

## Recent advances in the low latitude ionospheric irregularities- a review Recent advances in the low latitude ionospheric irregularities- a review

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Scientific research on the low latitude ionospheric irregularities continues to be of interest due to their adverse effects on communication and navigation systems. Understanding the physical processes and governing free energy sources leading to develop forecasting capability is the current focus. Low latitude ionospheric E and F regions become unstable both during day and night and irregularities are formed at different height regions. While understanding the F region processes with forcing from below and extra-tropics has been paid attention, research activities are also focused on understanding fascinating details of E- and valley- region plasma processes, such as instabilities linked with tidal ion layer, intermediate layer and daytime 150 km echoes. Recent experiments conducted from low latitudes in the Asian sector have added new observational knowledge on plasma irregularities. This paper will present the recent advancements made in understanding E and F region irregularities including coupling between the two regions and daytime 150 km irregularities based on observations made in the Asian sector.

## 全球大気圏電離圏モデルと高精細プラズマバブルシミュレーションの結合 Three-dimensional plasma bubble simulation driven by whole atmosphere-ionosphere coupled model

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Equatorial plasma bubble (EPB) is a well-known phenomenon in the equatorial ionospheric F region. As it causes severe scintillation in the amplitude and phase of radio signals, it is important to understand and forecast the occurrence of EPB from a space weather point of view. The development of EPB is known as a evolution of the generalized Rayleigh-Taylor instability. Numerical modelings of the instability on the equatorial two-dimensional plane have been conducted since the late 1970's, and the nonlinear evolution of the instability has been clearly presented. Recently, three-dimensional (3D) modelings became popular tools for further understanding of the development of EPB such as 3D structure of EPB, meridional wind effects and gravity wave seeding.

We have developed a new 3D high-resolution bubble (HIRB) model for EPB and presented nonlinear growth of EPB which shows very turbulent internal structures such as bifurcation and pinching. The eastward neutral wind in the evening produced reverse-C shape of EPB as frequently observed by various instruments. We are trying to integrate the high-resolution model for EPB with the whole atmosphere-ionosphere coupled model (GAIA) to study the growth of EPB under the realistic background conditions. The background electric field and neutral wind partially controlled by forcing from the lower atmosphere may cause the day-to-day variability of EPB occurrence.

キーワード: プラズマバブル, 赤道電離圏, シミュレーション, GAIA モデル, HIRB モデル  
Keywords: plasma bubble, equatorial ionosphere, simulation, GAIA model, HIRB model

## Predawn depletion observed by GRBR and GPS networks in Southeast Asia Predawn depletion observed by GRBR and GPS networks in Southeast Asia

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Deep plasma depletion during substorm at predawn (0412-0436 LT) on 6 March 2012 was captured by GRBR network and was confirmed by sparse GPS networks in Southeast Asia. The only available low-Earth-orbit (LEO) satellite during the event is DMSPF15 with NE-to-SW overpass. GRBR network covering both hemispheres is aligned along the ~100 E meridian. GPS network including 12 GPS receivers sparsely distributes from 25 N to 1 N and from 99 E to 105 E. The supporting information includes in-situ ion density data from DMSPF15 satellite, bottomside ionospheric data from ionosonde at Chumphon (10.72 N, 99.37 E) and data from the EAR at Kototabang (0.20 S, 100.32 E). This event was recognized by GRBR-TEC as having a steep TEC gradient that can trouble in positioning error on the aeronautical augmentation system. This finding was supported by the GPS-TEC. In addition to the depletion, the GPS-TEC revealed the co-locating sub-mesoscale Medium-Scale-Ionospheric-Disturbance-like (MSTID-like) structures. Because the sparseness of the observation points has restricted the resolution of the observations, several assumptions are necessary to interpret the data, such as the neglect of the temporal variations of their structures. As a result, a deep plasma depletion event was understood as having fossil plasma bubbles and sub-mesoscale MSTID-like structures collocating. The wavefront of the plasma bubbles and the MSTID-like structures are found to be the same. This event improves the predawn ionospheric information over Southeast Asia and is significant for being the prior-knowledge for the ionospheric modeling.

キーワード: TEC, GRBR, GPS, predawn depletion, plasma bubble, Southeast Asia  
Keywords: TEC, GRBR, GPS, predawn depletion, plasma bubble, Southeast Asia

## Effects of Pre-reversal Enhancement of E x B drift on the Latitudinal Extension of Plasma Bubble in Southeast Asia

### Effects of Pre-reversal Enhancement of E x B drift on the Latitudinal Extension of Plasma Bubble in Southeast Asia

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We investigated the effects of the F region bottomside altitude ( $h'F$ ), maximum eastward electric field (E), duration of eastward E, and the integral of eastward E on the latitudinal extension of equatorial plasma bubbles in the Southeast Asian sector using the observations recorded by three GPS receivers and two ionosondes. The GPS receivers are installed at Kototabang (0.2 deg S, 100.3 deg E; 10.0 deg N magnetic latitude), Pontianak (0.02 deg S, 109.3 deg E; 8.9 deg S magnetic latitude), and Bandung (6.9 deg S, 107.6 deg E; 17.5 deg S magnetic latitude) in Indonesia. The ionosondes are installed at equatorial stations Chumphon (10.7 deg N, 99.4 deg E; 3.3 deg N magnetic latitude) in Thailand and Bac Lieu (9.3 deg N, 105.7 deg E; 1.7 deg N magnetic latitude) in Vietnam. We analysed those observations acquired in the equinoctial months (March, April, September, and October) in 2010-2012 when the solar activity index F10.7 was in the range from 75 to 150. Assuming that plasma bubbles are the major source of scintillations, the latitudinal extension of the bubbles was determined according to the S4 index. Our results show that the peak of  $h'F$ , maximum eastward E within the pre-reversal enhancement period, and the integral of eastward E are positively correlated with the maximum latitude extension of plasma bubbles. Our statistical and observational findings emphasise that plasma bubble extending more than 10-18 deg in latitude from the magnetic equator can be generated when the peak value of  $h'F$  is greater than 250-450 km, the maximum vertical upward E x B drift is greater than 10-70 m/s, and the integral of vertical upward E x B drift is greater than 50-250 m/s. In contrast, the duration of eastward E shows only weak correlation with the maximum latitude extension of plasma bubbles. These findings suggest that the latitudinal extension of plasma bubbles is controlled mainly by the magnitude of eastward E and the peak value of  $h'F$  at the initial phase of development of plasma bubbles (or equatorial spread F) rather than by the duration of eastward E.

キーワード: equatorial ionosphere, plasma bubble, pre-reversal enhancement, scintillation

Keywords: equatorial ionosphere, plasma bubble, pre-reversal enhancement, scintillation

中・低緯度トップサイド電離圏でのプラズマ密度に対する電子温度とイオン温度の傾向  
Temperature trend of electron and ion with plasma density in middle and low latitude in the topside ionosphere

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It is important to understand energy flow from electron to ion and neutral species because main heat source of ionospheric plasma is photoelectron created by solar EUV. First, electrons are heated by photoelectrons, then heated electrons reduce their energy through the Column collision with ions. Finally, ions are cooled by inelastic collision with neutral species. Temperatures of electron ( $T_e$ ), ion ( $T_i$ ) and neutral species ( $T_n$ ) get close to each other during night time due to lack of significant heat source. Heating rate of electron by photoelectron is proportion to ambient plasma density while cooling rate of electron is proportion to square of the plasma density. Therefore,  $T_e$  decreases with increase of electron density ( $N_e$ ) in general. However, some satellite results show  $T_e$  increases with increase of  $N_e$  when  $N_e$  is high enough (more than about  $10^6 \text{ cm}^{-3}$ ). To understand the unexpected  $T_e$ , it is also important to know  $T_i$  variation because ion plays as a heat sink of electron. In this paper, we summarized correlation of  $N_e$  with  $T_e$  and  $T_i$  observed by HINOTORI, CHAMP and ROCSAT-1 in the topside ionosphere. Since these satellites did not observe  $T_e$  and  $T_i$  simultaneously,  $T_e$ ,  $T_i$  and  $N_e$  measured with the incoherent scatter radars at Jicamaruca and Millstone Hill are also shown. Using these data, we discuss possible cause of unexpected high  $T_e$  in high  $N_e$  region.

