Evidence of lower atmospheric influences/coupling in midlatitude long-term mesopause-region temperatures

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An unique midlatitude noctunal mesopause-region temperatures resulting from 25 years of Na lidar observations at Colorado State University and Utah State University reveals influences of tropospheric and/or stratospheric forcing. These includes signals of Mt. Pinatubo eruption and El Nino Southern Oscillation, as well as altitude-dependent (wave-like structures) responses to the 11-year and 27-day solar flux variability. Though the cause for these intriguing signals is not yet known, publications in 2015 by colleagues elsewhere have also shown similar effects in temperatures from satellite data.

Keywords: Mesopause temperatures, Lower atmospheric influences, 25 years Na lidar observation

Strong long-term cooling of the ionosphere observed by multiple incoherent scatter radars

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Compelling evidence for long-term changes in the upper atmosphere over the last several solar cycles has emergedfollowing a seminal modeling study by Roble and Dickson (1989), suggesting potential effects of increasedgreenhouse gases on the ionosphere and thermosphere. Direct measurements of the cooling trend come from in situ neutral density data available since 1960s, and from ground-based incoherent scatter radar (ISR) plasma temperature data available systematically at Millstone Hill (42.6N 288.5) since the late 1960s and elsewhere since the later years. Other observations also seem to show indirectly signs of the cooling which are not alwaysconsistent. However, the cool intensity from ISR data appear much more significant than expected from effects ofanthropogenic increases in the CO2 mixing ratio, as initially suggested by Millstone Hill data. We have now examined furth the strong cooling with additional new datasets of ISRs: the Sondrestrom (67.0N, 309.1E) ISR(1990-), which is typically located at cusp during the day, as well as Chatanika/Poker Flat (65.1N, 212.6E) ISRs(1976-) which is often considered as an aurora latitude site. New analyses of these observations continue toindicate strong ionospheric cooling, therefore imposing an important question as to what is really driving theselong-term changes in the upper atmosphere. We will make comparisons of these ISR results from mid- and highlatitudes, and discuss potential drivers for the unexpected strong cooling in the ionosphere.

Keywords: long-term change, ionosphere, incoherent scatter radar

Behaviour of the semi-diurnal tidal modes in the MLT using the SuperDARN meteor-radar chain

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Atmospheric tides in the mesosphere and lower thermosphere (MLT) have been shown to couple to the ionosphere, and may themselves be enhanced by the Joule heating associated with energetic particle precipitation. However, studies have shown that the efficiency of this coupling to and from the ionosphere depends on the spatial mode of the tides. While individual stations can provide accurate information on the temporal evolution of the tides, they do not allow the different spatial modes to be separated. Similarly, satellite observations can determine the spatial modes, but alias temporal changes in tidal amplitude and structure. A method has been developed to observe the spatial structure of atmospheric tides in the northern hemisphere (50^{o}-66^{o} 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 tidal amplitudes determined at each radar station in the chain can be combined to infer the zonal wavenumber 1 and 2 structure of the tide and its temporal evolution without the spatial-temporal aliasing present in satellite observations. Details of the method applied to the meteor radar data will be presented, and the amplitudes and temporal variations of the wavenumber 1 and 2 components of the semi-diurnal tide in the MLT will be examined during stratospheric warming and particle precipitation events.

Keywords: Dynamics, Tides, coupling

Coupling process among the mesosphere, thermosphere and ionosphere elucidated by the ISS-IMAP mission

Coupling process among the mesosphere, thermosphere and ionosphere elucidated by the ISS-IMAP mission

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ISS-IMAP (Ionosphere, Mesosphere, upper Atmosphere, and Plasmasphere mapping) mission was installed on the Exposed Facility of Japanese Experiment Module of the International Space Station, EF of ISS-JEM, and consisted of two sets of imagers to observe the structures in the Mesosphere, Thermosphere and Ionosphere (MTI) region. Visible-light and infrared spectrum imager (VISI) of ISS-IMAP observed the airglow of 730nm (OH, Alt. 85km), 762nm (O2, Alt. 95km), and 630nm (O, Alt. 250km) in the MTI region, and Extra ultraviolet imager (EUVI) observed the resonant scattering of 30.4nm (He+) and 83.4nm (O+) from ion in the Ionosphere and Plasmasphere. ISS-IMAP was operated from 2012 to 2015. VISI elucidated global distributions of the airglow structures whose scale size is 50-500km in he nightside. The wavy structures that are interpreted to be generated by atmospheric wave were frequently observed. Some of them showed clear relationship with tropospheric phenomena as its source. EUVI elucidated global distributions of He ion. Its seasonal distribution indicates the thermospheric wind dominates the ion distribution of the topside ionosphere and the plasmasphere. Coupling processes among the MTI region and the lower atmosphere will be discussed in the presentation.

キーワード：電離圏、熱圏、大気光
Keywords: Ionosphere, Thermosphere, airglow

3-years Occurrence Variability of Concentric Gravity Waves in the Mesopause Observed by IMAP/VISI

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We report the first statistical study on concentric gravity waves (CGWs) in the mesopause by using 3 years data obtained by IMAP/VISI. 235 CGWs events were found with horizontal wavelength ranging from 40 to 250 km and maximum radius of 200 to 3000 km. Occurrence of the CGWs was significantly higher during non-solstice months (February-May and August-November) than solstice months (June-July and December-January), suggesting low to moderate wind are preferable for CGWs upward propagation. The latitudinal distribution of the CGWs centers had peaks in mid latitude (40°N and 40°S) and minimum at low latitude (10°S). More events were found in the summer hemisphere mid-latitudes, with a clear transition between north and south hemisphere around equinoxes. The information of the preferable regions seen in the global distribution map and the seasonal distribution could be useful for region and seasonal selection of CGWs' future studies.

Keywords: Concentric gravity wave, O2 nightglow emission, Mesopause

A numerical study of the effects of migrating tides on thermosphere midnight density maximum

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We employed the NCAR Thermosphere Ionosphere Electrodynamics General Circulation Model (TIEGCM) and the extended Canadian Middle Atmosphere Model (eCMAM) to investigate the role of the migrating terdiurnal tide on the formation and variation of the thermosphere midnight temperature maximum (MTM) and midnight mass density maximum (MDM). The migrating terdiurnal tide from the eCMAM was applied at the TIEGCM's lower boundary, along with the migrating diurnal and semidiurnal tides from the *Global Scale Wave Model (*GSWM). Several numerical experiments with different combinations of tidal forcing at the TIEGCM's lower boundary were carried out to determine the contribution of each tide to MTM/MDM. We found that the interplay between diurnal, semidiurnal and terdiurnal tides determines the formation of MTM/MDM and their structure in the upper thermosphere. The decrease of thermospheric mass density after MDM reaches its maximum at ~02:00 local time is mainly controlled by the terdiurnal tide. Furthermore, we examined the generation mechanisms of the migrating terdiurnal tide in the upper thermosphere and found that they come from three sources: upward propagation from the lower thermosphere, in-situ generation via nonlinear interaction and thermal excitation.

Keywords: thermosphere, midnight density maximum, migrating tides

Ionospheric Effects of Strong El Niño Southern Oscillation Conditions

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The occurrence of a very strong positive phase in the El Nino Southern Oscillation (ENSO) in late 2015 has had effects on weather around the entire planet. Furthermore, recent investigations show that ENSO-related changes in tropospheric water vapor and rainfall drive significant changes in the temperature and wind structure in the middle atmosphere, through the modification of the spectrum of atmospheric tides. Given that several components of the tidal spectrum can propagate into the thermosphere, ENSO-related changes at altitudes above the mesopause and into the ionosphere may be expected. Based upon historical events in 1997 and 1998, we will show the ionospheric and thermospheric variations one may expect for El Ni\~no and La Ni\~na conditions. We will also show middle atmosphere conditions measured by the NASA TIMED SABER instrument for the 2015-2016 event. These efforts are enabled in part by modeling capabilities developed for the upcoming NASA Ionospheric Connection Explorer mission.

Keywords: El Niño, Atmospheric physics, ionosphere, thermosphere

Impact of tidal variability on the mean state of the ionosphere and thermosphere during sudden stratosphere warmings

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Observations from the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) satellites reveal a global reduction in the zonal and diurnal mean F-region peak electron density (NmF2) during sudden stratosphere warmings (SSWs). In the present study we investigate the source of the global NmF2 decrease using Thermosphere-Ionosphere-Mesosphere-Electrodynamics General Circulation Model (TIME-GCM) and Thermosphere-Ionosphere-Electrodynamics Global Circulation Model (TIE-GCM) simulations. The TIME-GCM simulations demonstrate that the reduction in the mean NmF2 coincides with an [O]/[N2] decrease, indicating that changes in thermosphere composition during SSWs drive the decrease in NmF2. To understand the source of the [O]/[N2] variability, we perform numerical experiments in the TIE-GCM using different forcing conditions at the model lower boundary (~97 km). The numerical experiments illustrate that variability in the migrating semidiurnal solar tide (SW2) during SSWs drives the changes in thermosphere composition. In particular, the enhancement of the SW2 during SSWs appears to alter the mean circulation in the MLT, leading to a reduction in atomic oxygen throughout the thermosphere. The results demonstrate that, in addition to modulating the low latitude electrodynamics, tidal variability during SSWs significantly impacts the mean state of the ionosphere and thermosphere.

