Status of Equatorial MU Radar project in 2016

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Research Institute for Sustainable Humanosphere, Kyoto University (RISH) has been studying the atmosphere and ionosphere by using radars. The first big facility was the MU (Middle and Upper atmosphere) radar installed in Shiga, Japan in 1984. This is one of the most powerful and multi-functional radar, and is successful of revealing importance of atmospheric waves for the dynamical vertical coupling processes. The next big radar was the Equatorial Atmosphere Radar (EAR) installed at Kototabang, West Sumatra, Indonesia in 2001. The EAR was operated under close collaboration with LAPAN (Indonesia National Institute for Aeronautics and Space), and conducted the long-term continuous observations of the equatorial atmosphere/ionosphere. The EAR, however, had a limited sensitivity to the MU radar as the total output power is just 1/10 to the MU radar. Our new project is to establish "Equatorial MU Radar (EMU)" just next to the EAR site in Indonesia. The EMU will have an active phased array antenna with the 163 m diameter and 1055 cross-element Yagis. Total output power of the EMU will be more than 500 kW. The EMU is the "MU radar class" facility, and can detect turbulent echoes from the mesosphere (60-80 km). In the ionosphere incoherent-scatter observations of plasma density, drift, and temperature would be possible. Multi-channel receivers will realizes radar-imaging observations. The EMU is one of the key element in the project "Study of coupling processes in the solar-terrestrial system" that is one of the important project in the Master Plan 2014 of the Science Council of Japan (SCJ). In 2015 the MU radar was awarded IEEE Milestone as the world first atmospheric radar with active phased array antenna system. For the EAR, preparation for construcion permission has almost completed. We will report current status of the EMU project together with stutus of the Master Plan 2017 of SCJ.

Keywords: Atmospheric radar, Equatorial atmosphere, Low-latitude ionosphere, Indonesia

