PROGRAM

6th IAGA/ICMA/SCOSTEP Workshop on Vertical Coupling in the Atmosphere-Ionosphere System

Taipei, Taiwan
July 25 – 29, 2016

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Hosted by:
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National Cheng Kung University
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Variability of the Sun and Its Terrestrial Impact

Workshop Schedule

Monday: July 25, 2016

Chair: **Petra Koucka Knizova** (afternoon 1), **Dora Pancheva** (afternoon 2)

11:00 - 13:00	Registration		
13:00 - 13:10	**Petra Koucka Knizova, Loren Chang**		Opening
13:10 - 13:50	**Dora Pancheva**	Solicited	Global Distribution and Climatological Variability of Quasi-Two-Day Waves: Results Based on the NOGAPS-ALPHA Reanalysis Model and MLS on the NASA Aura Satellite Measurements
13:50 - 14:10	**Jack C. Wang**		Quasi Two Day Wave Response in the Ionosphere Using TIME-GCM Nudged with NOGAPS-ALPHA
14:10 - 14:30	**Jia Yue**		Quasi-two-day wave coupling of the middle atmosphere and Ionosphere-Thermosphere
14:30 - 15:00	Coffee Break		
15:00 - 15:20	**Hiroyo Ohya**		D-region ionospheric oscillations after the 2011 off the Pacific coast of Tohoku Earthquake using LF transmitter signals
15:20 - 15:40	**Jaroslav Chum**		Infrasound waves in the ionosphere at far and near distances from the earthquake epicenters
15:40 - 16:00	**Hiroyuki Nakata**		Coseismic ionospheric disturbances at different altitudes observed using HF Doppler sounding
16:00 - 16:20	**Tiger J.Y. Liu**		Atmosphere-Ionosphere coupling due to dust storms occurring over the Sahara Area in May 2008
16:20 - 17:20	Coffee Break / Icebreaker		
17:20 - 20:00	Welcome Banquet		

Tuesday: July 26, 2016

Chair: **Christina Arras** (morning 1), **Tzu-Wei Fang** (morning 2), **Balan Nanan** (afternoon 1), **Charles Lin** (afternoon 2)

9:00 - 9:40	**Sushil Kumar**	Solicited	An overview of Ionospheric effects of Solar Eclipses: Gravity Wave Emphasis
9:40 - 10:00	**Petra Koucka Knizova**		Solar eclipses and their effects in the ionospheric plasma
10:00 - 10:20	**Daiki Takeo**		Long-term variation of horizontal phase velocity spectrum and propagation direction of mesospheric and thermospheric gravity waves observed by an airglow imager at Shigaraki, Japan
10:20 - 11:00	Coffee Break		
11:00 - 11:20	**P. K. Rajesh**		Medium scale traveling ionospheric disturbances using FORMOSAT-2/ISUAL 630.0 nm airglow images
11:20 - 12:00	**Laysa C.A. Resende**	Solicited	Study of the Sporadic E Layer formation considering the influence of the tidal winds and electric fields
12:00 - 12:20	**Christina Arras**		GPS radio occultation: Initial results on the estimation of ionospheric sporadic E intensities
12:20 - 14:00	Lunch		
14:00 - 14:40	**Tzu-Wei Fang**	Solicited	Impact of midnight thermosphere dynamics on the equatorial ionospheric vertical drifts
14:40 - 15:00	**Balan Nanan**		Recent developments in the understanding of upper atmosphere-ionosphere coupling at low latitudes
15:00 - 15:20	**Tarun Pant**		New inferences on the variability of the occurrence of F3 layers over the dip equator - a manifestation of atmosphere ionosphere coupling
15:20 - 15:40	**Jia-Ting Lin**		The influences of migrating semidiurnal tide variability on the low latitude ionosphere
15:40 - 16:00	Coffee Break		
16:00 - 16:40	**Federico Gasperini**	Solicited	Wave coupling between the lower and middle thermosphere as viewed from TIMED and GOCE
16:40 - 17:10	**Charles Lin**	Solicited	Exploration of global ionospheric plasma structure with FORMOSAT-3/COSMIC mission
17:10 - 17:30	**Loren Chang**		Coherent seasonal, annual, and quasi-biennial variations in ionospheric tidal/SPW amplitudes
17:30 - 17:50	**Wei-Han Chen**		Ionospheric TEC Variations During the 2009 Sudden Stratosphere Warming

Wednesday: July 27, 2016

Chair: **Amal Chandran** (morning 1), **Michal Kozubek** (morning 2), **Alfred Chen** (afternoon 1), **Loren Chang** (afternoon 2)

9:00 - 9:40	**Michal Kozubek**	Solicited	The two-core longitudinal structure of meridional wind in the middle atmosphere
9:40 - 10:00	**Potula Sree Brahmanandam**		Disturbed Hadley Cell Circulation over the Taipei region during 2004 and 2005- A case study
10:00 - 10:20	**Andrey Koval**		Simulating of the planetary waves amplitudes for the different QBO phases during stratospheric warming events in the middle atmosphere
10:20 - 11:00	Coffee Break		
11:00 - 11:40	**David Siskind**	Solicited	High altitude meteorology impact on thermosphere-stratosphere coupling
11:00 - 12:00	**Amal Chandran**		Vertical Coupling of the Atmosphere during Sudden Stratospheric Warming events
12:00 - 12:20	**Balan Nanan**		Coupling of mesosphere, thermosphere and ionosphere using MU radar and CMAT2 model
12:20 - 14:00	Lunch		
14:00 - 14:20	**Chuan-Ping Lien**		Numerical simulation on ionospheric electron density response to currents from lower atmosphere and lithosphere
14:20 - 14:40	**Alfred Chen**		The measurement of the vertical electric field near ground and an interesting signature associated with 0206 earthquake
14:40 - 15:00	**Alexei Dmitriev**		Unusual mid-latitude aurora
15:00 - 15:40	Coffee Break		
15:40 - 16:00	**Yi Duann**		Photochemical model for atomic oxygen ions retrieval from ground-based observations of airglow
16:00 - 16:20	**Tai-Yin Huang**		Investigations of Airglow Response to Solar Variation and CO2 Increase Over a Solar Cycle
16:20 - 16:40	**Azad Mansoori**		Impact of Solar Proton Events on High Latitude Ionospheric Conditions

Thursday: July 28, 2016

Chair: **Cornelius Cesar Jude H. Salinas**

9:00 - 9:20	**Cornelius Cesar Jude H. Salinas**		Impacts of SABER CO2-based Eddy Diffusion Coefficients in the Lower Thermosphere on the Ionosphere/Thermosphere
9:20 - 9:40	**Gerelmaa Dashnyam**		December anomaly in ionosphere using FORMOSAT-3/COSMIC electron density profiles
9:40 - 10:00	**Min-Yang Chou**		Ionospheric electron density inversion for GNSS radio occultation using aided Abel inversions
10:00 - 10:30			
10:30 - 19:00			Excursion: Taipei Tea House & Hot Stir Fry Dinner Social (Includes lunch and dinner. Sign-up Required)

Friday: July 29, 2016

Chair: **Loren Chang**

9:00 - 9:40	**Adekola Adewale**	Solicited	Vertical coupling of atmosphere-ionosphere: its physical mechanisms and effect on climate
9:40 - 10:00	**Potula Sree Brahmanandam**		Vertical coupling between ionosphere E and F-regions during evening times and ionospheric irregularities over Indian longitude sector
10:00 - 10:20	**Yan-Yi Sun**		El Niño–Southern Oscillation in ionospheric and thermospheric tides
10:20 - 10:40	**Evgeniya Rakushina**		Changes in the mean flow, temperature, and planetary waves observed during the last 36 years
10:40 – 11:00	**Kaiti Wang**		The Correlation of Outgoing Longwave Radiation and Temperature in the Tropical Tropopause Layer: FORMOSAT-3/COSMIC Observations
11:00 - 12:00	Coffee Break, General discussion		
	Petra Koucka Knizova, Loren Chang		Closing workshop

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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.

