Book of Abstracts

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A Comparison of the Auroral Electrojet Index to Overhead SuperDARN Convection Velocities

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The magnetic-field based Auroral Electroject (AE) index was developed as a convenient, ground-based tool to quantify the intensity of the convection velocity in the auroral electrojets.
The SuperDARN global convection maps were used to show that the AE index was more directly related to the intensity of the electrojet currents than to the strength of the convection pattern (as expected).
We use the sunward SuperDARN velocities measured in the dusk sector in the vicinity of the SuperMAG AE (SAME) magnetic field stations to investigate in detail the relationship between AE and plasma convection in the electrojets.
The comparison reveals a clear seasonal variation that is consistent with the seasonal variation of photo-induced conductance that affects the auroral electrojet currents and therefore also the AE magnetic field deviations.

A deep learning based approach to forecast the onset of magnetic substorms

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The auroral substorm is a transient and complex phenomenon that takes place in the Earth's magnetosphere and has been extensively studied over the last six decades.

However, our understanding of its driving mechanisms is still limited and so is our ability to accurately forecast its onset.

In this study, we present the first deep learning based approach to predict the onset of a magnetic substorm, defined as the signature of the auroral electrojets in ground magnetometer measurements.

Specifically, we use a time history of solar wind bulk speed (Vx), proton number density (Np), and interplanetary magnetic field (IMF) components (Bx, By, Bz) as inputs to forecast the occurrence probability of an onset during the next one hour.

The model has been trained and tested on a dataset derived from the SuperMAG list of geomagnetic onsets compiled between 1997 and 2017 and achieves ~75% precision and recall rates.

The ability of our model to forecast a substorm onset based on solar wind and IMF inputs prior to the actual onset time suggests a majority of the substorms may not be externally triggered by northward turnings of IMF.

Furthermore, we find that IMF Bz and solar wind velocity (Vx) have the most significant influence on model performance and thereby provide maximum predictive power.

Finally, principal component analysis shows a significant degree of overlap in the solar wind and IMF parameters prior to both substorm and non-substorm intervals.

This overlap shows that a recent history of solar wind and IMF alone may not be sufficient to forecast all substorms, and perhaps other factors, such as the dynamics of the magnetotail, or stochasticity are at play.

A long-lasting auroral bright spot around magnetic north pole: Is it the evidence of stable magnetic reconnection?

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An intense and large auroral bright spot appears around the magnetic north pole observed by the Special Sensor Ultraviolet Spectrographic Imager (SSUSI) on board four different Defense Meteorological Satellite Program (DMSP) satellites during long time northward IMF conditions.

The bright spot is even brighter than aurora in the auroral oval which is about 5-10° magnetic latitude equatorward of the bright spot.

The bright spot is lasting about 8 hours, and sometimes appears as a cyclone-shape with a clockwise rotation.

The DMSP in situ plasma observations suggest that the bright spot is clear associated with electron invert-V acceleration with 10s keV energy electron precipitations around the center regions and 1s keV energy electron precipitations around the egde regions.

There are also strong flow shears between the two sides of the bright spot: strong sunward flows on the duskside and antisunward flows on the dawnside.

These types of plasma should come from the high-latitude lobe region of the magnetotail due to the high-latitude lobe magnetic reconnections.

Is it the evidence of stable lobe reconnection during long time northward IMF conditions?

The detail and further analysis should be pursued in the following studies.

A network of HF Doppler sounding systems in Japan: possible collaboration with SuperDARN

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4. *ISEE, Nagoya University*
5. *National Institute of Information and Communications Technology*

Since 2003, a network observation of HF Doppler sounding has been conducted in Japan for remote-sensing the atmospheric, ionospheric and magnetospheric processes.

Currently, 1 transmitting station (Tx) and 7 receiving stations (Rx) are operative by a collaborative effort of four difference universities.

The main transmitting station is located at Chofu, Tokyo, Japan in the Campus of University of Electro-Communications (JG2XA). JG2XA transmits continuous waves at 5006 kHz and 8006 kHz with a transmitting power of 200 W.

By receiving this JG2XA signal at 7 Rx stations (Sugadaira, Oarai, Kure, Kashima, Iitate, Fujisawa and Sugito) we derive the Doppler shift imposed during the propagation and reflection in the ionosphere.

In particular, the Doppler shift data can be used to detect vertical motion of the ionospheric F region with a temporal resolution of 10 s.

At some stations, we also have observed signals from Radio Nikkei 1 (JOZ at 3925 kHz, JOZ2 at 6055 kHz, and JOZ3 at 9595 kHz) transmitted from Nagara, Chiba, Japan, which allows us to observe the vertical motion of the ionosphere at several altitude levels.

The data obtained from this experiment since2003 are all available at http://gwave.cei.uec.ac.jp/~hfd. Not only quick-look plots but also several types of digital data (raw wave form and Doppler shift data) can be retrieved from this database.

The experiment covers various ionospheric phenomena in the Magnetosphere-Ionospheric (M-I) coupling system, such as sporadic E-layer (Es), medium-scale traveling ionospheric disturbances (MSTIDs), large-scale traveling ionospheric disturbances (LSTIDs), global-scale electric field variation, geomagnetic pulsations, and sudden commencement (SC).

The data can also be used for the studies of vertical coupling between the lower atmosphere and ionosphere, for example, observations of ionospheric variation after large earthquakes, volcanic eruptions and typhoons.

In the presentation, we will give a brief introduction to the experiments and online database, and then discuss the future direction of the studies of atmosphere, ionosphere and magnetosphere using the HF Doppler sounding in a framework of international collaborations, for example with SuperDARN.

A new way to identify and quantify the sources of ionospheric convection

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We have developed a new technique that enable us to identify, separate, and quantify the sources of high latitude ionospheric convection. Usually, the ionospheric convection is examined by the electrostatic potential, as the convection will follow contours of equipotentials.

We will show that in order to identify, separate, and quantify the underlying processes responsible for the observed convection pattern, it can be more beneficial to look at a quantity we show is proportional to the divergence of the convection electric field.

We here use the Spherical Elementary Convection Systems (SECS) technique to describe the ionospheric convection electric field as the sum of the fields from a distribution of artificial nodes on a spherical surface, each having their own curl-free elementary field.

We show that such a representation is highly suitable for the identification and quantification of the sources of ionospheric convection as the strength of the elementary fields are proportional to the divergence of the convection electric field.

We use this method to study the ionospheric convection as observed with all SuperDARN radars in the northern hemisphere during the years 2010-2016.

We specifically consider stable northward IMF, and demonstrate the ability of the technique to separate the sources of ionospheric convection related to lobe reconnection and tail reconnection.

Utilizing this ability, we isolate the effect from lobe reconnection and study how different orientations of the Earth's magnetic dipole axis affect the lobe convection strength inside the dayside polar cap, in which we relate to the lobe reconnection rate assuming a strong coupling between the two regions.

We find that the inferred lobe reconnection rate increase linearly with increasing dipole tilt angle.

Our findings indicate that the summer hemisphere can typically have twice the lobe reconnection rate compared to winter conditions, suggesting a significant hemispheric asymmetry.

This asymmetry is for the first time quantified, as made possible with the new technique.

A novel technique to estimate the altitude of SuperDARN HF radar backscatter

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Since HF radio wave propagation refracts in the F-region ionosphere, the altitude of backscatter is not easy to determine using standard ray tracing which relies on knowing the plasma density at all points along the ray path.

In addition, even for low geomagnetic activity, the presence of atmospheric gravity waves makes for a significant source of uncertainty, especially at high latitudes.

Using the ion-momentum equation in the ionosphere, simplified for field-perpendicular ion motion only, we derive an expression for the ion-neutral collision frequency that depends primarily on the temporal and spatial variability of the ion velocity, i.e. the primary parameter observed by SuperDARN.

The ionospheric ion-neutral collision frequency depends primarily on the thermospheric neutral density.

Experiments performed by the CUTLASS-Hankasalmi and Longyearbyen radars, show that realistic estimates of thermospheric neutral density are obtained.

The altitude of backscatter is determined by comparison with the MSIS model.

A raytracing simulation of HF ionospheric radar performance at African equatorial latitudes

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We present an HF ray tracing simulation of the performance of 3 proposed equatorial HF radar systems for the African equatorial sector.

We use a number of realistic average ionospheres deduced from the International Reference Ionosphere (IRI) 2012 model and magnetic field geometries from the IGRF to determine likely propagation paths and orthogonality conditions for such radar systems.

This analysis provides a feasibility study for developing a SuperDARN-like radar for studying the equatorial ionosphere over the African longitude sector, for example, in determining the technical radar characteristics such as preferable operating frequencies, antenna boresight orientation and azimuth coverage and provides a simulation of the expected localisation of radar backscatter as a function of radar location and beam direction, as well as the time of day, season and sunspot number.

A Study of Effects of Solar Flares on Ionosphere and Radio Wave Propagation

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Over-the-Horizon (OTH) communication is strongly dependent on the state of the ionosphere, which is susceptible to solar flares.

Trans-ionospheric high frequency (HF) signals experience strong attenuation and delay during intense solar flares, commonly referred to Short-Wave Fadeout (SWF) and "sluggishness", respectively.

In this study, we analyse SWF and ionospheric sluggishness seen by SuperDARN radars and riometer observations during 31 X-class solar flare events.

This study is divided into two parts. First, we examine how sluggishness depends on solar zenith angle (SZA), flare rise time, and peak solar flux using SuperDARN HF radar & riometer observations.

Second, we compare the riometer observations with a modified EUVAC solar irradiance model that incorporates high-resolution solar flux data from GOES satellite X-ray sensors to compute the enhanced ionization produced during the flare events.

Specifically, the modelled HF absorption is compared with the data to determine which combination of dispersion relation and collision frequency formulation best reproduces the riometer observations.

From the observations we find that sluggishness is a non-linear function of solar zenith angle.

From the modelling work we find that the Appleton-Hartree dispersion relation in combination with Schunk-Nagy collision frequency profile produces the best agreement with riometer data.

Advantages and limitations of IQ-based SuperDARN interferometry

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Observations of the vertical angle of arrival (elevation angle) of the HF backscatter echoes provide crucial information on propagation modes of ionospheric echoes, altitude/geolocation of the effective scatter volume, and electron density at the scatter/reflection location.

The conventional SuperDARN elevation angle data are obtained from cross-correlation functions of the signals received by the main and interferometer antenna arrays, whose maximum possible sampling rate is limited by the integration time (~3 s). In this work, we examine feasibility of analysing elevation angle dynamics at much higher sampling rate (~0.1 s) by utilising non-averaged (IQ) samples of SupeDARN returns recorded between the first and second pulses of the emission sequence.

The observed range-time patterns of IQ elevation angle closely resemble those for the averaged (fitted) data, although the former show higher variance. Theoretically, the phase variance of IQ samples should be inversely proportional to the square root of the signal-to-noise power ratio (SNR).

This relationship has been validated against the observational data, which show acceptable levels of elevation angle variance at SNR > 15-20 dB.

We illustrate effectiveness of this approach by detailed temporal analysis of near-range (< 300 km) echoes from Saskatoon radar.

AgileDARN radar calibration: internal and external calibrations

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In order to improve the radar performance, AgileDARN adopts internal calibration and external calibration to reduce the system error.

To accomplish internal calibration, calibration signal is produced by a signal generator in digital signal processing unit (DPU).

By internal calibration, the difference among channels except antenna is eliminated.

During external calibration, meteor echoes are used as calibration signal.

Comparing with echoes from irregularities, echoes from meteor trail have higher signal-to-noise ratio.

The size of meteor trail is small and it can be regarded as a point target.

By external calibration, the unbalance among the whole channels (including antenna) can be reduced, which makes the pattern of the array closer to the ideal pattern.

Amplitude-ratio and the cross-phase methods to automatically identify FLR in the SuperDARN VLOS data

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Where the frequency of waves coming into the magnetosphere matches the eigenfrequency of a geomagnetic field line, which runs through the ground, the ionosphere, and the magnetosphere, the mechanism called the field-line resonance (FLR below) can cause the eigen-oscillations of the field line.

From the eigenfrequency one can estimate the plasma density along the field line, because the eigenfrequency is the function of the density and the magnetic field strength along the field line (models are usually used for the magnetic field strength).

The FLR-generated field-line eigenoscillation have particular dependencies of its amplitude and phase on the geocentric distance (translated to the latitude on the ground): the amplitude reaches the maximum at the resonance point, and the phase changes most steeply across the resonance point.

FLR-generated eigen-oscillations have been observed by satellites and ground magnetometers.

However, on the ground, it is known that eigen-oscillations are often difficult to identify because of superposed perturbations having larger amplitudes.

In this study we analyze SuperDARN radar data. Each SuperDARN radar observes VLOS (Velocity along the Line of Sight) in its observation area of the ionosphere.

FLR-generated field-line eigen-oscillations also oscillate the ionospheric plasma, thus VLOS can also monitor the eigen-oscillations.

Furthermore, SuperDARN radars have an advantage of two-dimensional measurement, enabling estimation of two-dimensional plasma density distribution.

We have been analyzing a few FLR events observed by SuperDARN radars, including an event after a Sudden Impulse for which the SuperDARN data analysis implied decreasing density with increasing distance from the subsolar region; however, until quite recently we visually identified FLRs, which took very long time and delayed the analysis.

In addition, as in the ground-magnetometer case, visual identification can miss FLR events because of superposed non-FLR oscillations of VLOS.

Thus, we have been developing computer codes to automatically identify FLRs by applying the methods called the amplitude-ratio method and the cross-phase method to the VLOS data.

These methods have successfully been used in ground-magnetometer data analyses: These methods use two latitudinally-separated ground magnetometers, take the ratio of the data from the two to cancel out the superposed perturbations, and searches for the typical FLR pattern in the amplitude ratio and the phase difference.

Our computer codes are designed to apply these two methods to VLOS's of every two virtual observatories"", i.e., Range Gates (RGs below), along each beam of SuperDARN, and to automatically identify the FLR patterns in the amplitude ratio and the phase difference of VLOS.

As an initial study, we applied the initial version of the codes to several RG pairs (with arbitrary distances between the two RGs) along a beam of a visually-identified FLR event.

As a result, the FLR was automatically identified at the visually-identified event latitude.

In addition, the code was successful only when the distance of the two RGs were about 80km; this should correspond to the resonance width of the FLR, which is an important quantity reflecting the diffusion and dissipation of the FLR energy. It is to be noted that the evenly-spaced distribution of ""virtual observatories"" (RGs) enables direct measurements of the resonance width.

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An examination of inner-magnetosphere shielding by Region-2 Field-Aligned Currents

Bharat Kunduri[1], Joseph B. H. Baker[1], J. Michael Ruohoniemi[1]

1. *Space@VT*

It has long been speculated that the inner-magnetosphere is shielded from the cross-tail electric field by a dusk-dawn directed shielding electric field, generated by charge separation associated with inner magnetosphere Alfven layers and the region-2 Field Aligned Currents (FACs).

However, during periods of large and rapid fluctuations of the Interplanetary Magnetic Field, the shielding balance is likely perturbed, resulting in either under-shielding or over-shielding of the inner-magnetosphere.

In this study, we present a methodology to use the relative imbalance between Region-1 and Region-2 FACs, derived from AMPERE measurements, as a proxy for inner magnetosphere shielding.

Specifically, we identify periods of rapid changes in the interplanetary electric field and utilize large-scale measurements of FACs from the AMPERE project in conjunction with electric fields in the mid-latitude ionosphere from SuperDARN to examine the extent to which the inner magnetosphere is under-/over- shielded and determine the relevant time scales under different geomagnetic conditions.

An Improved Estimation of SuperDARN Heppner-Maynard Boundaries using AMPERE data

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SuperDARN ionospheric convection maps are an invaluable tool in the study of Solar Wind-Magnetosphere interactions.
The low latitude limit of the convection region in SuperDARN convection maps is the Heppner-Maynard Boundary (HMB).
The latitude of the HMB is estimated using the location of scatter with velocities above a threshold value and, therefore, is inherently dependant on scatter availability.
This means the latitude of the boundary is susceptible to unphysical variations as areas of scatter light up or switch off.
This study improves SuperDARN convection maps by using an independent field-aligned currents (FACs) dataset to estimate the location of the HMB.
AMPERE (the Active Magnetosphere and Planetary Electrodynamics ResponseExperiment) provides measurements of FACs, which are used to determine the scale size of the FAC region.
Since both the FAC and convection regions are influenced by the state of the coupled magnetosphere-ionosphere system, we explored the relationship between the sizes of the two patterns.
A trend is seen between the size of the FAC region and the latitude of the HMB.
This trend is used to estimate a low latitude value for the convection region, which is then used to calculate the HMB curve.
This leads to an improved estimate of the latitude of the HMB, and hence an improved interpretation of the SuperDARN velocity data. Acknowledgements: the authors would like to acknowledge discussions with Dr A. G. Burrell on this topic.

