Development and Validation of NCAR Whole Atmosphere Community Climate Model with Thermosphere/Ionosphere Extension (WACCM-X)

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The NCAR Whole Atmosphere Community Climate Model with Thermosphere/Ionosphere Extension (WACCM-X) has been developed to study the solar impact on the Earth system, to understand and quantify couplings between atmospheric layers through chemical, physical and dynamical processes, and to investigate the implications of the couplings to climate (downward coupling) and to space environment (upward coupling). This talk discusses recent development of WACCM-X, including newly implemented modules of ionospheric electrodynamics, O+ transport and plasma temperatures, as well as modification of model dynamical core for the thermosphere, where mean molecular mass and specific heats are variables. With the interactive ionosphere modules and the improved dycore, we have made extensive simulations to validate the thermosphere and ionosphere results. The thermospheric compositional structure are in good agreement with climatology. Atmospheric tides, which are important in controlling the dynamics, transport and electrodynamics in the upper atmosphere but were underestimated in earlier versions of WACCM-X, are now well resolved and are in good agreement with observations. Ionospheric plasma densities, including the equatorial ionization anomaly (EIA) and zonal and vertical ExB drifts are found to be in good agreement with observations. Variabilities from day-to-day to seasonal scales and solar cycle dependence are also examined.

Keywords: Whole atmosphere model, space weather, lower and upper atmosphere coupling

The Navy Highly Integrated Thermosphere Ionosphere Demonstration System (Navy-HITIDES): Stratospheric Warming, Tides and Annular Modes in a Whole Atmosphere with Ionospheric Effects

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We present novel results of a new atmosphere-ionosphere integrated system developed at the Naval Research Laboratory (NRL) that allows the investigation of lower atmospheric effects on the upper mesosphere, lower thermosphere and the ionosphere (UMLT-I). The Navy-HITIDES prototype is flexible enough to couple with any neutral atmosphere model, and for the purpose of this talk we have coupled Navy-HITIDES with the NCAR Whole Atmosphere Community Climate Model, extended version (WACCM-X); the underlying ionospheric model is the NRL SAMI3. We will illustrate the motivation for developing Navy-HITIDES, the engineering that makes this model flexible, portable and accurate. We discuss in detail simulations with Navy-HITIDES where the lower atmospheric meteorology is constrained by the prototype Navy high altitude atmospheric analysis (0-90 km), the advantages of nudging with high altitude analysis, as well as its limitations. Particular attention is devoted to the morphology of the UMLT-I, how it changes with stratospheric warming, resolution of tidal motion and annular modes.

Keywords: thermosphere Ionosphere Coupling, whole atmosphere coupling

Observations of the thermal structure, composition, and energy budget of the mesosphere and thermosphere from 15 years of data from SABER

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The Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument has been observing the thermal structure, chemical composition, and energy budget of the Earth's mesosphere and thermosphere for over 15 years. The instrument is on the NASA Thermosphere-Ionosphere-Mesosphere-Energetics and Dynamics (TIMED) satellite and continues to operate nominally, routinely collecting over 1500 profiles of limb radiance daily in each of its 10 channels. These measurements produce over 30 unique data products. The length of the SABER dataset continues to enable scientific discovery on topics ranging from solar-terrestrial connections to global change due to carbon dioxide increases. In this talk we will review in particular the influence of solar variability on the energy balance, composition, and thermal structure of the upper atmosphere. A specific focus will be on the current state of the Sun as it progresses towards the next solar minimum, and the corresponding effects seen in Earth's atmosphere. We also will examine the effects of recent high speed solar wind stream events that are now becoming more common in this phase of solar activity, searching for evidence of previously-observed harmonics of the solar rotation period in the infrared cooling budget of the thermosphere. Prospects and requirements for new observations of the ionosphere-thermosphere-mesosphere will also be presented.