NASA Ionospheric Connection Explorer, Validation of Scientific Performance

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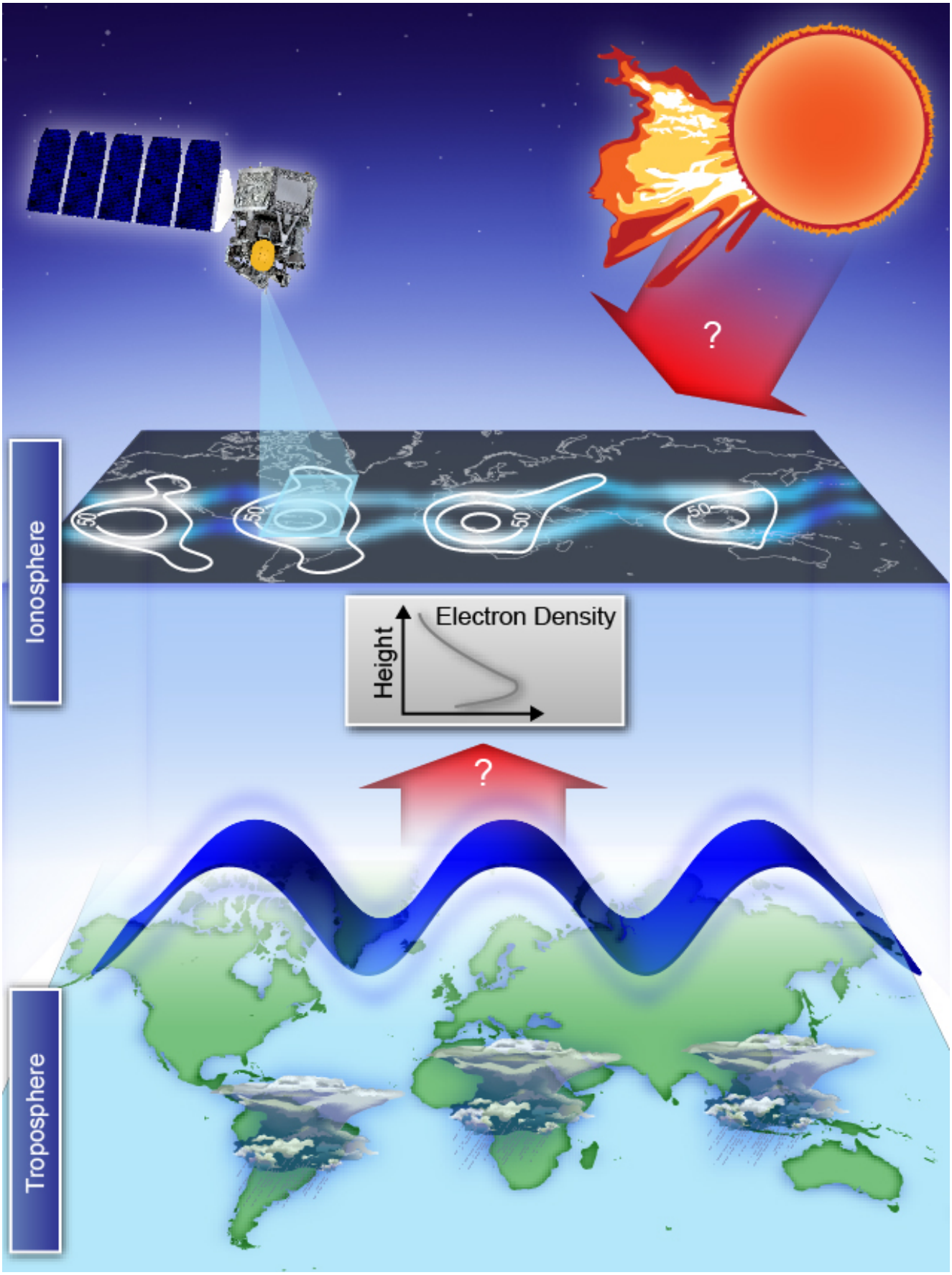
Earth's space environment is highly variable, changing in ways that we are currently unable to predict. Specifically, the ionosphere exhibits remarkable day-to-day changes that cannot be attributed to any known source, though forcing from the lower atmosphere is now considered of key importance. NASA's Ionospheric Connection Explorer, a mission designed to discover the causes of this variability, is in development for a June 2017 launch. Concurrent with the build of the instruments and spacecraft, a science validation effort has tracked the expected performance of the observatory. The predicted performance of the science retrieval algorithms developed for ICON will be reported. The current performance models show that ICON will have outstanding scientific capability and be able to address and resolve the open questions in space plasma physics that pertain to space weather. Here we will present the performance predictions and observational plans for the ICON mission, and discuss opportunities for collaborative measurements aligned with international research efforts.

Keywords: Thermosphere, Ionosphere, atmospheric physics



Early Results from pre-YMC 2015 Field Campaign in Sumatra

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The Years of the Maritime Continent (YMC) is designed to take place from mid-2017 to mid-2019 for improving our understanding and prediction of the weather-climate system over the Maritime Continent (MC) region and its global impact. During the campaign period, several intensive observations coordinated under the framework of YMC are planned in addition to the long-term monitoring by the MC local agencies. However, such coordination and conducting observations may encounter unforeseen difficulties. In addition, 2-year period is still insufficient to understand even local-scale phenomena as it may be affected by large/longer-scale phenomena such as El Nino. By considering these factors, we have conducted another field campaign as a pilot study for the YMC, and we call it as pre-YMC campaign. This campaign was conducted in Sumatra, Indonesia including Bengkulu (on and off the coast) and Kototabang from November through December 2015. While we deployed land-based radar/special radiosonde sites in Bengkulu and the R/V Mirai off Bengkulu to study precipitation mechanism, we also conducted water vapor/ozone-sonde observations at the EAR site in Kototabang to study upper troposphere/stratosphere interactions. Observations captured the atmospheric features in the transition phase from inactive to active for convection associated with the Madden-Julian oscillation. In this talk, some selected early results will be presented in addition to the basic information about the field campaign.

