Japan Geoscience Union Meeting 2014
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PEM05-01 Room:424 Time:May 2 09:00-09:15

A Brief History of Collaborative Study on Equatorial MLT Dynamics using Meteor and MF Radars in Indonesia

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In the tropics active cumulus convection generates various atmospheric waves, such as Kelvin waves, planetary waves, tides, and gravity waves. The wave energy and momentum are transported upward though propagating of these waves. Wave-mean flow interactions are crucially important for understanding of dynamical processes in the equatorial atmosphere, including the formation of peculiar long-term variations such as quasi-biennial oscillation (QBO) and semi-annual oscillation (SAO) in both the stratosphere and the MLT (mesosphere and lower thermosphere) region (70-120 km).

We constructed a total of five meteor and medium frequency (MF) radars in Indonesia since 1992 under close collaboration between RISH, LAPAN and the University of Adelaide. The MLT radar network has been expanded in India, Central and Eastern Pacific, and China. These radars have clarified the behavior of atmosphere dynamics in the MLT region. This paper gives an overview of our collaborative studies as well as highlights of scientific achievements using the MLT radar network

Keywords: mesosphere and lower thermosphere, equaotrial atmosphere, atmospheric waves, meteor radar, medium frequency radar, Indonesia

PEM05-02 Room:424 Time:May 2 09:15-09:45

Atmospheric Waves in the MLT: A Review

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Through their efficient transfer of energy and momentum, atmospheric waves propagating up from the lower atmosphere play an important role in determining the structure of the Mesosphere/Lower Thermosphere (60-100 km). A wide range of wave types are involved, with periods ranging from minutes to days. Here we review developments in our understanding of wave coupling and impacts on the MLT, with an emphasis on developments in the past decade.

Keywords: MLT Dynamics, Gravity Waves, Atmospheric Tides, Planetary Waves

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PEM05-03 Room:424 Time:May 2 09:45-10:00

Behavior of non-migrating tides in the MLT region

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It is well established that non-migrating tides have significant amplitudes in the mesosphere and lower thermosphere (MLT). Using a general circulation model that contain the region from the ground surface to the upper thermosphere, behavior and excitation sources of non-migrating tides are examined. In this study, behaviors of the westward moving semidiurnal tide with zonal wavenumber 1 (SW1), the semidiurnal tide with zonal wavenumber 0 (S0) and the diurnal tide wit zonal wavenumber 0 (D0) are examined in detail. There are two main sources for non-migrating tides. One is latent heat release due to the cumulus convection in the troposphere. The other is the nonlinear interaction between the migrating tide and the stationary planetary wave in the middle atmosphere. Our results indicate that the amplitudes of SW1, S0 and D0 are enhanced when the stationary planetary wave in the stratosphere and mesosphere is active. This means that SW1, S0 and D0 are mainly excited by the nonlinear interaction between the migrating tide and the stationary planetary wave. Furthermore, we discuss excitation sources of other non-migrating tides, such as the eastward moving diurnal tide with zonal wavenumber 3 (DE3) and the eastward moving semidiurnal tide with zonal wave number 2 (SE2).

Keywords: Tides, General Circulation Model

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PEM05-04 Room:424 Time:May 2 10:00-10:15

Long-term observations of MLT zonal wind variations in relation to stratospheric zonal winds over low-latitudes

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Long-term observations from medium-frequency and meteor radars (1993-2012) and rocket soundings (1979-1990 and 2002-2007) are used to study mesosphere lower thermosphere (MLT) zonal wind variations in relation to the stratospheric winds over Northern low-latitudes. The combined dataset provide a complete height profile of amplitude of semiannual oscillation (SAO) up to 100 km, with an exception around 75-80 km. The SAO signal has maxima around 50 km and 82 km and a minimum around 65 km. The MLT zonal winds show remarkable inter-annual variability during spring equinox and much less during fall equinox. Zonal wind mesospheric spring equinox enhancements (MSEE) appear with a periodicity of 2-3 years suggesting a modulation by the quasi-biennial oscillation, which we identified with the strength of stratospheric westward winds. Out of 20 years of observations, the stratospheric westward winds are strong during 11 years (non-MSEE) and weak during 9 years. Six of these years show large MLT winds (MSEE) and 3 years (1999, 2004 and 2006) show small MLT winds (missing-MSEEs). These unexpected small winds occur in years with global circulation anomalies as identified with strong sudden stratospheric warmings and an early spring transition of zonal winds, along with a minor enhancement in the tidal amplitudes.

