Development of MU radar real-time processing system with adaptive clutter rejection

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Strong clutter echoes from a hard target such as a mountain or building sometimes cause problems of observations with atmospheric radars. In order to reject or suppress clutter echoes, it is effective to use NC-DCMP (Norm Constrained-Directionally Constrained Minimum Power) method, which makes null toward the direction of the clutter, if we can receive signals independently from plural antennas [Nishimura et al., JTech., 2012]. It has been demonstrated that the NC-DCMP method is effective to real observation data with the MU (Middle and Upper atmosphere) radar, but it was processed in off-line. The objective of this study is to implement the clutter rejection by NC-DCMP method into the on-line processing system of the MU radar. NC-DCMP method suppresses clutter echoes with maintaining the shape of main lobe to add pseudo-noise.
The MU radar is operated in a troposphere-stratosphere standard observation mode for about 100 hours every month. First we implemented the NC-DCMP processing to this standard observation mode. Observation data in this mode is obtained once every 8 seconds. Therefore it is necessary to perform all of the signal processing within 8 seconds in order to perform the clutter suppression in real-time. Now we can process the NC-DCMP in 1 second in average. Since the echoes from mountains and buildings do not change so quickly, it showed good results to determine the optimum weight vector using the received signal of the incoherent integration 7 times (about one minute). We have applied the NC-DCMP realtime processing since November 2015. Although it is it not perfect for the echoes from the aircraft, the effect of suppressing is obtained.
We can apply the achievement of this study to the Equatorial MU radar (EMU), which is proposed to be constructed at West Sumatera, Indonesia. The EMU system is the similar as the MU radar, but its antenna consists of 1045 Yagi antennas with 55 groups.

Keywords: Atmospheric radar, Clutter rejection, NC-DCMP method, MU radar

Variability of Rain Microstructure over Sumatra from Micro Rain Radar Observation

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The vertical profile of rain microstructure such as raindrop size distribution (DSD) is important for understanding rain formation processes and to improve the accuracy of radar-derived rainfall estimates. The variability in the DSD substantially limits the accuracy of the DSD application. The aim of the present study is to investigate the natural variability of vertical profile of DSDs as a function of large-scale atmospheric conditions and storm characteristics using measurements from the Equatorial Atmospheric Radar (EAR) facility at Kototabang, west Sumatra, Indonesia. This study is a follow-up of our previous work on the DSD variability over Sumatra [1,2]. The vertical profile of DSD is obtained from a Micro Rain Radar (MRR) with a near continuous record of operation over four consecutive years (2011–2014). The DSDs from the radar are compared with those from an optical disdrometer. The data are partitioned according to diurnal, convective and stratiform precipitation classifications, monsoonal regime, and MJO phase. Findings support previous Sumatra studies suggesting a significant diurnal and DSD parameter signal associated with both convective–stratiform and MJO phase regime classification. Negligible monsoonal phase influence is determined for the DSD over the Kototabang location. The natural variability of vertical profile of DSDs leads to variability of Z-R relationships in rain column.

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Keywords: Raindrop size distribution, Micro Rain Radar, Sumatra

DIURNAL VARIABILITIES ANALYSIS OF METEOROLOGICAL PARAMETER OF CCAM-NWP OUTPUTS AND OBSERVATION AT KOTOTABANG

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The diurnal varibilities of some meteorological parameter (rainfall, temperature, relative humidity, and pressure) study, needed a model that can predict the behavior of the weather in the future by following the data history in the past. As a validation stage, outcomes such dynamic model of spatial and temporal very necessary compared with surface observational data from Automatic Weather Station (AWS) and u-v wind data from Equatorial Atmosphere Radar (EAR). The purpose of this study is analyzing the diurnal varibilities of meteorological parameter of dynamic model outputs Conformal Cubic Atmospheric Model-Numerical Weather Prediction (CCAM-NWP), and the surface observational data. The data used is the hourly output CCAM-NWP models in (12-15) February, (12-15) June 2014, and (2-14) January 2015, and surface observational data in (2-4) January 2015 as validation. The method on analyzing the output CCAM-NWP from the input models Global Forecast System (GFS-NOAA) with a resolution of the model 0.25^{o} x 0.25^{o}, and statistical analysis with method of T-test and F-test. Based on the results shown the diurnal variabilities and dinamic process of meteorological parameter for the model output and surface observation. Furthermore, we obtained a weak correlation between the temporal model output with surface observations from statistical analysis which mean that there are significant differences of the results found from the CCAM-NWP output and surface observations. Additionally, we compared spatial distribution of hourly output CCAM-NWP with satellite observation data such as MTSAT.
Keywords: rainfall, temperature, relative humidity, pressure, CCAM-NWP, T-test, MTSAT.