Keywords: sudden stratosphere warming, ionosphere variability, thermosphere composition

Global Responses of Gravity Waves to Planetary Wave Variations during SSWs Observed by SABER

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This study describes the global responses of observed gravity waves (GWs) to winter planetary wave (PW) variations during stratospheric sudden warmings (SSWs) using TIMED-SABER temperature measurements. Previous studies have shown responses of atmospheric temperature and parameterized GW drag to SSWs; however, the responses of actual global GW observations to SSWs have not been presented before. The responses are shown by calculating correlations between vertical components of Eliassen-Palm (EP) fluxes in the winter polar stratosphere and global GW temperature amplitudes derived from SABER observations. Consistent with previous ground-based and satellite observations, winter EP fluxes show positive correlations with GWs in the winter hemisphere. More interestingly, winter stratospheric EP fluxes are positively correlated with GWs in the tropics and in the summer mesosphere, indicating global variations of GWs in response to PW variations in the winter hemisphere. To study the mechanism of GW response to SSWs, global wind simulations from SD-WACCM are used. Zonal wind anomalies (differences in the wind before and during SSWs) extend from the winter stratosphere to the summer mesosphere. By comparing anomalies in background winds to the observed patterns in the correlations between GWs and winter EP fluxes, we find that regions of positive correlation follow changes in background winds and zero-wind lines. The results indicate that responses of SABER GWs in the summer hemisphere to winter PW variations during SSWs are likely caused by changes in GW propagation due to the changes in winds and atmospheric circulation. These observed changes in global GWs during SSWs can affect the ionosphere and thermosphere, and studying global GW variation during SSWs is important for understanding mechanisms of vertical coupling.

Keywords: Inter-hemispheric Coupling, Gravity Wave, Stratospheric Sudden Warming

大気圏電離圏の長期シミュレーションを用いた成層圏昇温時の超高層大気変動の研究
Tidal variabilities and their effects on the upper atmosphere during stratospheric sudden warmings studied with a long-term whole atmosphere-ionosphere simulation

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Recent studies have revealed that large-scale phenomena in the lower atmosphere have significant impacts on the upper atmosphere. For example, during the period of a prominent stratospheric sudden warming (SSW) in January 2009, the low latitude ionosphere was observed to perturb significantly. In previous study, we have simulated the event using a whole atmosphere-ionosphere coupled model called GAIA which implemented the meteorological reanalysis data in order to examine the effects of realistic lower atmospheric forcing. The model can reproduce overall main features in the middle and upper atmospheric variations during the SSW event, and the analysis suggests that the upward propagating planetary wave in the polar region can change not only global zonal wind distribution but also propagation of atmospheric tides, which leads to the perturbation of low latitude ionosphere [Jin et al., JGR, 2012]. In this study, we have carried out a longer run from 1996 to 2014, and analyzed statistically the effects of stratospheric sudden warmings on the upper atmosphere. We especially discuss the role of migrating tides in detail.

キーワード：成層圏突然昇温、大気潮汐、電離圏、熱圏、シミュレーション、モデリング
Keywords: stratospheric sudden warming, atmospheric tide, ionosphere, thermosphere, simulation, modeling

Quasi Two Day Wave Response in the Ionosphere Using TIME-GCM Nudged with NOGAPS-ALPHA

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The quasi two day wave (QTDW) is a planetary wave that can be enhanced rapidly to extremely large amplitudes in the mesosphere and lower thermosphere (MLT) region during the northern winter post-solstice period. The dissipation of the planetary wave can change the background dynamics and the composition of MLT. This feature can also drive robust variability of the ionosphere system, for example, the total electron content (TEC).
In this study, we present five January case studies of QTDW events (2005, 2006, 2008, 2009, 2010) by using the Thermosphere-Ionosphere-Mesosphere Electrodynamics-General Circulation Model(TIME-GCM) nudged with the Navy Operational Global Atmospheric Prediction System-Advanced Level Physics High Altitude (NOGAPS-ALPHA) Weather Forecast Model. With NOGAPS-ALPHA introducing a more realistic lower atmospheric forcing in TIME-GCM, we can investigate ionosphere system coupling with the MLT region when dramatic features associated with the QTDW occur in middle atmosphere. This work opens a new method to evaluate the physical mechanism of ionospheric coupling from below during QTDW events.

Keywords: Data Assimilation, Quasi Two Day Wave, TIME-GCM, NOGAPS-ALPHA, Ionosphere

Mesospheric, thermospheric, and ionospheric responses to acoustic and gravity waves at large amplitudes and small scales

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Acoustic and gravity waves (AGWs) are routinely observed in the Earth's mesosphere, lower thermosphere, and ionosphere (MLTI) from ground and space based platforms via remote sensing of mesospheric airglow intensity and ionospheric total electron content (TEC). Recent data from imagers and GPS receivers provide key insight into wave disturbances to the MLTI at high resolution above their respective sources, which include natural hazard events, orographic forcing, and tropospheric convection [e.g., Galvan et al., RS, 47(4), 2012; Nishioka et al., GRL, 40(21), 2013; Fritts et al., BAMS, 2015; Miller et al., PNAS, 112(49), 2015]. Gravity waves with short periods (~minutes) and small scales (~tens to hundreds of kilometers) may carry sufficient momentum to have very strong and localized effects on the state of the MLTI [Fritts et al., JGR, 119(24), 2014]. Evidence also suggests nonlinear impacts of acoustic waves (with periods ~minutes) in the ionosphere and thermosphere, for example as indicated by measured TEC depletions following the Tohoku 2011 earthquake [e.g., Kakinami et al., GRL, 39(13), 2012]; simulations by Zettergren and Snively [AGU FM, NH32C-02, 2015] also support this interpretation.
We investigate the observable features of acoustic and gravity waves at large amplitudes that can strongly perturb multiple layers of the MLTI system. New high-resolution, nonlinear, compressible, atmospheric dynamics models are used to drive airglow photochemical and ionospheric models [e.g., Snively, GRL, 40(20), 2013; Zettergren and Snively, JGR, 120(9), 2015]. Results elucidate the underlying dynamics of nonlinear short-period wave disturbances, in addition to the responses of both the mesospheric airglow and thermosphere-ionosphere systems to enable direct comparisons with data (airglow imagery and TEC). Modeling also reveals that apparently coherent AGWs, at large amplitudes consistent with observations, may have strong localized impacts that may (or may not) be readily observable. Observations and modeling of dynamics spanning multiple layers in the MLTI system may provide new insight into wave coupling processes, the evolutions of broad wave spectra, and wave effects over short time scales.

Keywords: Acoustic and Gravity Waves, Airglow, Ionosphere, Mesosphere and Lower Thermosphere

台風時の電離圏変動と大気変動との相関

Relationship between ionospheric and atmospheric perturbations associated with typhoons

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It is known that ionospheric disturbances are caused by extreme weather conditions, such as tornadoes and typhoons. In this study, we have examined the relationship between ionospheric and atmospheric disturbances caused by typhoons, using HF doppler (HFD) and a microbarometer. HFD observation system used in this study is maintained by The University of Electro-Communications (UEC). The receiver is located at Sugadaira, Nagano Prefecture and the transmitters are located at Chofu Campus of UEC and Nagara, Chiba Prefecture. The microbarometer is also located at Sugadaira, Nagano Prefecture. In examining typhoons which came closer to Japan since 2004, we have found ionospheric perturbations associated with 8 typhoons. In almost events, the amplitude of the doppler shift is about several hertz, which is much less than the cases for earthquakes. By dynamic spectral analyses, it is found that spectral intensity of both of ionospheric and atmospheric perturbations at frequency from 5 mHz to 50 mHz were enhanced. These results imply that the effect of the typhoon to the ionosphere is quite smaller and that the atmospheric waves propagated to the ionosphere drive the ionospheric perturbations. In this study, as a typical example, the perturbations asssociated with Typhoon WIPHA (No.18 in 2013) at 30 mHz are examined in detail. This is because the wind direction in the transmitter (Chofu), the receiver (Sugadaira), and the middle point (Chofu) is quite stable (eastward) when Typhoon WIPHA was closest to Japan for several tens of hours. The temporal variation of the spectral intensity of ionospheric perturbation is almost the same as the wind speed at Sugadaira, where is the windward of Chofu. This result shows that the ionospheric perturbations associated with typhoons is affected by the atmospheric perturbations windwardly below the ionosphere.

