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

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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.

Keywords: gravity waves, potential energy, synoptic scale factors, TIMED/SABER

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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The gravity waves are generated in the lower atmosphere, propagate upward and transfer momentum and energy to the middle atmosphere. It has been found that the gravity waves induce large scale meridional circulation and drive the middle atmosphere away from radiative equilibrium [Lindzen, 1981; Holton, 1982; Matsuno, 1982]. However, we have not completely known the quantification of gravity wave roles in the middle atmospheric circulation. A Rayleigh/Raman(RR) lidar was installed in January 2011 at Syowa Station, Antarctica (69°S,40°E). The lidar has measured temperature profiles between 5 and 80 km for more than 350 nights (before the end of October in 2014).
In this study, we investigated monthly mean gravity wave potential energy (*Ep*) in the height range of 15-70 km from May 2011 to October 2013. Above 35km altitude, *Ep* was maximized during winter. The seasonal dependence of *Ep* over Syowa was similar to *Ep* observed at Davis(69°S,79°E) [Alexander et al., 2011]. Below 35 km altitude, *Ep* was enhanced in around May, and did not decrease in September. Almost all monthly mean profiles have constant slope above 30 km altitude. *Ep* increases exponentially with height (increasing rate is approximately exp(z/H); H~7 km is scale height). Furthermore, almost all *Ep* profiles have a local minimum around 25 km altitude and a local maximum around 20 km altitude. In October 2012, *Ep* is significantly different from the other *Ep* profiles. As a result of comparison between the *Ep* profiles and zonal wind in the NASA MERRA reanalysis data, the reason was probably that weak zonal wind layer in 2012 descends earlier than the other years.

Keywords: gravity wave, middle atmosphere, lidar

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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Saburo MIYAHARA and Ying-Wen CHEN reported that Kyushu-GCM data analysis showed Variation of Global Mean Temperature connected with Stratospheric Sudden Warming (SSW) at 2015 Spring conference of the Meteorological Society of Japan. The report concludes that vertical thermal advection of semi-diurnal tide (zonal wave number = 2) causes about 50 % of Global Mean Temperature Cooling in the lower thermosphere.
Kyushu-GCM can express meteorological phenomena from the ground to 150 km height. In order to verify its conclusion of Kyushu-GCM case in higher atmosphere than 150 km, GAIA (75 layers) model is used. It can describe meteorological states up to 500 km height and then the analysis has been done about the Global Mean Temperature Cooling in the lower thermosphere just after SSW caused by tidal wave's vertical thermal advection. Therefore it has been confirmed that the semi-diurnal tide (zonal wave number = 2) disturbance dominantly contributes to the cooling as same as the case of Kyushu-GCM up to about 200 km height.
The semi-diurnal tide works cooling higher than 200 km, but diurnal tide (zonal wave number =1) works strongly warming and net migrating tide disturbance also works warming. Then in this case the global mean temperature cooling in the lower thermosphere cannot be explained due to the vertical thermal advection of tidal wave disturbance. All non-migrating tide almost does not only work cooling but also warming. Waltersheid (1981) proved theoretically that vertical thermal advection of internal gravity wave disturbance caused cooling in lower thermosphere.
Thus this research result may suggest that many internal gravity waves are dominant and work cooling in the lower thermosphere. Vertical resolution of GAIA(75 layers) is much lower than Kyushu-GCM(250 layers). The analyses of GAIA(150 layers) will be also shown at the conference hall.

Keywords: Stratospheric Sudden Warming, Atmospheric Tidal Wave, GAIA model

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.

Keywords: Meteor radar, Momentum flux, Mesosphere and lower thermosphere, Hocking method, Equator, Semi-annual variation

Tidal modulation of mesospheric gravity waves observed with MF radar at Poker Flat, and Tromsø

