SuperDARN

SuperDARN workshop 2015

31 May – 5 June, Leicester, UK

College Court Conference Centre
Knighton Rd, Leicester LE2 3UF, UK

Radio and Space Plasma Physics
University of Leicester

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Measurements of HF Radar Propagation from Low-Drag Satellites Flying Below The F-Region Ionosphere

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The NRL CARINA Program will place two spacecraft into limited life (45 to 60 day) earth orbits (LLEO) in the 150 to 250 km altitude range. The CARINA spacecraft will explore the lower thermosphere with direct, in situ observations and will be able investigate both sporadic-E layers below the payload and F-region structures above the payload using HF radio propagation from ground transmitters like SuperDARN. The CARINA spacecraft are cylinders with fins and they each have a large mass (200 kg) and low drag area (0.05 sq-m). CARINA is powered by primary cell batteries without recharging for over 45 days. Telemetry downloads occur twice a day with up to 20 GBytes per pass over a ground telemetry station. The sensors for the first CARINA mission are the orbiting GPS receiver (OGR), ram Langmuir probe (RLP) and an electric field instrument (EFI) covering the high frequency (3 to 13 MHz) range. The unique measurements with the CARINA payload include (1) direct fly-through of the regions of the ionosphere modified by high power radio waves, (2) tomographic mapping Sporadic-E layers using ground HF radio beacons, (3) detection of the ionospheric coupling of extreme ocean storms using HF radar surface wave sea scatter to the CARINA receiver, (4) monitoring of travelling ionospheric disturbances in the lower thermosphere by employing in situ plasma probes and orbiting GPS TEC receivers, and (5) detecting electric field transients from terrestrial lightning that can drive space-plasma fluctuations. Subionospheric CARINA experiments will expand the knowledge of lower thermospheric science at all latitudes and enhance our understanding of the direct coupling between large scale terrestrial disturbances and bottomside ionosphere. The first two CARINA payloads scheduled for launch in June 2016 into an orbit with 51.6 degrees inclination. International collaborations with complementary ground instruments and interested science teams are currently being built.

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The Charged Aerosol Release Experiment (Care II) for Investigation of Rocket Exhaust Interactions with the Ionosphere

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In September 2015, a sounding rocket launched from Andoya, Norway will carry 37 rocket motors and a multi-instrument daughter payload into the ionosphere to study the generation of plasma wave electric fields and ionospheric density disturbances by the high-speed injection of dust particles. A primary sensor for the Charged Aerosol Release Experiment (CARE II) will be the two SuperDARN CUTLASS radars that view the ocean north of Norway. The rocket motors firing simultaneously will produce 66 kg of micron-sized dust particles composed of aluminium oxide. In addition to the dust, simple molecular combustion products such as N2, H2, CO2, CO, H20 and NO will be injected into the F-layer. Charging of the dust and ion charge exchange with the molecules will produce plasma particles moving at hypersonic velocities. Streaming instabilities and shear electric fields will yield plasma turbulence that can be detected using ground radars and in situ plasma instruments. The instrument payload will be separated from the chemical release payload soon after launch to measure electric field vectors, electron and ion densities, and integrated electron densities from the rocket to the ground. The chemical release of high speed dust will be directed upward on the downleg of the rocket trajectory to intersect the bottomside of the F-Layer. The instrument section will be about 500 meters from the dust injection module at the release time. Ground HF and UHF radars will be operated to detect scatter and refraction by the modified ionosphere. Optical instruments will be used to map the dispersal of the dust using scattered sunlight. The plasma interactions are being simulated with both fluid and particle-in-cell (PIC) codes. CARE II is a follow-on to the CARE I rocket experiment conducted from Wallops Island Virginia in September 2009.

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Spatial and temporal structure of Pc5 ULF waves at high latitudes and in the polar cap

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We recently developed a technique for automatically identifying signatures of ultra-low frequency (ULF) oscillations in SuperDARN radar data. In this talk we provide a detailed analysis of two Pc5 oscillation events that were identified using our technique. The first event is a field line resonance observed simultaneously by two SuperDARN radars in a common geographical region. We combine the line-of-sight velocity measurements from each radar to obtain a more detailed picture of the spatial structure of the resonance event, including the wave polarisation direction. The second event was observed directly over the south magnetic pole using ionospheric backscatter returns from the McMurdo SuperDARN radar. These oscillations exhibit high coherence with ground magnetometer data and share many common features with auroral Pc5 ULF waves. The source of these oscillations is still under investigation.

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Experimental determination of the maximum range of the Buckland Park SuperDARN radar

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The Buckland Park radar, located near Adelaide, South Australia, was designed to detect backscatter from ranges up to approximately 5000km. Recent experiments, however, have shown that the radar routinely detects backscatter from longer ranges, up to about 8000km, and occasionally beyond. This result opens up new research opportunities for studying ionospheric phenomena from middle to polar latitudes using a single instrument. Backscatter from these very long ranges has been observed over the full frequency range of the radar but has been most commonly observed at higher frequencies. Our results highlight the importance of considering the capability of the radar hardware, in particular transmit power and receiver sensitivity, when defining the number of range gates and the multi-pulse increment (tau) in radar control programs. We recommend that similar experiments be conducted on other SuperDARN radars to determine whether the standard number of range gates needs to be revised.