Solar-Terrestrial Interaction as Studied from Total Solar Eclipse of 9 March 2016

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Total Solar Eclipse of 9 March 2016 provides a great opportunity to study the interaction between the Sun and Earth as a complex system. Several team of observers and scientists from National Institute of Aeronautics and Space will be dispatched to some observing points along the track of Lunar shadow and its proximity. The main missions are: (1) to study the physical nature of lower part of Solar corona, (2) to understand the ionospheric disturbance caused by a sudden drop of Solar radiation to the Earth, and (3) to measure the dynamics of local magnetic field that is influenced by the ionospheric disturbance. Preliminary result of those observations/experiments will be discussed in this paper.

Keywords: Solar Eclipse, Corona, Ionosphere, Geomagnet

RELATIONSHIP OF F LAYER HEIGHT RISE, ESF ONSET TIME, AND AMPLITUDE OF LARGE SCALE WAVE STRUCTURE

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Under favourable conditions ionospheric plasma at the bottomside of the F-region can become unstable. Plasma irregularities in several scales produced by Rayleigh-Taylor Instability mechanism. The recombination process at the E-region after sunset causing the bottom side F-region electron density gradient become steep. At the same time the eastward electric field intensified just before it reverses to the westward electric field causing the peak of the F region rise known as evening prereversal enhancement. The relationship between onset time of field aligned irregularities related to ESF observed by Equatorial Atmosphere Radar during 2010-2012 with F layer height rise observed by ionosondes near geomagnetic equator, Chumphon (10.7 N; 99.4 E; 0.86 N) and Bac Lieu (9.3 N; 105.7 E; 0.62 N) is discussed in correspondence with growth rate of Rayleigh Taylor instability development. The field aligned irregularities onset time associated with equatorial spread F observed into two different cases, first case where the EPB/ESF onset time concurrent with the peak of virtual height of F region - (h’F) time. Second case where the EPB/ESF onset time happened with delay of more than 30 minutes, with reference to the peak of virtual height of F region - (h’F) time. The possibility that the amplitude of Large Scale Wave Structure obtained from GRBR data effects the height of plasma instability development also discussed.

Keywords: F layer height rise, Large Scale Wave Structure, onset time of Equatorial Spread F

EIA structure and its relation to plasma bubble occurrence along longitude 100° E in 2012

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To reveal a relationship between EIA structure and plasma bubble occurrence along longitude 100° E in 2012, the ground-based observations i.e., GNU Radio Beacon Receivers (GRBR), GPS, ionosonde, and Equatorial Atmospheric Radar (EAR), are employed. GRBR is used to capture the precise structure of EIA. The Rate Of TEC change Index (ROTI) of GPS is used to monitor the plasma bubble occurrence. Temporal variation of the bottom side of the F layer is measured by the ionosonde. The EAR is for detecting Field Aligned Irregularities (FAI). In this paper, we will answer the following questions:
(1) What does the EIA structure look like on the plasma bubble on and off day?
(2) Is it necessary that plasma bubble will occur only when EIA is symmetric?
(3) How does the plasma bubble structure look like on the GRBR TEC?

