (the Russian GNSS) satellite.

On February 7th, 2016, a new rocket Kwangmyongsong-4, was launched southward from the same launch pad at 9:31 JST (0:31 UT), and succeeded in putting an earth-observing satellite (KMS-4) into orbit. Here we studied the ionospheric hole made by this launch. Unlike the previous case, we could detect clear hole signatures with multiple satellites of both GPS and GLONASS. The hole emerged at 6-7 minutes after the launch, and its position and emergence time were similar to the previous 2012 case. However, the areal extent and the amount of TEC decrease were much more in the 2016 case. In the attached figure, we compare the TEC time series observed with GPS Satellite 29 from GEONET stations in western Kyushu, together with the past three cases. Clearly, the TEC decreases in the 2016 case are much larger than the past cases.

In all the rocket (missile) launches from North Korea, the first stage engine did not reach the ionospheric height, and it was the second stage engine that made the ionospheric holes (Ozeki & Heki, 2010). The overall figure of the present Kwangmyongsong-4 rocket looks quite similar to the previous Unha-3, but its payload (satellite) is suggested to be larger in size than the 2012 case. The thrust of the second stage engine may have been made more powerful to put this relatively large satellite into orbit. However, the vertical TEC above the Yellow Sea in the present case was ~30 TECU, which is twice as large as in the 2012 launch, and the comparison of the thrust in the two cases may need a more quantitative discussion.

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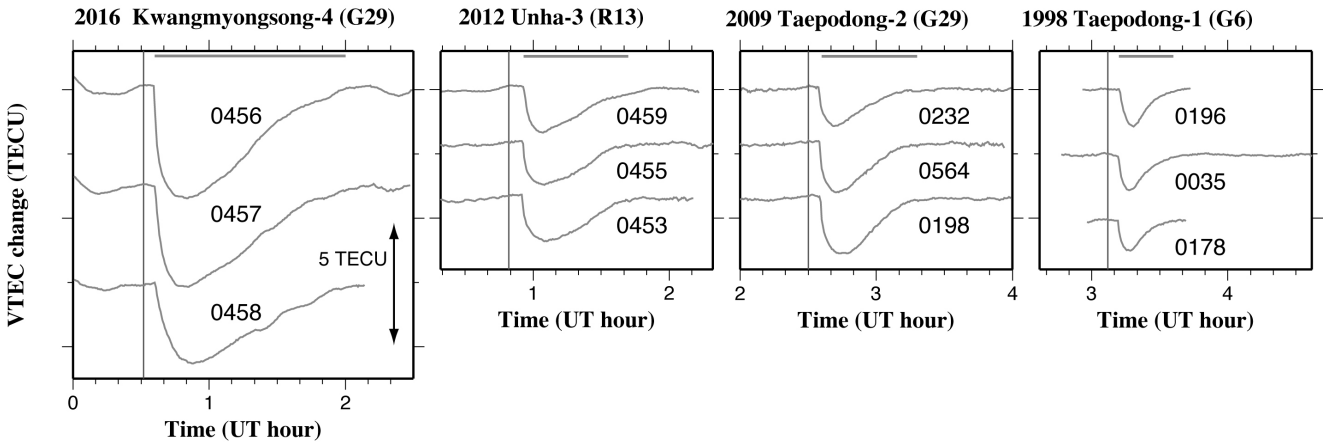
Figure caption: TEC time series in the 2016 February launch of Kwangmyongsong-4 from North Korea are compared with the past three cases, i.e. the 1998 Taepodong-1, the 2009 Taepodong-2, and the 2012 Unha-3 launches. The 2016 case shows much larger TEC decreases than these past launches.

Keywords: GNSS-TEC, North Korean rocket, ionospheric hole



Analysis of Spatial Distributions of Total Electron Content Variations Associated with Earthquakes

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It has been reported that ionospheric disturbances occur by giant earthquakes. This is because the acoustic wave and atmospheric gravity wave excited by ground perturbations or tsunami propagate into the ionosphere. Now that large-scale earthquake such as Tokai earthquake is predicted to occur, it is important to study ionospheric disturbances caused by the earthquake for revealing the mechanism of the earthquake.
In the previous studies, the variations of TEC associated with earthquakes have been confirmed by the frequency analysis of time-series data of total electron content (TEC) observed in Japanese GPS receiver net-work (GEONET). In this study, we have analyzed the spatial distribution of TEC variations in each directions of latitude and longitude by gaussian fitting. We examined the correlations of both spatial distributions of TEC variations and the magnitude. Ionospheric pierce points are assumed to be located at the height of the 350 km are determined. We calculated the spectral intensity in each frequency bands by the fast Fourier transform processing. We analyzed the 5 earthquakes of more than M6.8 that occurred around Japan since 2000.
As a result of the analysis, it is confirmed that the latitudinal distribution of TEC variations is highly correlated with the magnitude, while longitudinal one is not.