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The neutral wind velocity data from mesosphere to lower thermosphere observed by MF radars at Poker Flat in Alaska and at Tromso in Norway has been observed since the late 1990s. The present study examines the relation between short-period mesospheric gravity wave activities and the background state including diurnal and semidiurnal tides using these MF radars' data for 10 years of 1999~2008.
Observed wind velocities having the 1~4 hour period components are analyzed as short-period gravity waves and those having harmonic components with periods of 48, 24, 12, and 8 hours are calculated every 30 minutes. The previous study in IUGG2015 showed that the maximum of GW-KE occurs at Poker Flat when zonal wind is easterly from November to December and zonal wind transitions from easterly to westerly from January to February and from May to August from climatological 1-day composite plots of 12 hour components of zonal wind and GW-KE. The results of Tromso showed that the maximum of GW-KE occurs at local time when zonal wind is westerly from November to February and easterly from May to September. Next, considering the physical mechanisms under these relations, we confirmed that these relations can be explained by the critical level filtering of gravity waves except for summer cases at Poker Flat. We plan to investigate the summer relation at Poker Flat in more detail and discuss another physical mechanism.

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).

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.

Keywords: the Mesosphere and Lower Theremosphere, Temperature, Sudden Stratospheric Warming

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.

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

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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.

Keywords: nadir imaging, 630nm airglow, medium scale traveling ionospheric disturbance

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.

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

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

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Geomagnetic solar quiet (Sq) daily variation is generated by the large-scale ionospheric currents flowing in the E-region of the ionosphere. The ionospheric currents produce positive and negative variations of the H-component of geomagnetic field around the noon in the equatorial and middle-latitude regions, respectively. According to Ohm's law, the dependent variables of the Sq amplitude consist of ionospheric conductivity, polarization electric field and dynamo field. Therefore, to investigate the long-term variation of the Sq amplitude is important for understanding the long-term variation in the ionosphere and upper atmosphere. Many researches of the long-term variation of the Sq amplitude on the basis of global observation and model have been made so far. However, characteristics of the long-term variation of global ionospheric Sq electric field remain unknown due to the shortage of long-term ionospheric conductivity analysis at many geomagnetic stations. In this study, we investigate the characteristics of long-term variation of global Sq ionospheric electric field using the geomagnetic field and ionospheric conductivity data from 1958 to 2015, and clarify the mechanism of long-term variation in the ionosphere and upper atmosphere. In the present analysis, we used geomagnetic Kp index and 1-hour geomagnetic field data archived in the database of WDC for Geomagnetism, Kyoto University. In order to investigate the solar activity dependence of the Sq ionospheric electric field, we referred to the monthly-mean solar F10.7 index. We also used two-dimensional ionospheric conductivities integrated in the height range of 85-140 km. We first selected geomagnetic field data corresponding to the solar quiet day when the Kp index is less than 4. Then, we identified the Sq variation as a deviation from the value at midnight in both the X and Y components of the selected geomagnetic field data. Finally, we obtained the Sq ionospheric electric fields by solving Ohm's equation with the monthly-mean height-integrated ionospheric conductivity and Sq variation of geomagnetic field. As a result, the long-term variation of the Sq variation and ionospheric conductivities at Guam and Memanbetsu around the noon showed a clear seasonal variation and 11-year solar activity dependence during 1958-2015. Both the Sq variation and ionospheric conductivities tended to increase during each high solar activity. The pattern of the seasonal variation of the Sq field was different from the different component of geomagnetic field, indicating that the X component becomes maximum in March equinox while the Y-component becomes maximum in September equinox. This feature could not be seen in the seasonal variation of ionospheric conductivities. The Sq ionospheric zonal and meridional electric fields also showed a clear seasonal variation and 11-year solar activity dependence. The zonal electric field was positively correlated with the F10.7 index at Guam near the equatorial region while it was negatively correlated at Menambetsu in the middle-latitude region. This result implies that the solar activity dependence of zonal electric field is different from different latitude. In order to check if this relationship can be seen at all geomagnetic stations, we analyzed the Sq zonal electric field at 83 geomagnetic stations. As a result, the global distribution of correlation coefficient between the F10.7 index and zonal electric field with no lag showed positive and negative values in the equatorial and middle-latitude regions, respectively, without depending on the geographical longitude. Therefore, it can be concluded that the solar activity dependence of the Sq zonal electric field around the noon is globally different

between the equatorial and middle-latitude regions. In future study, we investigate the solar activity dependence of the zonal electric field at all local times, and clarify a cause of the electric field depression during the high solar activity.

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

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

