**Japan Geoscience Union Meeting 2011**
(May 22-27 2011 at Makuhari, Chiba, Japan)


PEM006-P01 Room:Convention Hall Time:May 26 10:30-13:00

# Asia VLF/LF wave observation network (AVON) system for monitoring of the lower ionosphere and lightning

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We explain the scientific goals and instrumentations of Asia VLF Observation Network (AVON) system for monitoring the lower ionosphere and lightning. The system consists of three observation sites: Tainan site (23.08N, 120.12E) in Taiwan, Saraburi site (14.53N, 101.03E) in Thailand, and Pontianak site (0.00N, 109.37E) in Indonesia. At each site, we use a monopole antenna and a dipole antenna for the electric field measurements and an orthogonal loop antenna for the magnetic field measurements. The signals detected through these antennas are split into three PCs and used for the monitoring of broadband lightning atmospherics (0.1-40.0 kHz), tweek atmospherics (0.1 ? 10.0 kHz), and transmitter signals (40.0 and 60.0 kHz etc). Analyzing the VLF/LF data obtained at three sites, we can monitor the lower ionosphere and lightning in Southeast Asia. This network system is utilized in cooperation with other ground-based and satellite-based observation projects to clarify the meteorological aspects of lightning activity and their effects on the middle/upper atmosphere, ionosphere, and magnetosphere. In the presentation, we introduce the AVON system and show the initial results.

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# Loss of high-energy electrons into the atmosphere during the magnetic storm and substorm

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Man-made VLF/LF radio wave observation at Ny-Alesund in Norway was used to study precipitations of high-energy (>100keV) electrons into the atmosphere during the geomagnetic storm and substorm. The observation system was installed at the NIPR station on March 2010 and measures transmitter signals operated at UK (60.0 kHz) and Germany (77.5 kHz). During three magnetic storms occurred on 5 Apr., 2 May, and 29 May, strong phase variations in the received signals were detected. Comparison of the phase change with the precipitation electron flux observed by the MEPED instrument onboard the NOAA/POSE satellites above the LF wave propagation paths showed the good correlation between them. It is expected that plasma waves excited in the magnetosphere are responsible for the energetic electron precipitation into the atmosphere through the pitch angle scattering. Therefore, local time distribution of the plasma wave would cause the local time dependence of the electron precipitation region. To investigate this process, local time distribution of the electron precipitation events was examined by using the LF wave observation and was compared with the substorm onset timing. At present, the substorm onset timing was determined by the Kakioka Pi2 and the positive bay observed by low-latitude magnetometers located near the local midnight. In the morning and noon sectors, it is found that onset of the precipitation is delayed ten to several tens minutes from the substorm onset. The delay time is consistent with the drift time of energetic electron with energy of >100 keV. On the other hand, the electron precipitation onset found in the dusk sector occurred at or just before the substorm onset. This implies that different types of plasma waves are responsible for the dependence of the electron precipitation characteristics on local time.

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# Global thunderstorm activities and OLR, and their dependence on solar cycle

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Global ELF observation network, GEON, constructed and operated by Hokkaido University, provides information of each cloud to ground lightning discharge, CG, that is, GPS time, location and energy, as well as Schumann resonance, SR, power, a proxy of global energy proxy of lightning discharge. From the standpoint of the relationship between the effect of solar activity to the climate, lightning activity estimated from the ELF measurement in the frequency range between 1 and 100 Hz and the outgoing longwave Radiation, OLR, an indicator of cloud amount, are examined for their periodicity in the periodic range of about one month. SR power shows about 27 day periodicity in solar maximum years and it becomes elongated toward solar minimum. On the other hand, OLR shows same kind of 27 day periodicity in solar maximum years, but only in the Western Pacific Warm Pool area. Both the spectra of SR and OLR have a peak around 35 days in solar minimum years. The average spectrum of OLR in solar maximum years also shows an enhancement in the range of 50 or 60 days corresponding to the main MJO period. In this paper the relationship between the global lightning distribution based on GEON measurement and OLR are discussed in detail, considering one-month periodicity. Especially synchronization of thunderstorm activity between different longitudes is focused.