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High-resolution vector velocity determinations from SuperDARN

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The potential mapping technique of Ruohoniemi and Baker [1998] provides global-scale patterns of the electrostatic potential based upon a fit of spherical-harmonics constrained by all available line-of-sight (LOS) observations and empirical model patterns keyed to the IMF. The finite order of the fitting limits the minimum size of features that can be represented in the resulting patterns. The result is that fine-scale features of the observations become essentially low-pass filtered.

This paper presents a technique for producing localized patterns with higher resolution than provided by the global-scale potential mapping. Vectors are generated using the full resolution of available LOS observations. Each local vector is determined based upon local observations. In addition to the LOS observations the fit is constrained by the global-scale pattern within the region, the requirement to produce a divergence free velocity field, and if desired, a smoothness criterion.

Initial results are presented along with overlays with all-sky imager observations to illustrate the correspondence of the velocity field to the auroral observations. Velocity vectors show a clear response to auroral arcs propagating through the field of view.

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Techniques to improve the angle-of-arrival calculations at high-frequency radars

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Elevation angles of returned backscatter are calculated at SuperDARN radars using interferometric techniques. These elevation angles allow the altitude of the reflection point to be determined, an essential piece of information for many ionospheric studies. The elevation angle calculation requires knowledge of several quantities, including the direction of arrival, the distance between the main and interferometer arrays, and any delays introduced by the hardware. One of these delays, the difference between signal travel times from the main array and the interferometer (TDIFF), is currently recorded as a single value in the hardware files, though it is known to have a frequency dependence. This introduces errors of several degrees into the elevation angle calculations. We present a method for estimating TDIFF at any SuperDARN radar using the observed meteor ablation, as well as a method of automatically determining whether backscatter returns originate from in front of or behind the radar.

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Solar cycle variations in the northern polar ionosphere

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The polar ionosphere is a dynamic region that readily responds to changes in solar irradiance, solar wind, the magnetosphere, and the neutral atmosphere. The most recent solar minimum brought to light gaps in the current understanding of the relationship between ionospheric structure and solar irradiance. The Super Dual Auroral Radar Network (SuperDARN) offers an invaluable dataset for studying long-term ionospheric variability at polar latitudes, as it has been continuously providing extensive coverage since 1995 (the solar minimum preceding the 23rd solar cycle). An under-utilised portion of the SuperDARN dataset is the ground-backscatter: the backscatter that returns from a reflection point on the ground along an open (or irregularity-free) propagation path. The ground-backscatter provides a measure the ionospheric density at the peak of the radar signal's path. These measurements are used to examine the solar cycle variations in the bottomside ionosphere at northern, polar latitudes.

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Dayside reconnection under IMF By dominated conditions: bending arcs, a reinterpretation

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Based upon a survey of global auroral images collected by the Polar UVI instrument, Kullen et al. 2002 subdivided polar cap auroral arcs into a number of categories, including that of `bending' arcs. We are concerned with those bending arcs that appear as a bifurcation of the dayside auroral oval, and which subsequently form a spur intruding into the polar cap. Once formed the spur moves polewards and antisunwards over the lifetime of the arc. We propose that dayside bending arcs are ionospheric signatures of pulsed dayside reconnection, and are therefore part of a group of transient phenomena associated with flux transfer events. We observe the formation and subsequent motion of a bending arc across the polar cap during a 30 minute interval on 8 January 1999, and we show that this example is consistent with the proposed model. We quantify the motion of the arc, and find it to be commensurate with the convection flows observed by both ground-based radar observations and space-based particle flow measurements. In addition, precipitating particles coincident with the arc appear to occur along open field lines, lending further support to the model.

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Simultaneous ground-based optical and HF radar observations of the ionospheric footprint of open/closed field line boundaries along meridian line

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Previous studies have confirmed that both the equatorward boundaries of OI 630 nm auroral emission and broad spectral width produced by the Super Dual Auroral Radar Network (SuperDARN) can be used as a good empirical proxy for the ionospheric footprint of the open/closed field line boundary (OCB) on the dayside. The existence of mapping location errors, however, is partly from the SuperDARN HF radar standard range finding algorithm; the understanding of how the mapping location error response to the background ionosphere condition and dayside reconnection activity is not clear completed. The settled optical instruments, such as meridian-scanning photometer (MSP) at Longyearbyen, Svalbard, at near zenith, have much higher spatial resolution than the SuperDARN HF radar common mode, and mapping errors of assumed OI 630 nm auroral emission height can be estimated. In this work, CUTLASS Finland radar range gates backscatter along the MSP meridian line were selected. An adjusted algorithm for synchronous identifying HF radar ionospheric backscatter boundary is introduced. The latitude boundary difference of HF radar ionospheric backscatter with the simultaneously observed OI 630 nm auroral emission is compared. A direct correlation of the mapping location offsets which relate to background ionospheric electron density is confirmed. While the intake of solar EUV ionized high density plasma from sub-auroral latitude will make lower ray path refracted, and finally cause more HF radar range overestimated.

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Scheduling working group report

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Highlights of the year in the SuperDARN scheduling world.