キーワード：電離圏擾乱、大気変動、台風、HFドップラー、微気圧
Keywords: Ionospheric perturbation, Atmospheric perturbation, Typhoon, HF Doppler, Microbarometer

高分解能版GAIAで得られた熱圏重力波のふるまいについて
Behavior of Gravity waves in the thermosphere simulated by high resolution GAIA

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It has been recognized that gravity waves play an important role on the momentum and energy balance in the thermosphere. The effects of upward propagating gravity waves on the general circulation of the thermosphere are studied using a whole atmosphere-ionosphere coupled model (GAIA). The GAIA contains the region from the ground surface to the upper thermosphere (about 500km altitude), so that we can simulate excitation of gravity waves in the lower atmosphere and their upward propagation to the thermosphere. The high horizontal resolution of the neutral atmospheric part of GAIA is about 0.5 degree longitude by 0.5 degree latitude, and this model can simulate wide ranges of gravity waves in their thermosphere. In this study, we focus our attention on gravity wave activity in the winter thermosphere. Our simulation result indicates that some of gravity waves in the winter thermosphere is originated from the polar night jet in the stratosphere/mesosphere. Moreover, the impacts of thermospheric gravity waves on variability in the ionosphere are investigated.

キーワード：大気上下結合、大気波動
Keywords: vertical coupling processes, atmospheric waves

衛星観測及び全大気モデルデータに基づく中間圏・下部熱圏の運動量収支解析

An analysis on the momentum budget in the MLT region based on satellite and whole atmosphere model data

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中層大気には重力波・潮汐波・ロスビー波の大気波動が卓越しており、これらの波と大規模場が相互作用することで、放射平衡とは異なる気候場を形成している。しかし、これら全ての波を含めた中層大気（特に中間圏および下部熱圏（MLT））の運動量収支はまだ十分解明されていないのが現状である。そこで本研究では、MLT領域における運動量収支と各波動成分の寄与を明らかにするため、衛星観測データと全大気モデルデータを用いた詳細な解析を行なった。ここで、大気内部における負の北向き渦位勾配（順圧・傾圧不安定の必要条件）の形成に関するロスビー波と重力波の共働にも着目した。解析は、東西平均子午面断面における各月のクライマトロジーを中心に行なった。衛星観測データとしては、Aura MLSの気温とジオポテンシャルハイト（MLSデータ）を、全大気モデルデータとしては、中性大気モデルと電離大気モデルを結合させたGAIAモデルの中性大気のデータ（GAIAデータ）を用いた。解析期間は、2004年8月8日～2015年6月19日の約11年である。
まず、MLSデータの解析を行なった。両半球とも、夏半球中間圏の低緯度から中緯度にかけてと、冬半球中間圏の高緯度に、渦位（PV）の絶対値の極大（渦位極大）が存在することがわかった。この渦位極大の極側には、順圧・傾圧不安定の必要条件（等温位面におけるPVの北向き勾配が負; PVy < 0）を満たす領域が存在する。東西平均からの偏差を擾乱とし、この擾乱に伴うEPフラックス（EPF）とEPフラックス発散（EPFD）を計算したところ、特に夏半球中間圏において渦位極大領域の上で強い上向きのEPFが見られることが確認できた。さらに、EPFDが正、PVyが負となる頻度の分布はよく対応することがわかった。この特徴は、中間圏の渦位極大から上向きにロスビー波が放射されていることを示唆する。
次に、GAIAデータを用いて成層圏～下部熱圏の運動量収支解析を行なった。まず、MLSデータの解析結果との比較により、GAIAモデルが現実的な場を再現していることを確認した。そこで、EPFを潮汐波成分・ロスビー波成分・重力波成分に分けて解析した。
ロスビー波成分については、夏半球中間圏のPVyが負となる領域においてEPFDが正となっていた。この正のEPFD域より上の領域で見られる強い上向き・赤道向きEPFは下部熱圏まで達していた。次に、この上向きEPFを伴う波の構造を調べた。ジオポテンシャルのスペクトル解析を行なったところ、周期約1.8日、東西波数s = 2～4の西向き伝播波が卓越することがわかった。これは、観測でよく知られている準2日波の特徴とよく一致する。また、PVy < 0の上の領域から強い上向き・赤道向きEPFが見られる特徴は、この波が傾圧・順圧不安定により発生したことを示唆する。
次に、重力波成分については、MLT領域において、EPFDは全体的に夏半球で正、冬半球では負であった。EPFの向きから夏半球では東向き、冬半球では西向き伝播波が卓越していることがわかった。夏半球のMLT領域での、東向き伝播を示す下向きEPFはPVyが負の領域の上で特に大きくなっていた。そこでこの領域でのリチャードソン数（Ri）を調べたところ、1/4以下となる頻度が高いことがわかった。これは、この東向き重力波がシア不安定によって発生した可能性を示唆する。
ロスビー波成分、重力波成分、潮汐波成分をあわせた解像されるすべての波強制は、MLT領域において夏半球で主に正、冬半球では負であり、重力波成分の寄与が大きいことがわかった。
この研究で用いたGAIAモデルの水平分解能は粗いため、サブグリッドスケールの重力波による強制（GWFP）はパラメタリゼーションにより組み入れられている。GWFPの大きさは、両半球とも中間圏上部高度約90 km付近で極大となっていた。また、MLT領域においてGWFPは卓越する高度域がやや異なるが、大きさとしてはモデルで解像される全波動によるEPFDと同程度であることがわかった。
最後に、GWFPとPVyが負の領域との関係について詳しい解析を行なった。まず、GWFPは夏半球中間圏で低緯度と高緯度に東向きのピークを、冬半球中間圏で西向きのピークを持ち、これらのピークは渦位極大と対応してい

た。また渦位極大は、冬半球ではN^2の、夏半球ではN^2と相対渦度ζ_θの両方の増大が寄与していることがわかった。さらに本研究では、より直接的にGWFPによる渦位の時間変化を見積もった。この解析により、GWFPが渦位極大を形成するように働いていることが明らかになった。

キーワード：中層大気、ロスビー波、重力波、順圧・傾圧不安定、運動量収支
Keywords: Middle atmosphere, Rossby wave, Gravity wave, Barotropic / baroclinic instability, Momentum budget

Terahertz Limb Sounder for Lower Thermosphere Wind, Temperature, and Atomic Oxygen Density Measurements

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In this paper, we present the concept of a high-sensitivity heterodyne spectrometer operating at 2.0 Terahertz (THz) for global lower thermospheric neutral wind, temperature and atomic oxygen density measurements from a low earth orbit. The instrument, THz Limb Sounder (TLS) is aimed to provide, for the first time, global neutral wind/temperature/density profile measurements globally during day and night, with focus at altitudes of 100-150 km where most of the ion-neutral energy/momentum couplings take place. TLS is an ambient-temperature Schottky diode based all solid-state heterodyne spectrometer designed to extend the limb sounding technique employed by Microwave Limb Sounder for density/temperature/wind measurements by measuring the Doppler line shape of atomic oxygen (OI) fine structure emission at 2.06THz. This atomic oxygen line emission is very bright and distributed nearly uniformly globally (at all latitudes including highly spatially structured aurora particle precipitation regions) and temporally (at all local times during both day, night, and twilight), thus ideal for thermospheric remote sensing. The instrument concept, measurement methodology, receiver performance, and the expected measurement capability will be presented and discussed in this paper.

Keywords: Lower Thermosphere Wind, Temperature, and Density, Remote Sensing Technique and Instrument, TeraHz Spectrometer

A review on recent upper atmosphere atomic oxygen measurements

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Atomic oxygen is a key player in upper mesosphere and lower thermosphere chemistry, energy balance, and vertical as well as global coupling. In recent years, a few new global datasets of this species have been presented. They are based on airglow measurements from low earth orbit satellites. Surprisingly, the atomic oxygen abundance differs by 30-50% for similar atmospheric conditions. This paper gives an overview on the various atomic oxygen datasets available so far and presents most recent results obtained from measurements of the SCIAMACHY instrument on Envisat. Differences between the datasets are discussed.

Keywords: atomic oxygen, mesosphere, thermosphere, coupling, energy balance

Double Crests of Peak Height in the Equatorial Ionospheric F2 Layer Observed by COSMIC

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For the first time, we report daytime double crests of peak height (hmF2) in the F2 layer based on the COSMIC observations during 2007-2014. Evident double crests of hmF2 occurred at around ±10° geomagnetic latitude (MLAT) with a trough over the magnetic equator at low solar activity and at March equinox. This phenomenon is referred to as an Equatorial Height Anomaly (EHA) of the ionospheric F2 layer. The double crests became less obvious at September equinox and disappeared at solstices. At solstices only one crest was observed in the summer hemisphere, which is probably associated with trans-equatorial neutral winds. In addition, the double EHA crests generally take place during 10:00-14:00 local times. Our results indicate that the EHA favors the conditions of strong vertical plasma drifts and weak trans-equatorial neutral winds during low solar activity. The EHA feature is reproduced by the TIEGCM at March equinox and low solar activity.

