大気成層構造の小型無人航空機・MUレーダー同時観測
Simultaneous observations of atmospheric structure with UAV and the MU radar

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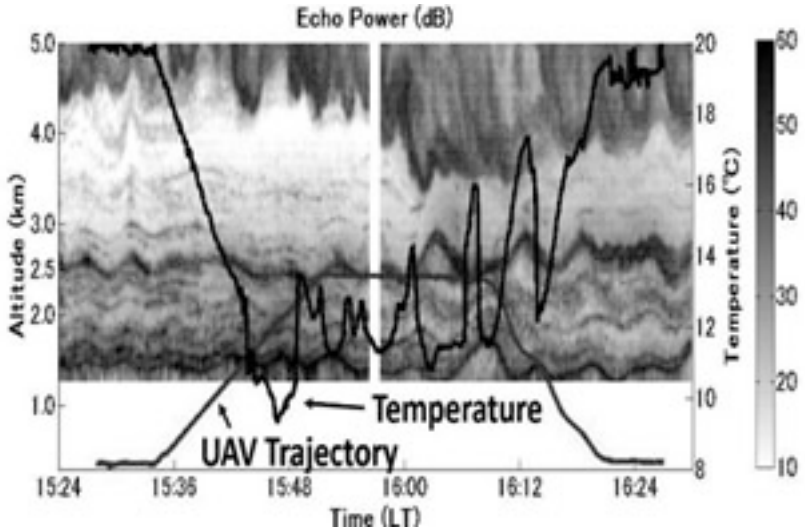
乱流混合は熱や物質の鉛直輸送に寄与する重要なプロセスであるが、そのスケールが極めて小さいことから観測が難しい現象の一つである。地上から上空に向けて電波を発射し、大気の乱れに散乱されて戻ってくる電波を受信することで、上空の風向風速等を高時間分解能で測定する大気レーダーは、大気乱流からの散乱エコーを観測すること、時間・空間的に連続観測可能である点で、大気乱流の観測装置として優位にあるが、従来空間分解能に限界があった。MUレーダーは滋賀県甲賀市信楽町に設置された、中心周波数46.5MHz、アンテナ直径103m、送信ピーク出力1MWの大気観測用大型レーダーであり、1984年から運用されているが、2004年に高機能化への大幅改修が行われ、レーダーイメージング(映像)観測が可能となった。その後、イメージング観測手法の開発・改良が重ねられ、現在ではレンジ分解能が飛躍的に向上した観測が可能となっている。MUレーダーは現在のところ乱流を最も正確に映像化でき、それらの発生・発達・形成メカニズムや、メソ～総観規模現象との関連を研究する上で最も強力な測器である。例えば、風速の変化が大きいところでは、ケルビン・ヘルムホルツ不安定により乱流が発生することが知られているが、雲底下で持続的に乱流が存在する様子がMUレーダー観測によりイメージ化されている。

近年、下層大気の観測手段として小型無人航空機(UAV)が注目されている。2015年と2016年の6月に気象センサーを搭載した小型UAVとMUレーダーとの同時観測実験を実施した。日米仏の国際共同研究により、コロラド大で開発されたUAVを用いて、MUレーダーとの同時観測実験(ShUREX(Shigaraki, UAV-Radar Experiment)キャンペーン)が行われた。UAVは、小型(両翼幅1m)、軽量(700g)、低コスト(約$1,000)、再利用可能、GPSによる自律飛行可能で、ラジオゾンデセンサーを流用した1Hzサンプリングの気温・湿度・気圧データに加えて、100 Hzの高速サンプリングの気温センサーによる乱流パラメータの高分解能データを取得可能である。UAVの離着陸は、信楽MU観測所から南西へ約1kmの利用休止中の牧草地を借用して行った。飛行方法は予め離陸前にプログラムしておくが、状況に応じて離陸後に飛行方法を変更することも可能であり、約1時間の連続飛行が可能である。