Keywords: MLT winds, MSAO, Meteor radar, MF radar, QBO

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PEM05-05 Room:424 Time:May 2 10:15-10:30

The saturation of gravity waves traveling from the lower to the upper atmosphere observed by the MU radar and understood

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The MU radar of Kyoto University was constructed in 1984. One of the main purpose of the radar construction is to observe atmospheric gravity waves particularly to find how gravity waves saturate in traveling from the lower atmosphere to the upper atmosphere. In the 1980s Matsuno, Geller and others put forwards an idea suggesting that the gravity wave saturation may release momentum for driving the mesosphere general circulation. Their idea is based on rocket and satellite global- observation of winds and temperature varying peculiarly with seasons in the mesosphere.

Our MU radar observation has been successful in proving the gravity wave momentum release to be in a good agreement with the required quantity for the mesosphere general circulation. Also our success of precise measurements of the saturated gravity wave power spectrum strongly supports to explain the gravity wave saturation idea in terms of a simple theory based on the linear or monochromatic gravity wave theory by Hines in 1960.

Our theory on the basis of our MU radar observation shows that the gravity wave saturation is attained for each gravity wave in amplitude reaching the phase speed due to a balance between the increasing amplification expected by the linear theory and non-linear braking effects. We can consider that the original gravity wave dispersion relation is maintained upon the saturation.

Gravity waves should experience a number of such saturations before
reaching the thermosphere on the way.

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PEM05-06 Room:424 Time:May 2 10:30-10:45

Ducted Concentric Gravity Wave Observed by IMAP/VISI Associated with Super Typhoon Haiyan

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Although the convection activity in the troposphere is generally accepted as one of important source of gravity waves in the mesosphere and lower thermosphere, however it is still uncertain how these waves can reach these regions and what types of waves are generated. For decades, the study of gravity waves has been classified into two categories; first is that the waves travel directly from the source and the second is that the waves are ducted or trapped. Many studies tried to explain both categories yet all studies focused on gravity waves produced by transient events. There were almost no observation reports of airglow emissions during a large storm and what type of gravity waves and typical wavelength can be produced from such event. To address this issue, a space-based observation is more preferable since it covers wider area. Until recently, IMAP/VISI is the only space-based instrument that capable of imaging gravity waves above the troposphere in the nadir direction. The Visible and near-Infrared Spectral Imager (VISI) of the IMAP mission was launched successfully on July 21, 2012 with H-IIB/HTV-3 and installed onto the International Space Station (ISS). IMAP/VISI is now operated in the night side hemisphere with a range of +/- 51 deg. GLAT. IMAP/VISI is measuring three different airglow emissions of OI at 630 nm, the OH Meinel band at 730 nm and the O_2 (762 nm) atmospheric band at 762 nm at an altitude of ˜400 km with the typical spatial resolution of 16-50 km.

We found concentric gravity waves events in the southeastern part of Australia that was observed around 13-15 UT for 3 days from 6-8 November 2013 in O_2 (0-0) airglow emission by IMAP/VISI. The waves have horizontal wavelength vary from 80 – 210 km. By using the least squares method, the curvature of the waves was fitted to a perfect circle. The center of the wave was found to be around 155^0E; -42^0S with the radius varies from 400-1200 km. From the meteorological satellite, we cannot locate any convective source around the center of the wave. The nearby local convective source was located a few hundreds km to the south of the wave center and the rainfall rate was less than 10 mm/hr. Therefore, we rule out the possibility of local convective activity as the source of these waves. From the past studies, there were evidences that the gravity waves may be ducted and traveled a great distance away from a specific convective source (e.g. Nakamura et al., 1999; Walterscheid et al., 1999; Hecht et al., 2001). Their studies suggested that the gravity waves observed in Australia were originated from convective activity several thousands km north of Australia. During the observed events, the Typhoon Haiyan was underway. On November 6, the typhoon was categorized as 5 – equivalent of super typhoon and reached its peak on November 7 and then made a landfall in Philippine on November 8. In this study, we argue that the concentric gravity waves seen by IMAP/VISI could be generated by the intense convective activity associated with the Haiyan Typhoon event. Background wind data from TIDI (TIMED Doppler Interferometer) and MF Radar will be used to examine the plausibility for the formation of a ducted/trapped region that can explain the long distance propagation of these waves. The temperature profile from MSISE-90 model will also be used to examine the mesospheric inversion layer and if it′s possible to get the data, we will also use the ground-based airglow imager data from Adelaide and Alice Spring.