Keywords: YMC, Pre-YMC, Sumatra

Cloud Propagation over Sumatera during Coupling Processes in the Equatorial Atmosphere Campaign I and II

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Cloud propagation determines the distribution of precipitation. Previous studies on cloud propagation over Sumatera are mostly focused on mean propagation. Marzuki et al. [1] investigated the propagation of individual cloud cluster using Hovmoller diagram of 10 years of brightness temperature data. However, cloud tracking through Hovmoller diagram has some disadvantages: 1) result significantly depends on the averaging window, 2) two or more cloud can be assumed as a single cloud if they lie at the same longitude at the same time, and 3) only possible to get one direction of propagation. Therefore, objectively identifying and tracking the cloud in latitude-longitude space is necessary. In this study, we present the result of cloud tracking based on three-dimensional brightness temperature (T_b) data during Coupling Processes in the Equatorial Atmosphere (CPEA) campaign I and II. The two campaigns have a different Madden-Julian Oscillation (MJO) phase in which active MJO was observed during the CPEA-I in contrast to the CPEA-II. Although during the CPEA-II strong actively convective due to the MJO was not observed, Sumatra received high daily rainfall during this period. Although mean outgoing longwave radiation (OLR) is much lower during CPEA-II than CPEA-I, the cloud size during the CPEA-I is larger than during CPEA-II. It was also found that the ratio of westward to eastward moving cloud during CPEA-I (II) is 7:1 (6:1). Both during CPEA-I and II, westward moving streaks generally have a longer span and faster speed than those of eastward-moving system.
[1] Marzuki, Hashiguchi, H., Yamamoto, M. K., Yamamoto, M., Mori, S., Yamanaka, M. D., Carbone, R. E., and Tuttle, J. D.: Cloud episode propagation over the Indonesian Maritime Continent from 10 years of infrared brightness temperature observations, Atmos. Res., 120–121, 268–286, 2013.

Keywords: Cloud propagation, Sumatra, CPEA-I and II

Coordinated observations of post-midnight irregularities and thermospheric neutral wind and temperature

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Field-aligned irregularities (FAIs) have been observed since last few decades by using UHF/VHF/HF radars. At equatorial F-region, FAIs are generated within plasma bubbles. The plasma bubbles are well-known to be initiated at evening terminator and occur frequently in equinoxes, especially during high solar activity conditions. On the other hand, recent observations show that the FAIs frequently occur at post-midnight around June solstice in low solar activity conditions. From the comparison of ionosonde data, it is found that uplift of the F layer could play an important role in generating the post-midnight plasma bubbles. However, mechanisms of uplift of the F layer has not been revealed yet.
In this study, we investigate an event of the post-midnight FAIs observed with the EAR (Equatorial Atmospheric Radar) at Kototabang in Indonesia. Two-dimensional map of rate of total electron content change index (ROTI) obtained from GPS receivers in Southeast Asia, thermospheric neutral winds and temperature observed at Kototabang by Fabri-Perot interferometer, and altitude of the bottomside of the F layer observed with ionosondes at Kototabang, Chumphon, and Chiang Mai, are compared. On the night of July 9, 2010, the post-midnight FAIs appeared within the field of view of the EAR. By estimating the vertical rise velocity of this FAI structure, we found that the FAIs could be accompanied by plasma bubble initiated at magnetic equator around 22:00 LT.
Two-dimensional ROTI map also showed an enhancement near magnetic equator around this time, then extended to the higher low latitudes and reached Kototabang at midnight. Thermospheric neutral wind was southward (magnetically poleward) from19:30 to 23:00 LT, and northward (magnetically equatorward) enhancement was observed from 22:30 LT. The altitude of the bottomside of F-layer increased at 15:30-16:00 LT. This altitude increase of the F layer could be caused by the enhancement of the equatorward thermospheric wind. Thermospheric neutral temperature was higher at north than at south from 22:30 to 01:00 LT on the subsequent day, indicating that Midnight Temperature Maximum (MTM) existed at the north of Kototabang. We discuss a role of MTM in the generation of post-midnight FAIs at low latitude region.