図にMUレーダーのレンジイメージングモードで得られたエコー強度の時間高度変化とUAVに搭載されたセンサーで得られた気温の時間変化を飛行高度とともに示す。15時50分～16時10分にUAVは水平飛行しており、4-5分周期でMUレーダーを中心とした半径400-500mの円を描いて半時計周りに旋回していたが、水平飛行中にも関わらず、大きな気温変化が観測された。気温変化は飛行高度辺りに存在する強いエコー層の上下変動と相関があり、MUレーダーで観測された鉛直流とも良い相関が見られた。その後の時間帯にUAVで測定された気温の鉛直プロファイルから、深い温度逆転層が存在し、強いエコー層はそれに伴うものであると考えられる。測定された気温プロファイルをモデル化し、その気温プロファイルがエコー層と同様に上下変動していると仮定して、気温変化を再現したところ、概ね観測と整合的な結果が得られた。次年度にもUAVを用いた第3回のキャンペーン観測を計画している。

キーワード：MUレーダー、小型無人航空機、大気乱流
Keywords: MU radar, UAV, Atmospheric turbulence



MUレーダー実時間アダプティブクラッター抑圧システムの開発
Development of MU radar real-time processing system with adaptive clutter rejection

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大気レーダー観測において、しばしば強い地形性クラッターエコー(山や建物からのエコー)や航空機クラッターエコーが問題になることがある。地形性クラッター抑圧法としてNC-DCMP (Norm Constrained-Directionally Constrained Minimum Power)法が提案され、MUレーダーによる実観測データに適用し、効果があることが実証されている[Nishimura et al., JTech., 2012]。NC-DCMP法では、所望信号方向を固定した上で、ウエイトベクトルのノルムをある値以下に制約して、信号電力を最小化するように制約条件付最適化問題を解く。我々は、NC-DCMP法によるクラッター抑圧処理をMUレーダーのオンライン処理システムとして実装することに成功した。これにより、観測データの記録容量を数百分の１に削減でき、外部記憶装置などの制約の少ない標準観測を行うことが可能である。

MUレーダーでは30年以上に渡って、毎月100時間程度の対流圏・成層圏標準観測モードによる観測を継続している。まず、この標準観測モードにNC-DCMP処理を実装した。このモードでの観測データは8秒に1回取得される。そのため、実時間でクラッター抑圧を行うためには全ての信号処理を8秒以内に行う必要があるが、処理方法の工夫により、NC-DCMP法の処理時間を平均1.0秒にまで高速化した。山や建物からのエコーは時間的に大きく変化しないため、インコヒーレント積分7回分(約1分間)の受信信号を用いて最適ウエイトベクトルを求めるようにしたところ、良好な結果を得た。2015年11月の標準観測からNC-DCMP処理を適用しているが、安定運用できている。

NC-DCMP法は移動する目標に対しては高い効果を得られず、航空機クラッターを十分に抑圧することはできていない。先行研究において、航空機クラッターを抑圧する手法として2段階NC-DCMP法が提案されている。この手法は、まず、各時刻における航空機クラッターの到来方向を推定し、NC-DCMP法を用いて航空機クラッターを分離再生した後、元の受信信号から差し引く。次に再度NC-DCMP法を用いて地形性クラッターを抑圧する、というものである。先行研究では、上空を全探索し航空機クラッターの到来方向を推定していたため、実時間処理は不可能であった。そこで、ADS-B (Automatic Dependent Surveillance-Broadcast)を利用することで航空機クラッターの到来方向の探索範囲を限定することを検討する。ADS-Bは、航空機が精度の高い位置情報や高度などを放送するシステムである。

インドネシア共和国の西スマトラに建設が計画されている赤道MUレーダーは、八木アンテナ19本を1群とする55群構成で、各群からの受信信号を独立に取得可能なシステムが提案されている。本研究の成果は、この赤道MUレーダーにも適用可能である。