Keywords: IMAP/VISI, O2 (0-0), concentric gravity wave, ducted, typhoon Haiyan

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PEM05-07 Room:424 Time:May 2 11:00-11:30

The MF Radar Technique: a Review

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The Medium Frequency (MF) radar technique has been applied for more than five decades to measure winds and turbulence in the upper atmosphere in the region between 60 and 100 km during the day, and between 80 and 100 km at night. It is one of the few techniques able to provide winds reliably in the 60 to 80 km height region during the day. Although some care is needed in interpretation of the results, it remains a powerful and very useful technique. In this paper, we review the technique and highlight some recent recent results.

Keywords: Radar, Medium Frequency, Spaced Antenna, Mesosphere Lower Thermosphere, Winds, Turbulence

PEM05-08 Room:424 Time:May 2 11:30-11:45

Tidal periodicity of mesospheric gravity waves observed with MF radar at Poker Flat, Alaska and at Tromso, Norway

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The interaction between gravity waves and tidal waves has been studied by using observations, although the phase relation between them was not fully understood (e.g., Saskatoon, Canada (Manson et al. 1998), Rothera, Antarctica (Beldon and Mitchell, 2010)). The neutral wind velocity data from mesosphere to lower thermosphere observed by MF radars at Poker Flat in Alaska and Tromso in Norway has been observed since the late 1990s. The long-term wind velocity data at Poker Flat and Tromso was analyzed for 10 years of 1999 ? 2008 to show daily and seasonal behaviors and climatology of mesospheric gravity waves and horizontal wind of the 12 and 24 hour components. First, we extracted these waves from the MF radar observation data. In this study, harmonic analysis was carried out for periods of 48, 24, 12, and 8 hours, which are extracted from the 5 day time series of wind velocity using. Gravity waves are defined as the 1 ˜12 hour period component of difference between observed wind velocity and these harmonic components. The method is applied to 30-minute-average data to calculate the 5 day running mean amplitude and phase of zonal wind of the 12 and 24 hour components. We made 1- day composite plots of kinetic energy of gravity waves for periods of 1 ˜4 hours and harmonic components. The results show that the kinetic energy of gravity waves in Tromso has a peak in 6UT from November to February which tends to coincide with the time when zonal wind of 24 hour component is easterly maximum and easterly wind of 12 hour components is switched westerly. This feature is different from results in Poker Flat and Saskatoon. On the other hand, the phase relation between 12 hour components of zonal wind and kinetic energy of gravity waves shows that their phase agrees for more than 10 days in several years in both observation points. We confirmed the phase agreement in Tromso continued about 10 days at the same time when that in Poker Flat is continued more than 20 days from November to December in 2000. However, the phase of gravity wave kinetic energy is shifted 90 degrees between Tromso and Poker Flat. We plan to discuss more detail of underlying physical processes, focusing on migrating and non-migrating tidal waves and background state of horizontal wind velocities.

PEM05-09 Room:424 Time:May 2 11:45-12:00

Characteristics of Short Period Tidal Components in Antarctic MLT above Syowa and Davis

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The behaviour of short period atmospheric tidal components in the Antarctic mesosphere and lower thermosphere is studied based on long term observations over Syowa (69.0S, 39.6E) and Davis (68.6S, 78.0E) stations. Semidiurnal tides in the Antarctic mesosphere and lower thermosphere have been extensively studied through the recently established Antarctic radar network [e.g., Murphy et al., 2006; 2008]. However, details of shorter period components such as terdiurnal and six-hour tides are less investigated and poorly known because of their smaller amplitudes compared to the semidiurnal and diurnal tides in the height region of conventional MF radar observations of around 70-90 km. These short period tides also fall in the frequency range of inertial gravity waves and are often hard to distinguish from these waves.