Anthony David Mortimer Walker (1937-2018)

Judy Stephenson

1. *School of Chemistry and Physics H block Westville Campus University of KwaZulu-Natal*

Anthony David Mortimer Walker was one of South Africa's most distinguished scientists.
Dave had considerable intellect and insight which, combined with a love of computer technology, made him a very effective researcher.
He published 85 peer reviewed journal papers, many of which were single authored.
A short biography of his contribution to the field of space physics will be given, with an emphasis on his involvement in SuperDARN.

Azimuthal fast flows in the nightside ionosphere: interplanetary magnetic field, auroral activity and latitude dependence

A. Grocott [1], J. N. Delaney [1], M.-T. Walach [1]

1. *Lancaster University*

We inspect an 18 year database of high and mid-latitude SuperDARN data for evidence of nightside azimuthal fast flows (NAFFs).

We specifically identify intervals where the midnight sector ionospheric return flows have an east-west velocity component of over 400 km/s, with the flows 1.5 h of magnetic local time to the east and west of midnight exhibiting the same east-west sense, with a velocity of at least 300 km/s.

We find 360 hours of NAFFs in total, of which 148 h are eastward and 212 h are westward.

80% of the NAFFs display the expected IMF By dependence, that is, eastward for By > 0 and westward for By < 0.

When splitting the NAFFs into two populations according to the latitudinal extent of the convection pattern, Lat_0, we find that, for $Lat_0 < 62$ degrees latitude, only 54% of NAFFs display the expected IMF By dependence, whereas for $Lat_0 > 62$ degrees latitude, 85% of NAFFs display the expected IMF By dependence.

We compare the occurrence of NAFFs to the IMF clock angle, auroral electrojet index (AE), and total ionospheric transpolar voltage (Vpc), and find that the By-dependent NAFFs tend to occur during intervals of weak solar wind driving, when the IMF is moderately northward, the AE index is low (AE < 150 nT) and the transpolar voltage is modest (20 < Vpc < 55 kV).

When the convection pattern expands to the mid-latitudes under stronger driving conditions the NAFFs become predominantly westward, irrespective of IMF By.

We suggest that this is due to the occurrence of intrinsically asymmetric phenomena, such as the Harang discontinuity and sub-auroral polarisation streams (SAPS), that are associated with inner magnetospheric processes that do not exhibit the same IMF By dependence as the high-latitude flows.

Borealis Project Update: A Digital Radar Design for SuperDARN Using Software-Defined Radios

K. Kotyk[1], M. Detwiller[1], K. Krieger[1], K. McWilliams[1]

1. *University of Saskatchewan*

As the current control hardware for SuperDARN becomes deprecated, the need for a new system has arisen.
Additionally, technological advances have made software-defined radios (SDRs) predominant in RF systems today.
In response, the engineering team at SuperDARN Canada has designed and built a new system for SuperDARN, using Ettus USRPs (Universal Software Radio Peripherals) to meet the hardware requirements of a new SuperDARN operations system.
The use of the USRPs eliminates analog beamforming and instead samples all antennas separately before digitally combining the signals.
These USRPs also provide many opportunities to expand the capabilities of the SuperDARN radars to accommodate experiments of greater complexity.
A new software package has been written, called Borealis, which allows for flexibility in writing experiments to incorporate imaging, multi-frequency operations, and real-time modifications and adjustments to the running program based on data feedback.
At the same time, this software makes experiments easier to write and interpret by researchers.
The Borealis project is currently running on the Saskatoon SuperDARN radar.
This talk will provide the preliminary results from the project and the next steps before datasets from the new system are released to the research community.

Characterizing the spatio-temporal response of high latitude convection using SuperDARN and DMSP

R. A. Stoneback[1], A. G. Burrell[2]

1. *The University of Texas at Dallas*
2. *Naval Research Laboratory*

High latitude convection is a highly variable system in time influenced by multiple processes, presenting a significant challenge when trying to reconstruct full convection maps from partial measurements.

We will present a data based method that can isolate systematic variations within the incomplete convection information provided by SuperDARN and DMSP as well as measurements of space weather parameters in time.

These variations are condensed into a limited set of basis functions with corresponding amplitudes in time that best reproduce the long term data set.

In effect, the process produces an estimate of convection at all locations measured by SuperDARN or DMSP and for all times under study.

Updated results demonstrating the assimilation of polar cap convection measurements, including single line-of-sight measurements, will be shown.

Collaborative ionosheric observations using VIPIRs in Japan and Korea

Takuya Tsugawa[1], Michi Nishioka[1], Hideo Maeno[1], Takumi Kondo[1], Mamoru Ishii[1]
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2. *Korean Space Weather Center, National Radio Research Agency, Korea*
3. *Korea Astronomy and Space Science Institute, Korea*

National Institute of Information and Communications Technology (NICT) installed Vertical Incidence Pulsed Ionospheric Radar (VIPIR) at four stations, Wakkanai (Sarobetsu), Kokubunji, Yamagawa, Okinawa (Ogimi), in 2016 for routine ionospheric observations in Japan.

VIPIR can separate the O- and X-modes of ionospheric echoes which have improved the availability of automatic scaling of the ionogram.

A new ionograms scaling method has been developed using these VIPIR ionogramsand AI method.

Using this method, the scaling accuracy and successful scaling rate for ionospheric parameters such as foF2.

Every 15 minutes, each VIPIR diagnose the ionosphere in the vertical incident manner and the other three VIPIRs perform oblique incidence observation.

Such oblique-incident observation can provide information on the ionosphere at the midpoint between the stations.

Korean Space Weather Center (KSWC) also installed VIPIR at two stations, Jeju and Icheon, in 2016.

NICT and KSWC have started trail international oblique-incident sounding observations with VIPIRs since September 2016.

Increasing the number of stations can increase the observation points even on the sea where is a blank area of vertical observation.

These observation data are important as input for ionospheric data assimilation and/or tomography.

On the other hand, it remains as an issue how to arrange the observation interval and observation mode of VIPIRs.

Comparative Analysis of Plasma Drift Measurements Inferred from Ground-based DPS-4D and SuperDARN HF Radar over Zhongshan Station, Antarctic

Xiangcai Chen[1]

1. *Polar Research Institute of China*

IBy means of high-frequency radio sounding, the ionospheric plasma drift can be measured by the Doppler frequency shift of signal.

In this paper we analyze the ionospheric F-region plasma motion performed by Digisonde Portable Sounder (DPS-4D) at cusp latitude over Zhongshan Station in Antarctic.

By restricting the echo arrival angle, and selecting the reflection height range at 175 – 475 km, we present the variation of the F-region plasma drift measurements by setting limits on the Doppler frequency shift.

The results indicate that properly restricting the Doppler frequency shift of the echo has a strong effect that contributes to the accurate and robust measurements of the ionospheric plasma drift.

Base on the 7.5 min interval Digisonde drift data in 2012, comparison of drift measurements show that the apparent velocities measured by DPS-4D are in generally agreement with the drift velocities observed by the collocated SuperDARN HF radar at Syowa, whereas for some points a strong disagreement is obvious.

Analyzing data indicate that fast temporal variations of the plasma drift and for strongly irregular flow over the station are contribute to the velocity inconsistencies between the two data sets, which is due to the different spatial and temporal resolution of the instruments.

Comparison of different interferometer calibration methods

Angeline G. Burrell[1], Aurélie Marchaudon[2], Gareth Chisham[3], Pasha Ponomarenko[4], Simon Shepherd[5]

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3. *British Antarctic Survey, Cambridge, UK*
4. *University of Saskatchewan, Saskatoon, Canada*
5. *Dartmouth College, Hanover, NH, USA*

Elevation angles of returned backscatter are calculated at the SuperDARN high frequency radars using interferometric techniques.
These elevation angles allow the altitude of the reflection point to be estimated, an essential piece of information for many ionospheric studies.
One of the most difficult parameters to measure is the time delay caused by the difference in the electrical path length between the main array and the interferometer (tdiff).
There are several methods available to calibrate interferometers using observations, and each are susceptible to different sources of error.
Here we present a comparison of two different interferometer calibration methods, both of which are suitable for use at a wide variety of HF radars.

Contributions of Professor A. David M. Walker to the Success and Recognition of STARE and SuperDARN

R. A. Greenwald[1]

1. *Virginia Tech*

I have known and worked with Dave Walker for more than 40 years.

When I first met him, he was on sabbatical from the University of Natal and had just received a Senior Scientist Fellowship from the Alexander Von Humboldt Foundation.

This fellowship was to be served at the Max Planck Institut fuer Aeronomie in Lindau, West Germany, where I was a member of staff and responsible for the STARE radar project.

Ian Axford, director of the institute, thought it would be a good idea if Dave worked with me.

Dave's primary research interest at that time was whistler generation and propagation in the Earth's magnetosphere, so I suggested that he might be interested in looking at another lower frequency wave process known as pulsating radar aurora.

Dave looked at pulsation examples in the STARE data base, read several theoretical works by Southwood [1974] and Chen and Hasegawa [1974] and, within a few weeks, explained to me that the radars were detecting backscatter produced by electric fields associated with resonant Pc-5 pulsations.

The energy for these resonances came from Kelvin-Helmholtz waves propagating in an anti-sunward direction along the dawn or dusk flanks of the magnetopause.

Over the next two years, at least 5 publications resulted from this new understanding.

Four years later, I had returned to the USA and obtained research funds for further studies with the STARE and GEOS-2 data sets.

Former colleagues at MPAe provided me with energetic particle and magnetic field data that showed evidence of pulsations.

Dave was able to obtain a short sabbatical from his university to visit me at APL and evaluate this data.

The satellite data showed evidence of sunward propagating pulsations in the magnetic field and energetic particles at geostationary orbit in the post-noon sector of the equatorial magnetosphere.

Reviewing the literature, Dave determined that these pulsations displayed properties consistent with a drift-mirror instability in the equatorial magnetosphere.

Energy from this instability was being coupled into poloidal mode field line resonances observable with the STARE radars.

Dave's work again created considerable interest in the pulsation community.

Dave returned to APL through most of 1985.

At that time, the Goose Bay HF radar had been put into operation and a new tool for studying the ionospheric manifestations of magnetospheric processes was available.

Dave was the first to use Goose Bay data to study pulsation processes near the dayside cusp.

In subsequent years, he also has continued to work with others in SuperDARN, most notably John Samson and Mike Ruohoniemi, and Judy Stephenson, to whom he was a scientific advisor and colleague.

When I proposed the creation of a global network of SuperDARN radars, Dave quickly volunteered to try to secure funding for a SuperDARN radar at SANAE, the South African base in Antarctica.

This radar was eventually funded with supporting contributions fromBAS(UK) and APL(USA).

Dave was one of the original SuperDARN PIs and a signatory of the original SuperDARN PIs Agreement. He will be missed!

Current Status of SuperDARN JAPAN database and website

Yuka Kadowaki[1,2,3], Akira Sessai Yukimatu[1,4], Tsutomu Nagatsuma[5], Nozomu Nishitani[6], Tomoaki Hori[6], Keisuke Hosokawa[7], Masakazu Watanabe[8], Hideaki Kawano[8], Kaori Sakaguchi[5], Aoi Nakamizo[5]

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5. *National Institute of Information and Communication Technology (NICT), Japan*
6. *Institute for Space-Earth Environmental Research (ISEE), Nagoya Univ. Aichi, Japan*
7. *Univ. of Electro-Communications (UEC), Tokyo, Japan*
8. *International Center for Space Weather Science and Education (ICSWSE), Kyushu Univ., Fukuoka, Japan*

SuperDARN Japan team consists of 5 main SuperDARN research institutions in Japan - NICT, ISEE at Nagoya Univ., NIPR, UEC (Univ,. of Electro-Communications), and ICSWSE at Kyushu Univ. who made a collaborative research contract among themselves in 2016.

We opened SuperDARN JAPAN website at NIPR* in August 2016 in order to introduce the activities of SuperDARN research in Japan, to maintain SuperDARN database, to provide useful information and data product including quick look and map potential plots (space weather map) with search and display functionality, and to promote collaborative research activities.

The outline of the SuperDARN Japan database and website and its current status will be introduced.

We discuss the future direction and perspectives, especially on relationships with other SuperDARN sites/database as well as those with other database/sites like SPEDAS/IUGONET to promote joint research with non-SuperDARN communities like ERG/Arase science group, other ground based research groups and theoretical/simulation groups.

* URL for SuperDARN JAPAN website: http://polaris.nipr.ac.jp/~SD/sdjapan/

Data Analysis Working Group (DA-WG) 2018-2019 report

Pasha Ponomarenko[1], Daniel Billet[2], Emma Bland[3], Angeline Burrell[4], Keith Kotyk[4], Marina Schmidt[4], Simon Shepherd[5], Kevin Sterne[6], Evan Thomas[7], Maria-Theresia Walach[2]

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3. *UNIS*
4. *University of Texas, Dallas*
5. *Dartmouth College, New Hampshire*
6. *Virginia Tech*
7. *Dartmouth College, New Hampshire*

Data Analysis working group activities since the previous SuperDARN workshop will be reported.

Data Distribution Working Group Annual Report

Kevin Krieger[1], Kevin Sterne[2], Paul Breen[3]

1. *University of Saskatchewan*
2. *Virginia Tech*
3. *British Antarctic Survey*

This presentation will include: an overview of the past years activity in the Data Distribution Working Group (DDWG), a review of the users of the previously available sftp server from Virginia Tech, and finally a list of issues requiring guidance and input from the PIs along with future work.

Deformation of Ionospheric Potential Pattern by Ionospheric Hall Polarization

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2. *Faculty of Sciences, Kyushu University*
3. *International Center for Space Weather Science and Education, Kyushu*

The present study shows that the ionospheric Hall polarization can deform the high-latitude ionospheric convection field, which is widely considered to be a manifestation of the convection field in the magnetosphere.

We perform the Hall polarization field separation with a potential solver by changing the conductance distribution step-by-step from a uniform one to a more realistic one.

We adopt dawn-dusk and north-south symmetric distributions of conductance and region 1 (R1) field-aligned current (FAC).

The pair of the primary field of the R1 system and each gradient of Hall conductance generates the Hall polarization field and consequently causes potential deformations as follows.

(a) The equatorward gradient causes clockwise rotation.

(b) The gradient across the terminator, together with the effect of the equatorward gradient, causes the dawn-dusk asymmetry.

(c) The high conductance band in the auroral region causes kink-type deformations.

In particular, a nested structure at the equatorward edge of the band in the midnight sector well resembles the Harang Reversal.

Result (a) can explain the clockwise bias inexplicable by the IMF-By effect alone, the combination of (a) and (b) can explain the clearness and unclearness in the round or crescent shapes of the dawn-dusk cells depending on the IMF-By polarity, and (c) suggests that the ionosphere may not need the upward-FAC for the formation of the Harang Reversal.

We suggest that the final structure of the ionospheric potential is established by the combined effects of both the magnetospheric requirements (external causes) and ionospheric polarization (internal effect).

Design of Low-Cost Software Defined Radio for SuperDARN Radar

Paul Kennedy[1], J. Michael Ruohoniemi, PhD[1], Kevin Sterne[1],
Robert McGwier, PhD[1], Joseph Baker, PhD[1]

1. *Virginia Tech*

Software defined radio (SDR) is a rapidly developing field enabled by continuing improvements in digital electronics.
Software defined radio has been used extensively in communication systems due to its flexibility and cost effectiveness.
Recently, SDR has been incorporated into radar systems, particularly for ionospheric research.
This work investigated the design of a high frequency (HF) SDR receiver for the next generation of Super Dual Auroral Radar Network (SuperDARN) radars.
The hardware selection for this receiver leveraged low-cost commercial off-the-shelf software defined radios and amplifier designs supplemented by custom filters.
The software implementation utilized GNU Radio, an open source SDR and signal processing platform, to process and record receiver data.
A prototype was successfully designed and constructed using the Red Pitaya software defined radio.
This prototype included a 4 channel receiver which was evaluated in the laboratory setting and tested at the Blackstone, Virginia radar site.
A comparison of results from the prototype receiver and the existing hardware showed promise for the use of this platform in future ionospheric research.
Additionally, digital beamforming and waveform techniques were analyzed showing that adopting a SDR approach to radar design could improve the performance of SuperDARN radars.

Direct-From-Data Basis Functions for SuperDARN Flow Characterisation and Prediction

Robert Shore[1], Mervyn Freeman[1], Gareth Chisham[1]

1. *British Antarctic Survey*

We present the results of applying a meteorological analysis method called Empirical Orthogonal Functions (EOF) to month-long samples of polar ionospheric plasma velocity data from SuperDARN.

The EOF method is used to characterise and separate contributions to the variability of plasma motion in the northern polar ionosphere.

EOFs decompose the noisy and sparse SuperDARN data into a small number of independent spatio-temporal basis functions, for which no a priori specification of source geometry is required.

We use these basis functions to infill where data are missing.

This infill only converges when it reinforces patterns present in the original data, thus providing a self-consistent description of the plasma velocity at the original temporal resolution of the SuperDARN data set.

Our study is a proof-of-concept, aimed to test the methodology which will subsequently be applied to SuperDARN data spanning a full solar cycle.

Initial results have found that the leading modes of the EOF decomposition are representative of the two-cell Dungey-cycle convection pattern associated with IMF Bz, a single-cell perturbation to it associated with IMF By, and other modes.