キーワード: トップサイド電離圏, 電子温度, 電子密度, イオン温度, 光電子加熱, 中低緯度電離圏  
Keywords: topside ionosphere, electron temperature, electron density, ion temperature, photoelectron, middle and low latitude

## Climatology of gravity waves in the mesosphere observed with the MU radar Climatology of gravity waves in the mesosphere observed with the MU radar

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The MU radar at Shigaraki, Japan has been operating periodically since 1986 and the extensive data set provides a unique opportunity to study the seasonal variations of gravity waves. The data has recently been made available publicly to the scientific community through a link in a large meta-database called IUGONET (Inter-university Upper atmosphere Global Observation NETwork). In our study we focus on gravity waves observed during daylight hours between 60 and 97 km. Several days of observations were made during most months during the 29 years of operation. We calculate the vertical fluxes of horizontal momentum and quantify the statistical characteristics and temporal variability of the waves. The spatial scales and intrinsic wave properties are determined, as well as their response to seasonal changes in the background conditions. The background conditions considered include changes in the mean horizontal winds and the atmospheric static stability. This study differs from those done previously in that we make extensive use of probability distribution functions as a complement to spectral analysis.

キーワード: mesosphere, gravity waved, climatology, Mu radar  
Keywords: mesosphere, gravity waved, climatology, Mu radar

ポーカークラット及びトロムソ MF レーダーで観測された中間圏重力波と潮汐を含む背景場とのカップリングについて  
On the coupling between gravity waves and background field including tides observed with MF radar at Poker Flat & Tromsø

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アラスカ・ポーカークラット及びノルウェー・トロムソに設置された MF レーダーにより中間圏から下部熱圏における中性風速データが 1990 年代後半以降観測されている。本研究では 10 年間 (1999~2008 年) の上記観測データを用いて、潮汐を含む背景場に伴う短周期重力波活動の日内変動及び夏季と冬季の特性について調べる。

まず始めに、水平風速データから重力波と潮汐成分の抽出を行った。ここで、潮汐成分は 30 分平均データ 5 日間分からトレンドを除き、8, 12, 24 時間周期の正弦波をフィッティングして振幅と位相を 30 分ごとに求めた。一方、1~4 時間周期を持つ擾乱を短周期重力波として解析した。その結果、半日潮汐の位相に短周期重力波運動エネルギー (GW-KE) の半日周期成分の位相が約 10~20 日間ロックされる様子を複数の年月で確認した。その中で、2000 年 11~12 月に観測された事例では、ポーカークラットとトロムソ両地点でほぼ同時期にロック現象が起こっていたが、GW-KE の位相が 180 度ずれていた (AGU2014)。そこで、潮汐波と GW-KE の半日周期成分の 1 日コンポジット解析をした結果、ポーカークラットでは 11~12 月において半日潮汐が東風時、1, 2, 5~8 月では東風から西風が変わる時、トロムソでは 11~2 月において半日潮汐が西風時、5~9 月では東風時に GW-KE が最大となることがわかった。従って、2000 年 11~12 月に観測された事例は平均的によく起こりうる現象であると考えられる。今後は、8, 24 時間周期及びそれ以外の成分について調べ、それぞれの地域で卓越する現象を特定し、その物理メカニズムを議論する予定である。

キーワード: 中層大気, 重力波, 潮汐波

Keywords: middle atmosphere, gravity waves, tidal waves

Distributions of horizontal phase velocity of gravity waves observed by ANGWIN, using a 3-D spectral analysis technique  
Distributions of horizontal phase velocity of gravity waves observed by ANGWIN, using a 3-D spectral analysis technique

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

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

キーワード: 大気重力波, 大気光イメージング  
Keywords: atmospheric gravity wave, airglow imaging



## Obervation of mesopause temperature by Kunming meteor radar Obervation of mesopause temperature by Kunming meteor radar

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A method to calibrate the initial temperatures derived from the meteor radar at Kunming in low latitudes area using SABER temperatures is presented in this paper. Most of the meteors are observed in the local morning by Kunming meteor radar, therefore, the daily mean temperatures measured by the meteor radar were biased by local morning values. The daily temperatures estimated using temperature gradient model technique are consistent well with the daily SABER temperatures which averaged from 1600 to 0600 UT, but fluctuate greater than SABER temperatures. The correlation coefficient between the meteor and SABER temperatures is 0.58. The Lomb Periodograms of meteor and SABER temperatures both exhibit clear seasonal and interannual periodicities, with annual, semiannual, quasi 90 day and terannual oscillations. The results of harmonic fit analysis show that the mean values are very close and these periodic oscillations have similar phases, however, the oscillation amplitudes of meteor temperatures are larger than SABER temperatures. The larger fluctuations of meteor temperatures were identified as larger amplitude of the temperature oscillation components. Thus, the amplitude calibration was used to adjust the larger fluctuations of meteor temperatures. After temperature calibration was performed, the fluctuations of meteor and SABER temperatures agree well, and the accuracy of the calibrated temperatures has been significantly improved. In addition, the temperatures determined by the temperature gradient model technique could effectively be used to study the waves and oscillations in the mesopause region.

キーワード: meteor radar, mesopause temperature, temperature gradient, temperature oscillation  
Keywords: meteor radar, mesopause temperature, temperature gradient, temperature oscillation

## 地磁気静穏日変化振幅の長期変動の特徴について Characteristics of long-term variation of the geomagnetic solar quiet daily variation

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Characteristics of long-term variation in the amplitude of solar quiet (Sq) geomagnetic field daily variation have been investigated using 1-h geomagnetic field data obtained from 69 geomagnetic observation stations within the period of 1947 - 2013. The Sq amplitude observed at these geomagnetic stations showed a clear dependence on the 10 - 12 year solar activity cycle and tended to be enhanced during each solar maximum phase. The Sq amplitude was the smallest around the minimum of solar cycle 23/24 in 2008 - 2009. The relationship between the solar F10.7 index and Sq amplitude was approximately linear but about 53 % of geomagnetic stations showed a weak nonlinear relation to the solar F10.7 index. In order to remove the effect of solar activity seen in the long-term variation of the Sq amplitude, we calculated a linear or second-order fitting curve between the solar F10.7 index and Sq amplitude during 1947 - 2013, and examined the residual Sq amplitude, which is defined as the deviation from the fitting curve. As a result, the majority of trends in the residual Sq amplitude that passed through a trend test showed negative values over a wide region. This tendency was relatively strong in Europe, India, the eastern part of Canada, and New Zealand. The relationship between the magnetic field intensity at 100 km altitude and residual Sq amplitude showed an anti-correlation for about 71 % of the geomagnetic stations. The decreasing trend of the residual Sq amplitude implies that the ionospheric Sq current intensity tends to weaken due to a decrease of the ionospheric conductivity associated with an increase of the ambient magnetic field intensity. Furthermore, the residual Sq amplitude at the equatorial station (Addis Ababa) was anti-correlated with the absolute value of the magnetic field inclination. The decreasing trend of the residual Sq amplitude in the equatorial region indicates movement of the equatorial electrojet due to the secular variation of the ambient magnetic field.