Keywords: F2 layer peak height, Latitudinal variation, Equatorial anomaly, Ionospheric ceiling

Local time evolution and longitudinal difference of equatorial ionization anomaly in the low-latitude topside ionosphere

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The latitudinal structure of topside ion density (N_i) was investigated in detail based on the N_i observations of the ROCSAT-1 and DMSP satellites. EIA double-peak structure can exist at 600 km, depending on longitude, local time, season, and solar activity, while it cannot extend up to 840 km even in the case of the strong fountain effect at solar maximum sunset. The complete local time evolution of the EIA at 600 km was presented. The double-peak structure begins to appear at noontime, being later than the appearance of the EIA in F_2-peak region. The pronounced EIA induced by the strong prereversal enhancement at solar maximum begins to appear at 19:00 LT and can last to pre-midnight; and EIA crest-to-trough ratio (*CTR*) reaches a maximum at 20:00 LT, with the largest (lowest) *CTR* at March equinox (June solstice). EIA structure shows evident longitudinal difference. Pronounced EIA exists around about 100°E at 13:00 LT at the two equinoxes and June solstice, while it exists at more extensive longitudes (about 90°E to 240°E) at December solstice. The trans-equator plasma transport induced by neutral winds can weaken the double-peak structure in the topside ionosphere. The longitudinal difference in the EIA structure at 600 km is related to the longitudinal variations of equatorial upward plasma drift and geomagnetic declination.

Keywords: Low-latitude Ionosphere, Topside Ionosphere, Equatorial Ionization Anomaly

GEONET GPS-TECに基づく実時間電離圏3次元トモグラフィー
Realtime 3D tomography of the ionosphere based on GEONET GPS-TEC

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Measurement of ionospheric total electron content (TEC) by using the ground-based GPS receivers is now widely used. We refer to it as GPS-TEC. As there are always several GPS satellites available for the measurement, it is a very good tool for constant monitoring of the ionosphere. One of the most dense and wide network of the GPS network is GEONET operated by Geospatial Information Authority of Japan (GSI). This is the network of more than 1200 points over Japan. We have been developing 3D tomography of the ionospheric plasma density from the GEONET data. This tomography technique uses a constrained least squares fit to reconstruct the electron density distributions. Recently we further develop the software system to conduct the GPS-TEC analysis in the realtime basis. In this system we collect “every second” GPS data from GEONET, estimate satellite and receiver biases for true TEC measurement, and obtain 3D tomography reconstruction of the ionosphere every 15 minutes with 10 minutes latency. We will show current status of the 3D tomography analysis and the realtime system.

キーワード：3次元トモグラフィ、GPS 全電子数、GEONET、実時間電離圏モニタリング
Keywords: 3D tomography, GPS TEC, GEONET, Realtime ionosphere monitoring

Extremely large longitudinal variation of ionospheric bubble generation and its possible relationship with ITCZ

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A close link between the atmospheric inter-tropical convergence zone (ITCZ) and ionospheric plasma bubble has been proposed since the last century. But this relationship has often appeared to be less than convincing due to the simultaneous roles played by several other factors, most importantly by the evening pre-reversal enhancement of eastward electric field (PRE) and its associated velocity shear, in shaping the global distribution of ionospheric bubbles. From simultaneous collaborative radar multi-beam steering measurements at Kototabang (0.2°S, 100.3°E) and Sanya (18.4°N, 109.6°E), conducted during September-October of 2012 and 2013, we find that there exists extremely large longitudinal variation in bubble generation but not in bubble occurrence. The total numbers of nights with bubble (i.e., occurrence rates) over the two stations are comparable, but the total number of nights with locally generated bubble (i.e., generation rate) over Kototabang is clearly more than that over Sanya. Further analysis reveals that a more active ITCZ is situated around the longitude of Kototabang. Considering that the two stations are separated only by 9.3° in longitude where the magnetic declination and the magnetic equator offset from the geographic equator are almost the same, the enhanced ionospheric bubble generation over Kototabang may be explained by upward propagating gravity waves (GWs) which could be generated frequently in the more active ITCZ and provide the seeding source for bubble development.

Keywords: ionospheric plasma bubble, atmospheric inter-tropical convergence zone, gravity wave

Equinoctial asymmetry in the east-west distribution of scintillation occurrence observed by GPS receivers in Indonesia

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We used GPS receivers installed in Pontianak (0.02°S, 109.3°E; 9.8°S mag. Lat.) and Bandung (6.9°S, 107.6°E; 16.7°S mag. Lat), Indonesia to observe azimuthal dependence of GPS-L1 scintillation occurrence rate. Crest of the equatorial anomaly region is located between both sites. We focus on analyzing east-west distribution of scintillation occurrences in equinox months. We collected scintillation data as indicated by S_4 index from those receivers for March and September from 2011 to 2015. Our findings statistically emphasized that scintillation occurrence rate is higher in the westward direction than that in eastward direction in March equinox. This east-west difference of scintillation occurrence is more distinct in March equinox than September equinox. In September equinox, the occurrence rate is almost comparable between westward and eastward direction. We can speculate that the equinoctial asymmetry in east-west distribution of scintillation occurrence could be likely caused by westward tilt of plasma bubble extending to higher altitudes/latitude, and that the plasma bubbles are more tilted westward in March equinox than in September equinox. We have analyzed zonal irregularity drift velocity observed by closely-spaced GPS receivers at Kototabang (0.2°S, 100.3°E; 9.9°S mag. Lat.), Indonesia for the same observation period. The results showed that eastward drift velocity decreases with increasing magnetic latitudes, and that the latitudinal gradient of eastward drift in March equinox is larger than in September equinox. Additionally, we used in-situ measurement of zonal wind velocity at ~400 km of altitude by CHAMP satellite in March and September from 2001 to 2005 for longitude 95-105°E. We found that latitudinal eastward wind velocity also show decrease of the magnitude with the increasing magnetic latitudes. The latitudinal gradient of eastward wind in March is larger than the latitudinal gradient in September. Thus, in March equinox, the large latitudinal gradient of irregularity drift and eastward wind velocity could be responsible for further westward tilt of plasma bubble extending to higher altitudes/latitudes. Consequently, the equinoctial asymmetry of east-west distribution of scintillation could be caused by the equinoctial asymmetry of tilted westward structure of plasma bubble.

Keywords: equatorial ionosphere, plasma bubble, irregularity, scintillation, equinoctial asymmetry, coupling neutral-plasma

Multiple excitation of large-scale traveling atmospheric disturbances (TADs) by solar wind 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 excite gravity waves in the auroral regions. These gravity waves, particularly large-scale (> ~1000 km) gravity waves, will give rise to traveling atmospheric disturbances (TADs) with typical amplitudes of 20~40% in the upper thermosphere. We report here the detection of multiple excitation of large-scale TADs by Alfvén waves embedded in high-speed solar wind streams, and also by interacting coronal mass ejections.

Keywords: solar wind fluctuations, gravity waves, thermosphere

A link between high-speed solar wind streams and extratropical cyclones

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Databases of extratropical-cyclone tracks obtained from two meteorological reanalysis datasets are used in superposed epoch analysis of time series of solar wind plasma parameters and green-coronal emission line intensity. The time series are keyed to times of maximum growth of explosively developing extratropical cyclones during northern and southern winters. The new statistical evidence corroborates the previously published results (Prikryl et al., Ann. Geophys., 27, 1-30, 2009). This evidence shows that explosive extratropical cyclones tend to occur after arrivals of solar wind disturbances such as high-speed solar wind streams from coronal holes when large amplitude magneto-hydrodynamic waves couple to the magnetosphere-ionosphere system. These MHD waves modulate Joule heating and/or Lorentz forcing of the high-latitude thermosphere generating medium-scale atmospheric gravity waves. Ray tracing of aurorally-generated gravity waves show that the gravity waves propagate upward and downward through the atmosphere. Simulations of gravity wave propagation in a model atmosphere using the Transfer Function Model (TFM) (Mayr et al., Space Sci. Rev., 54, 297–375, 1990) show that propagating waves originating in the thermosphere can excite a spectrum of gravity waves in the lower atmosphere. At the tropospheric level, in spite of significantly reduced amplitudes, they can provide a lift of unstable air to release the moist symmetric instability thus initiating slantwise convection and forming cloud/precipitation bands (Prikryl et al., Ann. Geophys., 27, 31-57, 2009). The release of latent heat is known to provide energy for rapid development and intensification of extratropical cyclones.
Since 2009, Japan Meteorological Agency has archived detailed annual reports on calamitous severe weather events occurring nation-wide (http://www.jma.go.jp/jma/menu/menureport.html). The starting dates of the events attributed to low pressure systems are used as key times in the superposed epoch analysis of solar wind plasma parameters and green solar corona intensity. It is observed that the events of heavy rain or snow, strong wind and high ocean waves caused by low pressure storms, particularly in winter, tend to follow arrivals of high-speed solar wind. This is consistent with the statistical evidence based on the study of explosive extratropical cyclones in relation to solar wind.