The relative importance of these modes (i.e., relative contribution to the total variance) is found to vary with season.

These modes have not proven to be recoverable from the SuperDARN data in all months considered.

We explore possible reasons for this, and present the latest status of the ongoing investigation.

Echo occurrence in the polar ionosphere as measured by Dome C East radar

Maria Federica Marcucci [1], Igino Coco[2], Stefano Massetti[1], Simona Longo[3], David Biondi[1], Enrico Simeoli[4], Aurélie Marchaudon[5], Alexandre Koustov[6], Victoriya Forsythe[7], Giuseppe Consolini[1],

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4. *CNR-Dipartimento Reti e Sistemi Informativi, Rome, Italy*
5. *Institut de Recherche en Astrophysique et Planétologie, Toulouse, France*
6. *Institute of Space and Atmospheric Studies, Department of Physics and Engineering Physics, University of Saskatchewan, Saskatoon, Canada*
7. *University of Alaska, Fairbanks, USA*

We present the results of a statistical study of the ionospheric and ground scatter echoes detected by DCE for selected 14 days intervals at equinoxes and solstices during the descending phase of the last solar cycle.

Echoes occurrence is investigated as a function of geomagnetic latitude and MLT location, season, geomagnetic activity and radar frequency.

A strong seasonal dependence of echo occurrence related to changing HF radio wave propagation conditions and ionospheric irregularities development is clearly evidenced, in agreement with previous studies.

Moreover, again in agreement with previous observations, we found that lower echo rates are observed for the larger frequency, especially in SUMMER and WINTER and that there is shift to farther ranges for the larger frequency.

DCE observations give also evidence of the geomagnetic activity role in the generation of irregularities and of the GS over IS masking effect.

Empirical ground scatter classification and geolocation

Evan Thomas[1], Simon Shepherd[1]

1. *Dartmouth College*

While ionospheric scatter (IS) from E- and F-region plasma irregularities is their primary target, SuperDARN radars also observe backscatter from land and ocean surfaces on a daily basis.

Typically, these ground scatter (GS) echoes are treated as noise and discarded using empirical criteria for separating IS and GS signatures.

The standard SuperDARN algorithm for identifying GS echoes was obtained by examining only 12 days of data from 2 radar sites and is known to falsely identify both meteor echoes and slow-moving ionospheric irregularities as GS.

Furthermore, the standard SuperDARN geolocation software uses an empirical virtual height model which varies as a function of range and assumes 1/2-hop propagation for both IS and GS echoes.

We re-evaluate these empirical classification and geolocation algorithms by performing a statistical analysis of fitted line-of-sight parameters (e.g., velocity, spectral width, etc.) from SuperDARN radars located at mid-, auroral, and polar latitudes.

ePOP/SWARM E and SuperDARN Observations during November 05 2018 Geomagnetic Storm

Ashanthi Maxworth[1], Glenn Hussey[1], Kathryn McWilliams[1], Eliana Nossa[2], Andrew Ya[3]

1. *University of Saskatchewan*
2. *Naval Research Laboratory*
3. *University of Calgary*

On November 05, 2018 there was a geomagnetic storm of Kp 6 which lasted for nine hours.
During this, the Radio Receiver Instrument (RRI) on ePOP/SWARM E observed an unexpected signature above the Arecibo HF heating facility.
During this observation, the Arecibo HF heater was operating with a Continuous Wave (CW) pulse mode, at a 5.1 MHz center frequency.
Based on the observed spectral characteristics we suggest that this wave signature is a form of Stimulated Electromagnetic Emission(SEE) due to the energy input from the ionospheric heating.
During this same period, the Saskatoon and Prince George SuperDARN radars also observed atypical radar echoes.
The radars observed a loss of mid-range echoes, but a unique situation of close-range and far-range echoes were present.
We present the spectral characteristics of the RRI observations and complementary SuperDARN radar echoes.
We have categorized the radar echoes as ionospheric and ground scatter and related them to the mid-latitude RRI heating observations in an attempt to better understand the global state of the ionosphere during a geomagnetic storm.

Equatorial ionospheric HF radar: Simulation, design, and plans

R. Todd Parris[1], Todd Pedersen[1], Eugene Dao[1], Ralph Kelly[2]
Sushil Kumar[3], Julie Moses[4]

1. *Air Force Research Laboratory*
2. *Space Dynamics Laboratory*
3. *Universitt of the South Pacific*
4. *Air Force Office of Scientific Research*

A new SuperDARN style radar is being built in the equatorial zone, as the cornerstone instrument of the planned Kiritimati Equatorial Ionospheric Observatory (KEIO), on Christmas Island, Kiribati.

This radar is expected to observe field aligned irregularities associated with plasma bubbles, the equatorial electrojet, and 150km echoes over very long oblique ranges.

This system is also expected to observe sea surface Bragg scatter, and to monitor HF propagation conditions.

Details of the expected science enabled by this radar will be presented.This new radar system builds on SuperDARN heritage, incorporating a modified antenna TTFD antenna that improves the EIRP of the array, and will utilize low cost COTS digital radios in a MIMO capable imaging array configuration.

Details of the antenna and new radio hardware will be presented.Expected performance of this radar has been informed by a full HF radar simulation using the High-frequency Channel Response Function (HiCIRF) tool.

The simulation results of the equatorial radar will be presented, as will a full 3-D ray trace used to estimate and map regions of expected propagation where perpendicular to B backscatter requirement is met.

Under collaboration with the University of the South Pacific (USP), a site for the radar has been selected on Christmas Island (Kiritimati), Kiribati.

This site, which will house a future USP teaching and research center, is also planning to host GPS scintillation and TEC receivers, a LEO beacon receiver, UHF scintillation receivers, all-sky optics, and VLF receivers.

Details of the site, and a discussion of logistics and construction issues unique to Kiritimati will be presented.

Fine-scale visualization of aurora in a wide area using color digital camera images from the International Space Station

Sota Nanjo[1], Yuta Hozumi[1], Keisuke Hosokawa[1]

1. *The University of Electro-Communications*

Various ground-based and space-based imagers have been used to observe aurora borealis and australis.

So far, however, it has been difficult to observe the detailed spatial structure of auroras in a wide area with sufficient spatial and temporal resolution.

Since the photographs taken from the International Space Station (ISS) have sufficient spatial and temporal resolution, it is possible to visualize the fine-scale structures of aurora in a wide area.

A calibration of imaging parameters of the photographs using star lights was proposed by a previous research.

The accuracy in the timestamp was not guaranteed by the method based on the star lights because the position of the star lights in the image did not change with elapsed time.

Thus, it is still difficult to use the mapped data for studying fast variations of aurora, for example pulsating aurora (PsA).

Therefore, in this study, we calibrated the images from the ISS using city lights which change their apparent positions with elapsed time.

In order to validate the calibration method using city light positions, we mapped two auroras events in the photographs to the geographical coordinate, and compared with those from ground-based all-sky imagers in Alaska and Canada.

We found that the approximate shape of discrete aurora and the temporal variation of PsA derived from the ISS images are consistent with those from the ground-based observation.

The accuracy in the timestamp is less than 0.5 sec and that in space in the direction perpendicular to the line of sight of the camera is within 5 km. In the presentation, we will also address how the mapped full-color images can be used for studying the dynamics of various types of aurora in collaboration with SuperDARN in the future.

First observation of subauroral polarization stream from Jiamusi HF radar

Jiaojiao Zhang [1]

1. *National Space Science Center, Chinese Academy of Sciences, Beijing, China.*

We report the first two-dimensional observation of a dynamic variation of subauroral polarization stream from Jiamusi HF radar.

During the strong storm of 26 August 2018 (minimum Dst=-174 nT), Jiamusi HF radar observed high velocity westward flow at dusk side lasting more than 4 hours.

The location of the SPAS varies between 40° and 53° in magnetic latitude, the peak westward speed varies between about 800 m/s and 2000m/s. The peak SPAS speed and latitude of it decrease with MLT, which are consistent with previous studies.

The more interesting finding is that, based on this general trend, the variations of latitude and speed of peak SAPS are closely related with the variation of the solar wind dynamic pressure.

Formation and Evolution of Polar Cap Ionospheric Patches and Their Associated Upflows and Scintillations: A Review

Qing-He Zhang[1], *Zan-Yang Xing*[1], *Yong Wang*[1], *Yu-Zhang Ma*[1]

1. *Institute of Space Sciences, Shandong University, Weihai, China*

Polar cap patches are common phenomena, especially during southward interplanetary magnetic field(IMF) conditions, in the polar ionosphere.

We summarized the recent new progress about the formation and evolution of patches as well as their impact on the magnetosphere-ionosphere-thermosphere(M-I-T) coupling processes and space weather.

The dayside reconnection and bursty sunward return flows produced by the modulation of nightside reconnection, are confirmed as the dominated mechanisms to separate the entering ionization into islands (patches).

The patches evolve along streamlines of the Dungey convection cycle from the dayside to the nightside and exit the polar cap modulated by pulsed nightside reconnection.

However, they slowly move and rapidly fade away behind a lobe "reverse" convection cell when the IMF suddenly changed to northward.

Rapidly moving patches are associated with clear ion upflows due to frictional heating and offer more upwelling ion fluxes.

Patches often produce significant scintillations due to strong density gradients at their edges, especially during their merging into the auroral oval, which will result in variable disturbances to High Frequency (HF) radio communications, over-the-horizon radar location errors, disruption and errors to satellite navigation and communication.

Geospace Explorations by the ERG/Arase project

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K. Shiokawa[1], K. Seki[4], T. Hori[1], M. Shoji[1], S. Kurita[1], C-W. Jun[1],
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1. *Nagoya University, Japan*
2. *JAXA, Japan*
3. *ASIAA, Taiwan*
4. *University of Tokyo, Japan*
5. *Osaka University, Japan*
6. *Kanazawa University, Japan*
7. *Kyoto University, Japan*
8. *Kyushu Institute of Technology, Japan*

In order to understand the dynamics of the radiation belts and inner magnetoshere, the Arase (ERG) satellite was launched in 2016.
The satellite has observed various phenomena since March 2017.
The satellite observes wide energy electrons from 20 eV to 20 MeV and ions 10 eV/q to 180 keV/q with mass discrimination.
The satellite also observes wide frequency range of electric fields (DC-10 MHz) and magnetic fields (DC-100 kHz).
These comprehensive observations provided detail data on acceleration/deceleration of plasma/particles and interactions with plasma waves.
The ground-based observations in the ERG project (aurora observations, ground-magnetometer observations, radar observations, VLF observations, riometer observations etc) have provided data at different MLT and invariant latitudes, which are important to understand the global variations of geospace.
In the ERG project, more than 2000 conjugate observations including SuperDARN-Arase observations have been realized and various phenomena such as pulsating aurora, heating of F-layer (SAR-arc), ULF pulsations, whistler waves have been observed.
Moreover, the Arase satellite has realized simultaneous burst operation with Van Allen Probes and MMS, which are important to discuss detail of wave phenomena.
In this presentation, we would like to show some highlight results from the Arase observations, especially for focusing on wave-particle interactions on the electron accelerations and decrease.
Moreover, we will discuss further collaborative studies with SuperDARN and other geospace observations.

Ground-based multi-point network observation of the inner magnetosphere at subauroral latitudes by the PWING project

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2. *Members of the ERG-Ground Coordinated Observation Team (PWING Project)*

The PWING project, which stands for “study of dynamical variation of Particles and Waves in the INner magnetosphere using Ground-based network observations”, is a 5-year (2016-2021) project of the Grant-in-Aid for Specially Promoted Research of the Japan Society for the Promotion of Science (JSPS) (16H06286).
The PWING project deploys all-sky cooled-CCD airglow imagers, 64-Hz sampled induction magnetometers, 40-kHz VLF receivers, and 64-Hz riometers at 8 stations at magnetic latitudes of ~60 degree around the north-pole to cover longitudinal variation of aurora and electromagnetic disturbances in the inner magnetosphere.
These PWING instruments are in automatic operation in Canada, Alaska, Russia, Norway, Finland, and Iceland.
These ground observations are combined with the measurements by the Arase and Van Allen Probes satellites in the inner magnetosphere as well as various global modelings, to understand plasma dynamics and particle acceleration/loss processes occurring in the inner magnetosphere.
Details of the PWING project can be seen at http://www.isee.nagoya-u.ac.jp/dimr/PWING/PWING_web_e.htm.
In the presentation, we introduce current status and some recent results obtained by the PWING multi-instrument ground network, including detachment of Stable Auroral Red (SAR) arcs from the main auroral oval, Pc1 pulsation measurements at multi-point ground-satellite instruments, and ELF/VLF wave measurements.

High latitude signatures of the interaction of the Earths magnetosphere with an ICME

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1. *University of Leicester*

We present a detailed case study of the high-latitude signatures of the interaction of an ICME with the Earth's magnetosphere on 16th-17th June 2012.
Under these disturbed conditions we explore the response of the aurora, field-aligned currents (FACs) and ionospheric convection, using DMSP (Defence Meteorological Satellite Program) auroral images, AMPERE (the Active Magnetosphere and Planetary Electrodynamics Response Experiment) current density measurements, and SuperDARN convection data respectively.
This study is divided into three main topics. Firstly, we observe a large area of cusp spot emission, in both Lyman-Birge-Hopfield and Lyman-alpha channels, obtained from the SSUSI (Special Sensor Ultraviolet Spectrographic Imager) instrument on the DMSP satellites. Multiple ion dispersion signatures are observed co-located with the cusp emission.
We track the cusp as it responds quickly to changes in the IMF By, and in relation to the NBZ field aligned current system.
The solar wind density is extremely high during this interval, over 30 cm-3.
The cusp spot ceases to be visible after a southward turning of the IMF. Secondly, we analyse the variation of the magnetosphere-ionosphere FACs, during this interval.
We present a new phenomenon that has been observed with AMPERE related to substorm onset, the formation of an additional region 2 (R2) current.
We explore the development of these features under the strong geomagnetic conditions of this period.
Finally, we assess the performance of SuperDARN convection maps during this period of increased geomagnetic activity.
We compare the performance of different techniques for determining the low latitude limit of the convection region, or Heppner-Maynard Boundary (HMB), and assess the realism of the resulting convection maps.

High speed flows in the nightside ionosphere during quiet solar wind conditions

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Following Dungey's (1961) model of the open magnetosphere it was for years assumed that substorms provided the mechanism for energy release and subsequent flux transport in the tail.

Efforts to observe the reconnection electric field (e.g. de la Beaujardiere et al., 1991) or resultant plasma convection (e.g. Williams et al. 1989) thus tended to focus on substorm intervals.

Statistical studies of the magnetotail flows hinted that they might be more ubiquitous, occurring at all AE levels (e.g. Baumjohann et al., 1990; Angelopoulos et al. 1992; de la Beaujardiere et al., 1994), although there remained much debate as to their role in the large-scale dynamics (e.g. Blanchard et al., 1997; Opgenoorth and Pellinen 1998; Fox et al., 1990).

The advent of SuperDARN provided an opportunity to resolve this issue, placing the observations of localised flow enhancements into the context of the large-scale convection pattern.

The first study of 'non-substorm' or 'quiet time' magnetotail flows to utilise SuperDARN was performed by Walker et al. (1998).

They observed bursts of fast (> 2000 m s-1) westward plasma flow in the midnight sector during an interval of northward IMF that were associated with sporadic energy release during reconfiguration of the tail.

Walker et al. (2002) extended this study to include interhemispheric observations, employing the full capability of SuperDARN to deduce a likely origin of the flows at a tail reconnection line or viscously driven cell.

A number of authors have gone on to discuss similar observations of bursty or periodic nightside flow enhancements (e.g. Huang et al., 2001; Senior et al., 2002; Grocott et al., 2003) which are attributed to a range of physical mechanisms.

Here, we discuss the pioneering results of Walker et al. (1998, 2002) and briefly review the field of research that has subsequently evolved.

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History and Progress of Japanese SuperDARN Project

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The Super Dual Auroral Radar Network (SuperDARN) has been in operation for about 25 years and is proving to be one of the most successful tools for studying dynamical processes in the Earth's magnetosphere, ionosphere, thermosphere, and mesosphere, as well as general plasma physics questions.
We report here about the history and progress of Japanese SuperDARN project.
Syowa South radar in Antarctica operated by NIPR was one of the starting members of SuperDARN initiated in 1995.
Syowa South provided the bi-directional common-volume observations with Halley radar.
In 1997 Syowa East radar was installed.
King Salmon radar in Alaska organized by NICT was installed in 2001.
Hokkaido East radar organized by Nagoya University was installed in 2006, and the Hokkaido West radar began operation in 2014.
Corresponding to the Japanese activity, the 1998 SuperDARN Workshop was held in Tokyo by the host of NIPR.
The 2007 SuperDARN workshop was held in Hokkaido by the host of Nagoya University, and the 2019 Workshop is held at Fujikyuu High Land by the host of NICT.

Identifying ground scatter and ionospheric scatter signals by using their fine structure

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The analysis of the scattered signal was carried out in the cases of ground scatter and ionospheric scatter.

The analysis is based on the data of the decameter coherent EKB ISTP SB RAS radar. In the paper the signals scattered in each sounding run were analyzed before their statistical averaging.