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Maps of average ionospheric vorticity ordered by relationship with the open-closed magnetic field line boundary

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Spatiotemporal variations of ionospheric vorticity are a measure of the dynamical coupling of the magnetosphere to the ionosphere via magnetic field-aligned currents (FACs). Indeed, ionospheric vorticity measurements have often been used as proxy measurements for FACs. Previously, we have determined statistical models of ionospheric vorticity using 6 years of ionospheric convection velocity measurements made by the SuperDARN HF radar network in the northern hemisphere ionosphere and shown that the spatial variation of these probability distributions is well organised according to the well-established large-scale FAC structure in the polar ionosphere. However, to date, these statistical models have been parameterised solely by the state of the interplanetary magnetic field (IMF), and as such do not account for the range of polar cap sizes that occur for a single IMF state. This leads to a distortion of the shape of the resulting statistical maps that makes features in the statistical variations appear smoother than those in instantaneous/short-time averaged measurements. This is because the averaging process does not consider the variable size of the polar cap, by which spatial features in the ionospheric vorticity variation are ordered. Using open-closed magnetic field line boundary measurements determined from FUV imager data from the IMAGE spacecraft, we investigate the parameterisation of the statistical ionospheric vorticity models with polar cap size in addition to the state of the IMF. The results of this analysis have implications for other statistical models determined in this way, such as those for FACs and ionospheric convection.

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Polar cap plasma density variations and their impact as scintillation sources

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Using field-aligned current data we monitor the location of the region 1 current oval which is related to the location of the polar cap boundary (PCB). We identify intervals when the current oval and hence the PCB first moved equatorward and subsequently contracted back poleward. We find 490 such events between 2010 and 2012 and go on to study the dynamics of the total electron content in the high-latitude region in a superposed epoch sense. Immediately after the beginning of the expansion a plasma density increase formed at the poleward edge of the PCB and its edge moved from the location of the dayside PCB anti-sunward at speeds of about 500 m/s, consistent with ionospheric convection measurements. Our results show that the plasma density inside the polar cap locally increased by up to 20%. Averaged over the entire polar region poleward of 55 degree magnetic latitude, however, we find no significant increase in the plasma density, indicating that local increases and decreases were formed by transport and rearrangement of existing plasma rather than by impact ionization due to particle precipitation. Furthermore, the plasma density enhancement was structured, suggesting that it consisted of individual polar cap patches. We go on to study the scintillation impact of the electron density enhancement in the polar cap and find none, somewhat contrary to the believe that polar cap patches present a challenge for global navigation satellite systems.

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Outflow of heavy ions from the earth's upper atmosphere

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Plasmas entering the magnetosphere from the upper atmosphere play a very important role in altering the global magnetospheric dynamics. Landmark papers claim that mechanisms responsible for these upwellings and outflows include electron precipitation, joule heating and other suprethermal energization. Over seven hundred events of upwelling ions were identified from observations by the EISCAT Svalbard Radar (ESR) during the international polar year (IPY) of 2007. Analysis showed that the distribution of high velocity (> 200 ms-1) events in conjunction with Kp ≥ 4 is peaked around local noon while other upwellings of moderate and low velocities with same range of Kp is skewed towards the night-side. In addition, ion fluxes of the order ≥ 10^{13} m^{-2} s^{-1} cut across the altitude range of 100 – 500 km with over 75% occurring at altitudes ≥ 300 km. Furthermore, the case study of seven outflows was considered at a time that the Fast Auroral SnapshoT (FAST) satellite and ESR simultaneously detected ion upflow, and this is validated by CUTLASS ground based radar measurements. The results show that ESR observed upwelling ion fluxes of ~10^{13} m^{-2} s^{-1}. Enhanced electron and ion temperatures are also observed at the time of these events. The dominant mechanism identified is the electron precipitation which, it is suggested, leads to the creation of an ambipolar electric field, an increase in the ion scale height and ion upwelling as a result. The two striking events are clearly associated with the cusp identified by CUTLASS and a substorm onset identified by magnetometers.

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The interaction between transpolar arcs and cusp spots

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Transpolar arcs and cusp spots are both auroral phenomena that occur within the polar cap (i.e. poleward of the main auroral oval) during periods when the interplanetary magnetic field is northward. Transpolar arcs are large-scale auroral features which extend from the night side oval towards the dayside, often connecting to the dayside oval; they are formed by the closure of lobe flux by magnetotail reconnection, and hence indicate the 'trapping' of closed magnetic flux which is embedded within the lobe. When a transpolar arc does connect to the day side oval, this indicates that all of the magnetic flux in a narrow local time sector in the magnetotail is closed. Cusp spots are emissions at the footprint of a lobe reconnection site; hence they indicate the occurrence of lobe reconnection, most likely in a single hemisphere. Single lobe reconnection redistributes open magnetic flux in the lobe, causing flows in the lobe and polar cap; a key feature of single lobe reconnection is that it does not change the net topology of the magnetic flux in the magnetosphere (i.e. there is no net opening or closure of flux). However, the two phenomena are linked, as the circulation of lobe magnetic flux instigated by lobe reconnection causes the motion of transpolar arcs. We present observations from the IMAGE satellite on 15th September 2005, during which time a transpolar arc is observed to intersect a cusp spot. We argue that since the motion of transpolar arcs and the occurrence of cusp spots are both manifestations of lobe reconnection, the simultaneous occurrence of both should not be unusual. We demonstrate that when this interaction occurs, the topologies associated with single lobe reconnection change, and hence it has the net effect of opening closed magnetic flux in the magnetotail, contrary to the usual scenario for lobe reconnection.