Keywords: High-speed solar wind streams, Atmospheric gravity waves, Extratropical cyclones

PANSYレーダーおよびMFレーダーを用いた南極域中間圏エコーの性質の研究
Characteristics of mesosphere echoes over Antarctica obtained using PANSY and MF radars

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In the polar region characteristic radar echoes are observed from the mesosphere by using a VHF system. The nature of the echoes is distinctively different between summer and winter and those echoes are called Polar Mesosphere Summer Echoes (PMSEs) and Polar Mesosphere Winter Echoes (PMWEs), respectively. Since the PMSEs are usually very strong and can be easily measured with a small radar system, their nature is relatively well understood. On the other hand PMWEs are much weaker and they are still only poorly understood.
The PANSY radar (47MHz) at Syowa station (69S) is the only large aperture atmospheric radar in the Antarctic, and can continuously survey the dynamics of the middle atmosphere with high time and height resolutions [Sato et al., 2014]. Nishiyama et al [2014] reported the first study of PMWEs using PANSY radar and showed a seasonal and local time dependence of these echoes.
An MF radar system (2.4MHz) is co-located at Syowa, and has been operating for mesosphere and lower thermosphere observations. Although the MF radar has only a much poorer height resolution and is incapable of vertical wind measurement, it can almost continuously measure mesosphere day and night.
In this study the nature of the mesosphere echoes, mainly PMWEs, are being studied using the two radars based on the observation made in 2015. These radars are operated using largely different radio frequencies and can provide complementary information with each other such as wind velocities and also echo scattering mechanisms.
Horizontal wind velocities have been compared between the two radars with a great care mostly in the MF radar winds in order to avoid possible biases inherent in the correlation analysis technique employed for the MF radar wind measurement. A careful analysis has shown that the horizontal wind velocities agree well between the two systems with a high correlation coefficient around 0.8 throughout the height region of 65-85km.
Aspect sensitivities estimated using the MF radar data indicate that the winter time MF echoes in the lower mesosphere are more isotropic in winter than in summer, suggesting that the winter echoes are scattered by isotropic turbulences. A candidate that generates such isotropic structures is thought to be gravity waves, whose activity in the Antarctic mesosphere is maximized in winter [Dowdy et al., 2007; Yasui et al., 2016]. The height region of the low aspect sensitivity mostly corresponds to that of PMWEs, and this further suggests a possible connection between PMWEs and gravity wave activity. Aspect sensitivities based on the PANSY data are also to be analyzed and presented.

キーワード：南極、極中間圏冬季エコー、MSTレーダー、大気重力波
Keywords: Antarctic, PMWEs, MST radar, atmospheric gravity waves

Gravity Wave Instability Dynamics in Mesospheric Stratification and Shear Environments

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An anelastic numerical model is used to explore gravity wave instability dynamics in variable stratification and shear environments in the mesosphere and lower thermosphere (MLT). Recent computational advances facilitate the characterization of localized gravity wave packets in a deep atmosphere, enabling realistic amplitude evolution and enhanced sensitivity to transient nonlinear dynamics. The results reveal that gravity wave packets impinging on a sheet of high stratification and shear enable local Kelvin-Helmholtz instabilities (KHI) where gravity wave vertical displacements approach their maxima and mean and gravity wave shears combine. The KHI arise at smaller scales and evolve to larger scales with time, as seen in lidar, radar, and airglow observations. Such events tend to be highly localized and thus yield local energy and momentum deposition expected to have strong influences throughout the mesosphere, thermosphere, and ionosphere (MTI) region. These simulations illuminate one of the major mechanisms driving turbulence and mixing in the MLT at scales that are challenging or impossible to describe quantitatively with existing measurement capabilities.

Keywords: Atmospheric Gravity Waves, Gravity Wave Instability Dynamics

Equatorial Atmospheric Kelvin Waves during 2014-2016 El Niño episodes andtheir effect on Stratospheric QBO

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Equatorial atmospheric Kelvin waves are investigated during positive El Niño Southern Oscillation (ENSO) episodes using temperature data retrieved from GPS Radio Occultation (RO) observations of FORMOSAT-3/COSMIC 5 during the period from August 2006 to April 2016. Enhanced Kelvin wave activity is observed during the El Niño episodes of 2010 and 2014-2016 and it is also observed that the Kelvin wave amplitudes correlate with the Niño 3.4 index and also with outgoing longwave radiation and trade wind index. This study indicates that the enhanced equatorial atmospheric Kelvin wave activity might be produced by geophysical processes that were involved in the onset and development of the El Niño episode. Further, easterly winds above the tropopause during this period favoured the vertically upward propagation of these waves that induced a fast descending westerly regime by the end of 2010 but showing different behaviors during 2014-2016 period.The current study presents observational evidence of enhanced Kelvin wave activity during El Niño that has affected the stratospheric quasi-biennial oscillation (QBO) through wave-mean flow interactions. Detailed comparison between the ENSO episodes of 2010 and 2014-2016 will be investigated in this study.

Keywords: El Niño Southern Oscillation , quasi-biennial oscillation (QBO)

Analysis of the Distribution and Controlling Factors in the Atmospheric Gravity Wave Potential Energy

Analysis of the Distribution and Controlling Factors in the Atmospheric Gravity Wave Potential Energy

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In the past years, global morphology and climatology of gravity waves have been widely studied and the effects of topography and convection systems have been evaluated, but the complete gravity wave distribution could not be explained by these effects. To find the missing controlling factors, a series of synoptic scale analyses is performed in the present study to investigate relationships between synoptic scale factors and potential energy (E_p) associated with gravity waves. Global distribution of E_p during a 12-year period from 2002 to 2013 is derived using temperature profiles retrieved from observations of Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument onboard the Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) satellite. Synoptic scale factors obtained from ECMWF Interim reanalysis data are employed to investigate the correlation between synoptic systems and E_p. It is found that E_p values are high around extratropical cyclones over mid-latitudes (30° –60°) and around the Intertropical Convergence Zone (ITCZ) over low-latitudes (10° –30°). E_p values are low around subtropical highs over both mid- and low-latitudes. This is the first time that a synoptic scale analysis of E_p distribution is performed, and the influence of synoptic scale factors on E_p confirmed.

キーワード：gravity waves、potential energy、synoptic scale factors、TIMED/SABER
Keywords: gravity waves, potential energy, synoptic scale factors, TIMED/SABER

昭和基地レイリー/ラマンライダーライダー観測を用いた高度15-70kmの重力波活動の高度・季節変動の研究

Study of vertical / seasonal variation of gravity wave in the height range of 15-70km over Syowa Station in Antarctica using Rayleigh/Raman lidar

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下層大気で発生した重力波は上方伝播し、中層大気へ運動量・エネルギーを輸送する。その効果は、中層大気の水平平均風を変化させ、大規模子午面循環を引き起こし、中層大気の鉛直気温プロファイルを大きく変化させることが定性的に理解されている[Lindzen, 1981; Holton, 1982; Matsuno, 1982]。しかし、現在でも重力波の水平平均風への定量的寄与は理解が不十分である。そのため、国立極地研究所は南極昭和基地(69°S, 40°E)にレイリー/ラマン(RR)ライダーを設置し、2011年2月から高度約5-80kmの気温観測を行い、重力波による気温擾乱を観測している。2014年10月終わりまでに350晩以上の観測を行っており現在も観測を継続している。
本研究では、昭和基地上空の高度15-70kmの月平均ポテンシャルエネルギー（*Ep*）を2011年5月から2013年10月まで（11、12、1月を除く）求めた。高度35-70kmの活動度は、昭和基地に近いDavis基地(69°S, 78°E)でレイリーライダー観測を行った先行研究[Alexanderetal.2011]と類似した冬極大の季節変動が見られた。同様に高度35km以下でも晩秋(5月)に活動度が上昇するのが見られた。しかし、高度35-70 kmと異なり晩冬(9月)に活動度が下がらなかった。月平均*Ep*の高度変化については期間全体を通して、高度30 km以上では高度と共に指数関数的に増加し（増加率はおおむねexp(z/2H); H~7 km はスケールハイト）、高度30 km以下では25 km付近に極小、20 km付近に極大を持つことがわかった。しかし、2012年10月の月平均*Ep*プロファイルはこれとは異なり、高度40-45kmに極小を持つ高度変化を示していた。全球気象再解析データ（NASA/MERRA）による昭和基地上空の東西風の季節変化と、観測で得られた月平均Epの高度分布の関係を調べた結果、2012年10月のプロファイルが異なる理由は、東西風が弱い高度域が下りてくる速度が他の年に比べて早かったことが原因だと考えられる。