Keywords: Post-midnight F layer field-aligned irregularities (FAIs) , Plasma bubbles, Equatorial Ionospheric region

Coordinated Incoherent Scatter Radar and Fabry-Perot Interformeter observations of ionosphere-thermosphere disturbances during the March 17-18, 2015 great solar storm

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With a tremendous drop of the Dst index to ~ -230 nT, the geomagnetic storm during March 17-18, 2015 has been the largest during the current solar cycle. This strom was caused by a combined effect of the arriving solar Coronal Mass Ejection materials with high-speed solar wind streams originated from a nearby coronal hole. It was very fortunate for us to have coordinated an international campaign monitoring geospace disturbances during this period using ground-based facilities. These include incoherent scatter radars and Fabry-Perot Interferometers in the America sectors and other instruments in East Asia sectors, forming an observational network along approximately the 60W/120E meridional circle. The presentation will highlight these ground-based observations along with simultaneous DMSP in situ measurements and TEC from a network of dense GPS receivers, with a focuses on (1) the ion-neutral coupling processes at subauroral and mid-latitudes; (2) periodic midlatitude ionospheric disturbances; and (3) topside ionospheric variations. In particular, one of the most striking features to be discussed is the unexpected pre-midnight northward neutral wind surge, observed over multiple subauroral and midlatitude sites, accompanying strong westward winds developed at earlier times. We ascribe these wind disturbances to Subauroal Polarization Stream (SAPS).

Keywords: geomagnetic storm, magnetosphere-ionosphere-thermosphere coupling, incoherent scatter radar, Fabry-Perot Interformeter

Equatorial coastlines controlling Earth's atmosphere

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Just half a century has passed since the theories of vertically evanescent tides (Kato, 1966) and equatorially ducting modes (Matsuno, 1966) as varieties of atmospheric gravity waves. Horizontal convections as superimpositions of upward/downward gravity waves are generated between dayside and nightside hemispheres and between land and sea surfaces by insolation with diurnal cycles. Importance of the latter category, so-called sea-land breeze circulation, has been emphasized by ground-based and space-borne observations over the equatorial troposphere. The cloud activity has diurnal and annual cycles dominantly on land, in contrast to intraseasonal and interannual variations mainly over oceans, and the tropical rainfall amount is expressed by functions of coastal distance and length (Ogino et al., 2016; Yamanaka, 2016). This explains the global cloud activity-rainfall maximum located over the Indonesian maritime continent (IMC) with the world’s longest coastlines.

The diurnal cycle is generated directly by land-sea temperature contrast along a coastline: solid land becomes hotter than liquid sea by solar heating through clear sky before noontime, and opposite contrast appears before the sunrise by evening rainfall-induced sprinkler-like land cooling in tropics (different from infrared cooling at clear night in extratropics). This is why the diurnal cycle is dominant in the rainy season, and also why the rainy season appears exactly in the summer-side hemisphere, because land heating in the clear morning and water-vapor transport by afternoon sea-wind are strongest in the season of maximum insolation. El Niño causes less rainfall, because lower sea surface temperature makes morning maritime convection weaker.

Those lower-atmospheric features are reflected in the middle- and upper atmospheric dynamics. As suggested so far (e.g., Ogino et al., 1995; Tsuda et al., 2000), the stratospheric gravity-wave activity takes maximum near the equator and in particular near IMC as does the convective activity. Here it is suggested from the latter that these activities are generated with diurnal cycles and horizontal scales of about 300 km along coastlines, which are fixed with the major islands and the whole IMC with zonal scales of 1,000 and 5,000 km, respectively. 14-year hourly 25 km-resolution cloud-top height data are analyzed to show spectral slopes of around -2 for frequency and -5/3 and -3 for higher and lower zonal wavenumbers (with a border of about 300 km in zonal wavelength), as have shown already for tropopausal gravity waves or quasi-two dimensional turbulence (e.g., Nastrom and Gage, 1985). A part of the insolation over equatorial lands sequentially with Earth’s rotation may contribute (through infrared absorption) to generation of migrating tides. All the features mentioned here appear on a land-sea coexistent planet like Earth, and differences in other planets are also discussed briefly.