Keywords: EIA, Plasma bubble

New digital beacon receiver for the study of equatorial ionosphere with satellites TBEx and FORMOSAT-7/COSMIC-2

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We have successfully conducted observations of total-electron content (TEC) of the ionosphere using a satellite-to-ground beacon experiment. A unique dual-band (150/400MHz) digital receiver GRBR (GNU Radio Beacon Receiver) was developed for this purpose, which is based on the recent digital-signal processing technologies. The GRBR network was deployed into the southeast Asian and Pacific regions. By using beacon signals from the low-inclination satellite C/NOFS, we studied longitudinal “large-scale wave structures (LSWS)” in detail as a possible source of equatorial Spread-F (ESF) events. Now there are 2 new beacon-satellite plans. One is TBEx (Tandem Beacon Explorer), a project by SRI International, to fly a constellation of two 3U cubesats with triband beacon transmitters. Another one is a constellation of FORMOSAT-7/COSMIC-2 satellites, also with triband (or quad-band) beacon transmitters. All of these satellites will be placed into low-inclination orbits by the same launch vehicle in late 2016. This launch will provide great opportunities to enhance studies of the low-latitude ionosphere. Kyoto University, Ehime University and Hsing Wu University are now developing the new GRBR system that is expected to be used for the TBEx and FORMOSAT-7/COSMIC-2 beacon experiments. In the presentation we will show development of the new beacon receiver together with plan of observations.

Keywords: Satellite-ground beacon experiment, Ionospheric TEC, COSMIC-2, cubesat, equatorial ionosphere

IUGONET data analysis system for a study of coupling processes in the solar-terrestrial system