キーワード：大気レーダー、クラッター抑圧、ウエイトノルム拘束付DCMP法、MUレーダー
Keywords: Atmospheric radar, Clutter rejection, NC-DCMP method, MU radar

Statistical study on plasma bubble condition from Equatorial Atmosphere Radar, GPS scintillation, and GAIA model

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We have been studying the plasma bubble over a decade by using various techniques. Equatorial Atmosphere Radar (EAR) conducted multi-beam experiment of the plasma bubble, made it possible to distinguish spatial and time variations, and clarified its near sunset-terminator occurrence of the phenomenon. EAR also found that the plasma bubbles form several-hundred km scale zonal structures, which can be considered as earlier study of large-scale wave structures (LSWS). We now conduct statistical study on the plasma-bubble condition based on observations of GPS scintillation and atmospheric condition from the GAIA model. We are finding evidences that the stratosphere around the equator show enhanced fluctuations on the day of intense plasma bubble measured by the GPS scintillations. We try to expand the comparison bases including long-term data from the EAR.

キーワード：プラズマバブル、統計解析、大気上下結合
Keywords: Plasma bubble, Statistical analysis, Vertical coupling of atmosphere

New receiver system development for new satellite-ground beacon experiment

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GNU Radio Beacon Receiver (GRBR) is the very successful digital receiver developed for dual-band (150/400MHz) beacon experiment. We were successfully conducted observations of total-electron content (TEC) of the ionosphere over Japan and in southeast Asia. But we naw face a problem that number of beacon satellites are decreasing because of satellite aging. In order to overcome this problem we now have a project to start new satellite-ground beacon experiment with new satellite constellations. One of them is TBEx (Tandem Beacon Explorer), a project by SRI International, to fly a constellation of two 3U cubesats with triband beacon transmitters. Another one is a project of FORMOSAT-7/COSMIC-2 by Taiwan/USA. Well-known mission of COSMIC-2 is GNSS occultation experiment, but the satellites carry triband beacon transmitters. All of these satellites will be placed into low-inclination orbits by the same launch vehicle in 2018, which will give us great opportunities to enhance studies of the low-latitude ionosphere. We now develop a receiver system for experiment by using new satellites. In the presentation, we show current status of antenna and digital receiver parts of the new system.

キーワード：衛星ビーコン観測、観測機器開発、ディジタル受信機
Keywords: Satellite-ground beacon experiment, Development of instrument, Digital receiver

Automation of data analysis for satellite-ground beacon experiment

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We have been studying ionospheric structures by the satellite-ground beacon experiment. The main observation region is southeast Asia. For example, meridional chain of five beacon receivers along 100E meridian showed meridional distribution of total-electron content (TEC) of the ionosphere, and we revealed time and spatial variabilities of equatorial anomaly. The data analysis was, however, not easy mainly because of difficulty in estimating bias of the measurement. In this paper, we try to automate the bias estimation and lower the barrier for data analysis. The automatic bias estimation is divided in two stages. In the beginning, we make a rough estimation based on a single-station data. We assume that the TEC distributes uniform in a small section of the data, and estimated many bias candidates from all sections. The final bias is then selected based on the maximum frequent appearance basis. The second approach is the multi-station estimation. The basic idea is the same as usual two-station method, but we tried to find best match between several stations. In order to reduce computation, we start from matching between two station, and then connect the data to those from the next station. After this process, we match bias from all stations by the Brute-effort way. We now find the final bias estimation in about 80 seconds of computation by a desktop PC. Applying this multi-channel approach to the 100E meridional chain of five stations, resulted absolute TEC was close to the previous analysis obtained with much more manual efforts. We also organize these data into one NetCDF format file that helps easier use of the data.