The two-core longitudinal structure of meridional wind in the middle atmosphere

Michal Kozubek
Department of Aeronomy, Institute of Atmospheric Physics, Czech Academy of Sciences, Czech Republic

One of key stratospheric processes is the Brewer-Dobson circulation, which includes meridional transport. Kozubek et al. (2015) disclosed the existence of the two-core longitudinal structure in meridional wind at 10 hPa in January. Here the two-core structure in meridional wind is analysed based on MERRA data over 1979-2012 in order to find the altitudinal and seasonal dependence of this two-core structure and its other properties. The two-core structure covers the middle stratosphere (lower boundary ~50 hPa), upper stratosphere and lower mesosphere (up to at least 0.1 hPa). It is circulation response to the appearance of blocking Aleutian pressure high, which affects more or less also zonal wind, temperature and ozone fields. The well-pronounced two core structure occurs only in the winter half of the year (October-March) and only at the Northern Hemisphere. It displays a westward shift with increasing altitude. The two-core longitudinal structure in meridional wind is persistent feature; only a few winters (Januaries) display more complex structure. Its existence should influence the Brewer-Dobson circulation and also the zonal mean approach to investigations of the middle atmosphere.

Vertical coupling of atmosphere-ionosphere: its physical mechanisms and effect on climate

Adekola Adewale
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This paper attempts to further answer one of the key science questions that were the subject of the 5th IAGA/ICMA/SCOSTEP Vertical Coupling Workshop regarding the vertical coupling in the atmosphere–ionosphere system. The question can be summarized as: What are the physical mechanisms related to solar activity and space weather that influence atmospheric coupling and what is the role of these mechanisms in shaping Earth's atmosphere and climate in various scales? (Yiğit et al., 2016). This study is based on review of some recent developments in atmosphere-ionosphere science and investigation on comprehensive behavior of the lower and upper atmosphere. A comparison of GPS positioning 3-D vertical (MRSE) and horizontal (DRMS) root mean square positioning errors obtained from different pseudorange measurements at low and high latitude stations was employed. GPS observation data were processed and analyzed from 6th-12th November, 2004, using different pseudorange measurements i.e., L1 C/A, L1 P, L2 P codes and ionosphere-free combination ((C/A on L1 and P on L2) and (P on L1 and P on L2)). In order to assess the impact of the atmosphere on climate, different values of relative humidity were used. The study shows the effect of vertical coupling of atmosphere-ionosphere on climate.

Simulating of the planetary waves amplitudes for the different QBO phases during stratospheric warming events in the middle atmosphere

Andrey Koval
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One of the important factors of dynamical interactions between the lower and upper atmosphere is energy and momentum transfer by atmospheric internal gravity waves. For numerical modeling of the general circulation and thermal regime of the middle and upper atmosphere, it is important to take into account accelerations of the mean flow and heating rates produced by dissipating waves. The quasi-biennial oscillations (QBOs) of the zonal mean flow at lower latitudes at stratospheric heights can affect the propagation conditions of planetary waves. We perform numerical simulation of global atmospheric circulation for the initial conditions typical for the years with westerly and easterly QBO phases. We focus on the changes in amplitudes of stationary planetary waves (SPWs) and traveling normal atmospheric modes (NAMs) in the atmosphere during SSW events for the different QBO phases. For these experiments, we use the global circulation of the middle and upper atmosphere model (MUAM).

There is theory describing the PW waveguides in atmospheric regions where the background wind and temperature allow the wave propagation. There were introduced the refractive index for PWs and found that strongest planetary wave propagation is in areas of large positive values of this index. Another important PW characteristic is the Eliassen-Palm flux (EP-flux). These characteristics are considered to be the useful tools for visualizing the PW propagation conditions. Sudden stratospheric warming (SSW) event has significant influence on the formation of the weather anomalous and climate changes in the troposphere. Also, SSW event may affect the dynamical and energy processes in the upper atmosphere. The major SSW events imply significant temperature rises (up to 30 - 40 K) at altitudes 30 - 50 km accompanying with corresponding decreases, or reversals, of climatological eastward zonal winds in the stratosphere.

Thunderstorm graupel charging in the absence of supercooled water droplets and their relationship with sprites

Melina Yasmin Luque
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Transient luminous events (TLE) are atmospheric phenomena that occur in the region between thunderclouds and the ionosphere. Sprites are one of the most current TLEs. They commonly appear over the stratiform region of the Mesoscale Convective Systems (MCS) and they have been related with the electrical activity of these systems (e.g., Boccippio et al., 1995; Lyons, 1996; Neubert, 2003).
Many researchers consider that sprites are the result of the quasi-electrostatic field (QSF) attributed to the neutralization of a large amount of positive charges due to cloud-to-ground discharges of positive polarity (e.g. Pasko et al., 1997; Williams, 1998; Yaniv et al., 2014). As a result, a remaining charge of opposite sign above the thundercloud generates the QSF in atmospheric layers below the ionosphere, for a very short time periods. These researchers also suggest that the positive charge reservoir is located in the base of the mesoscale anvil near the isotherm of 0°C, where the charging process is inverted relative to the normal positive-over-negative charge structure of ordinary thunderstorms.

Our research seeks to confirm the existence of this positive charge reservoir and to explain how they form and why (Luque et al. 2016). In the presentation I will show our experimental results carried out into a cold chamber. We measured the magnitude and the sign of the charged transferred between ice particles (graupel and ice crystals) during collisions under representative atmospheric conditions of temperature, water liquid content and supersaturation of the stratiform region of the thunderstorms.

References

Boccippio, DJ, Williams ER, Heckman SJ, Lyons WA, Baker IT, Boldi, R. 1995. Sprites, ELF transients, and positive ground strokes. Science, 269(5227), 1088-1091.
Lyons WA. 1996. Sprite observations above the US High Plains in relation to their parent thunderstorm systems. Journal of Geophysical Research: Atmospheres, 101(D23), 29641-29652.

Neubert T. 2003. On sprites and their exotic kin, Science, 300, 747–748.

V. P. Pasko, U.S. Inan, and T. F. Bell. 1997. Sprites produced by quasi-electrostatic heating and ionization in the lower ionosphere, Journal of geophysical research, 102 (A3), 4529-4561.

E.R. Williams. 1998. The positive charge reservoir for sprite producing lightning, Journal of Atmospheric and Solar Terrestrial Physics, 60, 578-581.

R. Yaniv, Y. Yair, C. Price, J. Bór, M. Sato, Y. Hobara, S.Cummer, J. Li, A. Devir. 2014. Ground-based observations of the relations between lightning charge-moment-change and the physical and optical properties of column sprites, Journal of Atmospheric and Solar-Terrestrial Physics 107, 60-67

M. Luque, R. Bürgesser, E. Ávila. 2016 (in press). Thunderstorm graupel charging in the absence of supercooled water droplets. Quarterly Journal of the Royal Meteorological Society.