Keywords: solar cycle, climate, lightning, thunderstorm, OLR, ELF

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# Ionospheric heating effects on the polar lower thermospheric wind

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Of vital importance is to qualify significance of the magnetospheric forcing (such as the Joule heating and the ion drag) to the polar lower thermospheric wind dynamics, in order to obtain better understanding of the Magnetosphere-Ionosphere- Thermosphere (MIT) coupling process. Several measurements by Incoherent Scatter (IS) radars and Fabry-Perot Interferometers (FPIs) demonstrated neutral winds with speeds exceeding 300 m/s in the polar lower thermosphere during geomagnetically active intervals. The wind speeds are significantly larger than a typical wind speed (less than 200 m/s). This suggests that the magnetospheric forcing can accelerate the neutral wind. While a number of observations demonstrated relationships between the neutral wind variations and magnetospheric forcing, there are a few studies on examining quantitatively the forcing on the neutral wind based on observational data. A case study determined contributions of the Joule heating and the ion drag on the acceleration of neutral wind at 118 km, and suggested that the Joule heating was a major important factor. At lower heights (below 110 km), however, the heating effects on the neutral wind dynamics are little known. A couple of studies suggest that an anomalous heating on the atmosphere become important for the wind dynamics in the lower heights due to cooling of the heated electrons induced by the Farley-Buneman instability during the strong electric field.

We have investigated such ionospheric heating effects on the wind dynamics at 100-120 km using data obtained with the European Incoherent SCATter (EISCAT) Svalbard Radar (ESR) located in Longyearbyen (78.2N, 16.0E in geographic coordinates, 75.2 in invariant latitude). As a case study, we have determined contributions of the Joule heating, the ion drag, and also the anomalous heating on the neutral wind acceleration at 100–110 km during a strong electric field. The ESR result shows that electron temperatures in the cusp electrojet reach up to about 4000 K. The heat is transferred to the neutral gas by collisions (i.e., cooling of the heated electrons). This anomalous heating effect can be more important at 101–109 km, compared with that at higher altitude. We have found that the anomalous heating effect at 101 km was comparable to the Joule heating effect and occasionally became much more effective. On the other hand the ion drag contribution became less effective. During the strong electric field, at 101 km, the wind speed increase of 60 m/s was found, while the wind speed increase was decreasing with decreasing altitudes. These results suggest that main contributor to the wind acceleration at 101 km would be a total of the anomalous heating and the Joule heating.

Keywords: EISCAT, Polar region, Lower thermosphere, Neutral wind, Ionospheric electric field, Joule heating

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# Spatial and temporal variations of TEC fluctuations and losses of lock associated with equatorial plasma bubbles

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Equatorial plasma bubbles (EPBs) are depletion of the plasma density in the ionosphere and, inside of EPBs, there are field-aligned irregularities (FAIs) which affects wide-band radio waves. Therefore, EPB causes scintillations on GPS signals because of rapid variations of signal amplitude and phase, and limit the availability of carrier phase measurements. The spatial scale of FAIs that causes the scintillation is determined by Fresnel scale, which is about 2-300 m for GPS signals. This means that loss of phase lock (LOL) on GPS signals is a good proxy for hundred-meter-scale FAIs. It is also widely known that rate of TEC change index (ROTI) enhances around EPBs. Assuming that the altitude of the ionosphere is about 400 km, the velocity of the pierce point of GPS satellites at the ionospheric altitude is approximately 70 m/s around the zenith. ROTI averaged during 5 minutes is a reference of ten-kilometer-scale fluctuations.

In this study, we analyzed LOL and 5-min ROTI to examine the spacial and temporal variations of electron density disturbances associated with EPBs. Examining LOL and ROTI, the developments of two different-scale irregularities are identified. LOL and ROTI data are obtained from GPS data from GPS Earth Observation Network (GEONET) of Japan. From 630-nm airglow images obtained by all-sky imager at Sata, Japan, in 2001, we selected 11 EPBs where the EPBs reach to the geographic latitude of 30 degrees. This is because we compare the distributions of LOL and ROTI determined by GEONET with the airglow imager at Sata whose field of view is 26-34N in geographic latitude.

Both LOL and the enhancement of ROTI were observed in 7 events out of 11 events. The distributions of occurrence of LOLs are approximately in accordance with the depleted region of the airglow intensity, namely the ionospheric electron density. The distribution of the enhancement of ROTI spreads in the vicinities of EPBs, which is wider than that of LOL. The hundred-meter-scale irregularities are distributed within EPBs while the ten-kilometer-scale disturbances are located around EPBs.