キーワード: 太陽活動, 地磁気日変化, 電離圏電気伝導度, 電離圏ダイナモ, 地磁気永年変化, 熱圏風

Keywords: Solar activity, Geomagnetic solar quiet daily variation, Ionospheric conductivity, Ionospheric dynamo, Secular variation of geomagnetic field, Thermospheric wind

## レーダー長期観測による赤道域の中間圏・下部熱圏における大気力学過程の研究 Equatorial MLT dynamics using long-term radar observation

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赤道域では、対流圏で励起された大気波動が上方伝搬する過程で、成層圏下部における準2年周期振動 (Stratospheric Quasi-Biennial Oscillation: SQBO、平均周期は26-28ヶ月)、成層圏上部の半年周期振動 (Semi-Annual Oscillation: SAO) および MLT 領域では成層圏と逆相の半年周期振動 (MSAO) を駆動していると考えられている。

本研究では、インドネシアで長期間運用している流星レーダー等のデータを用いて、赤道域の中間圏・下部熱圏 (Mesosphere-Lower Thermosphere: MLT) の高度70-110 kmにおける風速の周期振動ならびにそれら不規則変動を研究する。特に MSAO の西向き風が2-4月 (北半球の春分季) に2年乃至3年の不定期間隔で非常に大きくなる特異現象 (Mesospheric Quasi-Biennial Enhancement: MQBE) に着目する。

M-QBE は秋分季 (9-10月) に発生せず、2-4月頃に限定的に発生する。よって1年周期を律するプロセスが重畳することで、M-QBE が2-4月のみに発生すると考えられるが、そのメカニズムは未解明である。本研究では2つのメカニズムを検討した。

(1)

南北風との相関

赤道 MLT 域では南北風が夏半球から冬半球に風が吹くことから、1年周期 (AO: Annual Oscillation) を示す。南北風と東西風とが結合する何らかのプロセスがあるならば、東西風に1年の周期性を生み出しうる。実際の観測により東西風と南北風の長期変動を調べると、南北風 AO と東西風 SAO の長期変動の間に同様の变化傾向が見られた。これにより、南北風と東西風とが結合する何らかのプロセスが存在する可能性が示唆された。

(2)

大気重力波による M-QBE の駆動

M-QBE の西向き風増大と MLT 高度での大気重力波強度の増加が明らかに同期していたことが先行研究で報告されている (N.V. Rao et al., 2012)。したがって、大気重力波が M-QBE を駆動している可能性がある。しかし、大気重力波と M-QBE の関係を明らかにするには、重力波の強度 (風速分散) だけでは不十分で、波動にともなう運動量フラックスを測定する必要がある。

運動量フラックスは水平風と鉛直風の摂動分の分散 ( $u' w'$ ) だが、2次の微小量であることから観測は容易ではない。大型大気レーダーについて、beam pair 法を用いて  $u' w'$  を測定する画期的な方法が開発された

(Vincent and Reid, 1983)。しかし、MU レーダー級の高性能大型レーダーは世界に数ヶ所しかないため、大気波動の効果の全球分布を知るには新たな計測手法の開発が求められた。

MU レーダーより小型簡便な流星レーダーを用いて beam pair 法を模擬し、 $u' w'$  を推定する手法が提案された (Hocking, 2005)。しかし、その測定精度に疑義が提示されている。

我々はインドネシアで同一仕様の2台の流星レーダーを同じ緯度 (赤道上) で水平に約4,000 km 離れた観測点で運用している。これら2台の流星レーダーによる  $u' w'$  の測定結果を統計的に比較し、観測手法の妥当性を検討した。

まず、約4,000 km 離れた東西端のパプア (Biak) と西スマトラ (Koto Tabang) で2011年以降に断続的に行われた同時観測のデータを用い、Hocking 法で  $u' w'$  を解析し結果を比較する。運動量フラックスのよく一致している期間は、Koto Tabang および Biak の両者においてデータ利用率が高い期間に含まれている。このことから、Koto Tabang および Biak における観測によって、ノイズではない、運動量フラックスの類似した変動を観測することができたといえる。

また、Koto Tabang では10年以上観測が継続されていることから、季節変動および年々変動、さらに高度層による差違を検討したところ、2月と8月に運動量フラックスが大きな正の値を取り、6月と11月に小さな値あるいは負の値をとる傾向が見受けられた。

M-SQO が大気波動の影響を受けているならば、 $u' w'$  にも半年周期が現れると期待されるが、本研究により、その予想と矛盾しない観測結果を得た。今後、大気重力波が MQBE を駆動している具体的なメカニズムを解明していくことが重要である。

PEM06-11

会場:A01

時間:5月27日 10:30-10:45

キーワード: 中間圏・下部熱圏, 準二年周期振動, 運動量フラックス

Keywords: Mesosphere and Lower Thermosphere, Quasi-biennial Oscillation, momentum flux, Hocking

## Deep ionospheric hole created by sudden stratospheric warming in the post-midnight ionosphere

## Deep ionospheric hole created by sudden stratospheric warming in the post-midnight ionosphere

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GONCHARENKO, Larisa<sup>1\*</sup>; COSTER, Anthea<sup>1</sup>; ZHANG, Shunrong<sup>1</sup>; ERICKSON, Phillip<sup>1</sup>; APONTE, Nestor<sup>2</sup>

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Multiple observational studies have demonstrated large ionospheric variations associated with sudden stratospheric warming (SSW) events during the daytime, but only limited evidence of ionospheric disturbances during the night-time was reported up to now. We use observations by GPS TEC receivers and Arecibo and Millstone Hill incoherent scatter radars to investigate large-scale disturbances in the nighttime ionosphere for several SSW events. We report a deep decrease in TEC that reaches ~70% of the background level and is observed between the local midnight and local sunrise (6-12UT). This decrease is observed for several consecutive days in the range of latitudes from ~60oS to ~45oN. It is accompanied by a strong downward plasma motion and significant decrease in ion temperature, as observed by both Arecibo and Millstone Hill radars. We discuss variations in electric field and F-region dynamics as possible drivers of this behavior.