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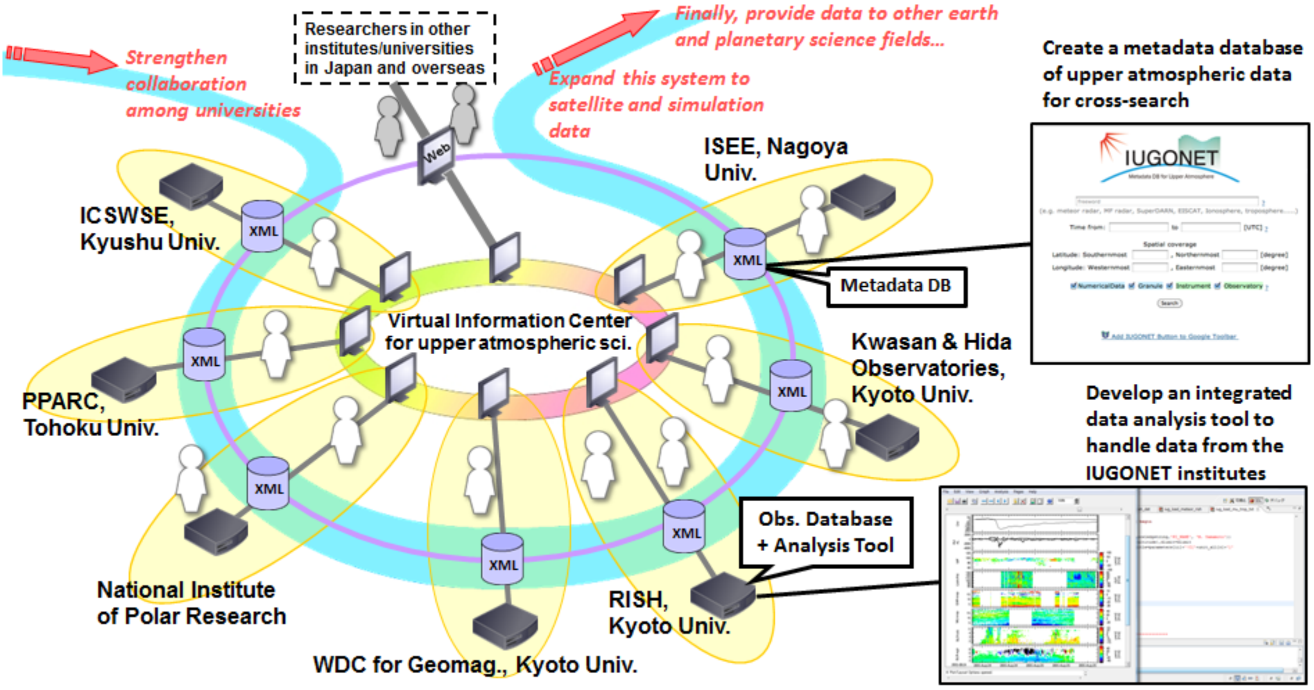
Various kinds of disturbance phenomenon and long-term variation in the upper atmosphere above 100 km are caused by energy input from solar radiation, solar wind, momenta and energies from the lower atmosphere via atmospheric waves, and chemical reaction. Such a disturbance phenomenon and long-term variation observed by various kinds of ground-based and satellite instruments are the result of such complicated processes. Therefore, in order to understand the mechanisms of these phenomena detected in this region, researchers need to conduct comprehensive analyses with various kinds of long-term observation data that have been continued by means of a global network of radars, magnetometers, optical sensors, helioscopes, etc. The IUGONET (Inter-university Upper atmosphere Global Observation NETwork) project initiated in 2009 is proposed to establish a cross-reference system for various kinds of ground-based observation data obtained from different techniques. The IUGONET participants consist of five universities/institutes: the National Institute of Polar Research (NIPR), Tohoku University, Nagoya University, Kyoto University, and Kyushu University. We have developed a metadata database (MDDB) and IUGONET data analysis software (UDAS) of ground-based observation data managed by these IUGONET universities/institutes with an international collaboration in order to promote a comprehensive study on coupling processes in the Sun-Earth system. MDDB provides researchers in a wide range of disciplines with a seamless data environment to link observation databases spread across the IUGONET universities/institutes. Researchers can find basic information of observation data (for example, observation period, data format, data use policy, instrument, observed region, observation site etc.) from the metadata for each observation data they are interested in. Recently, the metadata for several satellite observation data (for example, Akebono, GPS) have been registered to MDDB, and researcher can easily find the satellite database. UDAS will also be of great help in conducting integrated analyses and visualization of various kinds of solar-terrestrial observation data to investigate the long-term variation in the upper atmosphere throughout the Sun-Earth system. UDAS deals with 29 kinds of ground-based observation data provided by the IUGONET universities/institutes. Moreover, the executable file of SPEDAS/UDAS working on Interactive Data Language (IDL)-VM without IDL license has been released on the SPEDAS website. Owing to the executable file, anybody can use UDAS and conduct a comprehensive analysis of various kinds of solar and Earth’s atmospheric observation data. Moreover, in the IUGONET project, in order to enhance an international use of these IUGONET products, we held a mini-training workshop of how to use the IUGONET MDDB and UDAS at several developing countries (India, Indonesia, Nigeria, Peru etc). Now, the IUGONET products became an essential tool to study a mechanism of the solar-terrestrial environmental change. In this talk, we introduce a brief overview of the IUGONET project, and an application of the IUGONET products to typical examples of upper atmospheric researches.

Keywords: Inter-university Upper atmosphere Global Observation NETwork, Upper atmosphere, Metadata database, IUGONET data analysis software (UDAS), Long-term variation, Ground-based observation



Ionospheric weather in the dayside polar cap region

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Using European incoherent scatter radar (EISCAT) and EISCAT Svalbard radar (ESR), we have made simultaneous obserbations of the dayside polar cap ionosphere at Longyearbyen and Tromso. Five year observation data show significant disturbances in the polar cap region northward the ESR site even during geomagnetically quiet periods. This suggests that the energy input from the magnetosphere would play a fundamental role for dynamics and energetics in the region all the time. In addition, some researchers suggest effects from the lower atmosphere on the thermospheric variations in the polar region. In order to understand variations of the polar ionosphere/thermosphere from hour to hour, we should understand energy flows from the above (magnetosphere) and below (lower atmosphere). Numerical simulations with a GCM are also essential to do so. In particular, GCM simulations would reveal physical and chemical processes/mechanisms to produce the thermoshperic variations while the thermospheric observations are very few in the dayside.
In the present study, we overview the EISCAT and ESR observations during 2011-2016. The recent progress of our understandings from comprehensive observations and GCM simulations are also shown.