Based on the analysis, a model is constructed for ionospheric scatter and ground scatter signal, based on previously studied mechanisms.

Within the framework of the Bayesian approach and based on large number of the data, the technique for identifying the two types of signals is constructed based on their different nature.

The technique (IQ-algorithm) works without using traditional SuperDARN methods for estimating scattered signal parameters - spectral width, Doppler drift velocity or ray-tracing.

The statistical analysis of the results was carried out.

The total error produced by our IQ algorithm over the selected data was 13.3%, that is about two times less than total error produced by traditional algorithms.

The work of O.B. and K.G. was supported by RFBR grant #18-05-00539a.

IMF By dependence of polar cap patch occurrence: statistics using airglow data from Eureka, Canada in comparison with SuperDARN convection patterns

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Polar cap patches are known as regions of high-density plasma in the polar cap F region ionosphere.
It has been suggested that patches are produced by long-distance transportation of high-density sunlit plasma from the dayside towards the dark central polar cap region by the anti-sunward convection during negative Bz conditions.
Patches have been observed at various observation points in the polar cap.
To date, however, most stations were located at magnetic latitudes around 80 degrees.
Thus, continuous observations at a fixed point in the magnetic coordinate system have not yet been done due to the rotation of the Earth.
This has made it difficult to investigate the statistical characteristics of patches, especially the dependence of their occurrence on IMF By.
To solve this problem by observing patches near the magnetic pole continuously, we have been operating an all-sky airglow imager (ASI) of Optical Mesosphere Thermosphere Imagers (OMTIs) in Eureka, Canada (80.0 N, 85.9 W, 89 MLAT).
The imager at Eureka can observe a region near the magnetic north pole from an almost fixed point in the magnetic coordinate system thus, it is now possible to monitor the polar cap ionosphere for 24 hours during a period near the winter solstice.
In this study, we investigate the occurrence distribution of polar cap patches by using data from Eureka and clarify the factors controlling the generation of patches.
We have used 630.0 nm all-sky images from two winter seasons from 2015 to 2017.
The amount of data used is 87 days in 2015-2016 and 89 days in 2016-2017, respectively.
We automatically identified the appearance of patches from the time-series of the optical intensity at zenith and made a list of patches.
By using this list of patches, we investigated the dependence of patch occurrence on the IMF By statistically.
As a result, it was found that when the IMF By is positive, the number of polar cap patches was twice of that in the negative IMF By cases.
By deriving average convection patterns from the archived SuperDARN map potential data, we confirmed that the configuration of plasma convection is more appropriate for patches to be transported toward the magnetic pole during the positive IMF By conditions, which is the primary reason for the asymmetric occurrence of patches in respect to the sign of IMF By.

Implementation of Digital Multi-beam Forming in AgileDARN

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A new agile SuperDARN radar (AgileDARN) has been developed by NSSC, CAS. Based on highly digitized hardware and phased array, the AgileDARN has the potential to improve its performance with the Digital Processing Unit (DPU).

High performance and greater flexibility have been obtained using its distributed digital signal processing system.

One of the improvements is to create multiple receiving beams within the transmitting beam pattern in order to determine better the Direction of Arrival (DOA). In each beam, simultaneous 7 azimuth sub-beams are synthesized with 16 main digital receiver channels, each of them detects the echo around the transmitting boresight with an angular separation of 0.4643 degree.

Comparing the echoes from different sub-beams, the azimuth angle of the irregularity is improved when the volume of irregularity is relatively small than the beam width.

To implement multiple beam forming, extra processing resources in FPGA is required.

This presentation introduces the procedure of signal processing and analyzes the requirements on FPGA resources.

The method is tested with AgileDARN and demonstrated with observations.

Influences of the equatorward SuperDARN expansion on data coverage and measured parameters

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The Super Dual Auroral Radar Network (SuperDARN) has in recent years been expanded equatorward to observe ionospheric flows over a larger latitude range.

The SuperDARN expansion to midlatitudes started in 2005 with the building of the Wallops Island Radar at 37.93 degrees geographic latitude, and a geographic longitude of -75.47 degrees.

Since then, nine more mid-latitude radars have been added to the network, allowing us to measure ionospheric convection on a larger scale than ever before.

Using data from the years 2012 to 2018, we perform a statistical analysis on processed SuperDARN convection maps for the entire dataset.

We process a number of versions of the maps, using different background models both with and without the inclusion of data from midlatitude radars.

This enables us to explore the differences the addition these radars make to the dataset, as well as simulate how much information was missing from the previous decades of SuperDARN research.

To show the importance of growing the radar network to include measurements at mid-latitudes we study a variety of parameters, such as changes in the equatorward boundary of the ionospheric electric field, changes in the cross polar cap potential, changes in the locations of the minimum and maximum potentials, and the width of the return flow region.

We show that there is a clear difference between the datasets, especially when comparing the measured parameters to geomagnetic indices, such as AL.

Information on gravity wave propagation characteristics over long duration in the upper atmosphere as obtained using digisonde measurements

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Gravity waves (GWs) play a major role in the dynamics of ionospheric-thermospheric system.
As these waves propagate in the medium they perturb both neutral and plasma parameters.
GWs of different spectral and spatial characteristics exist in those regions.
Data from a digisonde situated at Ahmedabad, (23.0oN, 72.5oE), India, has been used to obtain such information of GWs.
The idea is to monitor different heights of ionosphere using digisonde measurements.
Phase offset information in the variation of heights of isoelectron density contours (corresponding to transmission frequencies of 8 – 12 MHz) have been used to derive gravity wave propagation characteristics.
As downward phase propagation is a characteristic signature of upward propagating gravity waves (Hines, 1960), investigations have been carried out for the days when phase propagation is seen in the height variations of isoelectron density contours.
Also, another condition that needs to be satisfied is that the altitude variations corresponding to different transmission frequencies show the presence of a common GW time period, which ensures that these perturbations are due to a common source.
The vertical phase speed (Cz) of the gravity wave has been calculated by the knowledge of the difference in heights (Δh) and the phase offset times (Δt), by using the relation, $Cz = \Delta h/\Delta t$, and the vertical scale size (λz) of the gravity wave have been estimated as: $Cz \times \tau$, τ being the common time period.
The resultant vertical scale sizes from this methodology agree well with the earlier reported measurements from MU radar (Oliver, W. L., Y. Otsuka, M. Sato, T. Takami, and S. Fukao, 'A climatology of F region gravity wave propagation over the middle and upper atmosphere radar', JGR, 1997) and theoretical estimates of vertical scale size distribution with altitude (Yamanaka, M. D. and Fukao, S., 'A simple model of gravity-wave momentum and energy fluxes transferred through the middle atmosphere to the upper atmosphere', JASTP, 1994).
To the best of our knowledge, gravity wave propagation characteristics corresponding to altitude of ~ 270 km are being derived for the first time.
By virtue of being a radio technique, this method of deriving gravity wave propagation characteristics can be used in all-weather conditions and is capable of filling-in the much needed gap of such information.
Using this method, digisonde data of ~520 days have been analysed.
The vertical scale sizes obtained show solar activity dependence and it has been seen that the occurrence of gravity wave activity in those altitude regions are omnipresent and do not show any seasonal variations.
However, the gravity wave activity in terms of different periodicities present in a given day increase with increasing solar flux.
Some of these new findings will be presented.

Ionospheric Flow Patterns Associated with NightsideDistorted Transpolar Arc: A Possible Formation Process Deduced from SuperDARN Measurements

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We investigate the ionospheric flow patterns associated with the dawnside(duskside) TPAs whose nightside ends distort toward the post- (pre-) midnight sectors, which were detected by the SuperDARN radars, and discuss how these nightside distorted TPAs were formed based on the ionospheric plasma flow profiles.

Nightside distorted TPAs were identified based on the auroral imager data obtained from the IMAGE Wideband Imager Camera observations during about 5 years between2000 and 2005.

Among the identified TPAs, "J" ("L")-shaped TPAs, whose nightside ends of the dawnside (duskside) TPAs got distorted toward pre-(post-)midnight, were found.

For a TPA event that occurred on 28th, January 2002 measurement of the concurrent ionospheric plasma flows by the SuperDARN radars were available.

The radars detected ionospheric flows typically associated with "Tail Reconnection during IMF Northward Non-substorm Intervals (TRINNIs)" on the nightside main auroral oval before and during the TPA interval.

These ionospheric flow profiles suggest that nightside magnetic reconnection is an integral process to the formation of nightside distorted TPAs.At the onset time of the nightside distorted TPA, equatorward plasma flows at the TPA growth point were observed flowing out of the polar cap and then turning toward the pre-midnight sector of the main auroral oval along the distorted nightside part of a TPA.

We suggest that these plasma flows play a key role in causing the nightside distortion of a TPA.

MAGDAS project: Research for global and local electromagnetic coupling from polar to equatorial ionosphere

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International Center for Space Weather Science and Education (ICSWSE) of Kyushu University is a research institute that conducts academic research and education in space weather and related fields.

We have constructed an observation network known as the "MAGDAS/CPMN (MAGnetic Data Acquisition System/Circum-pan Pacific Magnetometer Network)" in international collaboration with more than 60 organizations, including those in developing countries.

Currently, over 80 magnetometers and 4 FM-CW (Frequency Modulated Continuous Wave) radars have been installed all over the world.

To understand active role of ionospheric dynamics on the global and local Magnetosphere-Ionosphere coupling from polar to equatorial ionosphere, we conduct integrated studies of theory, numerical simulation, in-situ magnetosphere observation, and global ionosphere observation by MAGDAS.

Especially, ionospheric Hall effect strongly controls spatiotemporal evolution of M-I coupling system.

Generation of polarization electric field at conductance gradient regions causes rotation, shear, and acceleration/deceleration of ionospheric convection in both local and global manners.

The ionospheric polarization field activates upward shear Alfven wave that could cause ionospheric driven magnetospheric dynamics and induce new type of M-I coupled current system.

Generation of induction electric field at the wave front of ionospheric disturbances enables electric field of electrostatic potential type to propagate horizontally as a result of coupling between magnetosonic mode and shear Alfven mode induced by multistep Hall effect in a time domain, at the ionospheric E-layer.

Such combined effect of ionospheric Hall polarization and induction on the ionospheric dynamics is a key element for understanding formation process of global current system from polar to equatorial ionosphere.

In this talk, we will discuss how to identify elementary components of Hall-polarization and induction effect (generalized Cowling effect) from coupled phenomena, and possibility of collaborative studies between SuperDARN and MAGDAS project to further understand active role of ionospheric dynamics.

Measuring Planetary Waves and Tides in the MLT at 60°NUsing a Longitudinal Array of SuperDARN Radars

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1. *Norwegian University of Science and Technology and BCSS*

Atmospheric tides and planetary waves (PWs) play an important role in shaping the day-to-day and seasonal variability of the Mesosphere-Lower-Thermosphere (MLT).
Measurements of tidal and PW variability in the mid-latitude MLT have however remained sparse.
This study uses a new analysis technique on the meteor radar winds from a longitudinal array of SuperDARN radars.
These provide hourly measurements of the meridional wind at ~95km altitude from which we are able to investigate tides and PWs in the MLT at 65 degrees North.
Using the array of SuperDARNs, we can identify east and westward traveling S1, S2 and S3 wave components over a broad range of frequencies spanning tidal to planetary wave oscillations.
We present a study of the variability of the migrating and non-migrating tides and the longitudinal variability resulting from their interaction.
Additionally we examine the variability of the 2 and 5-day waves in the MLT, and their interaction with tides during stratospheric warming events.

Mid-latitude HF radar in China

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The first mid-latitude radar in China is JME radar.

It was built and began to operate at the end of 2017. Echoes from ionospheric irregularities under different geomagnetic conditions can be observed by the radar.

During geomagnetic storm, sub-auroral westward stream was observed by joint observation with Hok radars.

The irregularities move from east to west at very high velocity, even more than 1km/s.

Meanwhile, the convection pattern was improved significantly after adding the data of JME radar.

Supported by Chinese Meridian Project, another six HF radars will be established in the next four years, which will cover the mid-latitude region of China completely.

They will enlarge considerably the mid-latitude coverage of SuperDARN in the northern hemisphere.

Mid-latitude SuperDARN Review Paper

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2. *Virginia Tech*
3. *Univ. of Leicester*
4. *Univ. of Saskatchewan*
5. *Thayer School of Engineering, Dartmouth College*
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8. *IRAP, University of Toulouse,CNRS,CNES*
9. *Univ. of Lancaster*
10. *APL*
11. *NICT*

The first purpose-built mid-latitude SuperDARN radars started operation at sites in Virginia and Hokkaido in 2005 and 2006, respectively.

Subsequent construction of additional radars at mid-latitudes have greatly increased coverage and made accessible a range of research topics that are distinctive to the subauroral and mid-latitude ionosphere.

The scientific accomplishments of the mid-latitude component of SuperDARN have been summarized in a review paper that was published in March 2019.

The paper originated from approximately one-week long workshops in January 2017 and January 2018 at ISEE, Nagoya University, during which the content of the paper, its structure and future directions of the mid-latitude SuperDARN network were discussed.

The paper consists of the review of the accomplishments of the mid-latitude SuperDARN in five specified scientific and technical areas: convection, ionospheric irregularities, HF propagation analysis, ion-neutral interactions and magnetohydrodynamic (MHD) waves, as well as the history of the mid-latitude SuperDARN and its future directions.

The content of the paper, as well as its history, will be briefly introduced.

Modeling of ionospheric convection pattern with SuperDARN data using localized vector-valued basis functions

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The SuperDARN provides global information on the ionospheric plasma drift velocity distribution which is associated with the electric field distribution in the ionosphere. However, there are some wide gaps in the spatial coverage of the SuperDARN. In addition, each radar gives only the line-of-sight component of the drift velocity and data are frequently missing.

We propose a framework for expressing two-dimensional flow pattern by using a set of localized vector-valued basis functions, each of which is derived from a spherical Gaussian function such that divergence-free condition is satisfied.

This framework enables us to robustly estimate the global ionospheric convection pattern from SuperDARN data.

We also use the Kalman filter for considering a temporal evolution of the convection pattern.

Some results of the analysis of the SuperDARN data will be demonstrated.

Modelling probability distributions of vorticity fluctuations in the polar ionosphere

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1. *British Antarctic Survey*

Measurements of vorticity in the Earth's ionosphere enable the characterisation of turbulent structure in the ionospheric plasma flow, and how it varies spatially in relation to large-scale magnetic field-aligned current (FAC) systems.
We have determined the spatial variation of the probability density function (PDF) of ionospheric vorticity measurements made by the SuperDARN HF radars across the northern polar ionosphere for the 6-year interval 2000-2005 inclusive.
The PDFs are highly leptokurtic, with heavy tails, and are modelled well by Tsallis q-exponential probability distributions.
The scale and shape parameters of the model q-exponential distributions have been estimated from the measured vorticity PDFs using maximum likelihood estimation (MLE) in spatial bins of 1 degree AACGM latitude by 1 hr of magnetic local time.
The model parameters vary systematically across the polar ionosphere in relation to the well-known FAC regions (denoted region 0, region 1, and region 2).
These results provide insight into the variability of small-scale vorticity and FAC in the polar ionospheres, and can also help to estimate the probability of extreme values.

Multi Taper Analysis of a MSTID event above Antarctica

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A Medium Scale Traveling Ionospheric Disturbance (MSTID) was observed concomitantly by Sanae and Halley HF radars during the period 00-06 UT 17 March 2013.

We present an analysis of the MSTID which uses complex demodulation after application of multiple windows.

The Multi-Taper Method (MTM) mitigates spectral leakage and bias and furthermore, due to the orthogonality of the tapers, allows for confidence levels of peaks to be determined.

Complex demodulation of the MTM spectrum of backscattered power from one cell (beam range gate) in the radar's field of view, allows for the determination of amplitude and phase of the MSTID for the entire duration of the event in that cell.

This analysis is performed for each cell in which the MSTID is present, and is then used to determine several characteristics of the MSTID, for example, horizontal phase velocity.

Multi-instrument Observations of Dayside Ion-Neutral Coupling in the Auroral Zone

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4. *National Institute of Polar Research*
5. *Kyoto University*

Recent research into thermospheric ion-neutral coupling has revealed that auroral activity has a significant impact on the strength of the ion-drag force, via significantly increased ionisation.

This means that in regions of active aurora, mesoscale thermospheric winds are able to respond to changes in the ionospheric plasma drift on the order of minutes, as opposed to hours.

This has implications for the amount of energy deposited into the atmosphere via Joule heating, as well as the amount of atmospheric drag imposed on low Earth orbiting satellites.

In this study, we present the first observations of dayside neutral winds under the influence of poleward moving auroral forms, which also happen to coincide with a large transition of the IMF By component.

Using data from the Super Dual Auroral Radar Network (SuperDARN), EISCAT Svalbard Radar (ESR), Scanning Doppler Imager (SCANDI) and an all-sky imager, we compare neutral wind response times to changes in the plasma before and after the auroral forms appear, along with resultant Joule heating rates.