キーワード: sudden stratospheric warming, atmospheric coupling, ionosphere

Keywords: sudden stratospheric warming, atmospheric coupling, ionosphere

## Spatial and temporal extent of ionospheric anomalies during sudden stratospheric warmings in the daytime ionosphere

## Spatial and temporal extent of ionospheric anomalies during sudden stratospheric warmings in the daytime ionosphere

GONCHARENKO, Larisa<sup>1\*</sup>; COSTER, Anthea<sup>1</sup>; ZHANG, Shunrong<sup>1</sup>; BENKEVITCH, Leonid<sup>1</sup>; GALKIN, Ivan<sup>2</sup>  
GONCHARENKO, Larisa<sup>1\*</sup>; COSTER, Anthea<sup>1</sup>; ZHANG, Shunrong<sup>1</sup>; BENKEVITCH, Leonid<sup>1</sup>; GALKIN, Ivan<sup>2</sup>

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Recent studies have demonstrated large variations in the daytime ionosphere during sudden stratospheric warmings (SSW) and a debate has started about the relative importance of solar and lunar tides in these ionospheric variations. In this study we use GPS TEC data from the MIT Haystack Observatory Madrigal database along 75°W collected in 2000-2014 as well as several digisondes to examine the magnitude and spatio-temporal extent of ionospheric anomalies related to SSW. To separate ionospheric anomalies during SSW from regular ionospheric behavior, we develop empirical models of ionospheric parameters (TEC, NmF2) using available long-term records. The models describe variations in parameters for each lon/lat bin (or digisonde location) as a function of solar activity, geomagnetic activity, day of year, and local time. Ionospheric anomalies are obtained as difference between observations and empirical model. Analysis of anomalies shows that they are observed for both major and minor SSW events, reaching 50-100% variation from expected seasonal behavior for major SSW events and 30-60% variation for minor SSW events. SSW-associated variations are pronounced more strongly in NmF2 than in TEC. The largest variations in TEC in the daytime are observed both in the crests of equatorial ionization anomaly and at 40-60°S (geodetic). Variations in TEC and NmF2 are even discernable up to high latitudes (70°S) in the Southern Hemisphere and mid-latitudes (42°N) in the Northern Hemisphere. We discuss several possible mechanisms contributing to these anomalies, focusing on solar and lunar semidiurnal tides and interhemispheric coupling.

キーワード: sudden stratospheric warming, atmospheric coupling, ionosphere

Keywords: sudden stratospheric warming, atmospheric coupling, ionosphere

## Longitudinal Variations of Low-Latitude Gravity Waves and Their Impacts on the Ionosphere

### Longitudinal Variations of Low-Latitude Gravity Waves and Their Impacts on the Ionosphere

CULLENS, Chihoko<sup>1\*</sup>; ENGLAND, Scott<sup>1</sup>; IMMEL, Thomas<sup>1</sup>  
CULLENS, Chihoko<sup>1\*</sup>; ENGLAND, Scott<sup>1</sup>; IMMEL, Thomas<sup>1</sup>

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The lower atmospheric forcing has important roles in the ionospheric variability. Previous study suggested that atmospheric tides from the troposphere induce the wavenumber 4 signatures on the ionosphere. However, influences of lower atmospheric gravity waves on the ionospheric variability are still not clear due to the simplified gravity wave parameterizations in general circulation models (GCMs) and the limited knowledge of gravity wave distributions. In this study, we aim to study the longitudinal variations of gravity waves and their impacts on the ionospheric variability.

Variations of lower atmospheric gravity waves are characterized using SABER temperature observations from 2002 to 2012 and also the physically based gravity wave parameterization in the Specified-Dynamics Whole Atmosphere Community Climate Model (SD-WACCM). Longitudinal variations of gravity waves from SABER and WACCM show the largest variability in June-August at low latitudes. We have implemented these low-latitude gravity wave variations into the thermosphere-ionosphere-mesosphere-electrodynamics general circulation model (TIME-GCM) to study the responses of the ionosphere. TIME-GCM shows that wavenumber 3-4 components of TEC variations in June-August are increased by ~10-15% with the longitudinal variations of gravity waves but there are no significant changes in other months. Potential mechanisms of TEC responses to gravity wave variations will be discussed.

キーワード: Gravity Wave, Ionosphere, Tides

Keywords: Gravity Wave, Ionosphere, Tides

中低緯度で観測されたLF帯標準電波位相の周期とMSTIDの周期との関連性  
Relationship between phase variation of LF signals and GPS-TEC variations related with  
MSTIDs at mid-low latitudes

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It is known that phase of LF transmitter signals largely varies in nighttime rather than in daytime, because uniform solar ionization in daytime makes the D-region ionosphere smoother. However, the cause of the nighttime phase variations has not been revealed. In this study, we focus on the periods of the phase variations of the nighttime LF transmitter signals observed in Japan and South-east Asia. As for Japanese data, we investigated the periods of LF signals observed in 16 April, and 6 May, 2007 by wavelet analysis. The propagation path (40 kHz) of the LF signals was located at Fukushima to Kagoshima. Both on 16 April and 6 May, 2007, phase variations with a period of about 50 minute was seen at around 11:00 UT and 15:00 UT, respectively. An occurrence of medium-scale traveling ionospheric disturbances (MSTIDs) was confirmed at 15:00 UT on 6 May, 2007 from GPS Total Electron Content (TEC) data, while the MSTIDs did not occur on 16 April, 2007. In the presentation, we will discuss the periods of LF phase variations and GPS-TEC variations in more detail.



## 電離層 E 領域の Ca<sup>+</sup>密度と F 領域の中規模伝搬性電離圏擾乱の初同時観測 First simultaneous observation of Ca<sup>+</sup> densities in the E region and MSTIDs in the F re- gion

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EJIRI, Mitsumu K.<sup>1\*</sup>; TSUDA, Takuo<sup>2</sup>; NISHIYAMA, Takanori<sup>1</sup>; ABO, Makoto<sup>3</sup>; NISHIOKA, Michi<sup>4</sup>;  
MARUYAMA, Takashi<sup>4</sup>; SAITO, Akinori<sup>5</sup>; NAKAMURA, Takuji<sup>1</sup>

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Metropolitan University, <sup>4</sup>National Institute of Information and Communications Technology, <sup>5</sup>Department of Geophysics, Grad-  
uate School of Science, Kyoto University

In the mesosphere and lower thermosphere region, there are permanent layers of metal atoms and ions, the source of which is vaporization of cosmic dust and meteoroids during their entry into the Earth's atmosphere. Some metal atom layers e.g. Na, K, Ca, and Fe layers, and only Ca<sup>+</sup> (Calcium ion) can be observed by ground-based resonance scattering lidars. The National Institute of Polar Research (NIPR) is developing a new resonance scattering lidar system with a frequency-tunable laser. The lidar transmitter is based on injection-seeded, pulsed alexandrite laser for 768-788 nm and a second-harmonic generation (SHG) unit for 384-394 nm. The new lidar is able to measure density variations of minor constituents including Ca<sup>+</sup> (393.477 nm). As a part of the development, observation tests are carried out at NIPR (35.7N, 139.4E) since 2013, and we got the first light from Ca<sup>+</sup> layer on 21 August, 2014. The Ca<sup>+</sup> density profiles were obtained for ~5 hours (23:13 LT-28:28 LT) with temporal and height resolutions of 1 min and 15 m, respectively. During the night, high density and narrow Ca<sup>+</sup> layer was observed. The layer descended from ~107 km to 99 km with quasi-periodic density perturbations until ~17 UT and then stayed at around 99 km until sunrise. At the same night, sporadic E (E<sub>s</sub>) layer was observed with an ionosonde at Kokubunji by National Institute of Information and Communications Technology (NICT) (35.7N, 139.5E), also medium scale traveling ionospheric disturbances (MSTIDs) were observed with the dense GPS receiver network (GEONET). In this presentation, we compare these data in detail and discuss relationships between observed Ca<sup>+</sup> density perturbations, E<sub>s</sub> layer and MSTIDs

キーワード: 共鳴散乱ライダー, カルシウムイオン, 中規模伝搬性電離層擾乱, GPS-TEC, スポラディック E 層

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

Excitation of large-scale gravity waves in the upper thermosphere by interplanetary fluctuations  
Excitation of large-scale gravity waves in the upper thermosphere by interplanetary fluctuations

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Fluctuations on timescales of minutes to hours are common in the solar wind. When the fluctuations encounter the Earth, they could induce impulsive auroral intensification, which, in turn, excite gravity waves in the auroral regions. These gravity waves, particularly large-scale (>~1000 km) gravity waves, will give rise to traveling atmospheric disturbances with typical amplitudes of 20~40% in the upper thermosphere. We report here the detection of full constructive interference between two large-scale gravity waves excited in northern and southern auroral regions by an interplanetary shock, and the detection of extremely efficient multiple excitation of large-scale gravity waves by a long-duration Alfvén wave train carried by a high-speed stream.