Keywords: equatorial region, air-sea-land interaction, Earth's rotation and revolution

Ground network observation of ISEE, Nagoya University, for the study of coupling processes in solar-terrestrial system

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The Solar-Terrestrial Environment Laboratory, Nagoya University has been combined with Hydrospheric Atmospheric Research Center and Center for Chronological Research to become the Institute for Space-Earth Environment Research (ISEE) of Nagoya University since October 2015. Under the new institution, ground-based observation network has been kept operating to study coupling processes in solar-terrestrial system, particularly at ground stations in Asia and Africa from high to low latitudes. A new collaborative research system will be launched from April 2016 particularly to extend this ground network observations in collaboration with various Japanese and foreign institutions. The Center for International Collaborative Research (CICR) and Center for Integrated Data Science (CIDAS) are newly established under ISEE to promote international collaborative researches and to promote integrated analyses using various kinds of observation data and advanced computer simulations, respectively. These centers also contribute to the operation and database construction of the ground-based network observation by ISEE. In this presentation, we show ground-based network observations and domestic and international collaboration system newly developed under ISEE and its two centers.

Keywords: Ground network observation , Institute for Space-Earth Environment Research (ISEE), Nagoya University, cooperative research

Recent development of MAGDAS project: Strategy for international alliance of geomagnetic field network observation

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For space environment monitoring, Kyushu University has developed a real time magnetic data acquisition system (the MAGDAS project) around the world. The number of observational sites is increasing every year with the collaboration of host countries. Now at this time, the MAGDAS Project has installed 77 real time magnetometers –so it is the largest magnetometer array in the world. The history of global observation at Kyushu Univ is over 30 years and number of developed observational sites is over 140.
In this talk, we will introduce recent development of MGADAS project and stradegy for international alliance of geomagnetic field network observation based on the project "Study of coupling processes in solar-terrestrial system" that was approved by the Master Plan 2014 of Science Council of Japan and the Roadmap 2014 of MEXT.
Topics for open policy for MAGDAS data, development of Space weather index, and extension of Equatorial network will be also discussed.

Keywords: International aliance, geomagnetic field network, master plan

Magnetic ripples as observed by low altitude satellites, CHAMP and SWARM

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The low altitude satellites such as the CHAMP or the SWARM satellites have been observing the small amplitude (typically 0.5 –5nT on the dayside) magnetic fluctuations with period of a couple of ten seconds. They exist almost all the time and at any local time (LT) in middle and low latitudes. They were named as “magnetic ripples” because the magnetic fluctuations like ripples exist globally.
They have the following characteristics: (1) They are perpendicular to the geomagnetic main field. (2) Their amplitude has the magnetic conjugacy. (3) The amplitude and the period along the orbit have latitudinal dependence, and they depend also on the geographic longitude. (4) The amplitude is larger on the day side than on the night side. (5) The amplitude doesn’t have dependence on the solar wind parameters nor the magnetic disturbance. (6) The amplitude has the following seasonal and topographical characteristics. That is, the amplitude during the northern summer and northern winter is larger than those during the equinoxes. In the northern summer, the amplitude over South America, Eurasia, North Africa and Australia continents, and their magnetic conjugate regions is larger than those in the other regions. In the northern winter, the amplitude over the eastern Pacific Ocean is larger.
We assume that they are generated through the E-region dynamo driven by the acoustic mode of the gravity waves propagated from lower atmosphere. We discuss the consistency of the above mentioned characteristics and suggested mechanism of generation of the magnetic ripples with ground based observations such as the GPS-TEC, micro-barometric observation, etc..