Keywords: Total electron content

The ionospheric variations associated with volcanic eruptions observed by GPS-TEC and HF Doppler

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It is reported that ionospheric disturbances are caused by ground and atmospheric perturbations, e.g. earthquakes and typhoons. Even though it is known that the volcanic eruptions excite the atmospheric waves, there are few observations of ionospheric disturbances caused by volcanic eruptions. In this study, we have examined ionospheric variations associated with volcanic eruptions using GPS-TEC and HF Doppler (HFD).

We analyzed TEC data observed by observed in GPS Earth Observation Network (GEONET) which is maintained by Geospatial Information Authority of Japan. Each pairs of satellites and receivers determines the value of TEC every 30 seconds. In this study, TEC data, in which mask angle is larger than 30 degrees, is used. We calculated the spectral intensity of TEC perturbations by Fast Fourier Transform (FFT). We analyzed 19 volcanic eruptions in Mts. Asama, Ontake and Shinmoedake since 2000. As a result, the variations of TEC by volcanic eruption are detected in 2 events. Both events are the eruptions in Mt. Asama with medium-size explosion. The center of the variations of TEC is located south of the volcano, which the same as the case for the earthquakes. Therefore the generation of the ionospheric perturbation associated with volcanic eruptions is the same process of that for the earthquakes. On the other hand, the variations of TEC at the frequency band of 7 ~ 12 mHz are shown, which is higher frequency than earthquakes.

We also analyzed HFD data transmitted from the Chofu campus of UEC for 4 events in Mt. Asama with medium-size explosion. We used the data observed at Sugadaira which is the nearest observation point from Mt. Asama. As a result, variations of TEC are detected in 3 events. In these events, the spectral intensity has peak a remarkable at 3 ~ 5 mHz and several peaks in 8 ~ 18 mHz. A peak at 3 ~ 5 mHz and 8 ~ 18 mHz are remarkable and there are a few peaks in the later. 3 ~ 5 mHz is due to acoustic resonance modes between the ground surface and the lower thermosphere as in variations of TEC associated with earthquakes. The perturbations around 8 ~ 18 mHz are also observed by GPS-TEC data, this caused that the pressure fluctuation excited by the explosion of the eruption directivity propagates to the upper ionosphere.

Keywords: ionosphere, volcanic eruptions

Seasonal variation in sunset ionospheric disturbances found in a long-term HF Doppler observation dataset

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Ionospheric disturbances are regularly observed after sunset. These disturbances can be associated with two major causes; on the one hand it is caused by the ionosphere itself with the elimination of ionization after sunset, on the other hand it is caused by atmospheric gravity waves (AGWs) which originate in lower atmosphere -presumably in the stratosphere or lower mesosphere -when the air becomes cold after sunset. These ionospheric disturbances are observed with radio instruments such as ionosondes, incoherent scatter radars, HF Doppler (HFD), and GPS TEC. However, except for HFD, it is inherently difficult to identify the causes of the disturbance from data obtained by these methods. Recently, by employing HFD, one of the authors and his colleague identified the altitude of the source region of an AGW which caused an ionospheric disturbance after sunset; it is suggested that the source altitude was about 50 km, which roughly corresponds to the upper bound of the ozone layer. As a sunset is a regular periodic phenomenon, the seasonal variations of the ionospheric disturbances associated with a sunset can be isolated from others relatively easily. It is therefore useful to study ionospheric disturbances after sunset to understand the characteristics of atmosphere-ionosphere coupling. In this study, we present some features of seasonal variation in sunset ionospheric disturbance obtained from a long-term HFD dataset.

Keywords: ionospheric disturbance, sunset, HF Doppler

Improvement of the electron density automatic estimation algorithm in the ionosphere lower region

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In the lower ionosphere, the approximate electron density profile can be estimated from the comparison between these observation results obtained by sounding rocket and propagation caracteristics calculated with Full wave method. This estimation process, which is so-called ”wave absorption method”, has some problems. At first, we have no clear standard for comparing observation results and propagation characteristics calculated with Full wave method. In addition, we have to iterate many times correcting the electron density profile by handwork, calculating propagation characteristics with Full wave method and comparing observation results and calculated propagation characteristics. This iteration takes too long to estimate appropriate electron density profile. To reduce these problems, we developed an application to realize automated estimation of electron density profile by analyzing radio wave propagation characteristics.
In the past of the research, they were estimated electron density by automated estimate application. In the result, I realized high accuracy estimation because error was within 1.2 dB in all estimated area. And it can estimate at short time. However there was a large fluctuation of the electron density in low-altitude part. This is impossible in actual observation. So, we did consideration and improvement to algorithm.