Multi-point analysis of ionospheric responses to foreshock transients using SuperDARN radars

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The ion foreshock is an important energy source for solar wind-magnetosphere-ionosphere coupling on the dayside.

Transient ion foreshock phenomena, such as hot flow anomalies and foreshock bubbles, can drive field-aligned currents, traveling convection vortices, and ultra-low frequency (ULF) waves in the magnetosphere-ionosphere system.

Observations of convection in the ionosphere with the Super Dual Auroral Radar Network (SuperDARN) radars can be used to monitor ionospheric response effects.

Recent studies have shown that ULF waves generated by foreshock transients can be global or localized depending on the location, size, and lifetime of the foreshock transient.

Taking advantage of multiple radars operating simultaneously at different latitudes and local times on the dayside, we are able to monitor the ionospheric responses in large regions to foreshock transients and to characterize the ULF wave spatial distribution and propagation.

We report on two event studies of the ionospheric responses, particularly ULF wave generation/propagation and convection changes, to foreshock transients, using multiple SuperDARN radars and satellites monitoring conditions in the foreshock.

Multiscape Coupling of Sub-auroral Polarization Streams Observed by the SuperDARN Hokkaido East / West radars

N. Nishitani[1], T. Hori[1]

1. *ISEE, Nagoya Univ.*

Sub-Auroral Polarization Streams (SAPS) are fast westward flows slightly equatorward of the auroral precipitation boundary, and manifestations of magnetosphere-coupling processes.

Recently it was shown that SAPS sometimes contain perturbation in westward speed, typically with temporal scale of a few minutes (e.g., Hori et al., GRL, 2018).

However, it has not yet been clear how small the temporal scales of these perturbations can be and how perturbations with different temporal scales are related to each other. In this paper, multi-scale coupling of the SAPS will be studied, using multiple events observed mainly by the SuperDARN Hokkaido East / West radars.

Multistatic SuperDARN

R. Todd Parris[1], *Todd Pedersen*[1]

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SuperDARN is a network of HF radars that share common and overlapping fields of view to provide coverage of the sub-auroral, auroral, and polar-cap ionosphere for common science investigations.

The radars in the network are regularly scheduled with operating modes to maximize coverage and support varied research goals.

However, the radars have not been designed or operated to work as multistatic radars, with systems listening for signals from other radars.

The geometries of SuperDARN are unique in that there are many likely propagation paths that would provide a specular reflection geometry from field aligned irregularities between radar pairs that could significantly increase the spatial coverage of SuperDARN observations.

Developing a multi-static capability for SuperDARN could also provide new ways to observe large-scale ionospheric structure via changes in propagation paths, and could provide new opportunities for characterizing long-range HF propagation on the high-latitude regions.

However, implementing a multi-static capability within SuperDARN will require some hardware and software changes to allow accurate time synchronization between systems, and enable scheduling and communication of operating frequency and timing between sites.

To do this effectively across SuperDARN would require compatibility in design across the various institutions that participate in SuperDARN.

This presentation will discuss the science benefits and design considerations for developing a multi-static capability.

New methods for studying atmospheric winds and tides in SuperDARN meteor scatter using data from the mid-latitude Falkland Islands radar

Gareth Chisham[1], *Neil Cobbett*[1]

1. *British Antarctic Survey*

For over 20 years winds, waves, and tides from the upper mesosphere and lower thermosphere (MLT) have been studied using near-range (less than 500 km) backscatter from ionised meteor trails measured by the SuperDARN radars.

SuperDARN studies of this region have typically concentrated on the measurements of atmospheric tides using spatially and temporally averaged data which give meridional and zonal velocity components typically once an hour.

This resolution restricts the analysis of the tidal components to lower frequencies.

Here, we analyse Falkland Islands radar measurements at a higher resolution, showing significant tidal components at a wider range of frequencies.

We also employ a new time-series analysis technique (resistant non-linear smoothing) in an attempt to separate tidal and aperiodic components in the meteor velocity variation.

These aperiodic components are typically related to turbulence, which plays an important role in energy transfer and dissipation in the MLT.

NICT Research and Operation for Space Weather

Mamoru Ishii[1]

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Since September 6 2017, when X9.3 solar flare occurred most of Japanese people were scared of it, the situation of Japanese space weather operation has been changed so much.

The ionosphere observing network has been set more robustly with dual systems.

A backup center of space weather information service has been installed at NICT Kobe branch.

In addition, we will begin 24/7 operation of space weather forecast services in FY2019.

We have been collaborating with academic researchers under the framework of PSTEP which will finish the end of FY2019.

Through the activities, we have provided some applications for better service than before.

A radio propagation simulator, HF-START, and the estimation system of human radiation on flight, WASAVIES will be up on our web soon. In addition, we continue to discuss hazardous map against severe space weather disasters, which will be published within a year.

I would like to share our information and have close cooperation with Asia Oceania space weather researchers and operators.

Numerical Modelling of SuperDARN HF Radio Propagation in a Realistic Ionosphere

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Multiple ray tracing tool already exists, but often fail to model accurate wave propagation behavior in the ionosphere, mostly because a majority of them use the IRI model (International ReferenceIonosphere) as input.

Such model gives realistic physical properties estimation during "quiet" solar period but rather poor results during high solar activity.

In this poster, we present some results obtain with a new ray tracing tool developed at IRAP.

This new ray tracing tool solves in a three dimension spherical frame, the eikonal equation, derived from the Fermat principle.

It solves the HF wave trajectories of a few tenth of MHz.

In particular, this ray tracing tool is designed to use as input the ionosphere modelled by IPIM (IRAP Plasmasphere-Ionosphere Model).

IPIM is a numerical ionosphere model, solving the chemical, energetic and transport equations along magnetic field line with a 16 moment-resolution.

Therefore, using IPIM provides access to realistic ionosphere properties, during any kind of solar activity period.

We will present the numerical modelling of SuperDARN radars and we will analyze the trajectories obtained with our ray tracing tool in realistic ionosphere profile and process our data to locate the Effective Scatter Volume (ESV) along each trajectory.

Then we will estimate the error done when taking into account the refractive index impact on the wave velocity.

With the coupling of an accurate ionosphere model and a consistent ray tracing tool, we aim at giving a better understanding on the wave propagation across the ionosphere.

Observing a sub-Alfvénic compressional magnetospheric wave with intermediate azimuthal wave number using the EKB radar and the two RBSP spacecraft

Olga Mager[1], Maksim Chelpanov[1], Pavel Mager[1], Dmitri Klimushkin[1], Oleg Berngardt[1]

1. *Institute of Solar-Terrestrial Physics*

A Pc5 wave was observed in the post-midnight sector by the EKB radar which is similar to the radars of SuperDARN.
Simultaneously, a wave with the same frequency was registered by both RBSP spacecraft at approximately the same magnetic shells and longitudinal sector.
The data from both ground and in-situ instruments show that the wave with a frequency of 1.8 mHz propagated to the west and had an intermediate value of azimuthal wave number $m \approx -10$.
The oscillations also exhibit equatorward propagation as seen in the radar data, which implies the earthward propagation in the magnetosphere.
As the spacecraft data show, the field-aligned component was approximately two times larger than both transverse ones; the variations in the magnetic field were accompanied by anti-phase pressure oscillations, which indicates compressional and diamagnetic properties of the wave.
The frequency of the wave is lower than the frequency of the field line resonance, which was calculated using spacecraft data on magnetic field and particle density at the same L-shells.
The properties of the wave are typical of compressional storm-time Pc5 pulsations, whose presumable source is the wave-particle interaction.
Indeed, the spacecraft registered injected energetic protons modulated with the wave frequency at energies corresponding to drift resonance with the studied wave.
Thus, we believe that the wave was driven by the injected protons due to gradient instability, as bump on tail instability was ruled out.

Occurrence characteristics and geomagnetic activity dependence of SAPS observed by the SuperDARN Hokkaido East and West HF Radars

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We investigate occurrence characteristics of Sub-Auroral Polarization Streams (SAPS), using some Super Dual Auroral Radar Network (SuperDARN) radars.
Mainly we use the Hokkaido East and West radars data. In this study, we statistically analyzed about 10-year data for years 2007-2016 and studied the occurrence rate of flows that can be considered as SAPS, and its dependence on MLT and MLAT.
Assuming that the flows are in the westward direction, we set criteria of the flow velocity > 150 m/s and echo power of > 3dB to identify the SAPS events.
We obtained some of the overall characteristics of SAPS distribution that were reported in past studies, i.e., the equatorward shift of the high occurrence rate region with increasing MLT and geomagnetic activity.
Some other characteristics, however, are different from those identified by past studies (e.g., Kunduri et al., 2017).
The SAPS region seems to be expanded toward higher latitudes than the past studies, and the SAPS occurrence peak region is located at later MLTs.
These differences might be due to the difference in geographic longitude (Far-East Siberia to Pacific vs North American region).
We also found new characteristics, i.e., westward flows from midnight to morning at relatively low geomagnetic latitudes, which could not be studied by the past studies, probably due to the limited fields of view for low to mid latitudes.
Study of the dependence of SAPS distribution on solar activity is also in progress.

Optimization of ICEBEAR analysis and interferometry

Draven Galeschuk[1], *Glenn Hussey*[1], *Devin Huyghebaert*[1],
Kathryn McWilliams[1], *Jean-Pierre St.-Maurice*[1], *Juha Vierinen*[2]

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2. *University of Tromso*

The Ionospheric Continuous wave E-region Bi-static Experimental Auroral Radar, or ICEBEAR, is a fully digital radar developed at the University of Sasktachewan.
ICEBEAR utilizes advanced digital radio and software defined radio techniques to give simultaneous high spatial and high temporal resolution.
This, along with highly accurate timing and a binary pseudo-random code sequence on the CW (Continuous Wave) signal carrier make these highly novel and unique observations of the E-region ionosphere possible.
Nominal operation of ICEBEAR has a spatial resolution of 1.5 km and a temporal resolution of 100 ms.
Nonetheless, this can be easily reconfigured.
To analyze the radar data, a computationally intensive spectral analysis method is needed.
Increased computational throughput of ICEBEAR analysis has been achieved by implementing the parallel language CUDA on Nvidia GPUs (Graphical Processing Units).
The structure of GPU hardware allows for rapid parallel computation of repetitive calculations.
Optimizing and modularizing the ICEBEAR analysis code is needed for expedient analysis and the implementation of unique and advanced analysis techniques, both for timely evaluation of the large data sets produced, and to maximize the data utilization.
This presentation will demonstrate the ICEBEAR analysis process which is foundational for all future ICEBEAR E-region observation. Initial results using the improved analysis process will be shown, and simultaneous observation with the Saskatoon SuperDARN radar will be discussed.
In the long term, ICEBEAR, in collaboration with SuperDARN, will be used for MI (Magnetosphere-Ionosphere) coupling studies.

Origin of fast fluctuation of energetic electron precipitation: Data-driven simulations using the ERG plasma wave observations

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5. *Tohoku University*

Bursty precipitation of keV electrons can be a source of pulsating aurora which has quasi-periodic on-off switching of luminosity.
On the other hand, relativistic electrons also precipitate into the atmosphere with intermittent and bursty nature, which are observed as relativistic electron microbursts.
A common cause of the electron bursty precipitation is expected to be whistler chorus waves propagating along a field line.
In this study, we demonstrate electron precipitation by realistic whistler chorus waves.
Wave form data obtained from ERG satellite are applied to the simulation as a boundary condition at the magnetic equator.
The simulation shows that the whistler chorus waves propagating to high magnetic latitudes along the field line can precipitate electrons with energy from keV to MeV.
We found that amplitude modulation of a whistler chorus burst observed by ERG causes over ten Hz modulation of keV electron precipitation.
At relativistic energies fluctuation with higher frequencies and bursty/intermittent nature appear in time history of precipitation flux.
It suggests that whistler chorus bursts can cause electron precipitation in broad energy range, associated with pulsating aurora and relativistic electron microbursts.

Origin of the twin reverse convection cells for northward interplanetary magnetic field periods

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2. *Meteorological College*

Ionospheric convection in the polar region has been one of the main research topics using SuperDARN data.
Although the morphology seems fairly well established, underlying physical processes are still far from self-evident.
One example is the twin reverse cells that appear at dayside high latitudes during periods of northward interplanetary magnetic field (IMF).
Conventional interpretation of the reverse cells was the so-called lobe cells that appear on open field lines in response to IMF-to-lobe reconnection.
However, using SuperDARN and precipitating particle data, Watanabe at al. [JGR, vol. 115, A12230, 2010] suggested that one of the twin cells are on closed field lines (which they called reciprocal cells).
Their idea (which was based on pure theory) was controversial because it was and still is impossible in principle to determine the open-closed field line from observations.
To overcome the observational constraint, we show in this paper global magnetohydrodynamic (MHD) modeling that supports the idea of Watanabe et al.
The MHD simulation has successfully reproduced the reciprocal cells circulating on the closed field lies.
However, physical processes associated with the reciprocal cells are not so simple as Watanabe et al. originally thought.
From the point of view of energetics, we discuss a new view of the formation mechanisms of the reverse cells.

petitSat - A 6U CubeSat to examine the link between MSTIDS and ionospheric plasma density enhancements

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The mid- and low-latitude ionosphere is home to a variety of plasma density irregularities, including depletions (bubbles), enhancements (blobs), and small-scale scintillation, which result in the distortion of radio wave propagation.

Recent observations from the C/NOFS satellite suggest that multiple mechanisms are responsible for forming plasma density enhancements, with wave action in the thermosphere as a significant driver of the enhanced densities.

Indeed, statistical analysis of enhancements observed from satellites resembles the statistics of Medium-Scale Traveling Ionosphere Disturbances (MSTIDs) with respect to seasonal variability and solar activity.

In order to investigate the link between these two phenomena, both in-situ data of the plasma enhancement and remote data of the MSTID at the magnetic footpoint are required. petitSat is a CubeSat mission designed to provide in situ measurements of the plasma density, 3D ion drift, as well as ion and neutral composition.

The instrument suite includes a combined retarding potential analyzer and cross-track drift meter and a neutral mass spectrometer.

This instrument suite will provide comprehensive information about the fluctuations in plasma, as well as changes in the neutral profile.

petitSat will launch into a 51 deg inclination orbit at 400 km (consistent with an International Space Station deployment), allowing for numerous conjunctions with ground-based observations of MSTIDs over the mission lifetime.

Polarization Measurements of Proton Whistlers and other Natural Low-Frequency Radio Emissions Observed by ePOP- RRI

Ashanthi Maxworth[1], Glenn Hussey[1], Fraser Hird[1],
George Sofko[1], Gordon James[2], Andrew Yau[2]

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We present the polarization characteristics of proton whistlers and other natural emissions observed by the Radio Receiver Instrument (RRI) on the Enhanced Polar Outflow Probe (ePOP), which is on the CASSIOPE spacecraft. RRI consists of crossed orthogonal dipole antennas operated as a polarimeter.

Proton whistlers, which cannot be observed on the ground and are even extremely difficult to observe in space, were observed in a number of ePOP passes from May 19, 2018, to August 19, 2018.

Proton whistlers have numerous dispersion signatures, and we were able to categorize these signatures, map them to their source locations, and compare them to models.

The other natural emissions observed were the lightning-generated electron whistlers, including ducted, non-ducted, nose whistlers, chorus waves, hiss, lower hybrid waves in addition to proton whistlers.

Some quasi-periodic emissions were also observed.

PyDARN: Python Data Visualization Library

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2. *SRI Interanational*

We present pyDARN: a reliable, flexible, and extensible library for interacting with SuperDARN data. With a network of 36 radars running 24/7 in a collaboration between 16 countries, SuperDARN provides copious amounts of ionospheric data to be processed.

The SuperDARN community has developed several software packages to handle the processing and visualization of this data, each of which possesses limitations and poses challenges to users and developers.

DaViTpy is one of the software packages that is a data visualization library for post-processed SuperDARN data.

This library is widely used by the SuperDARN community to produce standard summary, fan, and convection plots.

Drawbacks of this software include the difficult installation process due to legacy code requirements and development challenges posed by the structure of the library itself, with an eclectic set of packages and modules.

To overcome these drawbacks, we introduce pyDARN, a Python data visualization library for SuperDARN data as a successor to DaViTpy. PyDARN uses supported and up-to-date libraries for easy maintenance, quick installation, and provides greater freedom in plotting.

We expect that pyDARN will provide a user-friendly Python interface while creating a conducive environment to developers.

pysat: A Bridge Between Worlds

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2. *Naval Research Laboratory*
3. *NASA*

Our scientific understanding of the ionosphere has been shaped, in part, by the evolution of tools capable of understanding and processing scientific data.

Across space science as a whole these tools have typically been developed in isolation, resulting in disparate tools across regions of the ionosphere.

The lack of common tools across disciplines reinforces divisions and can lead to a class of multi-region behaviors that go unexplained.

The Python Satellite Data Analysis Toolkit (pysat) provides a simple and consistent interface to data sets from low to high latitudes, and ground to space.

Pysat abstracts away all the tedious file and data handling that frustrates working with multiple instruments and extends this feature to support generalized instrument processing and data analysis.