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Interhemispheric differences of the high-latitude ionospheric convection patterns deduced from Cluster EDI observations over a full solar cycle

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We present a study of ionospheric convection at high latitudes that is based on satellite measurements of the Electron Drift Instrument (EDI) on-board the Cluster satellites, which were obtained over a full solar cycle (2001-2014). The mapped drift measurements are covering both hemispheres and a variety of different solar wind and interplanetary magnetic field (IMF) conditions. The large amount of data allows us to perform more detailed statistical studies. We show that flow patterns and polar cap potentials can differ between the two hemispheres on statistical average for a given IMF orientation. In particular, during southward directed IMF conditions, and thus enhanced energy input from the solar wind, we find that the southern polar cap has a higher cross polar cap potential. We also find persistent north-south asymmetries which cannot be explained by external drivers alone. Much of these asymmetries can probably be explained by significant differences in the strength and configuration of the geomagnetic field between the Northern and Southern Hemisphere. Since the ionosphere is magnetically connected to the magnetosphere, this difference will also be reflected in the magnetosphere in the form of different feedback from the two hemispheres. Consequently, local ionospheric conditions and the geomagnetic field configuration are important for north-south asymmetries in large regions of geospace. The average convection is higher during periods with high solar activity. Although local ionospheric conditions may play a role, we mainly attribute this to higher geomagnetic activity due to enhanced solar wind - magnetosphere interactions.

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Effects of the 20 March 2015 total solar eclipse on the ionosphere-thermosphere system

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A total solar eclipse is a spectacular natural phenomenon whose consequences over the underlying ionosphere and thermosphere remain complex and not fully explained, and which rarely occurs at high latitudes. On 20 March 2015, a total solar eclipse passed over the Atlantic Ocean, then over Svalbard to finally reach the north pole. These specific regions are extremely interesting as the corresponding ionosphere extends from midlatitudes to the polar cap. In addition, the eclipse path was covered by a large panel of ground-based instruments: the SuperDARN radars of Wallops Island, Pykkvibaer and Hankasalmi, incoherent scatter radars on Svalbard and in Tromsø (EISCAT Svalbard radar and EISCAT mainland), as well as magnetometers, ionosondes and imaging instruments. We take advantage of this excellent instrumental configuration coupled with results from detailed ionosphere models to study the dynamic consequences of this eclipse on the underlying ionosphere and thermosphere. In particular, we have run specific scanning modes on the SuperDARN radars in order to identify a possible generation of Atmospheric Gravity Waves (AGW) caused by the eclipse.

We present the observations of the different instruments and compare them with initial simulations made with the TRANSCAR ionosphere model. First results indicate that the effects on the high-latitude ionosphere were mostly observed above Tromsø. We plan to run additional numerical simulations with convection maps given by SuperDARN and using the latest parallel version of TRANSCAR which enables multi-tube computation. A possible influence of the solar corona during the eclipse totality is also studied with the model, and, as this eclipse is first located on closed field lines, we also investigate the potential exchange of energy and particle fluxes with the opposite sunlit hemisphere by running the interhemispheric version of TRANSCAR. Finally, we discuss the possible signatures of the eclipse in the SuperDARN observations.

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2-Parameter analysis software: A davitpy-based training tool for understanding how the time-dependent ionosphere impacts propagation and our measurements

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In this session, we demonstrate recently-developed davitpy software that uses the ray-tracing analysis developed by Sebastien de Larquier (Ph.D. Virginia Tech, 2014) to provide input parameters for various SuperDARN geolocation algorithms and compare the products of these algorithms with similar products from ray tracing. The ray-tracing analysis uses the International Reference Ionosphere (IRI), which is a time-dependent empirical model that, on average, accurately represents the diurnal, seasonal, and solar cycle dependencies of the actual ionosphere. Hence, the ray-tracing software is capable of investigating ionospheric propagation under a wide range of ionospheric conditions using an extended range of radar operating frequencies. In its current form, the ray-tracing analysis is limited to ½-hop backscatter on any beam of any northern hemisphere SuperDARN radar. The rays are typically traced as a function of group range and initial elevation angle of the ray. The most important output parameters are the great circle distance to the point on the Earth's surface that lies under the scattering volume, the geographic location of this ground point, and the refractive index of the scattering volume. Other outputs that either are or could be derived include the plasma frequency or electron density in the scattering volume, the virtual height of the scattering volume, and the inclination of the magnetic field in the plane of propagation. Using the group range associated with SuperDARN data, common SuperDARN geolocation techniques, such as the Standard and Chisham Methods, place SuperDARN measurements onto a geographic grid. Observations from two distinct radars within the same grid cell can be used to calculate a velocity vector, or observations from the full ensemble of radars can be used to determine a Map Potential pattern. The question arises as to how accurately this placement of SuperDARN data is done. In the 2-Parameter analysis software, we use the ray tracing products as data for the geolocation algorithms. For the Standard and Chisham Methods, the only input data required is the group range, since the assumptions or averages used in these models have already specified the virtual height or, equivalently, the initial elevation angle. Thus, the great circle distances derived from the Standard and Chisham methods can be compared directly with the same parameter derived from ray tracing and a comprehensive statistical estimation of differences or errors can be determined. The same type of analysis can be applied to the new 2-Parameter geolocation analysis, only in this case the required input parameters include the group range and the initial elevation angle. In this case, the statistical estimation of differences or errors is approximately an order of magnitude smaller than the errors for the Standard and Chisham Methods. The difference arises because the initial elevation angle is a critically important parameter that cannot be estimated by averaging a large amount of data or guessing. The error in estimation of great circle distance becomes exceptionally large if the radar is operated at lower frequencies during daytime hours. The 2-Parameter Method also provides a pathway for determining the refractive index. Estimates of this parameter are generally within ~1% of the ray-tracing determinations that are derived directly from the IRI model. Visitors to this demonstration will be able to test this software under different ionospheric conditions and as it is applied to any NH radar of interest.