キーワード：衛星ビーコン観測、データ解析手法、バイアス推定
Keywords: Satellite-ground beacon experiment, Data analysis technique, Bias estimation

Continuous monitoring of temperature profiles in the tropical troposphere with EAR-RASS

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This study aims to continuously measure temperature profiles in the tropical troposphere (from 1.5 km to about 15-17 km) with high accuracy and high time-resolution by adopting Radio Acoustic Sounding System (RASS) to the Equatorial Atmosphere Radar (EAR) at KotoTabang, west Sumatra, Indonesia. We installed high-power speakers in the antenna field of EAR.
Because propagation of sound waves in the atmosphere is largely affected by the background winds, we employed the 3D ray-tracing of acoustic waves in order to predict the shape of acoustic wave fronts. Then, we selected appropriate antenna beam directions of EAR that satisfy the Bragg condition, i.e., the wave number vectors for radar waves and the target acoustic waves must be parallel.
We successfully observed the temperature profiles from 1.5 km to 5-12 km continuously with the time and height resolutions of about 3 minutes and 150 m, respectively. Temperature profiles were sometimes obtained up to about the lapse rate tropopause at 16 km. Standard deviation of the temeprature difference between EAR-RASS and radiosondes was about 0.3 K. We tested the effect of sound pressure level on RASS observation. We also examined two correction methods of the background wind velocity on the sound speed.
EAR-RASS results are useful for the studies of peculiar atmospheric phenomena in the equatorial regions, such as the intense cloud convection, structure of the boundary layer, and atmospheric waves.

キーワード：RASS、EAR、対流圏界面、気温プロファイル
Keywords: RASS, EAR, tropical tropopause, temperature profile

Study of scale-sizes of ionospheric TEC gradients associated with plasma bubbles

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Spatial inhomogenuity or gradient of ionospheric total electron contents (TECs) is an issue in differential GNSS systems. Spatial gradients in TECs are characterized by a slope (TEC change per unit length), depth (total change in TEC), scale-size (width of the gradient), and velocity (propagation speed and direction). The slope has rather been studied well in mid- and low latitude regions. However, other parameters have not been studied well. Especially, lower bound of the scale sizes is a key factor in differencially corrected GNSS systems, because small but steep TEC gradients could fall between users and reference stations and may cause undetected user position errors.

We have installed five GNSS receivers with mutual distances of 80-1600m in Ishigaki, Japan and continue observation since 2008. We used single-frequency carrier-based and code-aided technique to derive TEC gradients. From temporal TEC variations derived from dual-frequency measurements by three receivers are used to derive velocity and scale sizes. In the case of the steepest gradient ever observed (3.38 TECU/km) associated with a plasma bubble, the velocity was estimated to be 114 m/sec in NNE direction and the scale-size was estimated to be 10 km. Analysis with more data is being conducted and the statistical results will be presented at the meeting. Possibles means to validate the results by using independent observations will also be discussed.

キーワード：Ionosphere、Plasma bubble、TEC gradient、GNSS
Keywords: Ionosphere, Plasma bubble, TEC gradient, GNSS

Preliminary results of the ionospheric observation by new ionosondes, VIPIR2, in Japan

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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.

キーワード：ionosonde、VIPIR、HF radar
Keywords: ionosonde, VIPIR, HF radar

Anomalous ambipolar diffusion observed using meteor radars in northern high latitudes

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Ambipolar diffusion coefficients are estimated through radar echo decay rates of ionized meteor trails. Information of neutral atmosphere temperature in the lower thermosphere can be further deduced from the ambipolar diffusion coefficient when electron and ion temperatures can be regarded the same with the neutral atmosphere temperature [e.g., Tsutsumi et al., 1994,1996; Hocking et al., 1999, 2004].
We found that the ambipolar diffusion in the polar mesopshere was sometimes anomalously enhanced in Arctic meteor radar observations. Comparison with collocated Na lidar and EISCAT radars in Tromsoe showed that such enhancements were not observed in neutral temperature field, and that enhanced electric field in the lower thermosphere seemed responsible for the anomalous ambipolar diffusion. This further indicates that meteor radar observations in polar regions have a potential to give a certain measure of electric field in the lower thermosphere and even the upper mesosphere, which is very difficult to observe without an incoherent scatter radar.