In the events associated with LOLs, the kilometer-scale disturbances can be more developed as showing the value of ROTI since there are lacks of observation due to LOL and ROTI would be smaller than the case where there is no lack of observation. In the events without LOL, on the other hand, the fresnel-scale disturbances are not developed enough to cause the scintillation in GPS receivers. The mean values of ROTI in the events associated with LOLs are larger than those not associated with LOLs. Therefore, the kilometer-scale and hundreds-meter-scale disturbances tend to grow and decay simultaneously.

Keywords: Ionosphere, plasma bubble, GPS, loss of lock, TEC, scintillation

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# Study of equatorial Spread-F with GNU Radio Beacon Receiver (GRBR) network in Asia, Pacific and Africa

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Equatorial spread F (ESF) is intense ionospheric irregularity that occurs around the geomagnetic equator. It can cause intense scintillation to satellite-ground communications, and serious error in the GPS measurements. The ESF has been a hot research topic of the equatorial/low-latitude ionosphere for long time. However, its day-to-day variability is not well understood. In the southeast Asian region, Japanese researchers developed a network of ground-based observations with the Equatorial Atmosphere Radar (EAR) of RISH, Kyoto University, the ionosonde network SEALION (SouthEast Asia Low-latitude IOnospheric Network) of NICT, and optical instrument network OMTI (Optical Mesosphere Thermosphere Imager) of STEL, Nagoya University. SRI International deploys a VHF radar, an ionosonde and several satellite beacon receivers on Pacific islands. In addition to these, we are deploying the digital satellite beacon receivers named ”GNU Radio Beacon Receiver (GRBR)” to fulfill observation gaps. The GRBR-TEC with C/NOFS successfully shows longitudinal large-scale wave structure that is in good relationship to the ESF occurrence. In 2010 we further expanded the network in Asia, Pacific, and African regions. In presentation, we review current status of the wide network of GRBR, and achievement from the observations.

Keywords: Equatorial Spread-F, Satellite beacon experiment, Total electron content

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# Study of impacts of ionospheric irregularities associated with plasma bubbles on GNSS and its day-to-day variability

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GNSS (Global navigation satellite system) has been widely used for various applications. Ionospheric irregularities are one of the most serious issues that prevent advanced use of GNSS. Plasma bubbles are among those irregularities that have a great impact on GNSS. Characterization of the ionospheric irregularities are demanded by GNSS applications to realize the high level of services with reliability.

For differential GNSS applications, spatial variability of the total electron content (TEC) is most important, because it directly leads to positioning errors and threatens safety. However, it has not been well studied. Scintillation of GNSS signals due to small-scale irregularities is another aspect of plasma bubble's impact on GNSS degrading the quality of signals.

Indeed, importance of the characterization of the ionospheric irregularities in the low latitude regions has been recognized in the GNSS community, especially in the field of air navigation that requires extremely high level of safety.

Electronic Navigation Research Institute (ENRI) is contributing to International Civil Aviation Organization (ICAO) to provide ionospheric information needed by their own applications. ENRI's activities on this issue are (1) ionospheric data (TEC, TEC gradient, and scintillation) collection in the low latitude regions and (2) leading coordination of the ionospheric data collection in the Asia-Pacific region collaborating with ICAO.

At the meeting, these activities of ENRI including the plan of observation network will be presented more in detail. We believe that these studies should be an important part of the CAWSES-II or ISWI activities and that more attentions should be paid to.

Keywords: ionosphere, plasma bubble, observation network, GNSS, space weather application

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# A New Project for Constructing a Magnetometer Array in Tasmania and New Zealand: A Preliminary Result

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A project for observations of quarter-wave length and higher harmonic modes of field line resonances is planned. In February 2011, we installed a magnetometer in Middlemarch, New Zealand for the first step to develop a magnetometer array in Tasmania and New Zealand region. Some magnetometers have been operated by previous projects in this region and its conjugate point. Coordination of their and our magnetometers will allow us to study spatial structure of quarter-wave and higher harmonic modes of field line resonances. Such results will give some boundary for latest Magnetosphere-Ionosphere coupling models.