Pysat currently provides support for over 30 instruments and models, achieved in part by incorporating a range of domain specific packages such as pydarn. Examples for SuperDARN, SuperMAG, DMSP, ICON, and COSMIC-2 will be covered.

Pysat is free and open source (https://github.com/rstoneback/pysat).

RadioICE: A bistatic multi-frequency HF Sounder in Antarctica

Alex T. Chartier[1], Ethan S. Miller[1]

1. *Johns Hopkins APL*

A new ionospheric HF sounder has been developed and installed at McMurdo and South Pole Stations, Antarctica.
The instrument is currently operating in a technology demonstration capacity.
Details of the system design and early results are presented.
The instrument is composed of a 160’ T2FD transmitter at McMurdo and a 6-channel receive array at South Pole.
The system produces continuous-wave BPSK-type emissions that cycle through a set of pre-defined frequencies to allow the system to observe different parts of the ionosphere.
We discuss challenges of implementation, encourage participation using the 100% open-source code of this project and describe future plans for the instrument.
One long-term goal is to provide density observations complementing SuperDARN’s drift measurements in Antarctica.

Real-time global convection mapping

Evan Thomas[1], Simon Shepherd[1]

1. *Dartmouth College*

SuperDARN was once known for providing real-time global convection products to the broader space science community, however this service ended more than 5 years ago.

The first steps were taken towards recovering this capability in November 2017, when a real-time implementation of the Thomas and Shepherd [2018] (TS18) statistical convection model became operational on the Dartmouth SuperDARN homepage.

Real-time solar wind conditions were obtained from the NOAA Deep Space Climate Observatory (DSCOVR) spacecraft located at the L1 Lagrangian point and used as input for the TS18 model.

Following 9 months of successful operation, an experimental real-time convection tool was developed which combines DSCOVR solar wind data and TS18 model predictions with line-of-sight observations from the SuperDARN radar at Clyde River using the assimilative Map Potential procedure.

The real-time global convection display went live on the Dartmouth SuperDARN homepage on March 1st2019 and currently ingests velocity measurements from 15 Northern Hemisphere radars.

In this presentation, we describe the features of the existing real-time convection tool and seek feedback from the SuperDARN community for improvements.

Real-time magnetosphere simulator for space weather using REProduce Plasma Universe code

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Mitsue Den[1], Yuki Kubo[1], Tsutomu Nagatsuma[1], Takashi Tanaka[2]

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2. *Kyushu University*

We are developing a real-time numerical simulator for space weather forecast using magnetosphere-ionosphere coupling global MHD simulation called REPPU (REProduce Plasma Universe) code.

The feature of the simulation code is highly robust to extreme solar wind parameters because the unstructured grid system has no singular point and is able to calculate in the uniform accuracy over the whole region.

We use the real-time solar wind data formatted in the GSM coordinate system observed by DSCOVR spacecraft.

On the other hand, the SM coordinate system is used in our simulation.

Therefore, we convert the coordinate system of the input solar wind from GSM to the SM coordinate system.

In this method, we can simulate the interaction between the magnetosphere and the solar wind including the daily variation of the magnetic dipole axis.

The resolution is 30722 grids in the horizontal direction and 240 grids in the radial direction. In this presentation, we compare the simulation results with the CPCP, AE index, and plasma variations observed by geostationary orbit satellites.

Reassessment of SuperDARN/SENSU near-range echoes

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SuperDARN is an international high-frequency radar network and a powerful and unique tool primarily contributed to space weather researches by providing global (high and mid-latitude) ionospheric plasma convection and electric field potential map, i.e., “space weather map”, in high temporal resolution of ~1-2 min in quasi real time with its wide global coverage of fields-of-view. It also contributes to a variety of plasma physics and also to MLT (mesosphare and lower thermosphere) or MTI (mesosphare, thermosphere and ionosphere) region dynamics and vertical coupling of ionised and neutral atmosphere in middle and upper atmosphere by observing TIDs (traveling ionospheric disturbances), neutral winds and PMSE/PMWE etc as well as ionospheric D and E region echoes.

SuperDARN near range echoes are important targets particularly for lower altitude echoes like those in D and E regions and in MLT/MTI regions. As typical range resolution of SuperDARN is rather coarse and HF ray paths bend in ionopshere, determining correct height/altitude information is key to correctly understand the physics in the regions.

These years SuperDARN community has tried to greatly improve and re-establish the method of interferometer calibration (in several ways). Some radars have also started to try higher azimuthal/range resolution using imaging (SDI/FDI) and pulse coding technique etc independently that could also improve the resolution and accuracy above.

Calibration of interferometer and elevatoin angles at all the available SuperDARN radars is esepcially important.

It will enable all the well-calibrated SuperDARN radars to obtain neutral wind vertical profile around mesopause region and its temporal evolution with more reliable height information if our raw time series analysis method for underdense meteor echoes is applied.

The ways forward to improve the SuperDARN neutral wind measurement as well as to make SuperDARN a global meteor radar network has been shwon and discussed in the past workshops.

Another important issue is to determine echo altitude more presicely for non meteor (non grainy) near range echoes.

We here try to re-calibrate the interferometer and elevation angles in our Antarctic Syowa SuperDARN SENSU radar data and to reassess the height information of the near range echoes.

Some recent papers related to this issue proposed near range echoes in summer midday obtained with some SuperDARN radars seem to originate not from mesopause region altitude but from slightly higher altitude so those echoes might not be related to PMSEs.

Reassessment of near range echoes in Syowa SENSU radars and origins of the echoes will be tried, shown and discussed.

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Receiving the SuperDARN Hokkaido East HF radar signal at a remote station using the USRP

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1. ISEE, Nagoya Univ.

USRP is a commonly used Software Defined Radio (SDR), and is capable of processing radio wave signals using easy-to-use software.

In this presentation we introduce our activity to receive backlobe signals from the SuperDARN Hokkaido East radar at Nagoya University main campus, using the USRP and retrieve several parameters such as Doppler shift of the waves due to the vertical motion of the ionospheric reflection point, and travel time of the HF waves which provides information of their travel paths.

Relationship between the large TEC fluctuation and ionospheric echoes observed by the SuperDARN radars in the auroral zone and midlatitudes during a geomagnetic storm

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3. *University of Alaska*
4. *Virginia Tech*
5. *Thayer School of Engineering, Dartmouth College*

In order to investigate a global distribution of ionospheric irregularities in the auroral zone and midlatitudes during a geomagnetic storm which occurred on May 27-28, 2017 with the minimum SYM-H value of -140 nT, we analyzed global navigation satellite system (GNSS) total electron content (TEC) data and midlatitude SuperDARN radar data at Adak Island East (ADE), Adak Island West (ADW), Blackstone (BKS), Christmas Valley East (CVE), Christmas Valley West (CVW), Fort Hays East (FHE), Fort Hays West (FHW), Hokkaido West (HKW), and Hokkaido East (HOK).

In this study, we calculate the GNSS-Rate of TEC Index (ROTI) as a good indicator of existence of ionospheric irregularities with the TEC data.

Here, ROTI is defined as the standard deviation of rate of TEC (the TEC fluctuations per minute) [Pi et al., 1997].

A comparison of two-dimensional polar maps between the ROTI and the ionospheric field-aligned irregularity (FAI) echo intensity observed by the SuperDARN radars shows that the ROTI enhancement appears in association with the auroral oval and the equatorward wall of midlatitude trough during the main phase of the geomagnetic storm.

The FAI echoes with the intensity of more than 15-20 dB is also observed with correspondence to the enhanced ROTI region in the afternoon to midnight sectors (14 ? 23 h MLT: magnetic local time) in North America.

The enhanced ROTI and FAI regions move equatorward as the geomagnetic storm develops.

More interestingly, another enhanced ROTI region with a scale of 600 km appears at 30o geomagnetic latitude (GMLAT) in North America at 1:00 UT on May 28, corresponding to the main phase of the geomagnetic storm.

The enhanced ROTI region almost coincides with a region where TEC decreases by 15 TECU.

This observational fact suggests that the plasma bubble having the enhanced ROTI value extends up to 50°N (GMLAT) at 2:30 UT during the main phase of the geomagnetic storm.

After that, the midlatitude plasma bubble propagates westward at a velocity of 355 m/s and enters the midlatitude trough near 4:00 UT.

When the enhanced ROTI region enters the field of view of the SuperDARN radar at FHE near 2:30 UT, FAI echoes are suddenly observed at the location of the ROTI enhancement.

From these analysis results, it can be concluded that the spatial distribution of ionospheric irregularities as seen in the ROTI data has good correlation with that of the FAI echoes observed by the SuperDARN radars.

Review of Magnetosphere-Ionosphere Coupling and Recent Results from Coordinated Observations

J. Michael Ruohoniemi

1. *Virginia Tech*

The collision of the magnetized plasma of the solar wind with Earth's magnetosphere initiates a transfer of energy and momentum into Earth's magnetosphere at distances of many Earth radii.

Magnetic reconnection and viscous interaction across the magnetopause boundary lead to bulk flows of magnetospheric plasma that reach to ionospheric heights (60 – 1000 km) at high latitudes by virtue of the associated large-scale electric fields that map with little attenuation along the highly conducting geomagnetic field lines.

This coupling of the magnetosphere and ionosphere extends to resistive loading of the magnetospheric generator that is due to current flow and Joule heating in the ionosphere.

Magnetosphere-Ionosphere coupling is further mediated by field-aligned currents, MHD pulsations, particle precipitation, and plasma outflows.

In this presentation we review the fundamentals of Magnetosphere-Ionosphere coupling and consider some recent findings that illustrate the benefits of combining and, where possible, coordinating, in-situ point measurements of magnetospheric effects from spacecraft with larger-scale views of ionospheric processes that are sensed remotely with ground-based instrumentation.

Scheduling Working Group report

Evan Thomas

1. *Dartmouth College*

Report on the Scheduling Working Group activity since the last SuperDARN workshop.

Seasonal influences on plasma convection at solar maximum

Angeline G. Burrell[1], Russell A. Stoneback[2], Manbharat Dhadly[3], Gareth Chisham[4], Tim K. Yeoman[4]

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Plasma convection over the poles shows the result of direct interactions between the terrestrial atmosphere, magnetosphere, and the sun.

The paths that the ionospheric plasma takes in the polar cap form a variety of patterns, which have been shown to depend strongly on the direction of the Interplanetary Magnetic Field (IMF) and the reconnection rate.

While the IMF and level of geomagnetic activity clearly alter the plasma convection patterns, the influence of changing solar irradiance is also important.

This study investigates the influence of season on plasma convection during quiet geomagnetic periods for southward IMF.

Ionospheric convection is mapped using Super Dual Auroral Radar Network (SuperDARN) backscatter and observations of the open-closed field line boundary taken from the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) Far Ultraviolet (FUV) imagers.

The influence of magnetosphere-ionosphere-thermosphere coupling on the temporal variations is explored using complementary data sets to provide insight into Magnetosphere-Ionosphere and Ionosphere-Thermosphere interactions.

SECS reconstruction of ionospheric flow map from SuperDARN observations on St. Patricks day 2015 storm

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2. *ISM*
3. *The Univ. of Tokyo*
4. *Virginia Tech.*
5. *Dartmouth College*
6. *Kyushu Institute of Technology*

We analyze detailed properties of the two-dimensional (2-D) structure of ionospheric flow fluctuations observed by Super Dual Auroral Radar Network (SuperDARN) during a short (~2 hours) break of the main phase of the 17 March 2015 magnetic storm.

Line-of-sight (LOS) Doppler velocities observed by two SuperDARN radars in the early morning sector were used to deduce the 2-D horizontal flows by means of the spherical elementary current system (SECS) expansion.

Similar to results deduced by the conventional map potential technique, the SECS reconstruction shows that ionospheric plasma in the subauroral region flowed primarily in the geomagnetically eastward direction before and after the period of the particular flow fluctuations.

The reconstructed flow pattern shows that, during the first half of the flow fluctuation interval, background convection subsides and circular/elliptically polarized flow fluctuations pass over the field-of-view of the radars as they propagate westward.

Multiple flow bursts likely associated with small injections occur concurrently during the second half of the interval, while the westward-propagating flow fluctuations still continue regardless of the flow bursts, until a major substorm activity starts later on.

Some eastward-propagating flow fluctuations are seen in the early morning sector upon the onset of the major substorm, which is supported by the fact that multiple injections are seen around midnight by Van Allen Probes and the SYM-H and AL indices resume growing.

A new finding from the reconstructed flow is that the eastward-propagating structures are also dominated by a poloidal component.

The common feature of poloidal-dominant flow fluctuations implies that the westward- and subsequent eastward-propagating fluctuations are both caused by a similar mechanism.

Simulations and Measurements of Radio Frequency Radiation (RFR) for a SuperDARN Radar

Kevin Sterne[1], Kevin Krieger[2]

1. *Virginia Tech*
2. *University of Saskatchewan*

In late 2017, an audit by Canada's Office of Spectrum Management was performed at the Kapuskasing SuperDARN site. During this audit, a number of health and safety concerns were raised with the licensee and site operators.

The results presented here show simulations and measurements of the intensity of the electromagnetic radio waves generated by two similar SuperDARN radars and how these radars are in compliance with the Canadian Government's health and safety standards for RFR exposure.

The simulations were based on an EZNEC antenna model of the Kapuskasing radar site while measurements were performed with an electric field strength meter at the Saskatoon SuperDARN site.

The results provided here could be used to address concerns about RFR at present or future SuperDARN sites.

Simultaneous observation of magnetospheric plasma waves and PMWE observed by Arase satellite and MST radars

Yoshimasa Tanaka[1,2,3], *Takanori Nishiyama*[1,3], *Akira Kadokura*[1,2,3], *Mitsunori Ozaki*[4], *Mitsunori Ozaki*[4], *YoshizumiMiyoshi*[5], *Kazuo Shiokawa*[5], *Shin-Ichiro Oyama*[1,5,6], *Ryuho Kataoka*[1,3], *Masaki Tsutsumi*[1,3], *Koji Nishimura*[1,2,3], *Kaoru Sato*[7], *Yoshiya Kasahara*[4], *Atsuki Kumamoto*[8], *Fuminori Tsuchiya*[8], *Mizuki Fukizawa*[8], *Mitsuru Hikishima*[9], *Shoya Matsuda*[9], *Ayako Matsuoka*[9], *Iku Shinohara*[9], *Masahito Nosé*[5], *Tsutomu Nagatsuma*[10], *Manabu Shinohara*[11], *Akiko Fujimoto*[12], *Mariko Teramoto*[5], *Reiko Nomura*[13], *Akira Sessai Yukimatu*[1,3], *Keisuke Hosokawa*[14], *Masafumi Shoji*[5], *Ralph Latteck*[15]

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Precipitation of relativistic electrons with energies greater than 500 keV to the polar atmosphere can reach altitudes lower than 70 km and causes atmospheric composition change, which leads to ozone depletion in the mesosphere and stratosphere.

Thus, it is important to understand the mechanism of the relativistic electron precipitation (REP). Possible mechanism for the REP is the interaction with plasma waves in the magnetosphere, such as electromagnetic ion cyclotron (EMIC) waves and whistler-mode chorus waves. In this study we compare between magnetospheric plasma waves and polar mesosphere winter echoes (PMWE) simultaneously observed with the Arase satellite and high-power atmosphere radars in both hemispheres, i.e., PANSY at Syowa Station (SYO; –69.00S, 39.58E), Antarctica, and MAARSY at Andøya (AND; 69.30N, 16.04E), Norway.

PMWE are often observed simultaneously with energetic particle precipitation during the solar proton events and substorms, and thus can be associated with REP.

We focus on the PMWE observed during 03-07 UT on March 21, 2017, during which the corotating interaction region (CIR) arrived and the footprints of Arase were located near Syowa Station, Antarctica, and Husafell (HUS; 65.67N, –21.03E), Iceland.

An isolated substorm occurred at 04-06 UT on March 21 during this interval.

The observational results are summarized as follows. (1) During 04:45-07:00 UT, the recovery phase of the substorm, PMWE were observed with both the PANSY and MAARSY radars and the lower-band and upper-band chorus waves (LBC and UBC waves) were observed in the magnetosphere.

The temporal variations of the PMWE at both hemispheres and the chorus waves were similar to each other. (2) Before the substorm onset (03:00-04:00 UT), PMWE at SYO coincided with EMIC waves in the magnetosphere.

The result (1) indicates an evidence that chorus waves during the substorm recovery phase cause REP that leads to PMWE.

During this period, pulsating auroras were also observed at HUS, Iceland.

If the LBC waves resonated with energetic electrons near the magnetic equator, the resonance energy is too low to cause PMWE at an altitude lower than 70 km.

However, it is found that the resonance energy becomes greater than 1 MeV, if the LBC waves propagate to the higher magnetic latitude than 30 degrees and resonate with the electrons there.

As for the result (2), EMIC waves have been identified as a potential driver of REP.

It is interpreted that EMIC waves were generated inside the plasmapause by ring-current hot ions with temperature anisotropy; this anisotropy was caused by magnetospheric compression due to the CIR.

We attempt to explain various phenomena observed in the magnetosphere, ionosphere and mesosphere by the interaction between the CIR in front of high-speed solar wind streams and the magnetosphere.