キーワード：両極性拡散係数、流星レーダー、極域中間圏下部熱圏
Keywords: ambipolar diffusion coefficient, meteor radars, polar mesosphere and lower thermosphere

D- and E-region ion temperature measured with EISCAT radar facility

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The energy from the solar wind is mainly transported to the polar upper atmosphere and causes various phenomena such as auroras characterized by their rapid variability in time and space. Incoherent scatter radars (ISR) located in high latitude are one of the most powerful tools to investigate generation mechanisms of such phenomena and their effects on the atmosphere. The ISR basically gives information of plasma parameters between the bottom-side and topside ionosphere. However, ISRs have several unavoidable limitations to derive ionospheric parameters in the D- and E-region ionosphere, due to limited information in the ISR spectra. In particular, D- and E-region temperature in the polar ionosphere measured with ISRs has not been fully verified by using other temperature measurements.
We have investigated ion temperature variations in the D- and E-region using the EISCAT UHF radars located in Tromsoe, Norway. Our results show that a lower limit of reliable ion temperature derivation was about 87 km altitude at noon in winter. Time variations of the daytime ion temperature at altitudes between 88 and 95 km derived from EISCAT were very close to those of ambipolar diffusion coefficients at the same altitudes from the Tromsoe meteor radar data even when geomagnetic activity was high. This indicates that ion temperature at 88-95 km altitudes seems to be equal to neutral temperature at the same altitudes. We discuss what decides lower limits of the reliable ion temperature derivation, based on EISCAT data analysis under several geomagnetic/geophysical conditions.

キーワード：超高層大気、温度、非干渉散乱レーダー
Keywords: upper atmosphere, temperature , Incoherent scatter radar

Spectral observations of aurora and artificial aurora in EISCAT radar site, Tromsø, Norway.

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We have developed a compact spectrograph, which is capable of measuring optical emission intensity in visible range from ~480 nm to ~880 nm with a resolution of ~1.6 nm. The aperture, i.e. F-number, is ~4, and the data sampling rate is 1 Hz. We installed the spectrograph in European incoherent scatter (EISCAT) radar site, Tromsø, Norway (69.6N, 19.2E), and started unmanned nighttime operation on 4 October 2016. The field-of-view (FOV) of the spectrograph is pointed at magnetic field-algined direction. Since then, aurora observations have been done continuously during this winter. In addition to the aurora observations, we plan to conduct EISCAT heater experiments for artificial aurora observations in February and March 2017. In the presentation, we will introduce spectral observations of aurora and artificial aurora in EISCAT Tromsø site.

キーワード：スペクトログラフ、オーロラ、人工オーロラ、EISCAT
Keywords: Spectrograph, Aurora, Artificial aurora, EISCAT

トロムソナトリウムライダーを用いた北極域SSLの統計解析
Statistical study of sporadic sodium layer (SSL) in the polar lower thermosphere and upper mesosphere by using the Tromsoe sodium LIDAR

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We will present statisitical results about sporadic sodium layers (SSLs) appearing in the polar lower thermosphere/upper mesosphere during winter (November –January). The sodium LIDAR at Tromsø (69.6N, 19.2E) has made simultaneous five directional (vertical postion, plus 4 horizontal positions with zenith angale = 30 deg or 12.5 deg and azimuth = 0, 90, 180, 270 deg) observations, and has obtained about 2100 hours of temperature, sodium density, and wind data beteween October 2012 and March 2016. Analyzing these datasets, we have identified twenty-four SSL events over the four winter seasons, and have investigated charactristics of the SSLs.