キーワード: interplanetary fluctuations, gravity wave, traveling atmospheric disturbances, thermosphere

Keywords: interplanetary fluctuations, gravity wave, traveling atmospheric disturbances, thermosphere

## Quasi-two day wave related variability in the background dynamics and composition of the MTI system

## Quasi-two day wave related variability in the background dynamics and composition of the MTI system

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Dissipating planetary waves in the mesosphere and lower thermosphere (MLT) region may cause changes in the background dynamics of that region, subsequently driving variability throughout the broader thermosphere / ionosphere system via mixing due to the induced circulation changes. We report the results of case studies examining the possibility of such coupling during the northern winter in the context of the quasi-two day wave (QTDW) - a planetary wave that recurrently grows to large amplitudes from the summer MLT during the post-solstice period. Six distinct QTDW events between 2003 and 2011 are identified in the MLT using SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) temperature observations. Concurrent changes to the background zonal winds, zonal mean column O/N<sub>2</sub> density ratio, and ionospheric total electron content (TEC) are examined using datasets from TIDI (TIMED Doppler Interferometer), GUVI (Global Ultraviolet Imager), and GIMs (Global Ionospheric Maps), respectively. We find that in the 5 - 10 days following a QTDW event, the background zonal winds in the MLT show patterns of eastward and westward anomalies in the low and mid-latitudes consistent with past modeling studies on QTDW-induced mean wind forcing, both below and at turbopause altitudes. This is accompanied by potentially related decreases in zonal mean thermospheric column O/N<sub>2</sub>, as well as to low latitude TECs. The recurrent nature of the above changes during the six QTDW events examined point to an avenue for vertical coupling via background dynamics and chemistry of the thermosphere / ionosphere not previously observed.

キーワード: quasi-two day wave, ionosphere, thermosphere, mesosphere, composition, dynamics  
Keywords: quasi-two day wave, ionosphere, thermosphere, mesosphere, composition, dynamics

## Simultaneous observation of planetary waves in the mesosphere and ionosphere Simultaneous observation of planetary waves in the mesosphere and ionosphere

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How variations of the neutral atmosphere, in particular planetary wave activity in the mesosphere-lower thermosphere (MLT), drive variations in the ionosphere has been the subject of recent attention. A method has been developed to observe planetary wave activity in the northern hemisphere (50-66° N) MLT using neutral atmosphere winds derived from meteor trail drifts observed by a longitudinal chain of Super Dual Auroral Radar Network (SuperDARN) radars. The method allows for the removal of tidal effects and provides the temporal variation of the wavenumber 1 and 2 amplitudes without the spatial-temporal aliasing present in satellite observations. The method has been extended to utilize the critical plasma frequency and virtual height of the ionospheric F-layer derived from a longitudinal chain of ionosondes. Details of the method applied to both the meteor radar and ionosonde data will be presented, and the amplitudes and temporal variations of the wavenumber 1 and 2 amplitudes in both the MLT and the F region will be compared.

キーワード: Planetary wave, Mesosphere, Lower Thermosphere, Ionosphere  
Keywords: Planetary wave, Mesosphere, Lower Thermosphere, Ionosphere

## Ground-based mesopause temperatures at high-latitude over Yakutia: Comparison with SABER measurements Ground-based mesopause temperatures at high-latitude over Yakutia: Comparison with SABER measurements

AMMOSOVA, Anastasia<sup>1\*</sup> ; AMMOSOV, Petr<sup>1</sup> ; GAVRILYEVA, Galina<sup>1</sup> ; KOLTOVSKOI, Igor<sup>1</sup>  
AMMOSOVA, Anastasia<sup>1\*</sup> ; AMMOSOV, Petr<sup>1</sup> ; GAVRILYEVA, Galina<sup>1</sup> ; KOLTOVSKOI, Igor<sup>1</sup>

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Ground-based mesopause temperature at high-latitude over Yakutia: Comparison with SABER measurements

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Rotational temperatures obtained from the O<sub>2</sub> Atmospheric (0?1) nightglow band, with an infrared spectrograph at the Maimaga station (63 N, 129.5 E) for the period September 2002 to March 2013 are presented. Time series includes the years of maximum and minimum solar activity. The set of spectrograph data has been used to analyze the seasonal behaviour of the mesopause temperatures. Atmospheric temperatures deduced from infrared spectrograph and from satellite observations with the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument on board the TIMED satellite, have also been compared.

The temperatures measured during the satellite passes at distances not larger than 300 km from the intersection of the spectrograph sighting line with the oxygen emitting layer (~94 km) have been compared. A seasonal dependence is observed regarding the difference between the ground based and satellite measurements. However, the time variations in the temperature obtained with the ground based device and on the satellite are similar. Based on the performed analysis, it has been concluded that a series of oxygen rotational temperatures can be used to study temperature variations on different time scales, including long-term trends at the temperature emission altitude (~94 km).

キーワード: mesopause temperature, O<sub>2</sub> airglow, SABER measurements

Keywords: mesopause temperature, O<sub>2</sub> airglow, SABER measurements

## All-sky measurements of short period waves nightglow emissions All-sky measurements of short period waves nightglow emissions

KOLTOVSKOI, Igor<sup>1\*</sup> ; AMMOSOV, Petr<sup>1</sup> ; GAVRILYEVA, Galina<sup>1</sup> ; AMMOSOVA, Anastasia<sup>1</sup>  
KOLTOVSKOI, Igor<sup>1\*</sup> ; AMMOSOV, Petr<sup>1</sup> ; GAVRILYEVA, Galina<sup>1</sup> ; AMMOSOVA, Anastasia<sup>1</sup>

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Will present the results of statistical analysis of the parameters of internal gravity waves registered on the variations of emission hydroxyl molecule. Wave patterns registered infrared all-sky camera installed on the optical station Maimaga (Yakutia). Analyzed data received during the winter period 2008-2013. 118 waves were registered, most of which propagated in a westerly direction. For the wave length range from 15 - 70 km (average value is - 29km) observed horizontal phase velocity varies from 17 to 140.8 m / s (average is -57m / s) and the estimated periods are within 7-40 min (the average is - 9min). Statistical characteristics of the waves do not differ from the results of the registration of such waves at middle and low latitudes. The azimuthal distribution of the direction of wave propagation is consistent with the theory of filtering background wind waves in the middle atmosphere. Probable sources of waves are assumed to mountain ranges, located 200 km to the east of the place of observation. There are a few large values of the average wavelength and wave propagation velocity than those registered at lower latitudes. Apparently, this is due to lower energy loss and wave velocity in passing from the source to the mesosphere, although not excluded for other reasons.

It is planned to identify all-sky measurements of short period waves in the green emission recording OI (557,7 nm) in the visible wavelength of the spectrum (the height of the airglow ~96 km). Will present the results of observations at two different heights (~87 and 97 km).