Keywords: geomagnetic field, ULF wave, field line resonance, magnetosphere-ionosphere coupling, plasmasphere, magnetosphere

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# SuperDARN contributions to CAWSES-II

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Super Dual Auroral Radar Network (SuperDARN) is an international collaborative HF-radar network originally designed to obtain global large scale two-dimensional polar ionospheric plasma convection patterns in both hemispheres with a temporal resolution of 1 to 2 minutes since 1995. SuperDARN is a powerful tool to be applied to many scientific issues, which can be used not only to deduce dynamics of global large-scale convection patterns, but also to study dynamics of transient meso-scale phenomena like flux transfer events (FTEs), magnetospheric responses to solar wind dynamic pressure like travelling convection vortices (TCVs) and polar cap boundary or open-closed field line boundary (OCB), to detect reconnection sites and to deduce reconnection rates, to study substorms, storms and phenomena related to subauroral regions like sub-auroral polarisation stream (SAPS), to deduce field aligned electric currents (FACs), to study MHD waves in a variety of frequency ranges, and also to study ionospheric irregularities in D-, E-, and F-regions. Moreover, it can be utilised not only to ionospheric researches but also to neutral atmospheric studies, e.g., on atmospheric waves e.g., traveling ionospheric disturbances (TIDs), tides and gravity waves, deducing neutral winds around mesopause region, and also detecting and studying polar mesospheric summer echoes (PMSEs), etc. These days, the fields-of-view (FOVs) of SuperDARN have been expanded to higher latitude (PolarDARN) and mid-latitude (StormDARN) which covers considerable portions of mid- and polar latitudes of earth's ionosphere in both hemispheres and enables us to address much wider ranges of scientific questions (including inner magnetospheric physics). SuperDARN has extensively evolved successfully and has been extremely productive by strong cooperation and competitions within the community and also by collaborative studies with other ground-based and satellite/rocket observations and theoretical research groups.

We present what SuperDARN has done so far and what could not be done by SuperDARN so far, and what SuperDARN will be able to do by recent technical development, e.g., by increasing spatial and temporal resolution and combining with other ground based and satellite observations, and then, discuss how SuperDARN can contribute to CAWSES-II program in terms of the main CAWSES-II themes, especially on the effect of short-term solar variability on the geospace environment (TG3), the geospace response to an altered climate (TG2), and the geospace response to variable inputs from the lower atmosphere.

Keywords: CAWSES-II, SuperDARN, magnetosphere-ionosphere coupling, MLT region dynamics, aurora, neutral winds

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# Long-term variation of auroral activity at Syowa-Iceland conjugate stations (1)

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Long-term variation of auroral activity at Syowa Station (SYO) (S69.00 deg) in Antarctica and Leirvogur (LRV) (N64.18 deg) in Iceland is investigated. Both SYO and LRV are located at auroral latitudes and in an unique geomagnetically conjugate relationship with each other. Geomagnetic variation data from 1958 and 1966 at LRV and SYO, respectively, are used for this analysis. Using those almost four solar cycle data, similarity and dissimilarity in the solar cycle variation, seasonal variation, and daily variation of geomagnetic activity at those conjugate stations are investigated to understand interhemispheric difference in auroral activity responding to the variation of the solar wind input and solar activity.

Keywords: aurora, magnetic activity, solar activity, long-term variation

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# Altitudinal response of global ionosphere to short-period recurrent geomagnetic activity during extreme solar minimum

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The deep solar minimum of solar cycles 23/24 was exceptionally quiet, with sunspot numbers at their lowest in at least 75 years. During this unique solar minimum epoch, however, solar wind high speed streams emanating from near-equatorial coronal holes occurred frequently and are the primary contributor to the continuous geomagnetic activity at the Earth. These conditions enable the isolation of forcing by geomagnetic activity on the preconditioned solar minimum state of the upper atmosphere caused by Corotating Interaction Regions (CIRs). Global observations of vertical electron density profiles by Formosat3/COSMIC provided a unique opportunity to study the altitudinal response of global ionosphere to this recurrent geomagnetic force caused by CIRs during the extreme solar minimum. The results indicate that the topside ionospheric response (above 350 km) appears to be dominated by changes in the plasma temperature and/or scale height and exhibits concurrent enhancements with the oscillations in geomagnetic activity during both day and nighttime. However, the electron density response at altitudes between 200 and 350 km is dominated by changes in the neutral composition and exhibits significant latitudinal, local time, and seasonal variations. The results are discussed in light of equatorward wind perturbations during enhanced geomagnetic activity and summer to winter transequatorial neutral wind patterns.

Keywords: Co-rorating Interaction Regions, recurrent geomagnetic activity, ionosphere, solar minimum