Keywords: magnetic ripples, small-scale field-aligned currents, acoustic gravity waves, low-altitude magnetic satellite

Observations of medium-scale traveling ionospheric disturbances using FORMOSAT-2 / ISUAL 630.0 nm airglow

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We reports observation results of space based imaging of medium-scale travelling ionospheric disturbances (MSTID) in 630.0 nm emission by Imager of Sprites and Upper Atmospheric Lightnings (ISUAL), onboard FORMOSAT-2 satellite. The limb integrated measurements, after removing background, reveal multiple bands of intensity perturbation when projected to a horizontal plane corresponding to the altitude of peak emission, with distinct southwest to northeast orientation in the southern hemisphere. The ISUAL observations in the year 2007 are further used to investigate the MSTID features as well as occurrence characteristics in the southern hemisphere, most of which are over the ocean where no ground based observations are available. The preliminary statistics shows more MSTID occurrence in solstices with peak in June-July months. Majority of the MSTID perturbations have wavelength in the range 150-300 km, and are aligned at about 30°-50° from the east-west plane. The orientation of the wave fronts indicate that Es-layer instability might be important in the MSTID generation.

Keywords: MSTID, FORMOSAT-2/ISUAL, airglow

Interhemispheric Coupling Study by Observations and Modelling (ICSOM)

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Recent observational and modelling studies suggest that the Northern and Southern Hemispheres of the earth atmosphere are potentially coupled by the Lagrangian mean flow in the mesosphere modulated by waves interacting with the mean flow. However, observations of modulated wave and flow fields which are needed for quantitative understanding of the interhemispheric coupling are not sufficient. Simultaneous observations of gravity waves at various locations are most important because they are a main driver of the Lagrangian mean flow in the mesosphere.
With the start of full system observation by the PANSY radar in the Antarctic in March 2015, a global mesosphere-stratosphere-troposphere (MST) radar network extending from the Arctic to the Antarctic has been realized. The MST radars are able to observe wind vectors with fine temporal and vertical resolutions including vertical wind components in the troposphere, stratosphere and mesosphere, although an observational gap of the middle and upper stratosphere remains. Thus, the characteristics of small-scale or short-period wave motions including gravity waves and the momentum fluxes associated with these waves can be estimated with a good accuracy.
In addition, recent high-resolution general circulation models enable an explicit simulation of gravity waves under ideal and/or climatological boundary conditions and allow us to examine the momentum budget in the MST region including gravity waves, although their resolution is currently not sufficient to resolve the entire gravity wave spectrum. Real atmosphere simulations utilizing such high-resolution models are still a challenge for the MST region. However, if such real atmosphere simulations are successful, they will help quantitative interpretation of the dynamical fields observed by the MST radar network, and the observations will provide invaluable validation data for the model improvement.
Therefore we will examine the interhemispheric coupling of the earth atmosphere through a combination of simultaneous observations by networking the MST radars over the world and high-resolution model simulations of the observed atmosphere. The first international campaign was performed in 22 January-17 February 2016. Two minor stratospheric warmings occurred in the Arctic. The second one was a minor warming by its definition but the temperature at the north pole increased by about 70 K in two days at 10 hPa. Seven MST radars over the world and a lot of complementary observations were performed by more than 30 participants in eight countries. Preliminary results from this campaign will be reported.

Keywords: interhemispheric coupling, middle atmospehre, sudden stratospheric warming, mesosphere-stratosphere-troposphere radars, general circulation, gravity waves