Software Practices: are they Practical for Scientists?

Marina Schmidt[1]

1. *University of Saskatchewan*

Writing code to gain insights from data and computationally test hypotheses has become a necessity in scientific fields.
Given the importance of code to researchers and the reliability of their results, achieving a high standard of quality and usability are of great interest.
In this presentation, we demonstrate how following software practices and standards can help produce code with these properties.
We compare a Python library nearing the end of its life cycle, DaViTpy, to pyDARN, another data visualization library for SuperDARN being developed with standard software practices in mind.
DaViTpy is widely used in the SuperDARN community as a framework for project-specific data analysis and for producing visualizations.
However, it presents the users with a challenging installation and interfaces due to depreciated libraries and legacy code.
In response, users often turn to non-standard visualization methods, which may lead to reproducibility issues.
We discuss how the pyDARN data visualization library avoids these problems by using software practices to produce more maintainable, user-friendly, and extensible code.
These properties help create a more open and collaborative research environment.

Solar wind imprint on gravity waves and intensification of tropical cyclones

Paul Prikryl[1,2]

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Solar wind coupling to the magnetosphere-ionosphere-atmosphere (MIA) system generates medium- to large-scale atmospheric gravity waves (AGWs) propagating from sources in the lower thermosphere at high latitudes both upward and downward [1,2].

In the ionosphere, they are observed as traveling ionospheric disturbances (TIDs) in the HF radar ground scatter and the GNSS TEC. Cases of one-to-one correspondence between TIDs and pulsed ionospheric flows or ionospheric currents, sometimes modulated by solar wind Alfvén wave coupling to the dayside magnetosphere/ionosphere, have been demonstrated [2].

In the lower atmosphere, the AGWs can be ducted over long distances and reach troposphere.

Despite significantly reduced wave amplitude but subject to amplification upon over-reflection in the upper troposphere they can trigger/release moist instabilities to initiate convective bursts, with the latent heat release leading to intensification of storms [3].

It was shown that explosive extratropical cyclones and rapid intensification of tropical cyclones tend to follow arrivals of solar wind high-speed streams (HSS) and/or interplanetary coronal mass ejections(ICMEs) [4,6,7].

The coupling of solar wind to MIA is most intense during the arrivals of co-rotating interaction regions and/or interplanetary shocks at the leading edges of HSSs and ICMEs when the amplitudes of aurorally-generated AGWs are largest.

Ray tracing of AGWs in a model atmosphere shows that they can reach tropical cyclones.

The interaction of aurorally-generated gravity waves with the tropical cyclone vortex and the inner primary eyewall may play a role in the intensification process.

Spiral gravity waves in typhoons were observed and simulated to propagate radially outward from the typhoon core [8].

The spectra of waves in surface pressure and surface wind measured by the Impacts of Typhoons on the Ocean in the Pacific buoy during nearby passages of intense typhoons are similar with spectra of incoming aurorally-generated AGWs and their sources.

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Some highlights of Dave Walker's many contributions to ULF wave research

Tim Yeoman[1]

1. *University of Leicester*

This talk will review some personal highlights taken from Dave Walker's many and profound contributions to ULF wave research.

Dave was central to the early confirmation of the MHD picture of ULF waves and field line resonance using high latitude radar data, both in the pre-SuperDARN era and with SuperDARN.

He also contributed seminal work on waves driven by wave-particle interactions.

He was a true innovator in both the theory of ULF waves as well as their observation.

His insight will be sorely missed, but his legacy will continue to be relied upon in future ULF wave research.

Spacecraft Working Group Report

Kevin Sterne[1], Tomo Hori[2], Rob Fear[3], Keisuke Hosokawa[4], Mike Ruohoniemi[1], Jim Wild[5]

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2. *Nagoya University*
3. *University of Southampton*
4. *University of Electro-Communications*
5. *Lancaster University*

The Spacecraft WG will present a summary of SuperDARN/spacecraft experiments over the last year as well as plans for the next year.

An overview summary will be presented about the current status of coordination with the Magnetospheric Multi-scale (MMS) mission, and the ERG/ARASE satellite mission.

Also, a general overview of the SMILE mission will be presented.

Spatial distribution of the polar thermospheric wind acceleration and importance of the 2D measurement

Shin-ichiro Oyama [1,2,3], Anita Aikio [2], Mark G. Conde [4], Heikki Vanhamäki [2], Ilkka Virtanen [2], Thomas Ulich [2], Lassi Roininen [5], Pekka Verronen [6], Takeshi Sakanoi [7]

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2. *U. Oulu*
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4. *GI UAF*
5. *Lappeenranta-Lahti University of Technology*
6. *Finnish Meteorological Institute*
7. *Tohoku U.*

Understanding the flow of energy and mass throughout the magnetosphere-ionosphere-thermosphere coupled system is a fundamental goal of solar-terrestrial physics.

Since substantial energy accumulated in the substorm growth phase in the magnetospheric tail flows into the polar ionosphere immediately after the substorm onset, investigating the energy dissipation process at high latitudes around the time of substorm onset can contribute significantly to achieving that objective.

The energy dissipation generates acceleration and heating of the ionosphere and thermosphere, but this might occur not only near aurora but also far from it by hundreds kilometers equatorward.

We analyzed ionospheric and thermospheric measurements in the northern Scandinavian area (65-80 N) during periods of considerably low geomagnetic activity but with some aurorae above Svalbard (75-80 N).

Thermospheric winds measured with a Fabry-Perot interferometer (FPI 630.0 nm) at Tromsø, Norway (69.6 N) showed westward accelerations coinciding with auroral brightening at the Svalbard area at the dusk sector though the relative distance from Tromsø to the aurora was 200-500 km in some cases.

Moving into the dawn sector with the earth’s rotation, the acceleration direction turned to southeastward through stagnation area or period seen at magnetic local midnight.

The acceleration pattern well represents thermospheric responses to the ionospheric convection, but of particular interest is its location, in which the thermospheric wind have been obtained at the sub-auroral region far from the main auroral oval.

In this analysis, we cannot infer to horizontal patterns of the wind acceleration because we have only a point measurement from the Tromsø FPI.

While this result suggests the importance of two-dimensional measurements of ionosphere and the thermosphere, we need a new configuration of the observation network to infer horizontal winds and accelerations.

In this presentation, we will introduce “SDI-3D” project, which aims at deploying 3 Scanning Doppler Imagers (SDIs) at the same area as for the EISCAT_3D, which may start in operation in 2022.

Spatially Resolved Neutral Wind Response Times During High Geomagnetic Activity Above Svalbard

D. D. Billett[1], J. A. Wild[1], A. Grocott[1], A. L. Aruliah[2], A. M. Ronksley[2], M.-T. Walach[2] M. Lester[2]

1. *Lancaster University*
2. *University College London*

In the high latitude thermosphere, it has been shown that sudden changes in plasma velocity (such as those due to changes in interplanetary magnetic field) are not immediately propagated into the neutrals.

This is because of non-ion drag forces which deviate the neutrals from perfect coupling with the ionosphere.

Furthermore, mesoscale variations in the plasma convection morphology, solar pressure gradients and other forces indicate that the thermosphere-ionosphere coupling mechanism will also vary in strength on this scale.

Using data from the Super Dual Auroral Radar Network(SuperDARN) and the Scanning Doppler Imager (SCANDI), a geomagnetically active event was identified which showed plasma flows clearly imparting momentum to the neutrals.

A cross-correlation analysis determined that the average neutral wind reaction times to changes in the plasma was 75 minutes and varied by up to 29 minutes within a 100km field of view.

It is clear from this that the mesoscale structure of both the plasma and neutrals has a significant effect on the strength of ion-neutral coupling.

Special-time observations for SuperDARN-Arase satellite conjunction

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3. *NICT*
4. *UEC*
5. *Kyushu Univ.*
6. *JAXA/ISAS*

Exploration of energization and Radiation in Geospace (ERG), a Japanese inner magnetosphere satellite also known as "Arase", was successfully launched in December 2016 and has been in orbit making tremendous observations on the Earth's radiation belts and related plasma wave activities in the inner magnetosphere.

In concert with in situ observations made by Arase, special mode observations, primarily proposed by Japanese SuperDARN (SD) members, have been carried out to study convection electric field and ultra-low frequency (ULF) waves seen at the ionospheric footprint of the satellite.

For these purposes, the interleaved normalscan mode was operated over several radars that were situated near the footprint of Arase.

In the presentation, we briefly summarize the results of the SD-Arase conjunction campaigns with the special time observations, which were conducted from September 2018 through January, 2019.

Sporadic appearance of 10-ms-order flashing variation in flickering aurora

Kiyoka Murase[1], Ryuho Kataoka[2], Yoshizumi Miyoshi[3], Hervert Akihito Uchida[1], Yoko Fukuda[4], Yusuke Ebihara[5], Donald Hampton[6]

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2. *National Institute of Polar Research*
3. *Nagoya University*
4. *National Institute for Environmental Studies*
5. *Kyoto University*
6. *University of Alaska*

We report an example of the fastest-ever-observed variation in flickering aurora, which was captured by ground-based sCMOS camera installed at Poker Flat Research Range, Alaska, on October 12, 2017.

The field-of-view was 4.5 deg by 2.3 deg, looking toward the magnetic zenith. At 0637 UT, flickering aurora was captured at 240 frames per second in the narrow field-of-view.

When typical interference pattern filled the field-of-view oscillating at approximately 10 Hz, patchy structure also additionally appeared and disappeared, changing their shapes every frame.

This example provides another piece of evidence that proton-band electromagnetic cyclotron waves contribute to flickering auroras (Fukuda et al., 2017).

Further, we found that the fastest variation sporadically emerged several times in 1.0 s and lasted only less than 0.1 s each time, although the lifetime of the background flickering pattern was more than 1.0 s.

In this presentation, we will discuss possible generation mechanisms of the fastest variation.

Study of Solar Zenith Angle Dependence of Subauroral Polarization Streams Observed by the SuperDARN HF Radars

Y. Zhang[1], N. Nishitani[1], T. Hori[1], S.G. Shepherd[2], W.A. Bristow[3]

1. *ISEE, Nagoya Univ.*
2. *Thayer School of Engineering, Dartmouth College*
3. *Univ. of Alaska Fairbanks*

The characteristics of the subauroral polarization stream (SAPS), with a main focus on the solar zenith angle (SZA) dependence are studied using the Super Dual Auroral Radar Network (SuperDARN) HF radars and NOAA POES spacecraft data.

In this study, we used 3 SuperDARN radars (HOK / CVE / ADW), and analyzed the data from 2008 to 2017 and found 124 SAPS events where the line-of-sight velocity is larger than 150m/s, magnetic local time is 13 to 19 hours and the flow regions are identified to be equatorward of the auroral precipitation region.

We found that the results of CVE radar are different from those of HOK and ADW radar, i.e., the SAPS observed by CVE radar can occur in high conductivity occasion when both hemispheres are illuminated.

However, we found that these illuminated SAPS could only occur under geomagnetically disturbed conditions and mostly in spring and fall.

In addition, when the geomagnetic activity is low, SAPS tends to appear when the minimum threshold of illuminated ionospheric altitude is 130 km or more, which is near and slightly above the altitude of the peak of Pedersen conductivity.

These results suggest that the generation of SAPS is affected by both geomagnetic activity and Pedersen conductivity.

SuperDARN Developments to Enable Studies of Wave Polarizaiton

W.A. Bristow[1], Tim Theurer[1], Bryant Klug[1]

1. *University of Alaska Fairbanks*

SuperDARN is an outstanding tool for HF radar design and application studies.
As a university based system of near global extent, it provides a unique opportunity for experimentation and for training of students.
Through such experiments performance of the radars has evolved steadily with improvements in resolution in both time and space, and with improved ability to execute complex experiments.
This paper describes the next iteration being developed by the UAF group, which will enable studies of the impact of wave polarization in HF radars.
SuperDARN radars have always used horizontally polarized antennas, which has not been a severe limitation on the system for its primary purpose.
It precludes, however, studies of ionospheric effects on wave polarization and it leads to a higher signal fluctuation level than would be observed if the full polarization of the return signals were received.
The new development will employ crossed log-periodic dipole antennas with separate transmitter and receiver chains on each half of the cross.
Each transmitter will be driven by its own direct digital synthesizer, and each receiver will be directly sampled at HF.
The two halves of the crossed antennas will be down-converted independently and recorded.
This configuration will enable full control of the transmitted polarization, and will enable determination of the received polarization as a function of range and time.
This capability has been in development for some time and it is nearing completion.
By the time of this year's meeting, we will have installed the crossed antenna elements on one antenna in the Kodiak array and will have sample data and an initial analysis.
This presentation will include those sample observations along with the theoretical background on their motivation.

SuperDARN elevation angle measurements of artificially-induced HF radar backscatter during a period of simultaneous topside and bottom side ion line enhancements induced in ionospheric modification experiments.

T. K. Yeoman[1], T. Rexer[2], B. Gustavsson[2],
T. Leyser[3], M. Rietveld[4], T. Grydeland[5]

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2. *Institute for Physics and Technology, Arctic University of Norway*
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4. *EISCAT Research Association, Ramfjordmoen , Norway*
5. *Northern research institute, Tromso, Norway*

The SuperDARN coherent-scatter signals will return to the radar as ionospheric scatter if they achieve orthogonality to decameter-scale irregularities.

The azimuth of the transmitted signal is constrained by the narrow beams, but a wide range of elevation angles are transmitted, and received, by the radars.

On March 9th, 10th and 11th 2016 the EISCAT Heating facility was operated in a 3-minute on, 3-minute off cycle, transmitting O-mode polarization in the magnetic zenith direction.

The experiments were conducted during quiet geomagnetic daytime conditions from 10:00 UT to 13:00 UT on all three days.

These experiments are described in detail in Rexer et al. [2018], and were characterised by the generation of bottom side HF ion line enhancements in many cases accompanied by topside HF ion line enhancements.

The raw SuperDARN backscatter was processed to obtain the phase lag the between the main and interferometer arrays that is used to calculate the elevation angle.

Once this parameter was obtained, a second level of processing was performed to reduce the error in elevation angle by removing the effective time delay caused by the difference in the electrical path length that connects the main array and the interferometer arrays to the correlator, as described by [Burrell et al., 2016].

This analysis allowed the discrimination between irregularities artificially-induced in the topside and bottom side ionosphere.

Here we demonstrate that the post-processing of the elevation angle calculation can be used to make finely distinguished measurements of elevation angle and HF propagation path to improve and extend the scientific remit of the SuperDARN radar systems, allowing better geolocation of data where observations are coordinated with e.g. rocket experiments, and aiding the determination of the altitude of the scatter in e.g. investigations of E and F region irregularities.

SuperDARN observations during geomagnetic storms, geomagnetically active times and enhanced solar wind driving

Maria-Theresia Walach [1], *Adrian Grocott* [1]

1. *Lancaster University*

The Super Dual Auroral Radar Network (SuperDARN) has in recent years been expanded to lower latitudes to observe ionospheric flows over a larger latitude range. This enables us to study extreme space weather events, such as geomagnetic storms, which are a global phenomenon, on a large scale (from the pole to magnetic latitudes of 40 degrees).

We study the backscatter observations from the SuperDARN radars during all geomagnetic storm phases from the most recent solar cycle(2010-2016) and compare them to other active times to understand radar backscatter and ionospheric convection characteristics during extreme conditions and to discern differences specific to geomagnetic storms and other geomagnetically active times.

We show that there are clear differences in the number of measurements the radars make, the maximum flow speeds observed and the locations where they are observed during the initial, main and recovery phases.

We show that these differences are linked to different levels of solar wind driving.

We also show that when studying ionospheric convection during geomagnetically active times, it is crucial to consider data at mid-latitudes, as we find that during 19% of storm-time the equatorward boundary of the convection is located below 50 degrees of magnetic latitude.

SuperDARN Observations during the 2017 Solar Eclipse

Simon G Shepherd[1], *Evan G Thomas*[1]

1. *Thayer School, Dartmouth College*

Between 16-18 UT on August 21, 2017 the path of a total solar eclipse passed through the fields-of-view of several mid-latitude SuperDARN radars.

The effects of the eclipse were most dramatically seen in the skip distance of ground scatter returns from the camping beam of the CVW radar.

We investigate the behavior of ground scatter using measured elevation angles and compare to ray-tracing results for ionospheric conditions expected and observed during the eclipse.

SuperDARN Status Report

Mark Lester

1. *University of Leicester*

Status of the different SuperDARN radars and teams will be reported.

Superposed Epoch Analysis of Nightside Subauroral Ionospheric Convection Response to Sudden IMF Bz Turnings

M. Maimaiti[1], *J. B. H. Baker*[1], *J. M. Ruohoniemi*[1], *Bharat Kunduri*[1],

1. *Virginia Tech*

Quiet time subauroral ionospheric plasma exhibits predominantly westward drifts of a few tens of m/s and its convection pattern has been characterized using measurements from satellite-based ion drift meters or incoherent and coherent scatter radars.

However, the exact driving mechanisms for this low-velocity plasma motion are not well understood.

Recent statistical studies suggest that, in addition to the neutral wind, penetration/leakage of high latitude convection election field through undershielding can also significantly influence the subauroral convection under even quiet conditions.