Keywords: Mesosphere-Thermosphere, Solar-Terrestrial Coupling, Global Change

Coupling processes in the upper atmosphere revealed by imaging observation of the ISS-IMAP mission

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Imaging observation of the ISS-IMAP (Ionosphere, Mesosphere, upper Atmosphere, and Plasmasphere mapping) mission detected the airglow in the mesosphere and the lower thermosphere (MLT), and the ion resonant scattering in the ionosphere from 2012 and 2015. It was installed on the Exposure Facility of Japanese Experiment Module of the International Space Station, EF of ISS-JEM, and consisted of two sets of imagers. Visible-light and infrared spectrum imager (VISI) observed the airglow of 730nm (OH, Alt. 85km), 762nm (O2, Alt. 95km), and 630nm (O, Alt. 250km) in the MLT region, and Extra ultraviolet imager (EUVI) observed the resonant scattering of 30.4nm (He+) and 83.4nm (O+) from ion in the Ionosphere. Horizontal two-dimensional imaging of VISI frequently detected concentric wave structures in the mesosphere. The wave features of the concentric wave structures imply the propagation direction and the center of the structure. Using them, some of them can be directly connected with the lower atmospheric phenomena, such as tornado and tropical cyclone. This observation revealed the coupling between the lower and the upper atmospheres with atmospheric gravity waves. On the topside of the ionosphere, EUVI detected the interhemispheric asymmetry of the He+ ion distribution. It shows clearly longitudinal variations, and implies that the interhemispheric neutral wind and the configuration of the geomagnetic field affect the transport of He+ as the result of the coupling process between the neutral atmosphere and the ionized atmosphere on the bottomside of the ionosphere. Results of the imaging observation of the MLT region and the ionosphere from ISS, and the coupling processes will be discussed in the presentation.

Keywords: Thermosphere, Ionosphere, Mesosphere, Atmospheric gravity wave, Airglow, International Space Station

Effects of thermospheric gravity waves on the thermosphere-Ionosphere system simulated by high resolution GAIA

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It has been recognized that short-period fluctuations (0.5 hour- 2 hour) associated with gravity waves play an important role on the thermosphere-Ionosphere (TI) system. In order to investigate effects of thermospheric gravity waves on the TI system, we have developed an atmosphere-ionosphere coupled model (GAIA) with high horizontal resolution (about 1.0 degree longitude by 1.0 degree latitude). The GAIA contains the region from the ground surface to the upper thermosphere (about 500km altitude), so that we can simulate excitation of gravity waves in the lower atmosphere and their upward propagation to the thermosphere. Furthermore, the GAIA simulation with higher horizontal resolution (about 0.5 degree longitude by 0.5 degree latitude) is conducted. In this study, we focus our attention on gravity wave activity in the winter thermosphere/ionosphere. Our simulation result indicates that fluctuations with periods (0.5 hour - 2 hour) associated with thermospheric gravity waves are more significant in the winter hemisphere. Fluctuations of electron density in the F-region due to upward propagating gravity waves are also studied.

Keywords: Thermosphere-ionosphere coupling, gravity wave, vertical coupling

Thermospheric nitric oxide response to shock-led storms

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We present a multiyear superposed epoch study of the Sounding of the Atmosphere using Broadband Emission Radiometry nitric oxide (NO) emission data. NO is a trace constituent in the thermosphere that acts as cooling agent via infrared (IR) emissions. The NO cooling competes with storm time thermospheric heating resulting in a thermostat effect. Our study of nearly 200 events reveals that shock-led interplanetary coronal mass ejections (ICMEs) are prone to early and excessive thermospheric NO production and IR emissions. Excess NO emissions can arrest thermospheric expansion by cooling the thermosphere during intense storms. The strongest events curtail the interval of neutral density increase and produce a phenomenon known as thermospheric “overcooling.” We use Defense Meteorological Satellite Program particle precipitation data to show that interplanetary shocks and their ICME drivers can more than double the fluxes of precipitating particles that are known to trigger the production of thermospheric NO. Coincident increases in Joule heating likely amplify the effect. In turn, NO emissions are more than double. For some events, there may be an additional factor of early NO production due to solar flares. Perhaps a more potent combination of solar wind events involves a series of ICMEs, especially if the interplanetary path has been “cleared” for the second or subsequent ICME. We discuss the roles and features of shock/sheath structures that allow the thermosphere to temper the effects of extreme storm time energy input. Shock-driven thermospheric NO IR cooling likely plays an important role in satellite drag forecasting challenges during extreme events.