キーワード: internal gravity waves, mesosphere, hydroxyl

Keywords: internal gravity waves, mesosphere, hydroxyl

## リチウム放出実験による昼間および月夜の熱圏中性大気風プロファイル Thermospheric neutral wind profile in daytime and moonlit midnight by Lithium release experiments

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阿部 琢美<sup>5</sup>; パフ ロバート<sup>6</sup>

YAMAMOTO, Masa-yuki<sup>1\*</sup>; KIHARA, Daiki<sup>1</sup>; KAKINAMI, Yoshihiro<sup>1</sup>; WATANABE, Shigeto<sup>2</sup>; LARSEN, Miguel<sup>3</sup>;  
YAMAMOTO, Mamoru<sup>4</sup>; HABU, Hiroto<sup>5</sup>; ABE, Takumi<sup>5</sup>; PFAFF, Robert<sup>6</sup>

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Neutral wind profiles were observed in lower thermosphere at about between 90 km and 130 km altitude by using resonance scattering light of sunlit and moonlit Lithium (Li) vapor released from sounding rockets in daytime and midnight (almost full moon condition) in 2013. As a target of the Daytime Dynamo campaign, Li release experiment was operated at Wallops Flight Facility (WFF) of NASA, U.S.A. in July, 2013, while the same kind of experiment in midnight was carried out in Uchinoura Space Center (USC) of JAXA, Japan also in July 2013. Since imaging signal-to-noise (S/N) condition of the both experiments was so severe, we conducted to apply airborne observation for Li tracers imaging so as to reduce the illuminating intensity of background skies as an order of magnitude.

Two independent methods for calculating the wind profile were applied to the image sequences obtained by the airborne imaging by special Li imagers aboard the airplanes in order to derive precise information of Li tracers motion under the condition of single observation site moving along the aircraft path in the lower stratosphere. Slight feedback motion of the aircraft 3-axes attitude changes (rolling, yawing and pitching) was considered for obtaining precise coordinates on each snapshot. Another approach is giving a simple mathematic function for wind profile to resolve the shape displacement of the imaged Li tracers. As a result, a wind profile in daytime thermosphere was calculated in a range between 20 and 95 m/s with some fluctuated parts possibly disturbed by wind shears. In this paper, we will introduce the method of wind profile calculation and final result of the profiles.

キーワード: 熱圏, 中性大気風プロファイル, リチウム放出, 航空機観測, 手法, 観測ロケット

Keywords: Thermosphere, Neutral wind profile, Lithium release, Airborne observation, Method, Sounding rocket

## Atmospheric dynamics InfraStructure in Europe: The ARISE project Atmospheric dynamics InfraStructure in Europe: The ARISE project

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There is currently a lack of observations, data and model parameters, which are needed in weather and climate models. ARISE is an EU-funded infrastructure project (FP7 2012-2014 and H2020 2015-2018) with a long-term objective to fill this gap and solve persistent problems facing the applications which depend on atmospheric dynamics. The atmosphere is a dynamic medium being continuously disturbed by winds and atmospheric waves over a broad range of time and spatial scales. Disturbances include large-scale waves such as gravity and planetary waves which transfer energy and momentum from one region of the atmosphere to another. Atmospheric extreme events such as volcanoes, stratospheric warming events, magnetic storms, tornadoes and tropical thunderstorms also constitute significant disturbances to atmospheric dynamics.

The ARISE project aims at establishing a unique atmospheric research and data platform in Europe and outlying regions, including the polar and equatorial regions. It will combine observations with theoretical and modelling studies to elucidate the dynamics of the middle and upper atmosphere. For the first time, several technologies (infrasound, lidar, airglow, radars, ionospheric observations and satellites) will be used simultaneously and in a complementary way. The measurements will be used to improve the parameterization of gravity waves in the stratosphere to better resolve climate models. Such description is crucial to estimate the impact of stratospheric climate forcing on the troposphere. The collected data are required to improve weather forecasting to monthly or seasonal scales, remote volcano monitoring, climate monitoring and other applications. The ARISE data portal aims to provide high-quality, easy-to-use data and advanced data products to a wide scientific community.

キーワード: atmospheric dynamics, infrasound, gravity waves, planetary waves, weather forecasting, climate monitoring  
Keywords: atmospheric dynamics, infrasound, gravity waves, planetary waves, weather forecasting, climate monitoring



## Observation of Ozone concentration relation to meteors echo duration distributions by a forward scattering radar Observation of Ozone concentration relation to meteors echo duration distributions by a forward scattering radar

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Several studies have concluded the existence of secondary maxima of ozone concentration at the mesospheric level of 85-90 km. At this level in atmosphere, meteor radio observations shows a consistent lack of long overdense echoes with certain durations where the number of meteor echoes drops for what is known as the 'knee' position. As the lack of long meteor echoes was significantly greater than being only a result of ambipolar diffusion, some studies linked this drop to ozone concentration in the meteor region. Baggley and Cummack (1974) suggested the drop to be the result of oxidation of meteors ions by the secondary maxima of ozone layer which causes the removal of ionization and consequently unreflected radio signals. Jones et. al (1990) and Cevolani and Pupillo (2003) supported this conclusion by analyzing meteor echoes duration distributions and determining approximately the height of meteor echoes at the knee point based on visual magnitude levels.

At Kochi University of Technology (KUT) we attempted to observe the knee position in selected meteor showers. The 5 channel HRO interferometer radar developed at KUT utilizes forward scattering of 53.75 MHz continuous radio signals emitted from Sabae station, Fukui prefecture, Japan (Fukui National College of Technology: FNCT) at a distance of 340 km from Kochi prefecture. The software HROFFT (Ham-band Radio meteor Observation Fast Fourier Transform) generates spectrogram images for meteor echoes in 10 minute intervals. These images are used by the developed auto counting software Meteor echo counter through image processing to automatically count meteor echoes and their durations. The critical duration  $T$  at which the drop occurs in long echoes counts can be indicative about the Ozone concentration by the relation derived by McIntosh and Hajduk (1977):  $O_3 = (\alpha T)^{-1}$ . As currently there is no developed mechanism for meteor height determination at KUT, the scope is focused on the analysis of meteor echoes duration, detection of the knee point and then finally comparing the ozone concentration measurements to the results of similar studies.

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キーワード: Ozone concentration, meteors, forward scattering, radar, mesosphere

Keywords: Ozone concentration, meteors, forward scattering, radar, mesosphere

## 南極昭和基地大型大気レーダーによる極域中間圏エコーと銀河電波吸収の同時観測 Simultaneous observations of polar mesosphere winter echoes (PMWE) and Cosmic Noise Absorption (CNA) by the PANSY radar

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In the lower thermosphere at the altitude of around 100 km, both neutral turbulence and ionization of atmosphere due to solar radiations cause irregularities of refractive index, and as a result back scatter echoes from that altitude are frequently observed by radars on the ground. In the mesosphere, Polar Mesosphere Summer Echo (PMSE) is reported to be a strong echo associated with ice particles, which are produced around the coldest mesopause region in the polar summer, by a number of past radar observations [Cho and Röttger, 1997; Rapp and Luebken, 2004]. It should be also noted that occurrence rate of PMSE is very high (80-90%) [Bremer et al., 2003]. On the other hand, Polar Mesosphere Winter Echo (PMWE) is also known as back scatter echo from 55 to 85 km in the mesosphere, and it has been observed by MST and IS radar in polar region during winter [e.g., Ecklund and Balsley, 1981; Czechowsky et al., 1989; Luebken et al., 2006; Strelnikova and Rapp, 2013]. Due to the lack of free electrons and ice particles in the dark and warm mesosphere during winter, it is suggested that PMWE requires strong ionization of neutral atmosphere associated with precipitations of Solar Energetic Particles (SEPs) during geomagnetically disturbed periods [Kirkwood et al., 2002; Zeller et al., 2006]. However, the detailed generation process of PMWE has not been identified yet, partly because the reported PMWE occurrence rate was quite low (2.9%) [Zeller et al., 2006].