Keywords: ionosphere, plasma waves, electron density profile, Full wave method

Rocket GPS-TEC Tomography method to obtain high altitude resolution

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In the high altitude atmosphere of the earth, there is a layer of atmosphere called ionosphere, filled with extricated electrons, and the observation of the electron density profile in the ionosphere is recently taken notice of.
As an approach to the observation of electron density profile in the ionosphere, there is the remote sensing method called GPS-TEC method, which calculates the total electron counts (TEC) on the transmission path of GPS wave, from its propagation delay. By applying tomography analysis on TEC values in multiple paths, which are one dimensional information, the electron distribution profile can be earned as two dimensional data, and this method is called GPS-TEC tomography method. However, this method has a defect, that it has low resolution in altitude direction.
In order to enhance the altitude resolution, we have proposed “Rocket GPS-TEC Tomography method,” which applies tomography analysis on the TEC values earned by rocket observation. Compared to the conventional GPS-TEC tomography, this method can observe TEC values in horizontal paths, as the observation rocket navigates in both range and altitude direction. By this approach, we assumed that altitude resolution of the tomography result will improve. In this study, we verified the efficacy of proposed method through simulation experiment.

Keywords: ionosphere, GPS-TEC, sounding rocket

Effect of intrinsic magnetic field decrease on the low-to-middle latitude ionosphere-thermosphere dynamics simulated by GAIA

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The Earth's intrinsic magnetic field has been fluctuated between 10^{22}-10^{23} Am^2 in past 0.8 million years and now under decreases at a rate of ~6% per century. The intrinsic field decrease would modify not only the ionosphere via electromagnetics, but also the atmosphere under interactions with the ionosphere. The relationship between long-term variations of observed Sq field and the intrinsic magnetic field has evaluated by simulation studies. Cooling of the upper atmosphere observed over past decades is also suggested to be contributed by the intrinsic field variation in addition to the effect by CO_2 enhancement in the low altitude. The upper atmosphere dynamics is largely affected by the lower atmosphere. This study investigates the effect of intrinsic magnetic field on the coupled system using a numerical model, GAIA (Ground-to-Topside Model of Atmosphere and Ionosphere for Aeronomy), which solves physical and chemical dynamics of the whole atmosphere region from troposphere to exosphere under interaction with the ionosphere.
The model simulation is operated with a reduced (50% and 75%) intrinsic magnetic field referring to February 2008 when the wave-4 structure is appeared and solar activity was quiet. In order to focus on the low-to-middle latitude profiles, this experiment excludes the cross-polar cap potential and auroral electron input.
The calculated parameters averaged over the 250 km shows small variations in the neutral wind velocity and electron density with magnetic field changes, while the dynamo electric field decreases and the ionospheric horizontal current increases with increasing magnetic field. In addition to the proportional dependence of the dynamo field on the magnetic field, the ionospheric conductance dependence with $\sim B^{-2\sim-1}$ due to an upward shift of the conductance shift affects the horizontal current. The decreased magnetic field provides the zonal wind enhancement and upward shift of electron peak altitude in the equatorial region. We will report the cause of these variations and their effects on the wave propagation.

Keywords: thermosphere-ionosphere, low-to-middle latitude, intrinsic magnetic field dependence

Horizontal structures of Helium ion in the upper ionosphere observed by ISS-IMAP/EUVI

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Horizontal structures of ionized Helium in the upper ionosphere of dusk side were obtained from observation of resonant scattering light. The Extreme Ultra Violet Imager (EUVI) of the ISS-IMAP (Ionosphere, Mesosphere, upper Atmosphere and Plasmasphere mapping) mission has taken image of He II radiation (30.4 nm) from the International Space Station (ISS) since October 2012. North-south asymmetry and longitudinal structure of ionized Helium were found. North-south asymmetry in solstice seasons are well consistent with previous in-situ measurement and numerical simulation. However, the longitudinal structure is not reported before and cannot be explained by numerical simulation with SAMI2-model. The longitudinal difference of meridional wind is a candidate of the Helium ion structure.

Ionospheric Scintillation Observations with GNSS receivers in Tromsoe, Norway

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Ionospheric scintillation is a phenomenon that received radio wave fluctuates in phase and amplitude. We have been operating dual-frequency GNSS (Global Navigation Satellite System) receivers at Tromsoe, Norway to measure signal intensity and phase of the radio waves at a sampling rate of 50 Hz.
We have analyzed ROTI, defined as a standard deviation of the differential of TEC (Total Electron Content) during 1 minutes. At 00:10-00:20 UT on 8 Februay 2014, ROTI increased to 0.7 TECU/min, but S4 did not increase. We have calculated cross-correlation coefficient (CCC) of TEC variation obtained at two-antennas installed with a mutual distance of 242 m, and found that CCC is close to unity. This result indicate that the plasma density in the ionosphere is spatially homogeneous although it varies temporally. On the other hand, at 11:30-12:00 UT on 27 October 2014, S4 index increased to 0.4 whereas ROTI was low. For this event CCF of TEC variations at the two-antenna is approximately 0.6, indicating the ionospheric plasma density was inhomogeneous to cause amplitude scintillation.

Keywords: ionosphere, GNSS, scintillation