Keywords: Thermospheric nitric oxide, Coronal mass ejections, Shock-led storms

Molecular Ion Up-flows and Hot Oxygen Atoms in Magnetosphere-Ionosphere-Thermosphere Coupling

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The CASSIOPE Enhanced Polar Outflow Probe (e-POP) has been in operation since its launch into a polar orbit in September 2013. In the present study, we use the high-resolution in-situ data from e-POP to investigate a specific magnetosphere-ionosphere-thermosphere (MIC) coupling process: the acceleration and up-flows of molecular ions in the auroral ionosphere and the subsequent production of hot neutral oxygen atoms. Specifically, we present observations of enhanced molecular NO^+ and possibly O_2^+ ion densities in the F-region and topside ionosphere (up to ~1000 km altitude), and density and temperature estimates of the hot oxygen atoms resulting from the dissociative recombination of the observed ions: we obtain these estimates by solving the Boltzmann equation for the collisional relaxation between the non-thermal nascent and ambient oxygen atoms, and compare them with previous observations and theoretical model predictions

Keywords: magnetosphere, ionosphere, thermosphere, molecular ions, oxygen

What Drives the Variability of the Mid-Latitude Ionosphere?

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The superposition of processes driving the short-term variability of ionosphere on scales from several minutes to several days remains one of the challenging topics in ionospheric research. In this study, we aim to 1) quantitatively describe short-term variability in the mid-latitude ionosphere and 2) investigate drivers of this variability. We use over 40 years of observations by the Millstone Hill incoherent scatter radar (42.6^{o}N, 288.5^{o}E) to develop updated empirical model of ionospheric parameters, and wintertime data collected in 2004-2017 to study variability in ionospheric parameters, focusing on ion temperature and electron density. We also use NASA MERRA2 atmospheric reanalysis data to examine possible connections between the state of the stratosphere & mesosphere and the upper atmosphere and ionosphere. Our analysis indicates that high-frequency variations (on time scales < 2 hrs) are the dominant contributor to the short-term ionospheric variability. Such variations are often associated with traveling ionospheric disturbances with periods in the range of 40-80 mins. Analysis of anomalies (data-model differences) in ion temperature show significant correlation with high-latitude stratospheric planetary wave 1 amplitude, with positive correlation during daytime and negative correlation at night. We suggest that this correlation results from differences in gravity wave filtering by mesospheric zonal wind altered due to the influence of stratospheric planetary wave 1.

Keywords: ionosphere, mesosphere

Large-scale dynamics derived from a longitudinal chain of northern hemisphere SuperDARN radars

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Although particular tidal and planetary wave modes are known to structure the ionosphere, wind observations from a single station produce a time-series from which only the total tidal harmonics can be detected. Similarly, long time-series from a single station can only give the net period and wind perturbation of the superposed spatial wavenumber components. While satellite data can give both temporal and spatial components, the time and spatial information is generally not separable without assuming stationarity. Here, hourly mean meteor wind data from a longitudinal chain of 8 mid-latitude northern hemisphere SuperDARN radars have been combined in order to provide the spatial tidal and planetary wave components as a function of time. This has been used to extract the migrating and non-migrating components of the semidiurnal tide, as well as the S1 and S2 planetary wave components in the lower thermosphere meridional wind between 1995 and 2016. Unlike in the southern hemisphere, the semidiurnal tide is dominated by the migrating (W2) component, though small but significant W1 and W3 contributions to the semidiurnal tide are measured, especially around the equinoxes. The large planetary wave amplitudes in the northern hemisphere can also couple into these tidal components. Data analysis and validation will be presented, together with initial results on the inter-annual variability of the tidal and planetary wave components and their possible coupling to the ionosphere.