Impact of Solar Proton Events on High Latitude Ionospheric Conditions

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We have investigate the ionospheric response to the solar protons which are accelerated to different energies (MeV-GeV) and thought to be originated at the solar atmosphere during the various energetic phenomena knows as solar transients viz. Solar Flares, Coronal Mass Ejections (CMEs). These transients are believed to be a manifestation of same energy release processes from a highly complex condition in the magnetic field configuration on the solar surface. We have taken six solar proton events (SPE) of solar cycle 23rd for analysis in the various energy bands of the protons. In order to find the ionospheric responses to these incoming solar protons ionospheric total electron content (TEC) is taken as the characteristic parameter. We have taken the data observed by GOES satellites which provides the data for different energy channels (0.8-4 MeV, 4-9 MeV, 9-15 MeV, 15-40 MeV, 40-80 MeV, 80-165 MeV, and 165-500 MeV). The enhancement in peak TEC (ΔTEC) was then obtained for the high latitude station Davis (Lat-68.35, Lon 77.58). To find the association of this enhancement with proton flux characteristics we derived the correspondence between spectral indices and ΔTEC . We obtained a strong correlation (0.84) to exist between the spectral indices and ΔTEC.

Key words: Solar Energetic Particles, Total Electron Content, High latitude ionosphere

Coupling of mesosphere, thermosphere and ionosphere using MU radar and CMAT2 model

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The MU (middle and upper atmosphere) radar (35ºN, 136ºE) of Japan and CMAT2 (coupled middle atmosphere-thermosphere) model of UCL (UK) are used to study mesosphere-thermosphere-ionosphere coupling. The MU radar was operated in alternate meteor and incoherent scatter modes to simultaneously measure the zonal and meridional wind velocities at MLT altitudes (80–95 km), meridional wind velocity in upper thermosphere (220–450 km), and electron density and peak height in ionosphere (200-600 km) with a time resolution of 1.5 hours under a project called MTECS (mesosphere-thermosphere experiments for coupling studies). Four long MTECS observations each lasting over a week were conducted in the four seasons in 2000-2001. Analysis of the data indicates that the upper atmospheric regions are dynamically coupled through mean winds, tides, and waves. 24-hour, 12-hour and 6-hour tides and waves of periods 16–20 hours and 35–55 hours coexist at MLT and upper thermosphere altitudes in all seasons, and the waves become stronger than tides at mesopause altitude (88 km) at equinoxes.

CMAT2 solves the coupled non-linear equations of continuity, momentum and energy, and includes mesospheric energetics, dynamics, composition, high latitude energy input and a model for the electrodynamic coupling between the ionosphere and thermosphere. Lower altitude limit is at 15 km where diurnal and semi-diurnal tidal forcing are introduced using the Hough modes (1,1), (2,2), (2,3), (2,4) and (2,5), and 10 iteration days are used for stabilization. The 24-hour and 12-hour tidal amplitudes at the lower height of MU radar observation (80km) are accessed to produce height variations of 600 m and 100 m at 15 km height over the equator, which are introduced according to the Hough modes. Preliminary model results show that the 24- and 12-hour tides propagate to upper thermosphere and affect the wind systems and electron density at all altitudes. Observations and model results are presented and discussed.

Recent developments in the understanding of upper atmosphere-ionosphere coupling at low latitudes

Balan Nanan
CEA-1, INPE, Brazil

Upper atmosphere-ionosphere coupling at low latitudes produces the major phenomena such as equatorial electrojet, equatorial ionization anomaly (EIA), equatorial plasma temperature anomaly (EPTA) and plasma bubbles and spread F. This talk reviews the recent developments in the understanding of equatorial plasma fountain and equatorial ionization anomaly (EIA) under magnetically quiet and active conditions. It is clarified that (1) field perpendicular ExB plasma drift, plasma diffusion due to gravity and pressure gradient forces, and neutral wind all act together all along geomagnetic field lines, and plasma flows in the direction of their resultant. (2) EIA arises mainly from the removal of plasma from around the equator by the upward ExB drift with very little accumulation of plasma at the crests when the crests are within ~±20º magnetic latitudes and no accumulation when they are at higher latitudes. (3) During daytime main phase (MP) of geomagnetic storms, EIA becomes very strong (up to 1500% increase in density and crests shifting to ~±30º magnetic latitudes compared to quiet-times) or strong positive ionospheric storms occur at low and mid latitudes when storm-time equatorward neutral wind (ENW) and eastward prompt penetration electric field (PPEF) act together, as observed during the Halloween space weather event on 30 October 2003. (4) ENW alone through its mechanical effects can also produce strong IEA while PPEF alone can produce only up to 50% increase as long as EIA crests are within ~±20º latitudes. (5) During later stages of magnetic storms, the composition change effect (N2/O increase) of ENW becomes effective and positive ionospheric storms turn to negative storms; and often EIA gets inhibited with peaks over the equator due to plasma convergence by the mechanical effects of ENW.

Infrasound waves in the ionosphere at far and near distances from the earthquake epicenters

Jaroslav Chum
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Vertical movements of the ground surface caused by strong earthquakes (M>7) generate infrasound waves at periods longer than 10 s. Infrasound waves of such long periods propagate to ionospheric heights, where they can be detected by remote sensing radio techniques before they dissipate. As the initial perturbations on the ground are relatively well known from seismic measurements, such events represent unique possibilities to study vertical coupling via infrasound waves. In addition, a proper distinguishing of co-seismic and co-tsunani disturbances from other fluctuations in the ionosphere may find a potential application in tsunami warning.

A comparison of co-seismic disturbances in the ionosphere at large and small distances from the earthquake epicenters are discussed on the basis of continuous Doppler shift measurements at specific altitudes. Namely, observations of co-seismic disturbances from three recent large earthquakes are presented: a) 11 March 2011 Tohoku M9.0 earthquake, recorded ~9000 km away from the epicenter in the Czech Republic. b) 25 April 2015 Nepal M7.8 earthquake observed in Taiwan (~3700 km from the epicenter) and in the Czech Republic (~ 6300 km from the epicenter). c) 16 September 2015 Chile M8.3 earthquake, measured over Tucumán, Argentina, about 800 km from the epicenter.

It is shown that the ionospheric disturbances can be in all these cases associated with long period infrasound waves that were excited locally by vertical component of the ground surface motion and propagated nearly vertically to the ionosphere. The infrasound waves are heavily attenuated and dissipate at the heights of F2 layer, so their amplitudes strongly depend on the altitudes of observations, which can be obtained from nearby ionosondes. The wave packets observed in the ionosphere far outside the epicenter are similar to the wave packets of vertical component of the local ground surface motion. However, the wave form observed in the ionosphere near the epicenter (~800 km) resembles a N-shaped shock wave. It is shown by numerical simulations that this shape cannot be explained by linear theory of infrasound propagation, including attenuation; the non-linear effects owing to large infrasound amplitudes in the upper atmosphere play an important role in the formation of the N-shaped disturbance.

Study of the Sporadic E Layer formation considering the influence of the tidal winds and electric fields

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This work presents a study about the formation of sporadic E-layers, Es, considering the tidal winds and electric fields over Brazilian ionospheric regions. We show the different types of Es layers observed in the ionograms obtained by digital ionosondes. We also use the frequency parameters, blankenting frequency (fbEs) and top frequency (ftEs), to analyze the Es layers. Furthermore, we present recent results of the Es layers using a theoretical model for the E region, called MIRE. This model is able to simulate the Es layers taking into account the E region winds and electric fields. It calculates the densities for the main molecular (NO+, O2+, N2+) and metallic ions (Fe+, Mg+) by solving the continuity and momentum equations for each species. These recent results show that the Es layer parameters computed by MIRE have a good agreement with the observed parameters obtained from the ionograms. Finally, this analysis presents interesting results that help us to increase our knowledge on the Es layer formation mechanisms in the Brazilian sector.