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Using ray tracing to evaluate the performance of various methods for predicting the location of ionospheric scattering volumes and their refractive indices

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Over the past two years a new technique for determining the location and refractive index of ionospheric scattering volumes has been under development at Virginia Tech. This technique, which we refer to as the 2-Parameter Method, will eventually use observations of the group delay and elevation angle of backscattered signals to make these determinations. At the present time, it is being tested by evaluating its consistency with 2-D ray-tracing software developed by Sebastien de Larquier (Ph.D. Virginia Tech, 2014). The software uses the International Reference Ionosphere (IRI) and is capable of predicting propagation in an ionosphere that displays diurnal, seasonal, and solar cycle variations. Ray tracings are carried out as a function of group range and initial elevation angle and data products include determinations of the great circle distance to and refractive index of each scattering volume. These products are important within the context of SuperDARN since they identify where the measurements are being made and what the refractive index and electron density are in each scattering volume. In this paper, we use the group ranges of scattering volumes identified from ray tracing as inputs to the SuperDARN Standard and Chisham Methods. The great-circle distances predicted by these methods are then compared with the results from ray tracing. We also use the group ranges and initial elevation angles obtained from ray tracing as inputs to the 2-Parameter Method and obtain its predictions for the great-circle distance and refractive index of each scattering volume. These predictions are also compared with ray tracing results. Our results, to date, have been limited to ½-hop ionospheric backscatter, but they show that the 2-Parameter method is far superior to either the Standard or Chisham Methods for determining the great circle distance to ionospheric scattering volumes and can also determine the refractive index of ionospheric scatter volumes with high accuracy. The following table shows typical differences between ray tracing determinations of the great circle distance to ½-hop ionospheric scattering volumes and the predictions of the same parameter using the Standard, Chisham, and 2-Parameter Methods. The table also shows the agreement between the 2-Parameter determination of refractive index and that obtained from the IRI model used in the ray tracing. These particular results are associated with post-sunset measurements by the Saskatoon radar and are typical of what has been obtained for a number of northern-hemisphere SuperDARN radars for different local times and viewing directions:

Method	Parameter	Negative Limit (km)	Positive Limit (km)	σ (km)
Standard	Lgc	-146	55	43
Chisham	Lgc	-90	67	51
2-Parameter	Lgc	-3	11	3.5
2-Parameter	N_r (unit-less)	-.006	.012	.004

Negative differences occur when the ray-tracing solution is less than the method solution. Positive differences occur when the ray tracing value is larger. These results demonstrate that two parameters must be known for accurate location of ionospheric scattering volumes: Group range and a second quantity that can either be the elevation angle of the transmitted or received signal, or the virtual height. However, the state of the second quantity must be known or measured. It cannot be estimated or derived from averaging measurements obtained under different ionospheric conditions.

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Comparative space weather climatologies derived using the SuperDARN Map Potential algorithm.

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SuperDARN is one of a number of space physics facilities that has an extensive data archive spanning more than a solar cycle. These databases are increasingly being put to use to study long-term trends in the solar-terrestrial interaction and to derive system-level space weather climatologies. It has been well demonstrated that significant benefits can be derived from the combination of complimentary datasets from different sources, although this process is often hampered by inherent differences in the data such as temporal and spatial resolutions, geographical and geophysical locations, and analysis techniques. To investigate a means to mitigate some of these constraints, we have performed an experiment utilising the SuperDARN map potential algorithm to produce climatological patterns of convection, ground magnetic disturbance, and auroral morphology using data from SuperDARN, SuperMAG, and the Cluster and IMAGE spacecraft. Here we present a comparative analysis of these initial results.

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Inferring vertical plasma motion with SuperDARN ?