Keywords: Dynamics, MLT, ionosphere

Characteristics of long-term variations in the ionospheric electric field estimated with geomagnetic solar quiet daily variation

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Geomagnetic solar quiet (Sq) variation observed on the ground is produced by the large-scale ionospheric currents flowing in the E-region of the ionosphere. The Sq currents are driven by the ionospheric electric fields consisting of polarization electric field and dynamo field (VxB), where V and B indicates the neutral wind and background magnetic field, respectively. The neutral wind is driven by atmospheric tidal waves in the mesosphere and lower thermosphere (MLT) (60-150 km), which are caused by atmospheric heating due to solar extreme ultraviolet (EUV) radiation and an effect of atmospheric gravity waves. Therefore, to investigate the long-term variation in the ionospheric electric field estimated with the Sq variation is important to find the signals of long-term variation in the MLT and ionosphere. In this study, in order to clarify the seasonal and solar activity dependence of the ionospheric electric fields estimated with the Sq variation from 1958 to 2015, we analyze 1-hour geomagnetic field data obtained from 83 geomagnetic observatories from the middle-latitude to equatorial regions with an aid of the IUGONET data analysis tool. These geomagnetic field data were provided by WDC for Geomagnetism, Kyoto University. In this analysis, we first selected geomagnetic field data for the solar quiet days, which is defined as a day through which the Kp index is less than 4. Next, we identified the Sq variation as a deviation from the value at midnight in both the X and Y components of the geomagnetic field data. Finally, we obtained the monthly-mean ionospheric electric fields by solving Ohm's equation with the two-dimensional height-integrated ionospheric conductivity and geomagnetic Sq variation. As a result, the ionospheric zonal and meridional electric fields show a clear seasonal variation and 11-year solar activity dependence at all of the investigated geomagnetic stations. The power spectra of the zonal electric field show three dominant peaks in period at 6, 12 and 132 months. Moreover, the 4-month periodic component is also found in the middle-latitude region. The intensity of the zonal electric field is positively correlated with the F10.7 index near the equatorial region (|q| < 20 degrees, q: magnetic latitude) with no time lag, while they show a negative correlation in the middle-latitude region (|q| > 20 degrees). Such a latitudinal difference is seen in all the geographical longitudes. As a cause of the negative correlation in the middle latitudes, we infer that the neutral wind originating from solar tidal waves in the lower thermosphere weakens during a high solar activity due to the enhancement of ion drag effect.

Keywords: Geomagnetic solar quiet daily variation, Ionospheric electric field, Seasonal variation, Solar activity, Long-term vairation, IUGONET

Dependence of ExB Drifts in the Night-Time Ionosphere on Winds and Conductivities

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Plasma ExB convection in the night-time ionosphere is driven largely by the F-region dynamo, with additional effects due to boundary electric potentials at dawn and dusk and at high latitude. In the evening a vortex of convection over the magnetic equator is established, of which the upward branch represents the pre-reversal enhancement (PRE) of the vertical drift around 18-19 magnetic local time. The PRE affects the height of the ionosphere, the latitude distribution of electron density, and the likelihood of plasma instabilities. An approximate minimization principle for the night-time convection helps explain its dependence on the winds and conductivities. F-region winds in the Equatorial Ionization Anomaly region determine most of the electrodynamics of the entire low-latitude region at night. After sunset eastward winds drive plasma convection that increases toward the east, and normally causes plasma to be drawn up across lower-altitude geomagnetic-field lines to produce the PRE. Cowling conductivity in the night-time E-region equatorial electrojet retards the upflow, making the PRE sensitive to variable and poorly known night-time ionization.

An unseasonal equatorial plasma bubble event observed over Southeast Asia

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Recent progress has been made in describing the daily variability of Equatorial Plasma Bubble (EPB) occurrence using global physics-based thermosphere-ionosphere modeling, particularly during "peak" EPB seasons. Presented in this study is an analysis of an "off-peak" EPB event over the Southeast Asian region on the evening of 28 July 2014 that was not captured by the modeling performed in previous work.