The characteristics of the terdiurnal tide above Davis and Syowa have been measured on a short-term to seasonal basis in the mesosphere and lower thermosphere using long-term simultaneous MF radar data at the two sites (1999-). The terdiurnal tide achieves moderate amplitudes in the winter at these heights but there are subtle differences between the two stations. These differences are explored further by differencing tide phasors in local time and checking the amplitude of the result on a seasonal basis. If the terdiurnal tide was made up entirely of migrating components, this difference would yield a zero-average amplitude. However, the observed non-zero values suggest that the terdiurnal tide at these latitudes contains strong non-migrating tidal components.

The Syowa MF radar has a great advantage over other MF radars in that it has been conducting simultaneous meteor wind measurements together with the conventional correlation based measurements, which enables wind observations in a very wide height range of 65-120km [Tsutsumi and Aso, 2005]. A clear enhancement in terdiurnal amplitudes is seen in early winter months of March-June. The amplitudes can reach 20 m/s around 110 km even in the composite plot made with more than 10 years of data. These amplitudes can be comparable or sometimes even larger than those of diurnal and semidiurnal tides, and indicate a possible significant role of short period tidal components in the polar lower thermosphere.

Keywords: Antarctic, mesosphere and lower thermosphere, short period atmospheric tidal waves

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PEM05-10 Room:424 Time:May 2 12:00-12:15

The SMILES observations of mesospheric ozone during the solar eclipse

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Solar eclipse temporally reduces the amount of solar radiation, providing an opportunity to verify the ozone photochemistry under changing solar radiation. During the longest annular solar eclipse in this millennium occurred on 15 January 2010, Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) successfully captured increased ozone mostly in the mesosphere with a decrease in solar illuminations. The ozone increment shows altitude dependence in the mesosphere. Using an atmospheric chemistry box model, it is found that the dependence results from the difference in chemical reaction rates to the solar radiation change. The model also predicts the difference in the ozone concentration evolution between the sunlight decreasing and increasing phases, although SMILES observation does not resolve the difference.

Keywords: SMILES, ozone, mesosphere

PEM05-11 Room:424 Time:May 2 12:15-12:30

Contribution of the IUGONET data analysis system to upper atmospheric researches

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Various kinds of atmospheric disturbances and long-term variation as seen in several parameters (temperature, mean wind etc.) in the upper atmosphere (mesosphere, thermosphere and ionosphere) is caused by energy input from solar radiation, momenta and energies from the lower atmosphere (stratosphere and troposphere) via atmospheric waves, and chemical reaction. Such atmospheric phenomena observed by ground-based and satellite instruments are the result of such complicated processes. In order to investigate the mechanisms of the atmospheric disturbances and long-term variations in the upper atmosphere, which may be affected by solar activities and global warming, 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 MST (Mesosphere-Stratosphere-Troposphere) radars, optical sensors, radiosondes, etc. The IUGONET (Inter-university Upper atmosphere Global Observation NETwork) project initiated in 2009 aims at the establishment of a cross-reference system for various kinds of ground-based observation data. 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 (MDB) of ground-based observations and IUGONET data analysis software (UDAS) in order to provide researchers in a wide range of disciplines with a seamless data environment to link databases spread across the IUGONET institutions. In particular, the MDB and UDAS will be of great help in data acquisition and integrated analyses to understand the dynamics on the mesosphere-lower thermosphere (MLT) throughout the Sun-Earth system. Therefore, the IUGONET MDB and UDAS will greatly contribute to upper atmospheric researches on the basis of integrated analysis of various kinds of long-term observation data covering a wide region from both the poles to the equator. In this talk, we introduce a brief overview of the IUGONET project and an application of the IUGONET products for upper atmospheric researches.

Keywords: Upper atmosphere, Grand-based observation data, IUGONET, metadata search system, IUGONET data analysis tool

PEM05-12 Room:424 Time:May 2 12:30-12:45

Vertical and lateral wave coupling observed with network of MLT/MST Radars over Indian region