Disturbed Hadley Cell Circulation over the Taipei region during 2004 and 2005- A case study

Potula Sree Brahmanandam
Department of Physics, Madanapalle Institute of Science &Technology, India

The Hadley Cell, a zonal mean meridional mass circulation in the atmosphere, is nothing but a north and south direction cell from the equator. In the northern hemisphere, it starts raising up to tropopause and moves northern side in the northern hemisphere at around 300 N degree. It is known from the earlier studies that the Hadley Cell is in the upward direction between 00 and 150N latitudes and shows downward direction between 150 N and 300 N latitudes. Several reports have appeared in the literature about the Hadley Cell dynamics by utilizing the Mesosphere, Stratosphere, and Troposphere (MST) radar retrieved wind, since MST radar operating at VHF can provide a detailed picture about vertical wind information. As per as the seasonal changes of the Hadley Cell is concerned, it generally appears during winter i.e. December-January-February in the northern hemisphere. During the northern winter, it starts from the equator and moves northward in upper heights and southward in lower heights in the northern hemisphere.

This research reports about Hadley Cell dynamics over the Taiwan region by properly using radiosonde and model-based meridional wind information. It is found that over the Taipei region during 2004 and 2005, the Hadley Cell was disturbed, while it showed usual trends during other years. To the best of the authors' knowledge, this is the first of its kind research reported about a disturbed Hadley Cell over the Taipei region using meridional wind data retrieved from radiosonde and model-based data. The plausible physical mechanisms of the disturbed Hadley Cell are discussed in view of the available literature.

Vertical coupling between ionosphere E and F-regions during evening times and ionospheric irregularities over Indian longitude sector

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This research reports first observations of amplitude scintillations (250 MHz) recorded at Vaddeswaram (Lat. 16.310N, Long.80.30E, Dip 180 N), a low-latitude station in India, vertical drifts and diurnal variations of h'F (virtual height of the bottom side F-region) observed using an advanced digital ionosonde from an Indian equatorial station Trivandrum (Lat. 8.50 N, Long. 770 E, Dip 0.50 N), and equatorial electrojet (EEJ) ground strength measured using magnetometers during 05-08 November 2011. The interesting observations are that the higher E x B drifts, occurrence of a long-duration range-type spread F at Trivandrum and scintillations at Vaddeswaram, the presence of plasma depletions in TEC initially at Tirunelveli (Lat. 8.50 N, Long. 770 E, Dip 0.50 N), an equatorial station, later at Calcutta (Lat. 22.580 N, Long. 88.380 E, Dip 320 N), an anomaly crest station, and a proper anomaly as seen in global TEC data on 06 November 2011. The secondary peak around 1600 LT in EEJ strength followed by a higher upward drift velocity (more than 60 m/s) with a significant raise of the F region up to 470 km over the magnetic equator on 06 November indicating that the pre-sunset EEJ might have played a crucial role on the post-sunset F-region electrodynamics so as to initiate the ionospheric irregularities, and scintillations , though the exact physical mechanism between daytime EEJ and nighttime F-region electrodynamics has not been understood.

Impacts of SABER CO_2-based Eddy Diffusion Coefficients in the Lower Thermosphere on the Ionosphere/Thermosphere

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In this work, SABER/TIMED observations of monthly global-mean CO_2 profiles and a 1D model are used to estimate eddy diffusion coefficients (Kzz) in the mesosphere and lower thermosphere (MLT) region. Global mean CO_2 in the MLT region shows both an annual oscillation (AO) and a semiannual oscillation (SAO) with maximum during solstice seasons along with a primary maximum in boreal summer. Our calculated AO and SAO in global-mean CO_2 is modeled by AO and SAO in Kzz. Our CO_2-based Kzz at 98 km are then utilized as lower boundary condition in the Thermosphere-Ionosphere Electrodynamics General Circulation Model (TIE-GCM). Our model output shows that the CO_2-based Kzz can not induce the observed AO and SAO in Thermospheric composition and density. From these modeling experiments along with a comparison of our CO_2-based Kzz with the Kzz estimated from satellite-drag by Qian et al. [2009], our work concludes that our CO_2-based Kzz represents eddy diffusion solely due to gravity wave mixing. Furthermore, the difference between our CO_2-based Kzz and the Qian et al. [2009] satellite drag-inferred Kzz represents diffusion and mixing from other non-gravity wave sources not directly accounted for in the TIE-GCM lower boundary conditions.

Wave coupling between the lower and middle thermosphere as viewed from TIMED and GOCE

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Vertical coupling between the lower and middle thermosphere due to the eastward propagating diurnal tide with zonal wave number 3 (DE3) and the 3.5 day ultra-fast Kelvin Wave (UFKW) is investigated using Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics-Sounding of the Atmosphere using Broadband Emission Radiometry (TIMED-SABER) temperatures near 100 km and Gravity field and steady-state Ocean Circulation Explorer (GOCE) neutral densities and zonal winds near 260 km. The analysis is performed between ±45 deg. latitude during 2011, when reliable and continuous measurements are available. With geomagnetic and solar effects removed, DE3 and the UFKW are identified as dominant sources of day-to-day variability at both heights. Evidence is found for the vertical propagation of DE3 and the UFKW from the lower to middle thermosphere over a range of time scales. Over 60% of the variance due to DE3 and the UFKW at 260 km is traceable to variability occurring at 100 km. The not exact agreement is thought to be due to the influences of wave-wave interactions, zonal mean winds, dissipation, and inherent transience that interfere with one-to-one mapping of structures between 100 and 260 km. Spectral and temporal analyses of the SABER and GOCE data also reveal the presence of sidebands due to the modulation of DE3 by the UFKW. These secondary waves are responsible for up to 10% to 20% of the longitudinal and day-to-day variability. Overall, vertical propagating waves together with sidebands from DE3-UFKW nonlinear interactions are responsible for 60% to 80% of the total variability, while geomagnetic and solar effects correlated with ap and F10.7 account for less than 20% of the variance.

An overview of Ionospheric effects of Solar Eclipses: Gravity Wave Emphasis

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Solar eclipses (SEs) are natural phenomena that occur when major portion of solar radiation is suddenly blocked. Since entire ionosphere is affected by the SEs, they provides SE time valuable information both on upper (F-region) and lower ionosphere (D-region). The upper ionosphere has been mainly studied using ionosonde, HF radar and global positioning system (GPS) satellite measurements whereas D-region mainly studied using Extremely Low Frequency (ELF) and Very Low Frequency (VLF) radio waves which propagate by the process of multiple reflections in the waveguide formed by the Earth (ground or sea) and the lower ionosphere called Earth-ionosphere waveguide (EIWG). The lower ionosphere is the variable upper wall of the EIWG which can be affected by SEs. An overview of ionospheric effects of SEs using above techniques both in upper and low ionosphere will be presented with an emphasis of atmospheric gravity waves (AGW) which propagate outward and upwards to ionospheric heights and can cause the traveling ionospheric disturbances in the ionosphere. During SEs, the sources of AGWs could be in the lower troposphere (water vapor), stratosphere (ozone cooling) and in the thermosphere (temperature variation) among which cooling of the ozone layer in the stratosphere is considered to be the major source. The D-region ionospheric response using ELF-VLF radio wave techniques to recent solar eclipses of July 2009, November 2012 and May 2013 in the South Pacific Region and characteristic of associated AGWs will also be presented.