Ground-based GPS scintillation, ionosonde and space-based GPS Radio Occultation (RO) data show the existence of Equatorial F-region Irregularities (EFIs) shortly after sunset over a region spanning 30° in longitude and 40° in latitude, centered on the geomagnetic equator. This EFI event was observed during a season when EPBs are expected to be rare/infrequent in the Southeast Asian longitude sector. Interestingly, GPS RO data indicates that this EFI event over Southeast Asia coincided with a suppression of EPBs in the African and Pacific longitude sectors, which were both experiencing a "peak" EPB season. Supporting ionosonde data reveals the presence of a strong pre-reversal enhancement (PRE) in the upward plasma drift over Southeast Asia on this day after sunset, and that this PRE was significantly stronger than on any other day of July 2014. An analysis of the geophysical conditions during this event reveals that this enhanced PRE was not caused by geomagnetic activity, and therefore was not due to storm-time penetration electric fields. Instead, it is suggested that forcing from lower altitudes, perhaps from tidal/planetary waves, could have caused this strong PRE. This strong PRE subsequently created favorable EPB growth conditions during an off-peak EPB season in the Southeast Asian sector, which manifested as unseasonal ionospheric scintillation activity across the region. The present inability to forecast such events is a significant and continuing challenge for ionospheric physics and space weather prediction.

Keywords: Equatorial Plasma Bubbles, Ionospheric Scintillation, Space Weather Forecasting, Thermosphere-ionosphere coupling

Spectral analysis of equatorial plasma bubbles obtained by high-resolution bubble model and C/NOFS satellite

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Equatorial plasma bubbles (EPBs) are a well-known phenomenon in the equatorial ionospheric F region. As it causes severe scintillation in the amplitude and phase of radio signals, it is important to understand and forecast the occurrence of EPBs from the space weather point of view. EPBs are presently considered to evolve from the generalized Rayleigh-Taylor instability. It has been proposed that large-scale wave structure (LSWS) at the bottomside of the F region should be an important seeding of EPBs. However, it is quite difficult to observe the evolution of EPBs from a specific LSWS structure. Therefore, numerical modeling is a powerful tool to study the condition of EPB occurrence and day-to-day variability. In order to simulate the instability in the equatorial ionosphere, a three-dimensional high-resolution bubble (HIRB) model with a grid spacing of as small as 1 km was developed. Using the HIRB model, the nonlinear growth of EPBs from LSWS-like seeding, the formation of very turbulent internal structures such as bifurcation and pinching, and the east-west asymmetry of EPBs have been demonstrated.
A recent upgrade of the HIRB model has made it possible to conduct simulations with sub-kilometer grid spacing. Once EPBs penetrate into the topside ionosphere, turbulent internal structures become very significant. From the preliminary spectral analysis of higher-resolution simulation results, we obtain the power law characteristics of the turbulent structures of simulated EPBs. There are two power law components with a break point at around a few km wavelengths. The power law characteristics are consistent with past in situ observations such as the C/NOFS satellite to some extent. For more detailed analysis, wavelet-based analysis can be applied for the turbulent structures of the simulated EPBs, and the results can be compared with the same analysis applied for the C/NOFS satellite data. Such spectral information may be useful for the quantitative evaluation of radio wave scintillation intensity.

Keywords: equatorial plasma bubble, simulation, C/NOFS

Study of ionospheric irregularities in the 'temperate' mid-latitude region using the SuperDARN radars

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The Super Dual Auroral Radar Network (SuperDARN) is a network of HF radars deployed in the high and middle latitude regions of both hemispheres. Characteristics of ionospheric irregularities is one of the important topics which can be dealt with, using the SuperDARN. Since this network covers a wide latitudinal range, it can assess generation of ionospheric irregularities under an extended range of conditions. The Hokkaido Pair (HOP) of radars, located in the Northen Japan, are the only SuperDARN installations monitoring irregularities below 50 deg of geomagnetic latitude, the region often referred to as ‘temperate’ mid-latitude region. Here irregularities are commonly ascribed to the generation of polarization electric fields inside the Medium-Scale Traveling Ionospheric Disturbances (MSTIDs), whereas some of them are embedded in the steady convection structures unrelated to MSTIDs. In this paper we review SuperDARN studies of the ionospheric irregularities at the temperate mid-latitudes over the past 10 years as well as discuss future perspectives.