We have addressed the following questions about SSLs: (1) in-situ generation or advection, (2) ionization of aurora is needed, (3) role of Es layers and temperature, and (4) local time dependence and advent height. Concerning (1), it is important to distinguish events if they were in-situ generated or just adveceted into the views of the LIDAR, since so far no proposed mechanisms can explain well the rapid increase of the sodium density found in the begging of SSL events. Based on investigation of timmings of detection at each beam direction, it is found that SSLs of the 10 events seemed to be in-situ generated, while those of 14 events were advected. Concerning (2), auroras would play an important role for generation of SSLs at high latitudes, but their role is not yet well understood. At Tromsø, several instruments monitor the aurora activity. These data showed that auroras appeared in 17 events. Concerning (3), exisitence of sporadic E layaer would be imporntat for generation (in particular, for providing sodium atoms), but its role is not well understood quantatively. Concerning (4), local time dependence and height of advent of SSLs are also keys to understand generation mechanisms of SSLs, in particular relationship with tide, planetary, and gravity waves. out of the 24 events, SSLs of 9 events appeared above 100 km before 21 UT, while SSLs of the 11 events showed up below 100 km after 21 UT.

Vertical motion of the neutral atmosphere above Tromsoe

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We will present results of vertical motion above Tromsoe (69.6 deg. N, 19.2 deg. E) mainly based on sodium LIDAR data. Vertical motion of the neutral gases in the upper mesosphere and lower thermosphere (MLT) is a peculiar issue, and its understanding is important in terms of substance transport as well as thermal structures. Observations of the vertical wind in the MLT region are rather difficult, because vertical velocities are generally thought to be about two orders smaller than horizontal wind velocities. It is believed that the cold summer mesopause is set up by upward wind with strength of a few cm/s in the mesosphere. During high auroral activity intervals, some observations conducted by Fabry-Perot Interferometer (FPI) reported about 10 m/s or larger vertical wind velocity in the polar lower thermosphere. FPI measurements, however, suffer from a serious weakness of passive measurements: no information on the height observed. On the other hand, observations of vertical winds by radars are also difficult. Thus, our understanding of the vertical motion in the polar MLT region is still limited. The sodium LIDAR operated at Tromsoe is capable of simultaneous measurements of wind velocities with five directions with a good accuracy (1-2 m/s). By using the LIDAR data (about 2100 hr data) obtained from October 2012 to March 2016 together with EISCAT, MF, and meteor radar data as well as auroral image data, we will discuss the characteristics of the vertical motion in the polar MLT.

We have found some events where the vertical wind blew with strength of about 10 m/s. In the case of January 14, 2015, the upward vertical wind with an amplitude of 10 m/s was found between 92 and 101 km over a few hours. During the night, the semidiurnal tide was strong with an amplitude of 100 m/s. This would confirm that strong vertical motion exists when such waves pass by the MLT region. In another event found in February 8, 2013, upward flows were observed between 94 and 96 km at the same time for 15 min, while no vertical flows were found at and above 97 km and at and below 93 km. Of particular interest in both cases is that a sporadic sodium layer (SSL) appeared nearby the height region where the upward vertical wind was observed at the same time (in the case of January 14, 2015) or 15 min later (in the case of February 8, 2013). In this presentation, we will address what conditions are needed for the vertical motion occurring, and also discuss possible relationship with the advent of SSLs.

キーワード：鉛直風、中間圏・下部熱圏、ライダー、トロムソ、EISCAT
Keywords: Vertical wind, Mesosphere and lower Thermosphere, LIDAR, Tromsoe, EISCAT

Quasi-periodic variation in electron density, conductance and electric field during pulsating aurora