In this study we have used measurements from six midlatitude SuperDARN radars in the U.S. continent to study the transient response of quiet-time nightside subauroral convection at different MLT sectors to sudden southward and northward IMF turnings.

To account for dynamic behaviour of the auroral oval, we apply particle precipitation measurements from Polar Operational Environmental Satellites (POES) to determine the location of the equatorward auroral boundary.

Our superposed epoch analysis reveals that signatures of undershielding/overshilding due to IMF southward/northward turnings are significant in the subauroral convection even during very quiet conditions (AL< -50 nT), with the most pronounced undershielding/overshilding effects appearing near dawn and dusk for zonal flows while near midnight and postmidnight for meridional flows.

Both zonal and meridional flow patterns at +/- 15 minutes of IMF northward and southward turnings are found to be similar to steady-state statistical model results, suggesting that the reconfiguration time of subauroral convection flow is ~ 15 minutes.

Furthermore, we found the shielding time constant to be > 30 minutes, which is inferred from the newly reconfigured flow pattern staying steady even after 30 minutes of IMF southward turning.

In this presentation, we discuss these features in terms of Ionosphere-Magnetosphere coupling processes and the penetration of electric fields to the nightside subauroral ionosphere.

Tauscan Multipulse Sequences – Alternative Multipulse Sequences and Processing that Overcomes Avoids Many Shortcomings of Traditional SuperDARN Techniques

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Approximately 15 years ago, Kjellmar Oksavik and I began working on a new multipulse scheme that used forward and reverse optimal-pulse sequences identified by Farley [1972].

At that time, we used a 13-pulse sequence comprised of a single initial pulse followed by forward and reverse versions of one of the 6-pulse sequences identified by Farley [1972].

An innovative aspect of this work is that we found that bad lags associated with the forward and reverse sequences were mostly complementary.

When both forward and reverse sequences were used, both sequences produced errors due to receiver blanking during transmissions or cross-range noise, but only rarely did they produce them at the same range gate.

Consequently, the quality of ACFs and XCFs produced with Tauscan-13 sequences was significantly improved.

In recent years, it has become increasingly apparent that the elevation angle of backscattered signals is an important measurement for SuperDARN radars.

This angle is needed to determine the ground point underlying each scattering volume and to correct Doppler velocity measurements for ionospheric refraction.

The elevation angle is derived from measurement of phi0, the phase shift in the backscattered signal between the main and interferometer arrays.

There is some evidence from simulations and observations that phi0 can be better determined with Tausan sequences.

During the past two years, I developed a slightly shorter 11-pulse sequence comprised of a single pulse followed by forward and reverse 5-pulse optimal sequences.

Recently, we began testing Tauscan-11 on the Blackstone radar, and, more recently, on the Saskatoon radar.

The most recent measurements, obtained on March 14, 2019 at Saskatoon, included determinations of phi0. In all tests, measurements were carried out during discretionary time for periods extending up to two days.

Data were collected as iqdat files.

These data were transferred to the home institution from where the iqdat files were obtained and processed on a Linux computer using Python code.

The Python code removes bad lags from the ACF and matches the remaining good lags of the ACF to a lag-restricted theoretical model of the ACF phase.

The quality of each fit is determined by the root-mean-square difference between the good ACF phase measurements and the lag-restricted phase measurements of the theoretical phase model. In this paper, results of this ACF phase analysis will be presented for both the Blackstone and Saskatoon radars.

The results include several new diagnostics that are useful in evaluating the quality of the fits.

Temporal and spatial evolutions of storm-time ionospheric disturbances in the low and midlatitudes as seen in the GNSS-TEC and SuperDARN radar observations

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Temporal and spatial evolutions of ionospheric disturbances in the low and midlatitudes during a geomagnetic storm that occurred on 27?28 September 2017 have been investigated using GNSS (Global Navigation Satellite System)-TEC (Total Electron Content) and midlatitude SuperDARN radar data.

The GNSS-TEC data analysis results show that the TEC enhancement related to the storm enhanced density(SED) first occurs around noon or afternoon (11:00-15:00 MLT: magnetic local time) at high latitudes, within one hour after the onset of the main phase of the geomagnetic storm, and moves to the mid- and low-latitude regions extending into both the latitudinal and longitudinal directions.

The signature of the TEC enhancement is not only observed in the American sector but also in the European, Japanese, and Australian sectors.

During the late main phase of the geomagnetic storm, another TEC enhancement related to the equatorial ionization anomaly (EIA) occurs in equatorial and low latitudes and extends to higher latitudes.

The two prominent TEC enhancements due to the SED and EIA finally meet each other at low latitudes.

On the other hand, the midlatitude ionospheric plasma flow observations taken by the SuperDARN radars at Adak Island East (ADE), Adak Island West (ADW), Blackstone (BKS), Christmas Valley East (CVE), Christmas Valley West (CVW), Fort Hays East (FHE), Fort Hays West (FHW), Hokkaido West (HKW), and Hokkaido East (HOK) show that a large westward flow with a speed of more than 400 m/s appears in the afternoon to evening sectors (12:00?23:00 MLT) near the high-latitude boundary of SED and inside the midlatitude trough.

The location of the midlatitude westward flow moves equatorward together with the SED and midlatitude trough as a geomagnetic storm develops.

Sometimes, the large westward flow is observable in the TEC enhancement related to SED.

From these analysis results of the GNSS-TEC and SuperDARN radar data, it can be considered that the mid-latitude TEC enhancement related to SED is not generated by the high-latitude expansion of the EIA, but by the uplifting and westward transportation of ionospheric plasma in the sunlit region due to localized intense electric field drifts associated with enhanced subauroral polarization stream (SAPS) during the geomagnetic storm.

Temporal and spatial variation of GPS TEC and phase scintillation during substorms and auroral breakups

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Ionospheric structure caused by precipitation of energetic particles can adversely affect the GPS signals resulting in phase scintillation and cycle slips (loss of lock).

GPS phase scintillation has been found correlated with auroral emission intensity, particularly with rapid changes in auroral forms and their brightness [1,2,3].

Total electron content (TEC) enhancements that were observed during substorm expansion phase within the night side downward (R1) current appear to be associated with enhanced precipitating particle fluxes [4].

Such TEC enhancements cause phase scintillation, which is most intense just after substorm onsets and auroral breakups.

Phase scintillation index is computed for sampling rate of 50 Hz by specialized GPS scintillation receivers from the Canadian High Arctic Ionospheric Network (CHAIN).

A proxy scintillation index is obtained from dual frequency measurements of geodetic-quality GPS receivers sampling at 1 Hz, which include globally distributed receivers of RT-IGS network that are monitored by the Canadian Geodetic Survey in near-real-time.

Temporal and spatial changes of TEC and phase scintillation are investigated in the context of equivalent ionospheric currents derived from ground magnetometer network using the spherical elementary current method [5,6].

The relation of phase scintillation with auroral emission observed by THEMIS all-sky imagers and the far-ultraviolet scanning imager SSUSI onboard the DMSP satellites is also examined.

In general, GPS phase scintillation is mapped to regions of strong westward electrojet (upward R2 currents or the interface with downward R1 currents) and to the poleward edge of the eastward electrojet (upward R1 currents).

Following substorm onsets and auroral breakups, strong phase scintillation associated with TEC enhancements are mapped mainly to the upward R2 current or the equatorward edge of the downward R1 current at or near the Harang discontinuity region [7].

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The Dome C North radar: first light.

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The Dome C North radar (DCN) is located nearby the Dome C East radar at the Concordia research station in proximity of the Southern geomagnetic pole.

The installation of DCN was completed during the 2018-2019 Antarctic Campaign and first light was in January 17, 2019.

We present some initial observations and the status of the radar.

The search for ion-neutral coupling and Joule heating in the polar cap

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It is commonly postulated that thermal expansion of the neutral atmosphere due to Joule heating may be responsible for anomalously-large neutral densities experienced by satellites near the Earth's poles.

Direct measurements of Joule heating rates are difficult due to the dependence on the neutral wind, and .

In a recent paper, we investigated heating rates in the auroral regions using neutral measurements from the Poker Flat Scanning Doppler Imager (SDI) and ion velocities from SuperDARN.

We have now applied that technique to data from the Antarctic SDIs in order to better study ion-neutral coupling and Joule heating in the polar cap.

Preliminary results suggest that ion-neutral coupling is much less common due to lower ion velocities and less precipitation outside of the auroral region however, the stronger neutral winds due to thermal gradients across the pole serve to buoy the Joule heating rate even when ion velocities are small.

We present ion-neutral coupling and Joule heating measurements during both isolated and extended periods of geomagnetic activity.

Transient ionospheric convection associated with magnetospheric sudden compression as observed by SuperDARN radar

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Ionospheric convection measurements just after an interplanetary (IP) shock impingement is investigated by coordinated SuperDARN radars in southern hemisphere.

KER radar, scanning over Zhongshan station in cusp ionosphere and monitoring into polar cap ionosphere, observed sudden disappear of radar backscatter echoes in far ranges between 2500km (55 gate) and 3200km (70 gate) after the IP shock arrival identified by the onset of a sudden impulse (SI) event.

This disappearance of radar echo lasted approximately 10 min with subsequent reappearing power echoes.

Coordinated ionospheric observation by ZHO radar covering postnoon sector showed significant and prompt plasma flow reversal from large positive (toward radar) to moderate negative (away fromradar) value.

It is concurrently found that the number of echoes decreased dramatically after SI, but with enhanced Doppler spectral width observed by ZHO radar.

Simultaneously, plasma flow reversed from antisunward to sunward just after SI onset in the central polar cap.

This midday transient decrease of SuperDARN backscatter just after SI is suggested to be a result of the absorption of the HF radio signal by the enhanced energetic electron precipitation in the cusp region under strong M-I coupling, and ionospheric convection flow reversal in central polar cap caused by high-latitude magnetopause reconnection process triggered by the prompt compression.

Using Tauscan-11 to Measure Phi0

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1. Virginia Tech

This paper is a continuation of the previous report on ionospheric measurements with SuperDARN radars using the Tauscan-11 multipulse sequence.

In this case, the discussion will focus on the determination of phi0 at the Saskatoon radar.

Measurements of phi0 have always been difficult because inadvertent changing of even one cable inside the radar building can lead to phase shifts that significantly alter elevation angle determinations.

However, we are not interested in offsets in phi0, but rather the stability with which this parameter can be determined.

Phi0 is defined as the offset between lag0 of the ACF and XCF, but if everything is well-determined, the same offset should be measured at each lag-pair of the ACF and XCF.

For several reasons, including the smaller size and larger beam width of the interferometer array, this need not be the case.

Differences in the phase measurements can result in errors in the determination of phi0.

The quality of phi0 measurements are defined as the root-mean-square difference between the median phase offset and the observed phase offset measured at each good lag of the XCF and ACF. In general, this quality parameter is somewhat larger than the quality parameter associated with Doppler velocity measurements.

We shall present results from the Saskatoon phi0 measurements of March 14, 2019 including plots of range-time-phi0, plots of ACF and XCF phase, and plots of range-time-rms_xphase_err.

These results will be compared with prior measurements of phi0 using the Saskatoon radar and reasons for any observed differences will be discussed.

Validation of the SuperDARN range-finding algorithms in the polar cap

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In the absence of strong horizontal gradient in the electron density, knowledge of the group delay and the elevation angle of radar returns is sufficient for determining the range to the ground footprint of the ionospheric scatter point.

Unfortunately, the intrinsic technical difficulties with accurate calibration of SuperDARN interferometry forced to replace observational elevation angle data with those derived from virtual scatter height models.

The original approach postulated constant virtual heights for the E and F layer echoes and provided satisfactory accuracy for mapping large-scale plasma circulation features.

Later on, the necessity of comparing SuperDARN data with other instruments required more accurate mapping and stimulated development of a more accurate empiric model based on the elevation angle data from the Saskatoon radar [Chisham et al, 2008].

Poleward and equatorward expansion of the network, which started in mid-2000s, required validation of the existing range-finding algorithms in the polar and mid-latitude regions.

However, systematic evaluation of the virtual height models has become possible only recently with the advent of reliable elevation angle calibration techniques [Chisham, 2018 Ponomarenko et al., 2018].

In this work, we applied the Ponomarenko et al [2018] technique to two-frequency data from the PolarDARN Rankin Inlet radar in order to analyse diurnal, seasonal and solar cycle variations in the elevation angle as a function of the group range.

This analysis allowed identification of the main propagation modes and provided estimates of the range-finding errors introduced by the virtual height models.

The study was restricted to group ranges < 2000 km due to the scarcity of the ionospheric returns at farther ranges.

For the F layer echoes, Pedersen mode tends to dominate summer daytime propagation while the low-angle mode is typical for winter and nighttime conditions.

Both original and Chisham models overestimate the ground range under daytime conditions with maximum deviation exceeding 200 km during solar maximum.

While the Chisham model shows comparatively smaller range offsets, they regularly exceed one range gate.

During nighttime, the conventional model still overestimates the ground range, although to a lesser extent, but the Chisham model tends to underestimate it, especially under solar minimum conditions.

Based on the obtained results, we discuss possible ways of improving SuperDARN range-finding algorithms.

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Variations in occurrence of polar cap SuperDARN echoes and their causes

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Observations by six Super Dual Auroral Radar Network (SuperDARN) polar cap radars, three in the Northern hemisphere and three in the Southern hemispheres, are considered to assess F region echo occurrence rates over solar, season, and day cycles and to establish relationship between the echo occurrence rate and the background electron density and plasma flow velocity magnitude.

The echo occurrence rate is shown to increase toward the solar cycle maximum, more distinctly on the nightside, consistent with a general trend of the background electron density.

Over the last five years, the echo occurrence rates decline at a rate of 5-7% per year.

The pattern of seasonal and diurnal variations in echo occurrence is found to be consistent with previous SuperDARN publications.

In winter solstices, minor dips in echo occurrence rate occur, and these are related to overall decrease in the electron density.

In most of time sectors, the echo occurrence rate increases with the electron density but only up to a certain threshold value after which the dependence saturates.

The level of the saturation depends on season, local time and average plasma flow velocity magnitude. For the summer daytime observations, the echo occurrence rate correlates with variations of both electron density and plasma flow velocity magnitude.

Variations in PolarDARN Doppler characteristics Angeline

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Doppler spread, a measure of broadening of the Doppler spectrum, can be caused by hardware considerations such as the radar resolution and length of the integration time, as well as geophysical conditions such as velocity gradients, vertical ionospheric motion, and the turbulent motion induced by plasma instability mechanisms.

Previous statistical studies have found a strong dependence of Doppler spread from ionospheric backscatter on location and time.

Here we examine the variations of the Doppler spread and other Doppler characteristics of both ionospheric and ground backscatter as functions of local time, location, and season.

Velocity of SuperDARN echoes at intermediate radar ranges

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It is established that the velocity of SuperDARN HF echoes at short ranges of <600 km (E region) is substantially smaller than the line-of-sight (LOS) component of the ExB plasma drift while at far ranges of >1200 km (F region) it is close to the ExB drift.

At intermediate ranges, SuperDARN echoes can be detected from either E region or F region or from both simultaneously, and the relationship of the echo velocity with the ExB plasma drift is less clear. In this study, we consider one fortunate period on 6 March 2016 when the RISR-C incoherent scatter radar monitored the plasma drift along Rankin Inlet (RKN) beam 5, and HF echoes were present in a wide band stretching from ~500 km to ~1000 km. At short ranges, the RKN velocities were below, or equal to, the nominal ion-acoustic speed of the E region plasma Cs.

At far ranges, the RKN velocities were close to the ExB drift LOS component, as expected. At intermediate ranges, the velocities were either close to the Cs or the ExB drift component, depending on range and HF radar frequency used.

We show that the boundary between E and F region echo detection is very dynamic reflecting, very likely, quickly changing radio wave propagation conditions in the ionosphere.

We discuss implications of the reported observations for the plasma physics of E region irregularity formation and for the ExB vector derivation with the SuperDARN radars.

Where are we now? Moving towards adaptive, high-latitude coordinates

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The high latitude atmosphere is a dynamic region with processes that respond to forcing from the Sun, magnetosphere, neutral atmosphere, and ionosphere.

Historically, the dominance of magnetosphere-ionosphere interactions has motivated upper atmospheric studies to use magnetic coordinates when examining thermospheric and atmospheric processes.

However, there are significant differences between the dominant interactions within the polar cap, auroral oval, and equatorward of the auroral oval.

Locating data within these boundaries has been shown to improve climatological and statistical studies, but the process of doing so is complicated by the shifting nature of the auroral oval and the difficulty in measuring its poleward and equatorward boundaries.

We present several advances that will aid researchers seeking to use adaptive, high latitude coordinates in their studies.

These include expanding the existing database of Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) far ultraviolet (FUV) open-closed field-line boundaries (OCBs) to include equatorward auroral oval boundaries, creating a new set of OCBs from the Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE) field-aligned current boundaries, and a software tool to convert between adaptive, high-latitude coordinates (with either only an OCB or both an OCB and equatorward auroral boundary) and geographic or magnetic coordinates.