Keywords: ionospheric irregularity, SuperDARN, mid-latitude

Impact of Midnight Thermosphere Dynamics on the Nighttime Middle- and Low-latitude Ionosphere

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Simulations using the coupled Whole Atmosphere Model and Global Ionosphere Plasmasphere Model (WAM/GIP) have successfully reproduced the unusual upward drift during the post-midnight period (~2-3 LT) that were observed by C/NOFS satellite during the recent solar minimum. Model produces significant day-to-day variability in the nighttime equatorial ionosphere and also reveals strong seasonal and longitudinal dependence of the nighttime upward drift. 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. The longitudinal variation of the drifts depends on the magnitude and position of the MTM peak relative to the magnetic equator. In this talk, we will present the morphology and characteristics of the post-midnight upward drift shown in the simulations and explain its causal mechanism. Additionally, simulation of growth rate of Rayleigh–Taylor instability associated with the nighttime upward drift and brightness waves produced by the MTM will also be discussed.

Keywords: Midnight Temperature Maximum, Low-latitude ionosphere, Equatorial Vertical Drift

Energetic particle impact on the Na layer

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The metallic atom and ion layers, its source is considered as ablation of meteoroids coming into the atmosphere, are generally distributed mainly height range of 80-110 km or higher in the upper atmosphere. An importance of the metallic ions, such as Na^+ and Fe^+, is their longer chemical lifetimes, i.e. slower recombination rates, compared with major ions, such as NO^+ and O_2^+. This can contribute to maintain dens electron concentration, which can influence radio propagation in the upper atmosphere, e.g., satellite communication between the ground and space. The metallic atoms, such as Na and Fe, are also important as a reservoir of the metallic ions through their chemical processes. Thus, it is socially important to investigate the metallic atom and ion layers for understanding or prediction of the radio propagation environment in the upper atmosphere.

In this presentation, we will introduce our recent investigation, which focuses on energetic particle impact on the Na layer. There are several previous studies on this issue. Of interest is that the previous studies reported conflicting results and/or suggestions in the response of Na density to auroral activity. In some cases the Na density increased, and in others it decreased. Thus, the Na density response to auroral activity is still unclear. We have been working on this issue using ground-based observations, such as Na resonance scattering lidar and European incoherent scatter (EISCAT) radar, as well as Na dayglow measurements from space, such as Optical Spectrograph and InfraRed Imager System (OSIRIS) onboard the Odin satellite. As the results of our investigation, we conclude that the basic auroral effect to the Na density is a decrease not an increase and the decrease is probably induced through Na ion chemistry triggered by ionization due to energetic particle precipitation related with the auroral activity.

Keywords: Na layer, energetic particle precipitation, auroral activity

Meteor radar observations at Mohe, China

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In this talk, we report the observations of the VHF all-sky meteor radar operated at Mohe (53.5 °N, 122.3° E), China, since August 2011. The kinetic temperature profiles retrieved from the observations of Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) onboard the Thermosphere, Ionosphere, Mesosphere, Energetics, and Dynamics (TIMED) satellite are processed to provide the temperature (T_{SABER}) and temperature gradient (dT/dh) at 90 km height. Based on the SABER temperature profile data an empirical dT/dh model is developed for the Mohe latitude. First, a semiannual variation is dominated in the peak height of the height distribution of meteor echoes and there is an annual variation in the half width of the height distribution of meteor echoes. Secondly, we derive the temperatures from the meteor decay times (T_{meteor}) and the Mohe dT/dh model gives prior information of temperature gradients. Thirdly, the full-width of half maximum (FWHM) of the meteor height profiles is calculated and further used to deduce the temperatures (T_{FWHM}) based on the strong linear relationship between FWHM and T_{SABER}. The temperatures at 90 km deduced from the decay times (T_{meteor}) and from the meteor height distributions (T_{FWHM}) at Mohe are validated/calibrated with T_{SABER}. The temperatures present a considerable annual variation, being maximum in winter and minimum in summer. Harmonic analyses reveal that the temperatures have an annual variation consistent with T_{SABER}. Our work suggests that the FWHM has a good performance in routine estimation of the temperatures.