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We report simultaneous radio and optical observations of pulsating aurora (PsA) in Tromsoe (69.60N, 19.20E), Norway, using an all-sky TV camera (ATV) and the EISCAT UHF/VHF systems. During an interval within this campaign period, PsA with periods of 8-17 s was observed by the ATV in the morning local time sector (approximately 05 MLT). In this interval, quasi-periodic oscillations were identified in the raw electron density obtained by the EISCAT UHF system. The electron density at the lower part of the E region (95-115 km) was enhanced by a factor of 3-4 immediately after the optical pulsation became "on". The height-integrated Hall conductance was also elevated by a factor of 1.5-2 almost in harmony with the electron density variation. Interestingly, the remote antenna at Kiruna observed systematic redirection of the horizontal electric field when the PsA was "on". We propose a model in which the enhancement of the Hall conductance within patches of PsA caused charge accumulation at the edges of the patches, and the electric field was then modified by the resulting polarization electric field. An estimation of the electric field modulation based on this model well reproduced the actual electric field variation measured by EISCAT, which implies that the ionization caused by high-energy electron precipitation associated with PsA has a significant effect on the ionospheric current system. During the same interval of PsA, a significant ionization was observed by the EISCAT VHF system not only in the E region but also in the upper part of the D region (80–95 km). An altitude profile of the Pedersen conductance derived from EISCAT exhibited two distinct layers of enhanced conductance. The upper one occurred at ~120 km altitude which corresponded to the normal Pedersen current layer carried by the ions. The lower one appeared as a thin layer between 80 and 95 km in altitude, which was mainly carried by the collisional motion of electrons. Such an electron Pedersen layer is detectable only when the electron density is sufficiently high for allowing an appreciable current to flow in the D region. The electron Pedersen current flows exactly in the altitudes where the pulsating ionization occurs; thus, it would play more important role in the closure of electric current associated with patches of PsA.

MAGDASプロジェクトEE-indexの磁気赤道域現象への適用事例
Equatorial magnetic field variations using EE-index (MAGDAS project)

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MAGDAS project is the global ground-based magnetic field observation network and participates in the project "Study of coupling processes in solar-terrestrial system" that was approved by the Master Plan 2014 of Science Council of Japan and the Roadmap 2014 of MEXT. The MAGDAS magnetometer network allows to understand the energy transfer and propagation process from the poles to the equator, in the terms of the coupling the solar-magnetosphere-ionosphere-atmosphere.
In 2008, International Center for Space Weather Science and Education, Kyushu University (ICSWSE) proposed the EE-index (Uozumi et al., 2008; Fujimoto et al., 2016), which is an index to monitor quantitatively various equatorial geomagnetic phenomena in real time. EE-index separates the magnetic disturbances in the equatorial region into the global (EDst) and local (EUEL) magnetic variations. Especially, the detail analysis of EUEL index provides the quantitative and visible information in order to reveal the electromagnetic phenomena affecting the fundamental structure of Equatorial Electrojet (EEJ). This paper will show some examples applying EE-index to the equatorial magnetic variation: solar cycle variation of EEJ peak, semiannual EEJ variation and semidiurnal EUEL variation. The amplitude of semidiurnal EUEL variations increased in January and decreased around July. The seasonal dependence of semidiurnal variation agrees with the seasonal profile of atmospheric neutral wind (2.2) mode. The semiannual EEJ variation has two peaks in March and September. In other words, the amplitude of EEJ is weaker during solstices (January and July). We demonstrated these characteristics with time series analysis of EE-index. We are trying to understand the sources affecting the total current intensity flowing the equatorial ionosphere by separating the different contributing factors from the magnetic field variations.

キーワード：グローバル地磁気観測、赤道ジェット電流、MAGDASプロジェクト
Keywords: Global magnetic filed obsevartion, Equatorial electorjet (EEJ), MAGDAS project