Keywords: ionosphere, thermosphere, EISCAT, GCM, simulation

Using Vondrak smoothing method to improve the prediction of Sunspot Maximum

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About 11-year cycle of solar activity is the most significant quasi-periodic component, which largely represents the strength of solar activity and is the basis for dividing solar cycle. Many studies have proven that solar activity can affect the developing process of many phenomena on the Earth, such as climate, geophysical and marine changes etc. In order to meet the demands of heliophysics and solar activity variation characteristics studies, especially, for the demand of Solar Terrestrial Relations studies and space science development, studies of solar activity characteristics and prediction are getting more attention. Some authors summerized a variety of methods for the maximum predictions of 22nd, 23rd, 24th solar cycles, the incomplete statistics are 63, 54 and 75 cases respectively, results of the methods, which the difference between forecasting and observed values within the range of ±15%, are 27.0%, 25.9% and 24.3% respectively. Using the 13 points smoothed value of monthly sunspot numbers, we studied correlation between sunspot number rising rate of the first 24 months of the solar cycle and the coming cycle maximum, published forecasting result that the maximum value was 139.2 ±18.8 for 23rd solar cycle (Han et al., 2000), and the observed value is 120.8, the error is about 15.2%. The present paper introduces our improved forecasting methods. Vondrak smoothing method is used to deal with the monthly sunspot numbers. It is studied that the relationship between the rise rate of earlier months of sunspot numbers of this smoothed sequence and the coming maximum value in each solar cycles. The results show that the first 22, 23, 24 months rise rate of sunspot numbers are highly related with the coming maximum values, and simulated prediction of maximum for 22~24 cycles show that using the 22-month rise rate of three solar cycles, the maximum forecasting error is about 13.2%, using 23-month rise rate, the maximum error is about 11.2%, while using 24-month rise rate, the maximum error is only about 9.3%. The new method can make the forecasting time in advance at least half a year than the common method using 13 points monthly smoothed value, which the difference between prediction and observed values within the range of ±15%. The results also show that the maximum error is about 20% if we use 18-month rise rate, and it can make the forecasting time in advance at least one year than the common method using 13 points monthly smoothed value.

Keywords: Sunspot Maximum, Prediction

D- and E-region ISR spectra measured with EISCAT radars

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The energy from the solar wind is mainly transported to the polar upper atmosphere and causes various phenomena such as auroras characterized by their rapid variability in time and space. Incoherent scatter radar (ISR) located in high latitude is one of the most powerful tools to investigate generation mechanisms of such phenomena and their effects on the atmosphere. The ISR basically gives information of plasma parameters between the bottom-side and topside ionospheres. However, the ISR has several unavoidable limitations to derive ionospheric parameters in the E- and D-region ionospheres, due to limited information of the ISR spectra.
We have investigated ISR spectra in the D- and E-region using the latest techniques of the EISCAT UHF and VHF radars located in Tromsø. Previous studies indicate that the EISCAT UHF and VHF radars have limitations of plasma parameter derivation below 90 and 100 km altitudes, respectively. We show lower limits of reliable plasma parameter derivation using the latest pulse coding techniques of the EISCAT radars. Based on the knowledge and experience of the current EISCAT radar observations, we will discuss possibility and limitation of future E- and D-region observations of the EISCAT_3D radar.

Keywords: ionosphere, Incoherent scatter radar, plasma

National/International joint studies with the Tromsø OMTI for studying the polar upper atmosphere