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It is well known that gravity waves and tides play an important role in delineating the middle atmospheric structure and dynamics. There have been several studies in recent years, using different measurement techniques, to understand significant roles played by gravity waves and tides in the lower, middle and upper atmospheres. However, only a few studies addressed this problem with simultaneous observations of all the three regions. Moreover, no efforts have been made so far to understand the lateral forcing of these waves and tides since such a study needs a network of radars located nearby which was missing. With the establishment of an advanced meteor radar at Sri Venkateswara University, Tirupati (13.63oN, 79.4oE), India, and up gradation of MF radar at Kolhapur (16.8oN, 74.2oE) together with MST radar at Gadanki (13.5oN, 79.2oE), Meteor radar at Thumba (8.5oN, 77oE) and MF radar at Tirunalveli (8.7oN, 77.8oE) forms a unique network of radars in the tropical region. Importantly, all these radars are located within 1000 km distance. Accordingly, this network is suitable to study the lower atmospheric forcing and its impacts on middle and upper atmospheric structure and dynamics. For the present study, all these radars were simultaneously operated for a few days in September 2013. These observations show the presence of short period gravity waves and tides (diurnal, semi-diurnal and ter-diurnal) at all locations. Large day-to-day day variability in gravity waves and tides is observed within a station and among different stations providing insight on lateral coupling. Phase propagations of the three tidal components at different stations is used to further understand the lateral coupling. Using simultaneous MST radar, Rayleigh lidar and SVU meteor radar (which are nearly co-located), lower atmospheric forcing and its impacts on the mesosphere and lower thermosphere are investigated. This study showed need for long-term measurements, with simultaneous operation of all the above mentioned network of radars, to effectively address the problem of vertical and latitudinal wave forcing.

Keywords: Coupling, Meteor/MF radars, Tropical MLT region

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PEM05-P01 Room:Poster Time:May 2 16:15-17:30

Diurnal tide and QTD wave in the tropical stratosphere and MLT region: Long-term trends and solar cycle influence

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In the present study, long-term trends and solar cycle influence on the diurnal tide (DT) and quasi two day wave (QTDW) in the stratosphere, mesosphere and lower thermosphere (MLT) region over a tropical station Tirununveli (8.7oN, 77.7oE) are investigated using ERA-Interim datasets and MF radar observations available since 1993. As no ground truth is available over Tirununveli, suitability of the ERA-Interim data for the present study is ascertained using simultaneous radiosonde and MST radar observations over Gadanki (13.5oN, 79.2oE) and good consistency is found between the two. Amplitudes of the DT and QTDW over Tirununveli show a long-term linear increasing trend, which becomes prominent in the MLT region. Role of solar cycle on the DT and the QTDW is investigated by separating them with respect to the solar activity (minimum and maximum of solar cycles). Both the DT and QTDW show higher amplitudes during solar minimum and vice versa. Significant higher amplitudes in the recent extended solar minimum are noticed in the MLT region. However, no consistent relation is found between solar activity and DT in the stratosphere although increasing trend is clearly observed. Though increasing trend in the tropical convection is noticed at nearby locations, similar to the DT, it varies from location to location which may be due to large scale circulation effects. This demands data from network of radars located across the globe to see the combined effects of lower atmospheric forcing, circulation and their effects on MLT region.

Keywords: Diurnal Tide, Quasi-two day wave, Long-term trends, Solar cycle, Extended minimum

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PEM05-P02 Room:Poster Time:May 2 16:15-17:30

MQBE and Amplitude Modulation of SAO in the MLT

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Characteristics of various atmospheric waves in the mesosphere and lower thermosphere (MLT) have been investigated by long-term ground-based and satellite-based observation. In the equatorial region, the westward monthly mean wind is enhanced in March in 2 or 3 years in MLT, which is called Mesosphere Quasi-Biennual Enhancement (MQBE) [Rao et al., 2012]. Recently, They showed that MQBE appears once in 2 or 3 years until 2002, based on data analysis of meteor/MF radars in the Asia-Oceania region. However, the occurrence features remained unknown due to no sufficient wind data with high-time resolution from 50 to 80 km.

We analyzed the long-term wind data from 1990 to 2013 obtained from meteor/MF radars in the Asia-Oceania region, such as Kauai, Christmas island, Tirunelveli, Koto Tabang in order to identify the occurrence features and mechanism of MQBE. And also we investigated relationship of the monthly-mean wind between MLT stratosphere using MERRA retrospective-analyses data provided by NASA. We used integrated analysis tool " UDAS " provided by " IUGONET " (Inter-university Upper atmosphere Global Observation NETwork). And We use Stockwell-transform to detect the temporal variation of frequency and amplitude in time series data.