Decomposition of the wave elements of the global high-correlation Pi 2

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Global high-correlation Pi 2 pulsations are observed in wide latitudinal and longitudinal ranges on the nightside [e.g., *Uozumi et al.* 2009, 2011, 2016; *Keiling et al.*, 2014]. In those Pi 2 events, the waveforms observed at different stations were highly correlated. It is noted that localized and low-correlation Pi 2 oscillations, such as those observed near the auroral electrojet currents [e.g., *Pashin et al.*, 1982; *Samson and Rostoker*, 1983], should be treated separately from high-correlation Pi 2 events. In high-correlation Pi 2 events, systematic group delays ($|dT| <\sim 100$ s) were typically observed in the *H* components of middle- to high-latitude Pi 2 pulsations, which typically have high correlations with low-latitude *H* component oscillations. While the time lags of the *D* component oscillations relative to the low-latitude *H* component oscillations were not significant ($|dT| <\sim 10$ s) in the low- to high-latitude nighttime sector, high correlations with the low-latitude *H* component oscillations were observed.
The generation mechanisms of global high-correlation Pi 2 events were investigated by *Uozumi et al.* [2009, 2011]. They proposed that three possible wave elements exist in these events: (1) fast-mode waves (dB_{FW}) propagating from the Pi 2 source region in the nightside magnetosphere and observed in the low-latitude *H* components of Pi 2 pulsations, (2) SCW oscillations (dB_{SCW}) observed mainly in the low- to high-latitude *D* components of Pi 2 pulsations, and (3) directly driven Alfvénic waves (dB_{DA}) [*Kepko et al.*, 2001; *Uozumi et al.*, 2000, 2007, 2009] generated by dB_{FW} through the mode conversion process and observed as the main oscillations of the middle- and high-latitude *H* components of Pi2 pulsations with some group delay.
The middle- and high-latitude Pi 2 pulsations in the *H* component consist dB_{DA} and dB_{SCW} (dB_{DA} is dominant element in the *H* component Pi 2 pulsations). According to the report by *Uozumi et al.* [2016], it can be assumed that the ionospheric footprint of the upward FAC of the SCW was approximately located at the auroral onset position in each event. Thus, if we can specify the location of the auroral breakup position by using global auroral image, we can estimate dB_{SCW} in the H component from dB_{SCW} in the *D* component. Then one of the wave elements of dB_{DA} must be decomposed from total Pi 2 oscillations in the *H* component. In this study, we examined the possibility of decomposition of the wave elements of the global high-correlation Pi 2 with some typical Pi 2 events. We will present some typical cases of the decomposition. Those cases evidently demonstrate that the wave elements of the global high-correlation Pi 2 can be decomposed properly.

Keywords: global high-correlation Pi 2, aurora, substorm

スペースデブリ環境推移モデルにおける大気密度モデルの改良と宇宙天気活動の影響評価

Improvement of atmospheric density model in space debris evolutionary model and evaluation associated with space weather activities

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スペースデブリは宇宙ゴミとも呼ばれる、宇宙空間に存在する不要な人工物体の総称である。スペースデブリの増加は、人類の安全安心な宇宙開発を妨げるため、適切な時期までに適切なデブリ低減対策を実施することが求められる。その評価のために、現在の地球周辺のスペースデブリ環境を再現し、かつ、今後の打ち上げや実施されたデブリ低減対策、宇宙環境の変化を加味した将来の軌道環境を予測することが必要である。これらの課題に対し、九州大学とJAXAでは、地球周回全領域デブリ環境推移モデル (NEODEEM：Near-Earth Orbital Debris Environment Evolutionary Model）を共同で開発し、地球周回全領域（静止軌道-静止トランスファ軌道-中軌道-低軌道）のスペースデブリ環境予測をおこなっている。スペースデブリの軌道変更や消失に寄与するのは、大気から受けるドラッグである。大気密度は、太陽活動度や地磁気活動度の影響を受けて変動するため、スペースデブリ環境予測において宇宙天気活動を考慮することは必須である。今回我々は、より精密な大気密度の推定と、スペースデブリ軌道計算への応用を目指し、大気密度モデルの改良を試みた。その結果、太陽周期などの長期の宇宙天気現象に加え、磁気嵐などの突発的な宇宙天気現象の影響も考慮した、スペースデブリ軌道計算に適した大気モデルを構築することができた。本講演では、更新された大気モデルと、地球周辺の宇宙天気現象がスペースデブリ環境推移に及ぼす影響について評価した結果を紹介する。

キーワード：宇宙天気、スペースデブリ、宇宙環境
Keywords: Space Weather, Space Debris, Space Environment