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Every day the Earth looses a significant amount of plasma through ion and electron outflow from the polar cap regions. This upflow and outflow represent a vertical motion of plasma. Due to the low energy of the outflowing ions and electrons, direct measurements of this outflow is notoriously difficult. SuperDARN observes the motion of plasma irregularities along the line-of-sight (LOS) of the radar beam in the terrestrial ionosphere. Typically, only the horizontal component of the plasma motion is considered, though. In this presentation, which is more a challenge to the SuperDARN community, we ask whether it would be feasible to utilize SuperDARN to infer vertical motion of plasma above the polar caps, and whether such studies have been conducted. We put forward two ideas; First, a direct measurement utilizing the vertical component of the motion along the LOS. The second suggested approach is to utilize the vorticity in the horizontal plasma motion. We ask the SuperDARN community for comments and feedback about the feasibility of these methods.

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The ERG project: Current status and related scientific activities

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The ERG (Exploration of energization and Radiation in Geospace) is a Japanese geospace exploration project and its scientific goal is comprehensive understanding of geospace storm with a special focus on dynamical evolution of the radiation belts around the Earth. The core component of the project is the ERG satellite carrying the full set of scientific instruments for plasma/particles, electric/magnetic field, and plasma waves provided by both domestic and foreign institutes/universities. The satellite has been being developed by the Institute of Space and Astronautical Science (ISAS) / Japan Aerospace Exploration Agency (JAXA). Currently the launch window of the satellite is set during summer in 2016. Toward the successful launch, the integrated test of the satellite has been being carried out since last October until the satellite is shipped to the launch site in 2016. Besides the satellite development, the ground-based observation team runs on their own and coordinates the multipoint ground-based observation network of magnetometers, radars, imagers, and so forth. The ground network observation will play a crucial role in capturing the global picture of geospace dynamics, which is combined with the in situ satellite observation. These observations can be interpreted extensively in virtue of numerical simulations/modeling provided by the integrated data analysis/simulation team. ERG Science Center (ERG-SC) has been actively working on promoting close collaborations of these teams and other collaborating/partner projects and thereby maximize the science achievement out of the ERG project. ERG-SC will also act as a science data center for the ERG project by providing the international research community with various kinds of the project science data in the standardized Common Data Format (CDF) as well as the integrated data analysis tools based on the Space Physics Environment Data Analysis Software (SPEDAS) formerly known as the THEMIS data analysis software (TDAS). Among the ERG-related scientific activities, recently the Japanese SuperDARN group, some researchers and students have joined to start the ERG-SuperDARN collaboration task team. In this task team, we have been discussing scientific strategies with ERG and SuperDARN and also seeks to propose various collaborative observations with ERG-satellite/ground.

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IMF-By dependence of transient ionospheric flow perturbation associated with sudden impulses: SuperDARN observations

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A statistical study using a large data set of Super Dual Auroral Radar Network (SuperDARN) observations is conducted for transient ionospheric plasma flows associated with sudden impulses (SI) recorded on ground magnetic field. The global structure of twin vortex-like ionospheric flows is found to be consistent with the twin vortices of ionospheric Hall current deduced by the past geomagnetic field observations. An interesting feature, which is focused on in this study, is that the flow structures show a dawn-dusk asymmetry depending on the combination of the polarity of SI and IMF-By. Detailed statistics of the SuperDARN observations reveals that the dawn-dusk asymmetry of flow vortices due to IMF-By appear during negative SIs, while the flow vortices are fairly symmetric during positive SIs, regardless of IMF-By polarity. On the basis of the upstream observations, we suggest that this particular dawn-dusk asymmetry is caused by the interaction between the pre-existing round convection cell and a pair of the transient convection vortices associated with SIs.

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Abstract

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Stagnation of a polar cap patch and decay of the accompanying plasma irregularities

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We report an event in which a polar cap patch, as detected by an all-sky imager (ASI) at Resolute Bay, Canada (74.73N, 265.07E; AACGM latitude 82.9), stopped its anti-sunward motion and wandered around within the field-of-view of the ASI for more than 1 h. During the wandering motion of the patch, a significant reduction of the cross-polar cap plasma convection was observed by the SuperDARN radars. 10-15 min before the stop of the patch, the IMF observed by the Geotail spacecraft showed a clear northward turning. Such a change in the IMF orientation could lead to the halt of the cross-polar cap convection and resultant stagnation of the patch. The 10-15 min delay between the northward turning of the IMF and the stopping of the patch suggests that the response of the nightside polar cap convection to the change in the upstream IMF orientation is not instantaneous but requires a certain equilibrium time for the dayside equatorial reconnection-driven excitation of twin-cell flow to propagate toward the nightside. During the interval of interest, one of the SuperDARN radars at Rankin Inlet, Canada observed a cluster of field-aligned irregularities (FAIs) in the region of enhanced 630.0 nm airglow associated with the patch. These patch-associated FAIs promptly decayed following the weakening of the optical patch, which was obviously due to a convolution effect of the decrease in the patch-associated density gradient and the reduction in the background convection caused by the northward turning of the IMF. However, the decay of the FAIs was much quicker than that of the optical patch. This suggests that the abrupt reduction of the convection probably played a more important role than the gradual decrease of the patch-associated density gradient in causing the prompt decay of the patch-associated FAIs. This indicates that the strength of the background electric field is very crucial in maintaining small-scale density structures in the polar cap.