Current Status of EISCAT_3D and Japan's Contribution

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The European Incoherent Scatter(EISCAT) Scientific Association with associate members from Sweden, Norway, Finland, UK, China and Japan, including affiliated member organizations from South Korea, France and EC, is planning for the construction of the next generation near-earth space and upper atmosphere radar system in northern Feno-Scandinavia, called EISCAT_3D. The technical design work is currently being almost finalized and the project has now entered the new phase of production engineering. The Swedish Research Council, the Academy of Finland, the Research Council of Norway and the European Commission have now granted funds for the development, construction and operation of EISCAT_3D, which covers approximately 70% of the total costs of establishing the first stage of the system. EISCAT_3D is the major upgrade of the existing EISCAT mainlamd radars, with a multi-static phased array system composed of one central active (transmit-receive) site and 4 receive-only sites to provide us 50-100 times higher temporal resolution than the present system. The construction of EISCAT_3D is planned to implement by 4-staged approach, starting from the core site with half transmitting power about 5MW at Skibotn (Norway) and 2 receiving sites at Bergfors (Sweden) and Karesuvanto (Finland) at the 1st stage. The Japanese EISCAT user community has been pursuing the opportunity to contribute in-kind to the construction of EISCAT_3D. Our proposal is to supply the power amplifiers for the radar as a joint venture with EISCAT in cooperation with Japanese industry. The EISCAT_3D program in Japan has been successfully granted as as one of 27 high-priority programs of Master Plan 2014 and 10 new Roadmap 2014 programs as a part of 'Study of Coupling Processes in the Solar-Terrestrial System' (PI: Prof. Tsuda, Kyoto Univ.). Supported by this decision, National Institute of Polar Research has made a funding proposal to MEXT for EISCAT_3D, collaborating with Institute for Space-Earth Environmental Research, Nagoya University. In parallel to the funding proposal, we started a development for a high energy-efficient power amplifier collaborating with the EISCAT headquarter and Japanese industry. In this paper, we will overview the current status and outlook on Japan's national contribution to the EISCAT_3D project.
Figure. Location of existing EISCAT radar and planned EISCAT_3D radar sites.

Keywords: incoherent scatter, radar, arctic, geospace

Significance of the D-region ion chemistry in the atmospheric forcing from above by precipitating high-energy particles

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Although the ionisation degree of middle atmosphere -lowere thermosphere region is low, it surprisingly turns out that ion chemistry plays a significant role in causing variations in concentrations of neutral chemically active minor constituents during events of excess ionisation, such as auroral particle precipitation. Here we first give an overview of the D-region ion chemistry, pointing out the relevant processes, which can be both direct and indirect via first generating chemically active minor constituents of the atmosphere, such as odd nitrogen and odd hydrogen, which in turn can affect for example atmospheric ozone via catalytic reactions either directly in-situ, or after transport in atmosphere to lower altitudes and lower latitudes. We show recent results using the detailed coupled neutral and ion chemistry model, the Sodankyla Ion Chemistry model. We also show how the upcoming new incoherent scatter radar facility EISCAT_3D, together with coordinated other currently planned measurements, will enhance the research opportunity in studying the coupling between geospace environment and atmosphere of Earth during high energy particle precipitation into the atmosphere.

Keywords: Ion chemistry, D region, aurora

Variations of the polar lower thermosphere and mesosphere in February 2016 using EISCAT radar, meteor radar, MF radar, and sodium LIDAR observations

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We made an EISCAT special program (SP) experiment, under collaborations of Japan, Sweden, and Norway, to study variations of a quasi-two day wave (Q2DW) and tidal waves in the polar lower thermosphere using the EISCAT UHF radar at Tromsoe (69.6N, 19.2E) and the EISCAT Svalbard radar at Longyearbyen (78.2N, 16.0E) for 45 hours. The SP started at 23 UT on February 10, 2016, just after EISCAT CP2 (Common program 2) run made for 135 hrs, and ended at 20 UT on February 12, 2016. By combining the EISCAT CP2 run and our SP run, we have, in total, made a data set of 7.5 day length. Unfortunately, there was a data gap from about 01 UT to 07 UT on February 7 due to a problem of data recording at the Tromsoe site. Except for the gap, the operations went well without no seirouous problems at both the EISCAT radars. Sodium LIDAR observations of wind, temperature, and sodium density collocated at the Tromsoe site were also made during dark time intervals together with meteor and MF radar contiunual observations. We have analyzed the data sets, and derived Q2DW and 24h/12h tides. An SSW occurred in this time interval, so we focus on changes of the waves around time interval of the SSW.

Keywords: Lower thermosphere, Mesosphere, tidal waves, quasi-two data wave, EISCAT radar, sodium LIDAR