We present occurrence characteristics of PMWE from June 2012 to October 2013 and its relation to Solar Energetic Particles. When PMWE was detected by the PANSY (Program of the Antarctic Syowa MST/IS) radar, highly energetic particle precipitations, either protons or electrons, were frequently observed by NOAA satellite particle measurements above Syowa Station. During the SPE that occurred in May 23, 2013 PMWE and a significant Cosmic Noise Absorption (CNA) of about 1 dB were simultaneously detected by the PANSY radar. MF radar also showed Isolated Lower Mesosphere Echo (ILME) at the same time [Morris et al., 2011], suggesting enhancement of electron density in ionospheric D-regions. Moreover, occurrence of PMWE was likely related to the flux of precipitating electrons in the medium energy range (30-300 keV) during recovery phase of geomagnetic storms. We would like to show correlations between PMWE and CNA using dataset for mesospheric observation mode.

キーワード: 冬季極域中間圏エコー, 高エネルギー降下粒子, 電離圏 D 領域, 大気乱流, 銀河電波吸収, 南極昭和基地大型大気レーダー

Keywords: Polar Mesosphere Winter Echo, Energetic Particle Precipitation, Ionospheric D-region, Trubulence, Cosmic Noise Absorption, the PANSY radar

## 南極昭和基地 (69S) 上空の高度 65-110km における大気重力波活動度 Gravity wave activity in a wide height range of 65-110km over Syowa st. (69S), Antarc- tica

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There are very small number of ground-based observation techniques in the lower thermosphere, especially above around 100 km, although the region is a pronounced transition region in terms of the thermal structure, chemistry and dynamics. Radio meteor echo measurement in a low radio frequency such as MF is a possibility of atmosphere observation above 100 km. We have applied a meteor wind measurement technique, which is widely used in VHF, to MF radar systems, and have successfully obtained meteor winds up to 120 km altitude [Tsutsumi et al, 1999; Tsutsumi and Aso, 2005]. The technique was applied to the MF radar at Syowa station, Antarctica and meteor winds have been continuously obtained since May 1999, simultaneously with conventional correlation based wind measurements in the mesosphere.

In this study we try to estimate seasonal behavior of gravity wave activity over Syowa in a wide height range from 65 to 110km using the accumulated 16 years of data. Gravity wave activity is estimated in two ways. One is a commonly used wave variance estimation technique based on time series of wind velocities [e.g., Vincent, 1994]. Hourly mean winds are used for the purpose in the present study. The other is a recently developed technique by Mitchel and Beldon [2009], where residuals after the hourly mean wind estimation are used as a proxy of short period wave activity. The former and the latter correspond to wave periods longer and shorter than about two hours, respectively. Obtained wave activities show a broad winter time maximum and summer time minimum in both wave periods, which is consistent with previous results in the mesosphere over Antarctica [Dowdy et al.,2007]. We further found that wave activities above 100 km are enhanced in late summer to early winter in both wave periods, which has not been known so far. Details of these features are discussed in the presentation.

キーワード: 大気重力波, 中間圏・下部熱圏, 南極, MF レーダー, 昭和基地  
Keywords: atmospheric gravity waves, mesosphere and lower thermosphere, Antarctica, MF radar, Syowa station

## Variability of the Equatorial Ionization Anomaly on seasonal and day to day time scales Variability of the Equatorial Ionization Anomaly on seasonal and day to day time scales

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The Equatorial Ionization Anomaly (EIA) is a persistent feature of the F layer, around 300 km altitude in the thermosphere, generated by the E-region dynamo driven equatorial fountain. When the EIA is present, electron densities on either side of the magnetic equator will become much higher during the local afternoon times. In our study we want to quantify short term EIA variability due to atmospheric, solar, and geophysical sources. Short-term anomalies in EIA region total electron content (TEC) from GPS-derived global ionosphere maps (GIM) at 105 degree West longitude are compared to anomalies in three different geophysical sources: solar flux (F10.7 solar flux proxy), geomagnetic storms (Kp index), and atmospheric zonal winds near the semidiurnal tidal peak at northern mid-latitudes (GAIA assimilative general circulation model). We present spectral and coherence analysis of EIA TECs and the aforementioned geophysical indices in 2008 and 2012, to illustrate the variability on seasonal and day to day time scales. The variability of the F10.7 solar flux proxy is dominated by 23-27 day periodicities. The Kp index indicates significant 9 day periodicities in 2008 for entire year, though 2012 is dominated by significant variations with 9-13 day periods during equinox and 5-7 day periods during boreal summer. F10.7 and Kp index both demonstrate good coherence with EIA TECs during specific seasons. With regard to the neutral zonal winds, TECs at the equator show good coherence with 100 km mid-latitude zonal winds in the same longitude region at specific planetary wave periods during the certain local times, suggesting modulation of the E-region dynamo.

キーワード: Equatorial Ionization Anomaly, ionosphere, mid-latitude, planetary wave, Kp index, E-region dynamo  
Keywords: Equatorial Ionization Anomaly, ionosphere, mid-latitude, planetary wave, Kp index, E-region dynamo

## Topside Ionospheric Plasma Temperatures Retrieved From FORMOSAT-3/COSMIC Observations

### Topside Ionospheric Plasma Temperatures Retrieved From FORMOSAT-3/COSMIC Observations

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Bottom-side ionospheric electron profiles now can be well-determined thanks to mature development of ground-based instruments, such as ionosonde, or incoherent radar. However, the topside ionosphere, located above the F2 layer peak to the exobase (from 200~400 km to 600~1000km, depending on solar activity) is still not well understood. Previously, the electron density distribution and plasma temperatures in the topside ionosphere could only be measured by incoherent scatter radar, in-situ sounding rocket, or certain satellite instruments, making it hard to draw a global map of electron density and plasma temperatures in the topside ionosphere. FORMOSAT-3/ Constellation Observing System for Meteorology, Ionosphere, and Climate (F3/C) using the GPS radio occultation method (GPS-RO) now can give us great opportunities to determine the global electron density profiles above the F2 layer peak. We also present results showing how the plasma temperatures may be estimated from such GPS-RO observations.

This study first examines the structure and variability of electron densities in topside ionosphere. Seasonal F3/C observations will first be assimilated into a gridded model in latitude, longitude, altitude, and local time. The resulting vertical profiles at each gridpoint will then be used to infer the vertical scale height of the topside ionosphere. Next, we retrieved the seasonal and local-time variabilities of topside plasma temperature from the scale height of topside ionospheric electron densities. This is one of the first times that topside plasma temperatures can be globally determined using remote sensing techniques.

キーワード: Ionosphere, Topside ionosphere, Plasma temperature, Formosa-3/COSMIC  
Keywords: Ionosphere, Topside ionosphere, Plasma temperature, Formosa-3/COSMIC

## リアルタイム GPS-TEC3次元トモグラフィの開発 Development of real-time three-dimensional GPS-TEC tomography

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Recently, a new three-dimensional GPS ionospheric tomography technique is developed which uses total electron content (TEC) data from the dense GPS receiver network, GPS Earth Observation Network (GEONET) in Japan. It uses the least squares fitting method constrained by the spatial gradient, and does not require an ionospheric model as the initial guess that could bias the reconstruction of electron density. But it refers to the NeQuick model to determine constrained parameters. The purpose of this study is to develop this technique and incorporate into the real-time GPS-TEC monitoring system. First we increase the computation speed by using a sparse matrix algorithm when solving the least squares fitting method. Programmed with Python, it takes less than 5 minutes to calculate a tomography by using 1.7GHz Intel Core i7. We could also improve the stability of the calculation. Furthermore we try to find a new method for determining the constrained parameters by analyzing a large amount data. As the tomography uses absolute TEC, it is necessarily to estimate instrumental delay bias which is originated in the hardware of the GPS satellite and receiver. We develop the bias estimation procedure that uses RINEX-OBS data of the previous day. Organizing these parts, we develop a system to conduct three-dimensional tomography analysis in the real-time basis.