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Institute for Space-Earth Environmental Research (ISEE) has been operating various kinds of optical instruments for more than 15 years at the Tromsø European Incoherent Scatter (EISCAT) radar site in Norway (Geographic: 69.6N, 19.2E, Geomagnetic: 66.7N, 102.2E, L=6.4), which is one of the state-of-art observatories at high latitudes. In January 2009, we began operation of a Fabry-Perot interferometer (FPI) and an all-sky type cooled CCD camera (ASC) at dark nights of the winter months (from middle of September to early April in most years). The FPI (#01 of the Optical Mesosphere Thermosphere Imagers (OMTIs)) measures airglow and aurora by rotationally changing optical wavelengths of 557.7 and 630.0 nm for most of the nights in order to derive the thermospheric wind and temperature. Four cardinal points with zenith angle of 45 or 15 and the geographic vertical (i.e. five directions) are measured sequentially. The combination of data from the four cardinal positions provides the horizontal components of the neutral wind velocity. The all-sky camera (camera #12 of OMTIs) includes a filter wheel used to select one of the six optical filters (channel 1: 557.7 nm, channel 2: 630.0 nm, channel 3: OH band (720 ~1000 nm), channel 4: 589.3 nm, channel 5: 572.5 nm, and channel 6: 732.0 nm). While the exposure time for FPI and ASC measurements is tuned as good for individual scientific objectives, in the case of FPI typical values are 1 minute or 15 seconds for airglow and auroral measurements, respectively, and in the case of ASC those are about 30 and 10 seconds for the individual targets, respectively. However, shorter exposure times have been applied for measuring fine structures of aurora. Other optical instruments such as photometer, digital camera, and all-sky camera (486.1 nm) are collocated with the OMTI FPI and ASC. Data from these instruments have been provided to national and international researching activities. For example, the FPI was operated together with the EISCAT radars as a key diagnostic instrument for providing thermospheric parameters during periods of geomagnetic disturbances. Integrated studies of the FPI-measured wind and the EISCAT-measured ionospheric parameters (including full vector of the electric field) improve our understanding of the energy dissipation and momentum transfer processes and of polar ionospheric/thermospheric responses to the solar-wind change. Effects of energetic electron precipitation (EEP) on the atmosphere are also analyzed using data from our optical instruments and EISCAT radars. This topic is proceeded under collaboration with Chemical Aeronomy in the Mesosphere and Ozone in the Stratosphere (CHAMOS) group. Sodankylä Ion Chemistry (SIC) model, which is used in the group, is a powerful tool for estimating atmospheric responses to EEP, in particular variations in the atmospheric minor components such as NO_x, HO_x, and O_3. Ionospheric and atmospheric variations associated with EEP will be one of the important scientific objectives in the ERG project. This presentation will make a brief introduction of a few results from the national/international join studies.

Keywords: Aurora, Airglow, Optical instrument, Ionosphere, Thermosphere, High latitude

Study on pulsating aurora-induced sodium density variation: high-speed sodium lidar observation

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We have been made observations of the sodium density, neutral temperature and wind velocity in the polar MLT region since October 2010 by a sodium lidar installed at Tromsø, Norway. By using the sodium lidar together with EISCAT radars, MF radar, meteor radar, FPI, and aurora imagers, we have studied and reported several results, such as the upward propagating gravity wave, the comparison of the neutral temperature and ion temperature, and the generation mechanism of the sporadic sodium layer, whose time scale are a few minutes to several hours.
Energetic electrons, which can be the source for the pulsating aurora, release their energy by collision with neural particles below 100 km. The periods of the pulsating aurora are seconds to sub-seconds. This implies that the neutral atmosphere may change in the similar time scales in terms of composition, temperature, and wind velocity by the energy input from the energetic particles. To date, however, there are no observations of the neutral atmosphere in these time scale at polar region as far as we knows. Thus, the high-speed observation would be essentially important for understanding in the neutral atmospheric response during the pulsating aurora.
In this study, we have been made an upgrade in the data recording and laser control system for the Tromsø sodium lidar system. We have installed the new recording system in January 2016, and already started test observations. Currently, we are successful to make the sodium density observation with time resolution of seconds to sub-seconds. In this presentation, we will introduce the high-time resolution data in the sodium density obtained from January to March 2016.