As a result, we found that MQBE occurred in spring of 2005, 2008 and 2011 with amplitude over 32 m/s in an altitude from 80 to 100 km . From an S-transform spectral analysis of zonal wind in MLT, MQBE coincides with the enhancement of the amplitude of 6-months component of zonal wind. Furthermore, comparing the 6-month component in the lower thermosphere at 90 km and stratosphere using retrospective-analyses data of MERRA, 6-months component of lower thermosphere(90 km) and stratopause (1 hPa) are well negative correlated. And also 6-months component of lower thermosphere and lower stratosphere (70 hPa) are well positive correlated. Their correlation coefficients are about 0.6, and lags are under 3 month. the former result is consistent with the fact that the phase of SAO are reversal in the lower thermosphere and in the stratosphere.

Although Rao et al.,[2012] reported that MQBE did not appear after 2002, the present results showed that MQBE takes place after 2002. Next, the SAO amplitude in MLT obtained from the S-transform analysis tends to be enhanced significantly, corresponding to the occurrence of MQBE. This relationship can be a clue of occurrence features of MQBE. Furthermore, the relationship of mean wind between in MLT and stratosphere indicates that MQBE is driven by coupling process of the mesosphere-stratosphere system. We can infer that MQBE is caused by atmospheric gravity waves, which is similar to the generation mechanism of QBO.

In addition, we need to detect and analyze the gravity wave in equatorial region to identify the mechanism of MQBE.

Keywords: meteor radar, MF radar, stratosphere, SAO, MQBE

PEM05-P03 Room:Poster Time:May 2 16:15-17:30

Meteor Wind Radar Application for the study the dynamics of the neutral winds above at Kototabang and Biak station

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Currently for meteor observations is not only done with the naked eye and optical equipment such as a telescope, the latest development to detect natural phenomena meteor shower rained almost every day the Earth can be detected using radar technology. Meteor Wind Radar (MWR) is a radar system used to detect, analyse and display meteor entrance events to the Earth's atmosphere. By using of radar meteors (SKiYMET Meteor Radar) was used to observe the meteor trail (ionized air columns) that moves with the wind neutral layer of mesosphere. When a meteor enters the atmosphere it rapidly vaporises leaving behind a trail of ionised gas along its path of travel, this trail can form a target for a radar transmission. Generally the frequencies used for the detection of radar, located on the VHF band wave spectrum. The results of the analysis of radar data output consists of 7th meteor parameter can be used to study the behavior of neutral winds in the Mesosphere. In this paper the utilization of SKiYMet shown to detect Wind speed Meridional and Zonal Wind speed, Temperature in the Mesosphere and the number and received Flux meteor in the Earth, as a sources of data to better understand the dynamics of the neutral winds at an altitude of 70-110 km region of observation locations. Simultaneously measurement data will be shown at Kototabang observations that have been operating since year 2006 and in Biak Station since year 2011. All of the radar installation is a collaboration between LAPAN and RISH - Kyoto, NICT Japan.

Keywords: Meteor radar, Indonesia, Equatorial regiona, Koto Tabang, Biak

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PEM05-P04 Room:Poster Time:May 2 16:15-17:30

Concentric structures in molecular oxygen emission observed by ISS-IMAP/VISI

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Concentric structures in airglow emissions were often observed from ground based imagers. Some of them were thought to be caused by the active clouds in the troposphere. It was not able to observe the overall structures from the imagers on the ground under the cloudy condition. Field of views of the imagers were not enough to observe whole structure. Space borne imagers are able to observe the structures caused by the disturbances in the lower atmosphere with wider field of view. Concentric structures of the O_2 airglow emission in 762-nm wavelength were found by the Visible and near-infrared imager on the International Space Station on June 1, 2013 over the U. S. This is the first case which took the image from edge to the center of the concentric structure. Spatial scale of this concentric structures were estimated to be 1,200 km. Fine structures with 80 km wavelength and no dumping in the intensity were observed in this VISI observation. Amplitude in these fine structures were about 10 % to the background intensity. Circular structures were also observed in the GPS-TEC observations before the VISI observation. These concentric structures were estimated to be caused from the active clouds after tornado and atmospheric gravity waves had propagated in horizontal direction in the emission layer.