キーワード: ジオネット, 全電子数, トモグラフィ, 疎行列, リアルタイムシステム  
Keywords: GEONET, TEC, tomography, sparse matrix, real-time system

## 中間圏重力波観測用低廉大気光カメラの性能評価 Performance evaluation of low-cost airglow camera for mesospheric gravity wave measurements

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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 a low-cost airglow camera to enlarge the airglow imaging network (Optical Mesosphere and Thermosphere Imagers: OMTIs) operated by the Solar-Terrestrial Environment Laboratory, Nagoya University. This camera 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 OMTI cameras, but has a highly sensitive CCD sensor with 768 x 494 pixels. OH airglow emissions are imaged at intervals of 4 sec with 4-sec exposure.

In this presentation, we will report some results of performance evaluation of this camera based on test observations at Shigaraki (35-deg N, 136-deg E), Japan, where is one of the OMTI station. By summing 15-images (i.e., 1-min composition of the images) we recognized clear gravity wave patterns in the images with comparable quality to the OMTI's image.

**The FORMOSAT-3/COSMIC Radio Occultation Data Assimilated to NCAR/TIE-GCM to study the horizontal winds in the ionosphere**  
**The FORMOSAT-3/COSMIC Radio Occultation Data Assimilated to NCAR/TIE-GCM to study the horizontal winds in the ionosphere**

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The NCAR Thermosphere-Ionosphere Electrodynamics General Circulation Model (TIE-GCM) is a self-consistently electrodynamic-coupled thermosphere and ionosphere model subjected by a few parameters and boundary conditions. The migrating tidal waves are parameterized with the amplitudes and phases of the diurnal and semidiurnal tidal waves (Hough modes) as the forcing sources to modulate the TIE-GCM at the lower boundary. We constructed a data assimilation method to assimilate the FORMOSAT-3/COSMIC (F3/C) occultation total electron content (OTEC) observations to the Model with the optimal parameters of the TIE-GCM. The assimilated OTEC of the F3/C data could modulate the ionospheric electron densities, the neutral winds and the temperatures in the TIE-GCM due to the optimal parameters of the Hough modes. The horizontal wind in the assimilated model will be compared with the observations with ground based and the space-borne instruments (TIDI data).

キーワード: ionosphere, thermosphere, FORMOSAT-3/COSMIC radio occultation data, data assimilation  
Keywords: ionosphere, thermosphere, FORMOSAT-3/COSMIC radio occultation data, data assimilation



## Periodic variations in the thermospheric density Periodic variations in the thermospheric density

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We examined the periodic variation of thermosphere in this study using the thermospheric total mass density at 400km altitude derived from more than 5000 flying objects during 1967-2013, and also those measured by the accelerometer aboard the CHAMP satellite during 2001-2010. Among the periodic variations, we found a prominent 2-3 year period. Correlation of this density variation with QBO and ENSO indices are carried out to investigate possible lower atmosphere driver of this thermosphere variability.

キーワード: thermosphere

Keywords: thermosphere

## Kyushu-GCM 及び 準 3 次元ダイナモモデルを用いた Ultra Fast Kelvin 波による Equatorial Electro Jet 変動の評価 Evaluation of EEJ variation due to Ultra Fast Kelvin Waves using the Kyushu-GCM and the Quasi-3D dynamo model

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Sq 電流系と Equatorial Electro Jet (EEJ: 赤道ジェット電流) は、Kyushu-GCM(Yoshikawa and Miyahara 2003, 2005) の中性風データと準 3 次元ダイナモモデルを使用することにより、それらの電流観測値の日々変化とほぼ整合性のある計算値を示すことができた (Kawano-Sasaki and Miyahara 2008, Aramaki 2012: 修士論文)。

また Kyushu-GCM データ内のケルビン波解析 (Chen and Miyahara 2012) では対流圏を励起源とする Ultra Fast Kelvin (UFK) 波 (東西波数 1, 周期 2.5 - 4 日) が、赤道上空 高度 約 100 km の中間圏・下部熱圏 (MLT) 領域で卓越しており、大気力学場に影響を及ぼしていること、また UFK 波の振幅は、約 10 日間周期で変動していることが示された。

そこで、本研究は、Kyushu-GCM (Yoshikawa and Miyahara 2003, 2005) の風速データより抽出し再合成した UFK 波の中性風データと赤道反対称成分も記述できる準 3 次元ダイナモモデル (Aramaki 2012: 修士論文) を使用して、UFK 波変動による EEJ 変動への寄与の程度を定量的に評価した。

結論として、UFK 波変動は EEJ の日々変動に寄与しており、Kyushu-GCM のオリジナル中性風による EEJ 電流値の 1 ヶ月分標準偏差の比較により、シミュレートされた赤道上空東向きの強い EEJ 電流値の日々変動の 25% は、UFK 波の日々変動によるものと見積もる事ができた。更に統合的な解析結果と詳細な評価等は大会会場にて公表する予定である。

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キーワード: 赤道ジェット電流, Ultrafast Kelvin 波, Kyushu-GCM, 準 3 次元ダイナモモデル  
Keywords: Equatorial Electro Jet, Ultra Fast Kelvin wave, the Kyushu-GCM, the quasi-3D dynamo model

## 大気電場と地磁気日変化の関連 The relationship between the electric field in the lower atmosphere and Sq variations

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The vertical atmospheric electric field ( $E_z$ ) variations depend on the state of the global electric circuit. Geomagnetic phenomena can influence  $E_z$  through ionospheric disturbances [e.g. Kleimenova, 2008]. The daily quiet geomagnetic field variations (Sq variations) are mainly caused by electric field currents flowing in the E region of the ionosphere. It is likely that Sq variations are relevant to  $E_z$  variations. In this study, we aim to investigate the relationship between  $E_z$  and Sq variations at a low-latitude station. We analyzed the  $E_z$  and ground magnetic field data (H) at KAK (G.G. Lat.: 36.2 N, G.G. Lon.: 140.2 E) station during 2006 - 2014. The data was provided by the Kakioka Magnetic Observatory of the Japan Meteorological Agency. In here, we adopt the same definition for Sq amplitudes as defined by Yamazaki et al. [2010]. The daily amplitude of the Sq variation is derived by subtracting nighttime (22-24 LT and 00-02 LT) H values from daytime H (peak) values. Similarly, we calculated the daily  $E_z$  variation. The daytime  $E_z$  values were selected at the time when daytime H values show their peaks. The obtained Sq and  $E_z$  variations show annual and semi-annual variations. The annual variations are clearly seen every year, becoming the smaller values in winter. The semi-annual variations in  $E_z$  are clear in 2011 and 2014. As just described, we found similarities between Sq and  $E_z$  variations in several respects and, therefore, conclude that the  $E_z$  variations depend on the condition of the ionosphere.

キーワード: 大気電場, 地上磁場

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