Quasi-two-day wave coupling of the middle atmosphere and Ionosphere-Thermosphere

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In this talk, the coupling mechanisms of the middle atmosphere and ionosphere-thermosphere via the quasi-two-day planetary waves (QTDW) will be reviewed. Results from TIME-GCM numerical simulations and satellite observations will be presented. First of all, the QTDW winds in the lower thermosphere modulate the dynamo electric fields in the E-region ionosphere. The modulated electric field is transmitted into the F-region along the magnetic field and leads to quasi-two-day oscillations in the ion drift and electron densities. The second mechanism is via the dissipation of the QTDW in the lower thermosphere and acceleration of the mean wind. The driven poleward meridional circulation enhances the mixing of constituents in the lower thermosphere. Through molecular diffusion, the decrease of the O mixing ratio and the increase of the N_2 and O_2 mixing ratios propagate from the lower thermosphere into the upper thermosphere. As a result, the mean O/N_2 ratio and electron density near the ionospheric F2 peak is reduced by about 16-20% at low and mid latitudes. The third mechanism is through the interaction between the QTDW and migrating tides in the mesosphere and lower thermosphere. This interaction reduces the amplitude of the migrating diurnal tide in the lower thermosphere in neutral winds and also generates sum and difference secondary waves in the lower thermosphere and E-region ionosphere. As a result of the changed migrating diurnal tide and sum/difference secondary wave, vertical ion drift and electron density vary with local time at different longitudes. The sum and difference secondary waves can cause additional oscillations in vertical ion drift and ionospheric electron densities.

GPS radio occultation: Initial results on the estimation of ionospheric sporadic E intensities

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The GPS radio occultation (RO) technique is employed to study ionospheric sporadic E (Es) layers on a global scale. Our data set is based on FORMOSAT-3/COSMIC radio occultations of the years 2006 and 2013 and comprises about 2,200 globally distributed RO measurements per day. GPS RO signals are sensitive to strong vertical electron density gradients that are found in the presence of Es layers. These gradients cause strong fluctuations in the signal to noise ratio (Signal-to-noise ratio) of the 50 Hz GPS L1 occultation signal which are attributed to sporadic E events. The GPS RO data set was used to obtain a global picture of sporadic E occurrence and its special and temporal variability. We could demonstrate that Es formation is influenced by several geophysical parameters such as tidal winds in the upper atmosphere, the presence of metallic ions and the Earth's magnetic field.

Recently, we extended the existing numerical sporadic E detection algorithm in order to receive information on the intensity of the detected sporadic E layers. We present initial results, which are validated with coinciding ionosonde measurements of the foEs parameter. We also introduce initial global maps of Es intensities based on GPS RO data in dependence on location, altitude, local time and season.

Investigations of Airglow Response to Solar Variation and CO2 Increase Over a Solar Cycle

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Airglow intensity and Volume Emission Rate (VER) variations induced by the increase of CO_2 gas concentration and F10.7 variation (used as a proxy for the 11-year solar cycle variation) are simulated for the period of 1980 to 1991. Two airglow models (OHCD and MACD) with the MSIS-90 model as a reference model are used to simulate the induced variations of O(1S) greenline, O_2(0,1) atmospheric band , and OH(8,3) airglow for this study. Three scenarios are studied. The first scenario is to allow F10.7 to change while keeping CO_2 as constant. The second scenario is to allow CO_2 to change but keep F10.7 as constant. The third scenario is to allow both the F10.7 and CO_2 to change. Results of airglow and VER response to these factors will be presented. We will also present results on the peak airglow altitude variation in response to these factors. The results of our study indicate that airglow emissions and their VERS in the Mesosphere and Lower Thermosphere region do respond to these forcings (CO_2 and F10.7) in different ways.

Global Distribution and Climatological Variability of Quasi-Two-Day Waves: Results Based on the NOGAPS-ALPHA Reanalysis Model and MLS on the NASA Aura Satellite Measurements

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Quasi-two-day waves (QTDWs) are one of the most important features in the dynamics of the middle atmosphere. They have been intensively studied since recent decades. The primary features of the QTDWs were revealed first from ground-based observations. Although significant achievements have been attained these observations cannot provide insight into the global picture of the QTDW distribution. Satellite measurements can do this however they suffer from aliasing and poor temporal resolution problems. In order to overcome the above mentioned weak points of the satellite observations we employ a version of the NOGAPS-ALPHA reanalysis model that has been configured to supply output on an hourly basis. It allows for short-term, observationally-based, estimates of tides and planetary waves to be performed. We analyze 14 months (January 2009–February 2010) continuous hourly measurements of all meteorological fields (neutral winds, temperature and geopotential height) for altitudes between ~15 and ~95 km and latitudes between ±80°. Additional data for January-February, 2005, 2006 and 2008 have been used for tracking out the interannual variability of the QTDWs. The use of the hourly reanalysis data allows for the comprehensive understanding of the global spatial QTDW distribution by simultaneous separations of all tides and considered planetary waves without aliasing. To prove that eastward propagating QTDWs are genuine waves, not products of nonlinear interactions, a new approach for investigating the planetary wave variability is used. The climatological variability of the QTDWs in the fields of temperature and geopotential height is studied by the use of the MLS/Aura satellite measurements for the period of time 2005-2014.

Changes in the mean flow, temperature, and planetary waves observed during the last 36 years

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In our research we analyzed changes in the zonal mean flow, temperature and variability of stationary planetary waves with zonal wave number 1 during January-February and March-April months. That period was taken to consider a period during stratospheric spring transitions. To investigate changes observed in the last 36 years in the large-scale dynamics of the winter stratosphere in the Northern Hemisphere, the MERRA data were used. Analysis of inter-annual and intra-seasonal variability was performed. We compare two periods: 1979-1996, 1997-2014 and showed that there is an increase in the magnitude and the inter-annual variability of SPW1 during the last decades. The distinctions in parameters at winter (JF) and spring (MA) periods were shown. Considerable changes in zonal wind and temperature in high latitudes of the stratosphere were shown at various QBO phases.

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.

Photochemical model for atomic oxygen ions retrieval from ground-based observations 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.

D-region ionospheric oscillations 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 by MF/HF radio sounding method such ionosondes, because the MF radio waves are highly attenuated in daytime D-region, and HF radio waves penetrate into the D-region in both night and day. 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) over Japan and BPC (China)-RKB (Japan). 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 intensity and reflection height show oscillations with a period of about 100 s. The one-to-one correspondence 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. In addition to the oscillations of the 100 s, there were longer term variation with a time scale of ~1000 s in both the intensity and phase of the two LF transmitter signals based on Wavelet analysis. The time difference between the earthquake onset and the 100 s-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 68 km altitude vertically. Thus, the LF oscillations may be caused by the acoustic waves excited by the Rayleigh waves.

The influences of migrating semidiurnal tide variability on the low latitude ionosphere

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Since modifications of the ionospheric tidal signatures during the 2009 stratospheric sudden warming (SSW) event has been observed by radio occultation soundings of FORMOSAT-3/COSMIC. The ionosphere perturbations during the 2009 SSW generally exhibit semi-diurnal behavior, although the exact coupling mechanisms during the 2009 SSW are yet to be fully understood, it is now generally accepted that the modification of atmospheric tides during the SSW is the primary mechanism for coupling between SSWs and ionosphere. Especially the variability of the semi-diurnal migrating tide (SW2) in MLT region, it has been reported the amplitude and phase of SW2 reveal notable changes during the 2009 SSW in several whole atmospheric models, and that can significantly impact the ionosphere though electrodynamics. To investigate the SW2 effects on the low-latitude ionosphere during SSWs, the SW2 tidal forcing applies in the TIE-GCM on the lower boundary is amplified twice and shifted by 2-hours earlier respectively. The dramatic changes in SW2 influence the dynamo generation of electric field and neutral compositions in the thermosphere, and their importance on the ionosphere variability is demonstrated by comparing simulation with and without modified SW2 forcing.