Keywords: sodium lidar, pulsating aurora

Comparison study between coherent radar echo and empirically-modeled electron density in the mesosphere based on the PANSY radar

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Polar Mesosphere Winter Echo (PMWE) is known as back scatter echo from 55 to 85 km in the mesosphere, and it has been observed by MST and IS radar in polar region during non-summer period. Since density of free electrons as scatterer is low in the dark mesosphere during winter, it is suggested that PMWE requires strong ionization of neutral atmosphere associated with Energetic Particles Precipitations (EPPs) during Solar Proton Events [*Kirkwood et al*., 2002] or during geomagnetically disturbed periods [*Nishiyama et al*., 2015]. However, studies on relationship between occurrence of PMWE and background electron density has been limited yet [*Lübken et al*., 2006], partly because the PMWE occurrence rate is known to be quite low (2.9%) [*Zeller* et al., 2006].
The PANSY (Program of the Antarctic Syowa MST/IS) radar, which is the largest MST radar in Antarctica, observed many PMWE events since it has started mesosphere observations in June 2012. We established an application method of the PANSY radar as riometer, which makes it possible to estimate Cosmic Noise Absorptions (CNA) as proxy of relative variations on background electron density. In addition, electron density profiles from 60 to 150 km altitude are calculated by Ionospheric Model for the Auroral Zone (IMAZ) [*McKinnell and Friedrich*, 2007] and CNA estimated by the PANSY radar.
In this presentation, we would like to focus on strong PMWE during two big geomagnetic storm events, St. Patrick's Day and the Summer Solstice 2015 Event, in oreder to compare observed PMWE characteristics to model background electron density. On March 19 and 22, recovery phase of St. Patrick's Day Storm, sudden PMWE intensification was detected near 60 km by the PANSY radar. At the same time, strong Cosmic Noise Absorptions (CNA) of ~ 0.8 dB and 1.0 dB were measured, respectively. However, calculated elctron density profiles did not necessarily demonstrate high elecetron density at the altitude where the PMWE intensifications were observed. On June 22, the Summer Solstice 2015 Event, strong nighttime PMWE near 80 km was detected around 16 UT, which is equal to 19 LT at Syowa station. Since PMWE observations are primarily confined to daytime because of relatively abundant free electrons in the illuminated mesosphere, this strong and long-lived nighttime PMWE implies that EPPs related to the storm caused the sporadic ionization sufficient for PMWE even in dark mesosphere. The modeled electron density profile agreed with the occurrence of the PMWE, showing density enehancement of 10^9 - 10^{10} cm^{-3} from 60 to 80 km altitude. The difference between the above two events is thought to be caused by overestimations of CNA in St. Patrick's Day Storm, which leads to underestimation of modeled electron density. We are going to validate CNA estimated by the PANSY radar and discuss about discrepansy between modeled elecron density and PMWE in detail.

Keywords: MST radar, Mesosphere, Polar Mesosphere Winter Echo, Ionopheric D-region

Antarctic Syowa station SENSU SuperDARN radars in the 9th phase of JARE Atarctic project (2016-2023)

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Syowa SENSU SuperDARN HF radars are important components of SuperDARN, the international HF radars network since 1995 and have significantly contributed to understanding not only magnetosphere-ionosphere coupling system but also MLT region dynamics. As SuperDARN radars were originally designed to reveal global polar ionospheric plasma convection patterns in both hemispheres in real time, its spatial resolution has been relatively low. As the number of new scientific targets like comparison with mid and small scale aurora phenomena, meso scale transient phenomena, elementary generation and decay process of field aligned irregularities, PMSEs and fine height profile of neutral wind has been increasing, higher spatial and temporal resolution observations have been essentially desired and of great importance. Imaging radar technique has been tried to be applied and developed to overcome these issues. We show the current status of the SENSU imaging radar system, and will discuss particularly on the scientific targets including coming JARE (Japanese Antarctic Research Expedition) project phase IX (2016-2023) and the future perspectives which can be revealed by this new technique using SuperDARN. In the phase IX JARE project. Our research group has proposed a research program to JARE project focused especially on possible grand minimum influences on geospace environment and inner magnetospheric dynamics and the detail plans including collaboration with other satellite and ground-based observation and its contribution to the project "Study of coupling processes in solar-terrestrial system" as well as the international VarSITI program will be discussed.

Keywords: SuperDARN, Antarctic Syowa Station, Japanese Antarctic Research Expedition project phase 9, Grand minimum, inner magnetosphere, VarSITI