Acknowledgments
The TIMED/SABER kinetic temperature (version 2.0) data are provided by the SABER team through http://saber.gats-inc.com/. The temperatures from the NRLMSISE-00 model are calculated using Aerospace Blockset toolbox of MATLAB (2016a). This research was supported by National Natural Science Foundation of China (41231065, 41321003). We acknowledge the use of meteor radar data from the Chinese Meridian Project and from Data Center for Geophysics, Data Sharing Infrastructure of Earth System Science. The Mohe meteor radar was operated by Beijing National Observatory of Space Environment, Institute of Geology and Geophysics, Chinese Academy of Sciences.

Keywords: mesosphere, meteor radar

Response of diurnal tides to ENSO in the MLT region: a 21-year reanalysis GAIA model simulation result

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The whole atmosphere model GAIA is employed to investigate potential ENSO effect on the upper atmosphere. Driven by reanalysis data, effects of the strong El-Nino events in 1997-98 and 2015-2016 and La-Nina events during 1999 and 2010 are examined. Distinct features are revealed about ENSO impacts on tidal components 100 km altitude. 1. Tidal response to ENSO in meridional wind is different from those in Temperature and zonal wind 2. Tidal response in temperature and zonal wind show consistent features, with DW1 component enhances in autumn during El-nino events, DE2 and DE3 increases during La-Nina events. These characteristics provide us with a necessary global context to better connect and understand the upper atmosphere observations during ENSO events.

Keywords: tides, ENSO, vertical coupling

El Niño - Southern Oscillation effect on quasi-biennial oscillation of temperature diurnal tides in mesosphere and lower thermosphere

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The El Niño - Southern Oscillation (ENSO) is known as a periodic (2 to 7 years) planetary-scale ocean-atmosphere-coupled phenomenon that affects global climate and weather systems at various space and time frames. Studies in the recent decade suggested that the ENSO is a significant source of tides variability in the mesosphere and lower thermosphere (MLT). In this study, we examine the ENSO signals in the two dominant temperature diurnal tides of DW1 (diurnal westward wavenumber 1) and DE3 (diurnal eastward wavenumber 3) on the quasi-biennial oscillation (QBO) scale (18 to 34 months) in MLT. The tides are derived from the 21-year (1996 to 2016) GAIA (Ground-to-topside model of Atmosphere and Ionosphere for Aeronomy) temperature simulations and the 15-year (2002 to 2016) TIMED (Thermosphere Ionosphere Mesosphere Energetics and Dynamics) / SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) temperature observations. The results show that the ENSO constrains the QBO not only in the stratosphere but also in the MLT. The anomalous stratospheric QBO in 2015–2016 enhances the DW1 in period from 1 to 1.5 years that is much shorter than the QBO period. The long-term decreasing trends in the DE3 QBO amplitude and the rainfall rate at low latitudes reveal the DE3 response to the climatological changes, of which the ENSO is one of the players.

Keywords: ENSO, QBO, diurnal tides

On the Relationship between Sporadic-E and ENSO Observed by FORMOSAT-3/COSMIC

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Sporadic E (Es) refers to dense layers of metallic ions that can form in the ionospheric E region due to the effects of vertical neutral wind shear, influencing terrestrial and satellite radio propagation. The effects of Es can be observed by means of GPS scintillation in the E region, parametrized as the S4 phase fluctuation index. Here we present a report on the long term variation of Es using S4 indices and the zonal mean tropopause height measured by the FORMOSAT-3/COSMIC satellite constellation from 2007 - 2014. We find that the monthly global median S4 index in the E region shows a prominent dependence on variation of the El Nino-Southern Oscillation (ENSO) in the troposphere that has not been previously reported. The ENSO related variation of the E region global median S4 indices varies in phase with that of the zonal mean tropopause height, with both parameters lagging the Oceanic Nino index by four months. Taken together, these results indicate that ENSO signatures can be transmitted to Es formation mechanisms, potentially through modulation of the atmospheric waves and tides that alter lower thermospheric neutral wind shears by vertically propagating and breaking in that region.

Keywords: Sporadic E, ENSO, Tides