キーワード：重力波、中層大気、ライダー
Keywords: gravity wave, middle atmosphere, lidar

GAIA モデルを用いた成層圏突然昇温後に伴う下部熱圏温度全球平均値下降現象に於ける潮汐波の鉛直熱輸送寄与の評価

Evaluation of Global Mean Temperature Cooling in lower thermosphere just after Stratospheric Sudden Warming due to Tidal wave's vertical thermal advection using GAIA model

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日本気象学会2015春季大会に於いて宮原三郎九州大学名誉教授と陳穎雯JAMSTEC博士研究員は「成層圏突然昇温（SSW）に伴う下部熱圏全球平均温度変動:Kyushu-GCMによる解析」について報告した．その解析結果によるとSSW直後の下部熱圏全球平均温度下降の５０％程度はsemi-diurnal tide(東西波数２)波動擾乱の鉛直熱輸送によると示された．
Kyushu-GCM は高度150 km までの大循環モデルである．更に上層の下部熱圏で前述の解析結果を検証するために高度500km までを表現できるGAIA(75層)モデルを用いて潮汐波擾乱によるSSW後の下部熱圏全球平均温度下降に対する寄与について解析を行なった．高度200kmまでの温度下降は semi-diurnal tide(東西波数2)擾乱による冷却が卓越しておりKyushu-GCMの場合と同様のことを結論付けることができる．
併し高度200km以上になるとsemi-diurnal tide 擾乱は冷却に働くがdiurnal tide(東西波数1)擾乱は加熱に働く．Migrating tide擾乱全体でも加熱に働き、SSW直後の下部熱圏全球平均温度下降を潮汐擾乱の鉛直熱輸送では説明できない．Non-Migrating Tide は冷却にも加熱にも寄与していない．Waltersheid (1981)は内部重力波擾乱の鉛直熱輸送により冷却効果が下部熱圏で働いていることを理論的に示した．
従って高度200 km 以上では下部熱圏全球平均温度下降は多くの重力波によるものである可能性を示唆している．GAIA(75層)は鉛直解像度が Kyushu-GCM(250層)に比べ低いので大会会場では GAIA(150層)の解析結果についても報告する予定である．

キーワード：成層圏突然昇温、大気潮汐波、GAIA model
Keywords: Stratospheric Sudden Warming, Atmospheric Tidal Wave, GAIA model

インドネシアに設置された2台の流星レーダーを用いた運動量フラックスの測定法について
Measurement of momentum flux Using two meteor radars in Indonesia

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Two nearly identical meteor radars were operated at Koto Tabang (0.20°S, 100.32°E), western Sumatra, and Biak (1.17°S, 136,10°E), western Papua in Indonesia, separated by approximately 4,000 km in longitude on the equator. The zonal and meridional momentum flux, $u'w'$ and $v'w'$, where u, v and w are the eastward, northward and vertical wind velocity components, respectively, were estimated at 86 to 94 km altitudes using the meteor radar data by applying a method proposed by Hocking [2005]. The observed $u'w'$ at the two sites agreed reasonably well at 86, 90 and 94 km during the observation periods when the data acquisition rate was sufficiently large enough. Variations of $v'w'$ was consistent between 86, 90 and 94 km altitudes at both sites. The climatological variation of the monthly averaged $u'w'$ and $v'w'$ was investigated using the long-term radar data at Koto Tabang from November 2002 to November 2013. The seasonal variations of $u'w'$ and $v'w'$ showed a repeatable semiannual and annual cycles, respectively. $u'w'$ showed eastward values in February-April and July-September, and $v'w'$ was northward in June to August at 90-94 km, which were generally anti-phase with the mean zonal and meridional winds, having the same periodicity. Our results suggest the usefulness of the Hocking method.

キーワード：流星レーダー、運動量フラックス、中間圏・下部熱圏、Hocking法、赤道、半年周期変動
Keywords: Meteor radar, Momentum flux, Mesosphere and lower thermosphere, Hocking method, Equator, Semi-annual variation

ポーカーフ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の半日周期変動
Tidal modulation of mesospheric gravity waves observed with MF radar at Poker Flat, and Tromsø

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アラスカ・ポーカーフ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、短周期重力波活動の半日周期変動と半日潮汐波を含む背景場の関係について詳細に調べる。
まず、これまで行ってきた解析と同様、水平風速データから重力波と潮汐波の抽出を行う。ここで、潮汐波は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。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各月ごとに10年分計算した結果、ポーカーフラットでは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に変わる時、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（IUGG2015）。この現象の物理メカニズムを考察した結果、夏季のポーカーフラットで見られた関係以外、重力波のクリティカルレベルフィルタリングによる減衰・砕波により説明できることが示された。今後は、夏季のポーカーフラットで見られたGW-KEと半日潮汐との位相関係及び、GW-KEの日周期成分においてクリティカルレベルフィルタリングでは説明できない現象ついてさらに解析を進め、物理メカニズムを議論したい。

キーワード：大気重力波、大気潮汐、中間圏
Keywords: Atmospheric Gravity Wave, Atmospheric Tide, Mesosphere

Recent Progress on Advanced Ionospheric Probe Onboard FORMOSAT-5 Satellite

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Advanced Ionospheric Probe (AIP) is a piggyback science payload developed by National Central University for FORMOSAT-5 satellite since 12 January 2012. The AIP is an all-in-one plasma sensor to measure ionospheric plasma concentrations, velocities, or temperatures in a time-sharing way. Meanwhile, the AIP is capable of measuring ionospheric plasma irregularities with sampling rate up to 8,192 Hz over a wide range of spatial scales. Electroformed gold grids used in the AIP can reduce quasi-hysteresis effect on current-voltage curves in a plasma injection test and approximate ideal electrical potential surfaces for accurate data available in the future. The AIP flight model has passed through preliminary and critical design review, functional and environmental tests, and then was delivered to the NSPO on 8 October 2013. It is scheduled to launch into a low Earth orbit on a Falcon 9 rocket manufactured by Space Exploration Technologies Corp. from Vandenberg Air Force Base in the 2nd quarter 2016 to carry out a two-year scientific mission on space weather and seismic precursors. At the beginning the AIP will be routinely operated within ±75° latitude in the night-side sector to meet a 5-W limit in average power per orbit due to high power consumption and a heat dissipation issue. Up to 1.5 gigabits per day in data storage, the AIP is capable to perform 8,192 electric current readings per second with duty cycle under 10% to resolve fine structure of equatorial ionospheric plasma irregularities within ±18° latitude.

Keywords: AIP, FORMOSAT-5, Ionosphere

Conjugate observations of low-latitude travelling ionospheric disturbances by a 630-nm airglow imager at Indonesia and the CHAMP satellite

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We report the first comparison of ground and satellite measurements of equatorial travelling ionospheric disturbances (TIDs) by using a 630-nm airglow imager and the CHAMP satellite. The airglow images are obtained at Kototabang (KTB), Indonesia (geographic coordinates: 0.2S, 100.3E, geomagnetic latitude: 10.6S), during a 7-year period from October 2002 to October 2009. Only three TID events with ground and satellite conjugate measurements are found on April 30, 2006 (event 1), September 28, 2006 (event 2) and April 12, 2004 (event 3). All three events were southward-moving structures in 630-nm airglow images. The events 1 and 2 are single pulse with horizontal scales of ~500-1000 km. The event 3 show three wave fronts with horizontal scale size of 500-700 km. For event 2, the neutral density shows in-phase variations with the airglow intensity. However for events 1 and 3, they are out of phase. The relation between electron density and airglow intensity is out of phase for event 1, while their relationship are unclear for event 2 and 3, suggesting that ionospheric plasma variation is not the cause of the observed TID. If the TIDs are caused by gravity waves in the thermosphere, in and out of phase relationships between neutral density at an altitude of 400 km at CHAMP and airglow layer at 250 km, should depend on the vertical wavelength of the gravity wave, which is highly affected by background wind. We estimate possible vertical wavelengths for those events to explain the observed phase relationships between neutral density and airglow intensity.

Keywords: Travelling Ionospheric Disturbances, CHAMP, Airglow Imager

The Occultation TEC Assimilated to NCAR/TIE-GCM to Simulate the Ionosphere During the Storm Time

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We will construct a data assimilation model with the Thermosphere-Ionosphere Electrodynamics General Circulation Model (TIE-GCM) for the ionosphere by assimilating the FORMOSAT-3 occultation total electron contents (OTEC). The TIE-GCM was developed by NCAR/HAO is a self-consistently electrodynamics coupled thermosphere and ionosphere model subjected by a few parameters with the lower and upper boundary conditions to describe the dynamics of the ionosphere and the thermosphere. The measured occultation total electron contents (OTEC) along the light path from GPS to LEO satellites could be assimilated with the TIE-GCM as a realistic model for the space weather in the ionosphere. We assimilated the FORMOSAT-3 OTEC data with TIE-GCM to optimize the parameters for atmospheric tides at lower boundary used in the model that improved the simulation of the electron density distribution in geomagnetic quiet days. The assimilated OTEC data during the geomagnetic storm time will optimize the sensitive physical control parameters of the model such as hemispheric particle participation power (HP), polar cap potential drop (CP). We simulate the ionosphere in storm time in the day Sep. 09, 2011 with the assimilated data with 3 hours per cycle. The optimized time dependent parameters, HP and CP, used in TIE-GCM will be compared with the values in the geophysical indices database (GPI).