Coseismic ionospheric disturbances at different altitudes observed using HF Doppler sounding

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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 gravity wave excited by Rayleigh wave propagated on the ground from the epicenter. The acoustic wave perturbs 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 profiles of acoustic waves using the single observation instrument. Using HF Doppler sounding system (HFD), we are observing ionospheric disturbances at different altitudes simultaneously. 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 the foreshock of Tohoku earthquake (March 9, 2011), we have found coseismic disturbances observed at 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 amplitude ratios of the acoustic-mode wave from ground to the ionosphere were calculated in 3 bands (10.0-25.6, 25.6-45.5, and 45.5-76.9 mHz). Theoretical amplitude ratios were also calculated based on energy conservation law, considering absorption by viscosity, thermal conductivity, and relaxation losses of atmosphere (Chum et al., 2012). These amplitude ratios are roughly consistent with theoretically-estimated profiles of the acoustic wave. On the other hand, the amplitudes of lower-frequency disturbances are smaller than the theoretical values at all altitude, while the higher-frequency components fit them. The reflection of the acoustic wave in the lower atmosphere might cause the differences of this amplitude ratio because of the increase in the refractive index with altitude.

Long-term variation of horizontal phase velocity spectrum and propagation direction of mesospheric and thermospheric gravity waves observed by an airglow imager at Shigaraki, Japan

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There have been many studies on atmospheric gravity waves (AGWs) by using radars, lidars and airglow imagers, and various AGWs parameters such as wavelengths and phase velocities were studied. However, long-term (>10 years) variation of horizontal phase velocity spectrum of the mesospheric small-scale AGWs, which can be measured by airglow imagers, is not been studied. We analyze the horizontal phase velocity spectrum of AGWs by using 557.7-nm (altitude of 90-100 km) and 630-nm (altitude of 200-300 km) airglow images obtained at Shigaraki MU Observatory (34.8 deg N, 136.1 deg E) over ~17 years from October 1, 1998 to July 26, 2015. The amplitude of airglow intensity variations were normalized by 1-h averages of airglow intensity. We used 3-dimensional Fourier analysis procedures of airglow images proposed by Matsuda et al. (JGR, 2014), making it possible to analyze large amount of data automatically.

First, we considered about 557.7-nm results. Seasonal variations of propagation direction of AGWs was clearly identified (spring: northeastward and southwestward, summer: northeastward, fall: northwestward, winter: southwestward). The power spectrum density (PSD) of horizontal phase velocity changes with time scales of 7-8 years in winter and 2-3 years in spring. The east-west anisotropy (summer: eastward, winter: westward) of AGW propagation is probably caused by filtering of gravity waves due to mesospheric jet (summer: westward, winter: eastward). We also investigate the location of possible AGW sources relative to Shigaraki by using tropospheric re-analysis data about vertical flow velocity to understand the north-south anisotropy. There are regions of strong vertical velocities at south of Japan due to the Baiu seasonal rain front in summer and at north-east of Japan due to wintry low pressure in winter. Thus we consider that the north-south anisotropy of AGW propagation direction is due to the location of AGW sources in summer and winter. There is a correlation between 17-year variations of PSD and tropospheric re-analysis data at south of Japan during summer and north-east of Japan during winter. These regions nearly correspond to the rain front in summer and the wintry low pressure in winter, as we described before. We could not find any clear correlations of 17-year PSD variations with NINO3 index, AO index and sunspot numbers.

Second, we considered about 630-nm results which mainly detects medium-scale traveling ionospheric disturbances. Major propagation direction is always southwestward with a minor northeastward propagating component. The southwestward preference is the same to those obtained from previous reports by visual inspections, while minor northeastward component is newly identified by the present spectral analysis. For long-term variations, we found clear negative correlation between PSD variations and sunspot numbers in the thermosphere. This result indicates suppression of ionospheric instabilities during solar maximum time at middle latitudes. This anti-correlation with solar activity is consistent with growth rate of the Perkins instability, which may play an important role in generating the nighttime MSTID at mid-latitudes.

Solar eclipses and their effects in the ionospheric plasma

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Terrestrial atmosphere shows a high variability over a broad range of periodicities, which mostly consists of wave-like perturbations characterized by various spatial and temporal scales. The interest for short time variability in ionospheric attributes is related to the role that ionosphere plays in the Earth's environment and space weather. Acoustic-gravity waves (AGWs), waves in the period range from sub-seconds to several hours, are sources of most of the short-time ionospheric variability and play an important role in the dynamics and energetics of atmosphere and ionosphere systems.

During solar eclipse, the lunar shadow creates a cool spot in the atmosphere that sweeps at supersonic speed across the Earth’s atmosphere. The atmosphere strongly responds to the decrease in ionization flux and heating. The very sharp border between sunlit and eclipsed region, characterized by strong gradients in temperature and ionization flux, moves throughout the atmosphere and drives it into a non-equilibrium state. Acoustic-gravity waves contribute to the return to equilibrium. At thermospheric heights, the reduction in temperature causes a decrease in pressure over the totality footprint to which the neutral winds respond. Thermal cooling and downward transport of gases lead to neutral composition changes in the thermosphere that have significant influence on the resulting electron density distribution. Although the mechanisms are not well understood, experimental studies show direct evidence that solar eclipses induce wave-like oscillations in the acoustic-gravity wave domain.

Medium scale traveling ionospheric disturbances using FORMOSAT-2/ISUAL 630.0 nm airglow images

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In this work characteristics of nighttime medium-scale travelling ionospheric disturbances (MSTID) are investigated using 630.0 nm limb images by Imager of Sprites and Upper Atmospheric Lightnings (ISUAL), onboard FORMOSAT-2 satellite. The limb integrated measurements, when projected to a horizontal plane, reveal bands of intensity perturbation with distinct southwest to northeast orientation in the southern hemisphere. Airglow simulations are carried out to confirm that such azimuthally oriented features are related to MSTID. Further statistical analysis shows more MSTID occurrence in solstices with peak in June-July months. The wavelengths of the observed perturbations were in the range 150-300 km. The wave fronts were oriented about 30°-50° from the east-west plane, indicating that coupled Perkins and Es-layer instability might be important in the MSTID generation.

December anomaly in ionosphere using FORMOSAT-3/COSMIC electron density profiles

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December anomaly in ionosphere refers to the observation of greater value of global average ionospheric peak electron density (NmF2) in December-January months than in June-July months. So far there has been no satisfactory explanation to account for this difference, which is also known as annual asymmetry, leading to the speculation that forcing from lower atmosphere may be important. In this work, FORMOSAT-3/COSMIC electron density profiles are used to investigate the characteristics of December anomaly at different local times and longitudes in varying levels of solar activity. The observations in the years 2008, 2009 and 2012 are used for the study. The results suggest that the anomaly exists in all the three years, and is pronounced during day. Detailed analysis is carried out using latitude-altitude electron density profiles at selected longitude sectors, revealing that neutral wind may play dominant role. SAMI2 model is used to further examine the role of neutral wind influencing the electron density in different solstices.

Impact of midnight thermosphere dynamics on the equatorial ionospheric vertical drifts

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Recent satellite and ground-based observations have revealed the existence of upward drifts in the post-midnight equatorial ionosphere (~ 0–3 LT). The phenomenon has not been explained by theoretical models. Simulations using the Whole Atmosphere Model (WAM) coupled with the Global Ionosphere Plasmasphere (GIP) model have successfully reproduced the unusual nighttime upward drifts. The simulations and observations by the Ion Velocity Meter (IVM) onboard the Communications/Navigation Outage Forecasting System (C/NOFS) also reveal substantial longitudinal dependence of the drifts. Our analysis indicates that the upward drifts are driven by thermosphere dynamics associated with the midnight temperature maximum (MTM). The MTM locally reverses the typical large-scale zonal and meridional wind pattern, in turn affecting the nighttime F-layer electrodynamics. In addition, the longitudinal variation of the drifts in different seasons depends on the magnitude and position of the MTM peak relative to the magnetic equator.