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Hemispheric asymmetry of the structure of dayside auroral oval and distribution of dayside auroral morphology

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A comprehensive analysis of long-term and multi-spectral auroral observations made in the Arctic and Antarctica demonstrates that the dayside auroral ovals in two hemispheres are both presented a two-peak structure, namely the prenoon 09:00 MLT and postnoon 15:00 MLT peaks. The two-peak structures of dayside ovals, however, are asymmetric in two hemispheres, i.e., the postnoon average auroral intensity is more than the prenoon one in the northern hemisphere, but less in the southern hemisphere. The hemispheric asymmetry cannot be accounted for by the effect of the IMF By component and the seasonal difference of ionospheric conductivities in two hemispheres, which were used to interpret satellite-observed real-time auroral intensity asymmetries in the two hemispheres in previous studies. We suggest that the hemispheric asymmetry is the combined effect of the prenoon-postnoon variations of the magnetosheath density and local ionospheric conductivity.

In addition, using the LBP-based representation method plus the k-nearest neighbor classifier, a statistical contrastive analysis of the dayside auroral morphology distribution in northern and southern hemispheres, specifically, auroras observed at Yellow River Station (YRS) and South Pole Station (SPS) is made. Experimental results show that, the four auroral types present very similar occurrence distribution in the two stations, but there are still some differences. We suggest that these differences of occurrence distribution are also related with the local ionospheric conductivities in the two stations.

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SuperDARN-NATION observations of mid-latitude storm-time ion-neutral coupling

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Ion-neutral interaction is known to be an important influence for driving ionospheric convection at high latitudes, particularly during the recovery phase of geomagnetic storms. However, at middle latitudes, the precise interplay between ions and neutrals is less understood, largely because of the paucity of measurements that have traditionally been available. In this work, we investigate mid-latitude ion-neutral coupling during the geomagnetic storm of October 2-3, 2013, using co-located measurements from SuperDARN radars and NATION Fabry-Perot Interferometers (FPIs). The timescales on which the coupling operates is analyzed using momentum exchange theory and time-lagged correlation analysis. During the main phase, we find the neutrals respond to the ion convection on a timescale of ~84 minutes, which is comparable to what might be observed at high latitudes, but significantly faster than what is expected from local ion-drag momentum forcing alone. This suggests other storm time-time influences are important for driving the neutrals during the main phase, such as Joule heating. During the late recovery phase, however, the neutrals were observed to drive the ions without any significant time delay, consistent with the so-called “neutral fly wheel effect” or disturbance dynamo.

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The impact of solar wind co-rotating interaction regions on the dynamics of the neutral middle atmosphere

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Long term studies have shown correlations between the solar wind pressure and features of the lower atmosphere such as the behaviour of the northern annular mode and the quasi-biennial oscillation. A definitive mechanism to explain these correlations remains elusive but a strong candidate is the chemical and dynamical changes due to energetic particle precipitation (EPP) into the middle atmosphere. This EPP is highly correlated with solar wind transients such as co-rotating interaction regions (CIR) and the subsequent high speed solar wind, which drive geomagnetic activity. Here we use the mesospheric winds derived from SuperDARN observations to investigate whether a significant effect can be observed in the dynamics of the middle atmosphere; an important link in the chain to explain possible impacts on the lower atmosphere.

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SuperDARN Hokkaido East radar observation of a possible SC-triggered wave event including FLR signatures

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In the ground/sea backscattered data obtained by the SuperDARN Hokkaido East radar, located at 36.5 (214.7) degrees in the AACGM latitude (longitude), we have found a relatively short-lived wave event which could be classified as a different type from the typical long-lasting waves in the ground/sea backscattered data. Our wave event appears to have been triggered by an SC which took place around 09:50UT on Aug 19, 2009. The 09:50UT corresponds to 18:50LT at the radar site. The event continued for about an hour. The event also included an interval during which the wave amplitude and phase showed the typical pattern of the Field-Line Resonance (FLR); this is the first time this pattern has been identified in the ground/sea backscatterd data of the SuperDARN Hokkaido East radar.

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Observations of Auroral Region Ion Outflow during the VISIONS Sounding Rocket Campaign

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The VISIONS sounding rocket campaign was successfully conducted in February 2013 from Poker Flats, Alaska. VISIONS has revealed important clues about low-altitude ion acceleration, which were hinted at by previous studies, but are revealed in a new light by ENA imaging. These include: 1) strong association of ion acceleration with regions of intense soft electron precipitation, 2) the fact that upwards ENAs dominate over horizontal ENAs imply either low-altitude wave processes or a pressure cooker geometry, which would have significant implications on the total ion outflow rate and its estimation from low-altitude measurements, and 3) the detailed temporal and spatial evolution of ion outflow during a 10 minute period can be used to estimate the ion outflow rate from a single substorm, to a much higher accuracy than previous efforts. Here we discuss the VISIONS sounding rocket results in the context of concurrent ground-based observations, including the auroral zone convection patterns.

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Near noon sunward flows: Are they strongest summer time?

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Occurrence of sunward flows during near hours for northward IMF Bz is a common feature of SuperDARN-based convection patterns. Theoretically, these flows are expected to occur more frequently in the summer hemisphere due to proper orientation of the earth's dipole with respect to the solar wind stream. One would then expect that, on average, the sunward flows to be stronger summer time as well. In this presentation, we statistically assess the line-of-sight velocities measured by the Rankin Inlet and Inuvik radars in their central beams oriented roughly toward the North Pole. For both radars, the near-noon anti-sunward flows are evident for observations at magnetic latitudes of > 81-82 deg. We show that the strongest flows occur in between the spring equinox and summer solstice, and not during summer. This feature is persistent for every year considered, between 2007 and 2013. We hypothesize on the reasons for the effect.