共鳴散乱ライダーで得られた中間圏下部熱圏における大気温度の時間-高度変動特性（36°N, 140°E）
Time and height variability of temparature in Mesosphere and Lower Thermosphere region based on resonance scattering lidar measurement at NIPR (36°N, 140°E)

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The National Institute of Polar Research (NIPR) is leading a six year prioritized project of the Antarctic research observations since 2010. One of the sub-projects is entitled ‘the global environmental change revealed through the Antarctic middle and upper atmosphere’. As a part of the sub-project, a Rayleigh/Raman lidar (RR lidar) was installed at Syowa, Antarctica (69S, 39E) in January, 2011. The operation has been conducted since February 2011 and the RR lidar has kept measuring temperature profiles continuously between approximately 10 and 80 km for almost 3 years. In order to extend the height coverage to include mesosphere and lower thermosphere region, a new resonance scattering lidar system with tunable wavelengths is developed at NIPR in Tachikawa (35.7N, 139.4E).
The lidar transmitter is based on injection-seeded, pulsed alexandrite laser for 768-788 nm (fundamental wavelengths) and a second- harmonic generation (SHG) unit for 384-394 nm (second harmonic wavelengths). The laser wavelengths are tuned into the resonance wavelengths by a wavemeter that is calibrated and validated using a wavelength-stabilized He-Ne laser and a potassium vapor cell for doppler-free spectroscopy. This lidar has capabilities to measure density variations of minor constituents such as atomic iron (Fe, 386 nm), atomic potassium (K, 770 nm), calcium ion (Ca+, 393 nm), and nitrogen ion (N2+, 390, 391 nm) and temperature profiles in the mesosphere and lower thermosphere (MLT) region. It can also estimate temperature profiles from the upper Storatosphere to the lower mesosphere using signals of Rayleigh scattering.
In this presentation, we will presnet time and height variability of temparature in the MLT region based on campaign observation in winter 2015-2016 focusing on Sudden Stratospheric Warming (SSW) impact on dyanmics in the MLT region. In addition, the obtained temperature profiles are validated by comparisons to those obatined from satellites data such as Aura/MLS. In addition, dynamical and/or chemical response to SSW and sporadic E-layer in MLT region are discussed using neutral Fe atom density data.

キーワード：中間圏ー下部熱圏、大気温度、成層圏突然昇温
Keywords: the Mesosphere and Lower Theremosphere, Temperature, Sudden Stratospheric Warming

共鳴散乱ライダーによるCa+密度観測で見られた電離圏E領域プラズマ中の微細構造

Fine structures in the E-region plasma density of the ionosphere observed by a Ca^+ resonance scattering lidar observation

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The National Institute of Polar Research (NIPR) is developing a new resonance scattering lidar with multiple wavelengths to install and operate it at Syowa, Antarctica. The lidar will observe temperature profiles and variations of minor constituents such as Fe, K, Ca^+, and aurorally excited N_2^+ in the mesosphere and lower thermosphere. In August 2014, it received the first light from Ca^+ in a sporadic E layer. After that, we increase the resolution of the Ca+ observation and have succeeded in getting the Ca^+ profile with time/height resolution of 5 sec/15 m. As a result of the high resolution observations, fine structures in a sporadic E layer with a vertical width of only 1 -2 km have become detectable clearly. In this presentation, we will show the observed fine structures and discuss atmospheric instabilities in the E-region plasma.

キーワード：共鳴散乱ライダー、カルシウムイオン、微細構造、スポラディックE層、中性大気・プラズマ相互作用
Keywords: resonance scattering lidar, Ca+, fine structure, Sporadic E layer, interaction of neutral and plasma atmospheres

First nadir imaging of medium-scale traveling ionospheric disturbances by the spectrographic imager on International Space Station

First nadir imaging of medium-scale traveling ionospheric disturbances by the spectrographic imager on International Space Station

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Medium-scale traveling ionospheric disturbances (MSTIDs) at mid-latitudes are wave-like structures of the ionosphere, which has been mainly observed by ground-based instruments. It is more challenging to observe MSTIDs from the space while it can clarify spatiotemporal characteristics of MSTIDs. In this presentation, we show the first result of nadir imaging of MSTIDs by the Visible and near-Infrared Spectral Imager (VISI). VISI is one of the instruments of the ISS-IMAP (International Space Station-Ionosphere, Mesosphere, upper Atmosphere, and Plasmasphere mapping) mission, which is designed to measure three nightglow emissions; O (630nm), OH Meinel band (730 nm), and O2 atmospheric band (762 nm), with two field of views (+/-45 deg. to nadir). Using 630-nm airglow data of an ionospheric observation mode, MSTIDs structures were successfully detected on May 22, 2014. Horizontal wavelengths of the MSTIDs were 200-500km, which agreed with those observed by ground-based instruments. The peak-to-peak amplitude of MSTIDs observed by the forward (backward) field of views were about 40% (60%) of the background. The difference of the ratios indicates the geomagnetic field-aligned structure of the MSTIDs.

キーワード：nadir imaging、630nm airglow、medium scale traveling ionospheric disturbance
Keywords: nadir imaging, 630nm airglow, medium scale traveling ionospheric disturbance

HFドップラーにより観測された異なる高度での地震に伴う電離圏変動
Coseismic ionospheric disturbances at different altitudes observed with HF Doppler

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Many studies have reported that ionospheric disturbances occur after large earthquakes. One of the main causes for these disturbances is acoustic wave excited by Rayleigh wave propagated on the ground from the epicenter. The acoustic wave perturbes ionospheric electron density in propagating the ionosphere. Several observations, such as GPS, HF Doppler, the ionogram, observed the ionospheric perturbations at appropriate altitudes for each observations. However, there are few reports for the direct demonstration of vertical propagation of acoustic waves using the single observation. Here, we have observed ionospheric disturbances at the different altitude simultaneously using HF Doppler system (HFD). In this system, radio waves at four different frequencies are observed, implying that the ionospheric perturbations at up to four different altitudes are observed by this system. In examining earthquakes occurred around Japan since 2003, we have found 3 events in which the ionospheric perturbations were observed with the multiple frequencies. From their wave forms, the higher components of the perturbations decay as the altitude is higher. In conjunction with the seismometer data observed below the reflection point of the HFD radio waves, the amplification ratio of the atmospheric wave from ground to the ionosphere have calculated in 3 bands (10.0-25.6, 25.6-45.5, and 45.5-76.9 mHz). Theoretical amplification ratio were also calculated based on energy conservation law, considering absorption by viscosity, thermal conductivity, and relaxation losses of atmosphere (Chum et al., 2012). In comparison of the theoretical amplification ratio, that determined by HFD is rather smaller. However, their height profiles are qualitatively consistent each other; higher frequency components are more greatly damped in at high altitude. There might be the reasons for this difference; attenuations of wave energy that is not considered, differences between model parameters and real values, and lesser conversion efficiency when ground motions excite infrasound waves.

キーワード：電離圏変動、地震、HFドップラー、音波
Keywords: Ionospheric perturbation, earthquake, HF Doppler, acoustic wave

Plasma Depletion Bays in the Equatorial Ionosphere Observed by TIMED and FORMOSAT3/COSMIC during 2007-2015

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An interesting new feature of three Northern (one Southern) ionospheric plasma depletion bays over the magnetic equator is for the first time found in airglow emissions of 135.6 nm by TIMED/GUVI in May (January) of 2007. Electron density profiles derived from FORMOSAT3/COSMIC are further used to study diurnal, altitude, seasonal, longitudinal, and solar activity variations of the plasma depletion bays. Results show that the plasma depletion bays become the most prominent at 250-300 km altitude around the midnight during the low solar activity year. The three (one) bays appear between 60W-180E (80W-150W) during April-September, especially May (October-March). Model simulations suggest that the trans-equatorial neutral wind in the thermosphere should play an important role.

Keywords: FORMOSAT3/COSMIC, TIMED/GUVI, IONOSPHERE

Seasonal variation of the equatorial wind jet at 250 km and 400 km: GOCE and CHAMP observations

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By using long-term in-situ wind observations from the GOCE satellite at 250 km, and the CHAMP satellite at ~400 km, this study examine the seasonal variation of the equatorial wind jet previously reported using short-term CHAMP and DE-2 satellite observations. The results show that the wind jet exists at both altitudes, and experiences similar seasonal variations. The wind jet is found to be strongest around the September equinox, and disappears around the June solstice at both altitudes. The jet shows little solar cycle and geomagnetic activity dependence. These seasonal variations are interpreted in the framework of ion-neutral interaction.