Unusual mid-latitude aurora

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It is well known that high-latitude thermospheric neutral winds are controlled by auroral precipitations. The intensity and location of discrete aurora, resulting from the precipitations, are important factors responsible for thermospheric and ionospheric disturbances during geomagnetic storms. Here we report observations of intense discrete aurora at middle latitudes during magnetic storms on October 2003, March and June 2015. We show that the low-latitude boundary of aurora during the October 2003 storm was predictable. In contrast, during the other two storms, the aurora occurred at abnormally low latitudes. This finding encourages a revision of the storm-time boundary conditions in the existing models of the thermosphere-ionosphere coupling.

Vertical Coupling of the Atmosphere during Sudden Stratospheric Warming events

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In this presentation, we summarize recent results in the coupling of the stratosphere–mesosphere during stratospheric sudden warming (SSW) events. We focus on the role of planetary and gravity waves in driving the middle atmosphere circulation and illustrate the stratosphere–mesosphere coupling during undisturbed wintertime circulation, during an SSW event, and after an SSW event during the formation of an elevated stratopause using simulations of past Arctic and Antarctic winters from the Specified Dynamics version of the Whole Atmosphere Community Climate Model (SD-WACCM). We illustrate the transition of the polar stratopause from being a gravity wave driven phenomena to a planetary wave driven phenomena during SSW events and its subsequent reestablishment and control by gravity waves. We also examine the synoptic structure of the stratosphere, mesosphere, and lower thermosphere using SD-WACCM data fields that show the structure of the vortex during specific dynamical events in both hemispheres. We illustrate the longitudinal asymmetry in the thermal structure in the stratosphere and mesosphere driven by differences in circulation over the polar cap regions during an SSW event.

Ionospheric electron density inversion for GNSS radio occultation using aided Abel inversions

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The Abel inversion of ionospheric electron density profiles applied for radio occultation soundings have a systematic error when the occultation rays trespass regions with large horizontal gradients due to its assumption of spherical symmetry. Aided Abel inversions were proposed by considering the asymmetry ratio derived from TEC or NmF2 of reconstructed observation maps, since knowledge of the horizontal asymmetry in ambient ionospheric density could mitigate the inversion error. Here we propose a new aided Abel inversion using electron density (Ne) from the climatological maps constructed from previous observations, as it has advantage of providing altitudinal information on the horizontal asymmetry. Improvement of proposed Ne-aided Abel inversion and comparisons with electron density profiles inverted from NmF2- and TEC-aided inversions are studied using observation simulation system experiment (OSSE). Comparison results show that all three aided Abel inversions improve the ionospheric profiling by mitigating the artificial plasma caves and negative electron density in the daytime E region. The equatorial ionization anomaly crests in the F region become more distinct. The absolute error percentage between the inversion result and model truth shows that the Ne-aided inversion has the greatest improvement among the three.

Numerical simulation on ionospheric electron density response to currents from lower atmosphere and lithosphere

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In this study, three-dimensional ionosphere electrodynamic model, NRL-SAMI3, is utilized to simulate the ionospheric perturbation due to external direct currents. We formulate a coupling model for a external current-ionosphere system considering field-aligned or perpendicular disturbance currents that may be propagated upward from lithosphere during seismics. The lithosphere driven current, ranging around 120±20°E, 30±20°N, and 85km altitude, are included in the electrodynamics solver of NRL SAMI3. Our simulation results indicate that the external current produces the total electron content perturbation (ΔTEC) as much as -2.6TECu. The negative ΔTEC response is mainly shown in the southwest of external current; while the positive ΔTEC appear in the southeast of external current. The ion/plasma drift velocity modified due to the external currents affect the equatorial plasma fountain effect and electron densities.Further analyses suggest that current along magnetic field line (in q direction) plays a relatively more important role in production of electron density and TEC variations in comparison with those in perpendicular directions (in meridional and zonal directions). The magnitude of elecric field perturbation and its polarity (eastward or westward) are related with the distribution of lithosphere driven current along magnetic field line at 85km alitude and the field-aligned integrated Pedersen conductivity. The electric field perturbation may be overestimated if one uses ionospheric conductivities at lower boundary of 85 km altitude instead of field-aligned integrated conductivities. The simulations of coupling the field-aligned current take into account the integrated conductivities, and results in smaller E×B drift and TEC perturbations. The simulation result has not compared with the observation result yet.

New inferences on the variability of the occurrence of F3 layers over the dip equator - a manifestation of atmosphere ionosphere coupling

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The equatorial ionosphere supports a variety of features like F3 layers/topside ledges, and also irregularities of varying scale sizes like equatorial spread F (ESF). The former is known to be a manifestation of ionosphere thermosphere interaction. The F3 layers of ionization in the ionosphere, which earlier could only be observed using topside sounders, have been observed from Trivandrum (8.5ºN, 77ºE, 0.5º dip) using ground-based digital ionsonde and single station Total Electron Content (TEC) measurements. The radio beacon namely 'RaBIT' onboard Indian small satellite 'YOUTHSAT' have also enabled ionospheric tomography over the equatorial and low latitude ionospheric processes clearly exhibiting the presence of F3 layer on certain occasions. Apart from this, a detailed investigation of the ground-based ionosonde measurements reveals that the occurrence of F3 in the pre and post noon hours follows different trends.

In the present study, occurrences of post noon F3 layer over Thiruvananthapuram (8.5°N; 77°E; dip latitude ~ 0.5 °N), a dip equatorial station in India have been investigated using ionosonde data for the years 2004-2008. The result indicates that post noon F3 layers appear predominantly during the January and February months during the years 2004 to 2008. However there is an enhanced occurrence during the summer months of 2008. Observations show that F3 layers occurring during winter solstice are formed at later local times, at lower altitudes and exhibit vertically upward movement. While F3 layers occurring during summer solstice form early, at a high altitude and exhibit vertically downward drift. Hence the F3 layers getting generated during summer and winter periods exhibit contrasting behavior. It has also been seen that presence of CEJ is an important condition for the occurrence of post noon F3 layers.

The present study shows that the coupling of the thermospheric zonal wind jet over equator and enhanced ionospheric density at lower heights over Indian longitude can account for the generation of post noon F3 layer through ion-drag. Further the combined effects of the EIA associated convergence and localized heating associated divergence over the dip equatorial region plays an important role in determining the vertical drift of F3 layer and explain the contrasting behavior of summer and winter post noon F3 layers. Thus it is shown that the pre noon and post noon F3 layers are manifestations of the same thermospheric ionospheric coupling process but the contributors as well as the degree of contributions are different. The other major aspects that have emerged are as follows. The lowered ionospheric height is established as an essential condition for the occurrence of F3 layer over the dip equatorial location of Thiruvananthapuram. Inhibited EIA is observed in the prenoon hours on F3 days. The role of ETWA like wind circulations in the generation and vertical drift of F3 layer has been proposed.

Ionospheric TEC Variations During the 2009 Sudden Stratosphere Warming by Assimilating F3/C RO and Ground-based GPSTEC

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The mechanisms of ionosphere variability during the 2009 sudden stratosphere warming (SSW) are generally accepted that the modification of atmospheric tides is the primary mechanism for coupling between SSWs and ionosphere. Especially the modification of semi-diurnal migrating tide (SW2) in MLT region, it has been reported the amplitude and phase of SW2 reveal notable changes in several whole atmospheric models that can significantly impact the ionosphere electrodynamics. This study assimilates the ionospheric electron density profile which retrieved from FORMOSAT-3/COSMIC (F3/C) GPS Radio Occultation observations and ground-based GPS total electron content (TEC) into a numerical simulation model called Thermosphere Ionosphere Electrodynamics General Circulation Model (TIE-GCM) by using ensemble Kalman filter (EnKF) during the 2009 SSW event. The EnKF assimilation system employed in this study is Data Assimilation Research Testbed (DART) which developed by National Center for Atmospheric Research (NCAR). To investigate the tide effects on the ionospheric variability during the 2009 SSW, the SW2 tidal forcing applies in the TIE-GCM on the lower boundary is shifted by 2-hours earlier. The assimilation result shows that the appearance time of TEC peak is earlier than 14LT and its amplitude is also decreased during the SSW period. More detail result will be discussed in the presentation.