Keywords: Near infrared, Airglow, Concentric structure, the Mesosphere, Atmospheric gravity waves

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Background Lamb waves coupled with thermospheric gravity waves

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Lamb waves of the Earth's atmosphere in the millihertz band have been considered as transient phenomena excited only by large events. Nishida et al. (2014) showed the first evidence of background Lamb waves in the Earth's atmosphere from 0.2 to 10 mHz, based on the array analysis of microbarometer data from the USArray in 2012. The observations suggest that the probable excitation source is atmospheric turbulence in the troposphere. Theoretically, their energy in the troposphere tunnels into the thermosphere at a resonant frequency via thermospheric gravity wave because the Lamb-wave branch intersects that of thermospheric gravity waves at 3.5 mHz and that of acoustic waves trapped near the mesopause at 6.5 mHz [Garrett 1969]. The observed FK spectrum shows a local minimum of Lamb-wave amplitudes at around 3.5 mHz, where the Lamb-wave branch is crossed by the thermospheric gravity-wave branch. Coupled Lamb waves leak a certain amount of energy from the troposphere to the thermosphere, reducing the Lamb-wave amplitudes at the crossover frequency relative to those at neighboring frequencies, when their excitation sources exist in the troposphere. The energy tunnels from the troposphere to the thermosphere at the resonant frequency, although Lamb waves themselves cannot induce an upward flux [Lindzen 1972]. The RMS amplitudes of the coupled modes are estimated to be 0.3 m/s at 150 km and 0.1 m/s at 120 km, respectively. These modes might contribute to the thermosphere energy balance by heating via viscous dissipation [Hickey et al. 2001]. The amplitude suggests that the Lamb waves partly contribute to the excitation of thermospheric wave activity associated with severe convection activity [Hunsucker1982].

Keywords: Atmospheric Lamb wave, Thermospheric gravity wave

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A proposal of simple resonance scattering lidar using an alkali metal vapor laser for monitoring the MLT region

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Many observations of metal atomic layers such as Na, Fe, K, Ca and Ca ion in the mesopause region have been conducted in many parts of the world. We have observed several mesospheric metallic layers at Tokyo and Indonesia using resonance scattering lidars consisting of a dye laser and a Ti:Sapphire laser [1]. Especially, in order to solve the formation mechanism of metallic sporadic layers occurred in the mesopause region, the simultaneous observation of Ca ion and the neutral metal atom is necessary. However since the output power of the Ti:Sapphire laser has a low damage threshold of a crystal, it is difficult to improve the output average power. We propose the resonance scattering lidar consisting of the alkali vapor laser for monitoring the MLT region. Optically pumped alkali vapor lasers have attracted increasing attention because of their potential of achieve high power in a high quality beam. The alkali vapor laser can easily realize narrow-linewidth and precise tuning.

Metal atomic layers in the mesosphere are an excellent tracer of the atmospheric wave motion in the region between 80 and 100km. sudden formation of thin metallic layers, superposed in the background mesospheric metallic layers was discovered and these enhanced layers are called the sporadic metallic layers. We have observed frequently the sporadic sodium layers (Nas) at Hachioji, Japan (35.6N, 139.4E) and the sporadic sodium and iron layers (Fes) at Kototabang, Indonesia (0.2S, 100.3E). The ion recombination mechanism invoking wind shear and sporadic E layers appears to be consistent with many observed characteristics, but their cause is still an open question.

Zhdanov et al. presented optically pumped continuous wave potassium vapor laser operating in a single longitudinal and a single transverse mode at 770 nm [2]. Zweiback et al. demonstrated a high efficiency potassium vapor laser using a 0.15nm bandwidth alexandrite laser as the pump source [3]. The alkali vapor laser operates in a three level scheme. The optical pump source excites the D2 line of alkali atom and lasing occurs on the D1 line. To provide a population inversion, fast quenching must be provided by using a buffer gas. We are developing a high peak power pulsed potassium vapor laser using alexandrite laser as the optical pump source. Sealed potassium vapor cell had AR coated windows, and filled with metallic potassium and helium. The cell was assembled inside an oven which had temperature controlled heaters. A pump beam polarized in the horizontal plane was focused through the polarizing beam splitting cube into the potassium vapor cell with a lens. A laser cavity was created for the vertical polarization by two mirrors and the beam splitting cube.

The development of these kinds of lasers is identified as one of the key topics for advancing the application of resonance scattering lidar systems.

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Keywords: mesopause, metal atomic layer, resonance scattering lidar, metal vapor laser