Keywords: wind jet, thermosphere wind, ion-neutral coupling

地磁気日変化振幅に見られる電離圏電場の長期変動

Long-term variation of ionospheric electric fields as seen in the amplitude of geomagnetic solar quiet daily variation

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地磁気日変化(Sq)は、電離圏E領域を流れる大規模電離圏電流によって引き起こされる。その電離圏電流は、正午付近の中緯度では負、赤道域では正の地磁気南北成分磁場をそれぞれ作る。オームの法則によれば、このSq磁場変動をもたらす物理パラメータは、電離圏電気伝導度、分極電場、そしてダイナモ電場からなる。したがって、Sq磁場変動の長期変動特性を調べることは、電離圏、および超高層大気の長期変動を理解する上で重要である。これまで観測とモデリングに基づくSq磁場変動の長期変動に関する多くの研究がなされてきたが、長期でかつ全球的な電離圏伝導度値の情報が不足していたために、全球にわたるSq電離圏電場の長期変動特性の実態はよくわかっていない。そこで本研究では、1958年から2015年までの地磁気と電離圏電気伝導度モデル値を用いて、全球のSq電離圏電場の長期変動特性(季節変動、太陽活動、長期トレンド)を調べ、電離圏と超高層大気の長期変動メカニズムを解明することを目的とする。ここでは、京大地磁気センターが管理するデータベースに登録されている地磁気Kp指数、および地磁気1時間値を使用した。また、Sq電場の太陽活動依存性を調べるために、月平均太陽F10.7指数を参照した。そして、高度80 km –150 kmの範囲を積分した2次元電気伝導度モデル値をSq電場の導出の際に用いた。まず、各日のKp指数で4を超えない日を地磁気静穏日と同定し、その日に該当する中緯度から赤道域の地磁気データを選定した。同定された地磁気静穏日のおのおのの地磁気東西、南北成分について、真夜中の値からのずれをSq場による変動とみなし、それらを各時間について1ヶ月平均をした。最終的にオームの法則からSq場の東西、南北の磁場振幅と2次元電気伝導度からSq場の電離圏電場を導出した。その結果、グアム(赤道域)と女満別(中緯度)における正午付近のSq場の磁場変動と電離圏電気伝導度の長期変動は、1958年から2015年の間、明瞭な季節変化と11年太陽活動周期性を示した。そして、両者ともに太陽活動期において増加する傾向が見られた。Sq場の磁場変動の季節変化のパターンは、地磁気の成分によって異なっており、南北成分は、春分の時期に最大となるが、東西成分は、秋分の時期に最大になる。このような季節変動特性は、電離圏電気伝導度には見られなかった。一方、Sq場の電離圏東西、南北電場もまた明瞭な季節変化と11年太陽活動周期性を示したが、東西成分の電場は、緯度によって太陽活動依存性が異なっていた。それは、赤道域のグアムでは太陽活動と正の相関を示したが、中緯度域の女満別は、太陽活動極小期に東西電場の調度が増加するという反相関の関係にあった。このような傾向が全ての観測点において見られるかどうかを調べるために、20年以上の連続した地磁気データが存在する83の地磁気観測点におけるデータ解析を行った。その結果、太陽F10.7指数と東西電場の間のラグなしの相関係数の全球分布は、地理経度に関係なく、赤道域では正の値を、中緯度では負の値を示していた。よって、この結果から正午付近におけるSq場の電離圏東西電場の太陽活動依存性が全球的に見て赤道域と中緯度域と異なると言える。今後は、全ての地方時において太陽活動とSq電場との相関関係を調べ、太陽活動期にSqの東西電場強度の減少要因を明らかにする予定である。

キーワード：地磁気日変化、太陽活動、電離圏電場、季節変化、超高層大気、赤道域
Keywords: Geomagnetic solar quiet daily variation, Solar activity, Ionospheric electric field, Seasonal variation, Upper atmosphere, Equatorial region

Coherent seasonal, annual, and quasi-biennial variations in ionospheric tidal/SPW amplitudes

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In this study, we examine the coherent spatial and temporal modes dominating the variation of selected ionospheric tidal and stationary planetary wave signatures from 2007 - 2013 FORMOSAT-3/COSMIC total electron content observations using Multi-dimensional Ensemble Empirical Mode Decomposition (MEEMD) from the Hilbert-Huang Transform. We examine the DW1, SW2, DE3, and SPW4 components, which are driven by a variety of in-situ and vertical coupling sources. The intrinsic mode functions (IMFs) resolved by MEEMD analysis allows for the isolation of the dominant modes of variability for prominent ionospheric tidal / SPW signatures in a manner not previously used, allowing the effects of specific drivers to be examined individually.
The time scales of the individual IMFs isolated for all tidal/SPW signatures correspond to a semiannual variation at EIA latitudes maximizing at the equinoxes, as well as annual oscillations at the EIA crests and troughs. All tidal / SPW signatures show one IMF isolating an ionospheric quasi-biennial oscillation (QBO) in the equatorial latitudes maximizing around January of odd numbered years. This TEC QBO variation is in phase with a similar QBO variation isolated in both the GUVI zonal mean column O/N2 density ratio as well as the F10.7 solar radio flux index around solar maximum, while showing temporal variation more similar to that of GUVI O/N2 during the time around the 2008/2009 extended solar minimum. These results point to both quasi-biennial variations in solar irradiance as well as thermosphere / ionosphere composition as a generation mechanism for the ionospheric QBO.

Keywords: Thermosphere, Ionosphere, Tides, QBO

The ionospheric characteristics over the northern equatorial anomaly crest during the prolonged solar minimum period

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In this study we have analyzed the diurnal, monthly, seasonal, and annual variation in NmF2, hmF2, foE, B0, scale height at F2 layer peak height (H_m), total electron content (TEC), and ionospheric equivalent slab thickness (tau symbol) over the northern crest equatorial anomaly area at solar minimum during 1995-1996 and 2008-2009. We collected the data from an ionosode station located at Chung-Li Observation (121.1.oE, 25.0oN) and GPS receiver (TWTF) located at Tao-Yuan (121.09oE, 24.57oN). The result shows the first maximum value for NmF2 and TEC occurred a time delay in 2008 comparison with values in 1995. The result of foE depicts a lower value during 2008-2009 than variation in 1995-1996. The variation of hmF2 in 2008-2009 was lower than values in 1995-1996. The ionospheric equivalent slab thickness during 0600-1200 LT was higher in 2008-2009 than values in 1995-1996, particularly in summer season. Furthermore, a comprehensive discussion of the physics processes for the variation of ionosphere during the prolonged low solar activity period.

Keywords: ionospheric physics, solar activity, ionospheric dynamics

LF帯標準電波を用いた2011年東北地方太平洋沖地震後のD領域電離圏擾乱
D-region ionospheric disturbances after the 2011 off the Pacific coast of Tohoku Earthquake using LF transmitter signals

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So far, a lot of studies for the F-region ionosphere associated with earthquakes have been reported, although few studies for the D-region ionosphere have reported. It is difficult to observe the D-region electron density because of high collision frequency between plasma and the neutral atmosphere. In this study, we investigate the D-region disturbances associated with the 2011 off the Pacific coast of Tohoku Earthquake using intensity and phase of LF transmitter signals. The phase was converted to reflection height based on Earth-ionosphere waveguide mode theory. The reflection height corresponds to electron density in the D-region. The propagation paths are Saga-Rikubetsu (RKB) and BPC(China)-RKB. As a result, clear oscillations of the intensity over both propagation paths were simultaneously observed about 6 minutes and 12 seconds after the earthquake onset. The both periods of the intensity and reflection height oscillations were about 100 s. The one-to-one corresponding between the intensity and reflection height was not seen clearly. The changes of the intensity and reflection height for the oscillations were about 0.1 dB and 50 - 65 m, respectively. The time difference between the earthquake onset and the oscillations was consistent with the propagation time of the Rayleigh waves (seismic waves) propagating from the epicenter to the LF propagation paths along the Earth surface, plus the propagation time of acoustic waves propagating from the ground to 70 km altitude vertically. Thus, the LF oscillations may be caused by the acoustic waves excited by the Rayleigh waves.

The photochemical model of atomic oxygen ions retrieving from ground-based observation of airglow

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To study the chemistry and composition of the upper atmosphere, we can utilize airglow emissions from the photochemical reactions of the ions in this region. When the atomic oxygen ions, which are distributed in the ionospheric F region, experience an energy level transition, visible light with a wavelength of 630 nm is released. We used the photometer system built by our team to perform ground-based observations of airglow over the sky of Taiwan at The Lulin Observatory (23°28′07″N, 120°52′25″E) during nighttime. We combined the mean values of our observations every 10 minutes with a photo chemistry model based on the formula derived from the theory of R. Link and L. L. Cogger. With this method, we can estimate how the density of oxygen atomic ions varies with time and altitude. This system will be used for long term observations to study the seasonal variation of upper atmosphere composition.

Keywords: photochemical, airglow, ionosphere