Exploration of global ionospheric plasma structure with FORMOSAT-3/COSMIC mission

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The FORMOSAT-3/COSMIC is a constellation mission consists of six micro-satellites performing GPS radio occultation soundings that launched in April 2006. The radio occultation soundings provide nearly 2500 worldwide vertical profiles of both lower neutral atmospheric temperature and ionospheric plasma densities. These occultation soundings of vertical ionospheric electron density profile make visualization of three-dimension global ionospheric plasma structure possible. With this advantage, new ionospheric plasma structures are observed and their physical mechanisms are better understood. In this presentation, a brief description of how FORMOSAT-3/COSMIC prompts discovery or better understanding of new ionospheric plasma structures will be given. Ionospheric plasma structures resulting from coupling with tropospheric and stratospheric meteorological phenomena will be presented. Other new ionospheric plasma structures, such as mid-latitude summer nighttime anomaly and equatorial plasma caves, will also be presented along with the theoretical simulations.

Case studies of the quasi two day wave and coupling between the mesosphere, thermosphere and ionosphere

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We have used a version of the Navy Operational Global Atmospheric Prediction System- Advanced Level Physics High Altitude (NOGAPS-ALPHA) forecast assimilation system to drive the bottom boundary of the NCAR/Thermosphere Ionosphere Electrodynamics General Circulation Model (TIEGCM). NOGAPS-ALPHA provides a synoptic analysis which extends to 95 km. This version of NOGAPS-ALPHA is configured to provide hourly output, reinitialized every 6 hours from the analysis. The use of hourly output to drive the TIEGCM allows for higher order tidal modes to propagate into the lower thermosphere. Hourly output is available, and used here, for 5 Northern winters (2005, 2006, 2008, 2009 and 2010). Of interest here is the quasi two day wave (Q2DW) which is generated in the mid mesosphere and peaks in the Southern summer. The Q2DW is shown to provide a significant source of westward momentum to the mesosphere and thermosphere and thus can have significant effects on the zonal mean state of the upper atmosphere. In addition, through oscillations in the ionospheric dynamo, it can cause oscillations in the total electron content of the ionosphere. Recent work has shown that in certain years, wave-wave interactions can lead to so-called child waves of the Q2DW. These waves also propagate up into the upper atmosphere and their effects, and their year-to-year variability are quantified.

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Atmosphere-Ionosphere coupling due to dust storms occurring over the Sahara Area in May 2008

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In this paper, MODIS onboard TERRA or AQUA is used to monitor dust storm occurrences of the globe, while the global ionosphere map (GIM) of the total electron content (TEC) and the ion/electron density/temperature and ion velocity probed by DEMETER are employed to study ionospheric responses during May 2008. The aerosol optical depth (AOD) of MODIS shows that a sever dust storm occurs over the Sahara Area on 28 May 2008, while it is a clear weather on 23 May. The GIM TEC and the DEMITER electron/ion density (temperature) along the Sahara longitude simultaneously reach their extreme maximum (minimum) values at daytime 10:00LT on 28 May 2008. The extrema of the GIM TEC and the DEMETER density/electron parameters at the global fixed local time at 10:00LT specifically and significantly appear over the Sahara region on 28 May 2008, which suggests that ionospheric dust storm signatures have been observed. The DEMETER ion velocity in the nadir and westward directions further show that the atmospheric electric fields in the upward direction have been induced by the dust storm, which in turn modifies the ionospheric plasma over the Sahara area.

The measurement of the vertical electric field near ground and an interesting signature associated with 0206 earthquake

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Recent studies show that a strong coupling driven by the electrodynamic processes exists between lithosphere, atmosphere and extending up to the ionosphere. Natural phenomena on the ground surface such as oceans variation, volcanic and seismic activities, earthquakes, and lightning possibly generate significant impacts at ionosphere immediately by electrodynamic processes. The electric field near the ground is one of the potential quantities to explore this coupling process, especially caused by earthquake. Unfortunately, thunderstorm, dust storm or human activities also affect the measured electric field at ground. To investigate the feasibility of a network to monitor the variation of the ground electric field driven by the lightning and earthquake, a filed mill has been deployed in the NCKU campus since Dec. 2015, and luckily experienced the earthquake on 6 Feb. 2016. The recorded ground electric field deceased steadily since 1.5 days before the earthquake, and returned to normal level gradually. Moreover, this special feature can not be identified in the other period of the field test. The detail analysis is reported in this presentation.

El Niño–Southern Oscillation in ionospheric and thermospheric tides

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El Niño–Southern Oscillation (ENSO) has been suggested as a potentially significant energy source that affects the Earth's upper atmosphere from the ocean and lower atmosphere. However, solid evidences and physical mechanisms still remain obscure. ENSO signal in the ionosphere is difficult to be resolved due to the complex natural of the atmosphere-ionosphere-solar system. Here we first resolve tidal components including DE3, DW1, and SPW4 in both ionosphere and thermosphere from the global FORMOSAT-3/COSMIC (F3C) TEC (integration from 200 km to LEO altitude) and TIMED/SABER temperature (at 100 km altitude) observations. Then the Multi-dimensional Ensemble Empirical Mode Decomposition from the Hilbert-Huang Transform is further applied to analyze the amplitude these tidal components in detail. The correlation between the Oceanic Niño Index (ONI) and the variation of those tidal amplitude shows that the ENSO single is pronounced in the TEC SPW4 of particularly near 30°N magnetic latitude during low solar activity period. ONI leads the ENSO signal in the SPW4 by 5 month. ENSO signal from troposphere may affect the SPW4 in ionosphere via the interaction of the DE3 and DW1 in thermosphere.

The Correlation of Outgoing Longwave Radiation and Temperature in the Tropical Tropopause Layer: FORMOSAT-3/COSMIC Observations

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The properties of lapse rate minimum (LRM), including its altitude and temperature, in the global tropical belt from 20°S to 20°N are analyzed to study the phenomena in the tropical tropopause layer (TTL). The data used include the 3-year data based on the radio occultation observations acquired from FORMOSAT-3/COSMIC mission in the period of November 2006 to October 2009. The correlations between Outgoing Longwave Radiation (OLR) and measured temperatures at LRM are derived, and the correlations are higher at regions where OLR is lower, that is, where the tropical convection is active. Two regions with higher correlations, 60°E to 180°E, and 90°W to 30°E, are selected to examine the averaged altitudinal dependence of such correlations so as to investigate the extent to which the convection may still dominate above LRM. The correlations reach maximum at the LRM altitude and gradually decrease as the altitude ascends, but the magnitude stays similar up to 2 km above LRM, which implies that the convection mechanism could be dominant up to this height. The correlations drop sharply from about 4 to 5 km above the LRM altitude, which is likely because the radiative transfer mechanism becomes dominant and the altitude is close to the cold point tropopause (CPT). Below the LRM altitude, the correlation decreases with a lower rate as the altitude descends to about 5km deeper, the lower limit of the altitude retrieved, suggesting that the convection is dominant throughout this altitudinal range.