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Data Distribution Working Group Report

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In this report the Data Distribution Working Group (DDWG) will summarize the data distribution progress and issues that have come up over the past year. Issues resolved include additional University of Saskatchewan (USask) files that were found to have a range error, break-in or testing period data from Christmas Valley that was previously distributed, erroneous data from the King Salmon radar, and outages to the USask data mirror . The group will also give the latest update on where we are with collecting data for radars and how things have progressed with the British Antarctic Survey (BAS) data mirror and their downloads. We'll also review available resources on the DDWG website including methods on how to download data from the USask data mirror and about the hdw.dat github repository.

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Effects of electric field component representation on estimated cross polar cap potential - Implications for interhemispheric asymmetries

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Ionspheric electrodynamics is well organized with respect to the Earth's magnetic field. The most commonly used coordinate systems which take this field into account are the Apex (Richmond, 1995) and Altitude Adjusted Corrected Geomagnetic (AACGM) coordinate systems (Baker and Wing, 1989). Both coordinate systems are based on field line tracing using the International Geomagnetic Reference field, which resolves structures in the Earth's magnetic field at approximately 3000 km resolution. Seen in a geographic grid, both coordinate systems are non-orthogonal and non-uniform. Despite the widespread use in the space physics community, the conversion of electrodynamic vector components are often handled in an approximate fashion, treating the coordinate system as orthogonal. In this study we investigate how such approximations affect the estimated electric potential. We show that an electric potential which is symmetrical between hemispheres can appear asymmetrical when vector component conversion is not exact. We investigate how these errors depend on longitude and universal time bias in a data set. We also apply the technique to measurements from the Electron Drift Instruments on the Cluster spacecrafts mapped to the ionosphere, and compare the results to previously reported inter-hemispheric asymmetries.

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Mapping substorm-time convection using SuperDARN

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Many studies use the continuous velocity observations provided by SuperDARN to generate global convection maps to elucidate ionospheric flows. Generation of the global convection maps employ the use of a functional model to provide a best fit to the data which falls back to statistical averages to fill in the gaps in data coverage. This implies that in times of limited coverage there could be a large discrepancy between the modelled and actual global convection pattern. This may be particularly relevant during substorms, where the patterns are known to differ significantly from the statistical averages, but where the level of radar backscatter is known to be severely affected. Often global convection maps are trusted with only rudimentary quality-checking procedures imposed such as a global threshold on the number of measurements. We therefore investigate the effect of radar coverage on the reliability of SuperDARN convection maps. The ultimate aim is to derive a more robust set of criteria to give some limitation on the amount and distribution of coverage needed for accurate mapping of the convection to be possible. We look initially at ~1500 substorms identified in the northern hemisphere by the Far UltraViolet (FUV) instrument onboard the IMAGE spacecraft and use a substorm-onset coordinate system to show how the backscatter varies temporally and spatially during substorms. We then inspect the resulting convection maps and identify the regions of backscatter most critical for resolving substorm-related features in the flows.

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Long-term analysis of HF backscatter

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A statistical analysis of almost two solar cycles of data from the two eastern-most Super Dual Auroral Radar Network (SuperDARN) radars located at Hankasalmi (Finland) and in Pykkvibaer (Iceland) is presented. The data used in the analysis spans 18 years from 1996 to 2013. The monthly mean, hourly mean and point occupancy enable us to demonstrate solar cycle effects, seasonal dependence and the diurnal variations of backscatter (ionospheric scatter and ground scatter) in both radars. The occurrence of ionospheric scatter and ground scatter peaks during the solar maximum with solar cycle 23 maximum showing higher occurrence than the maximum of solar cycle 24. We also found that a dip in the occurrence of ionospheric scatter and ground scatter is apparent during the two-solar minima. In a comparison of the two-solar minima, our analysis shows that the recent extended solar minima has lower occurrence of backscatter than the solar minimum of solar cycle 22/23. Our analysis show that occurrence of ionospheric scatter at far range gates is seen at local day more in solar cycle 23 than in solar cycle 24 with occurrence of near-range ionospheric scatter at nigh-time in winter month (December) during the whole period investigated while ground scatter is seen to occur at mid-range gates than at other ranges during the winter month (December).

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SuperDARN observations of ionospheric convection during a storm main phase

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Observations of the ionospheric convection during a storm main phase on 9th September 2011 were examined. Measurements were obtained by three SuperDARN radars (ZHO, SYE and MCM) located in the southern hemisphere, the conjunction of these 3 radars plays an important role in revealing the dynamic process in magnetosphere-ionosphere coupling system. During the storm period, MCM radar scanning polar cap ionosphere monitored sequential strong antisunward large-scale plasma irregularities, which clearly presents the polar cap patches moving across the pole to the nightside and eventually into the the nightside auroral oval in quasi-periodical variation. While the ZHO radar recorded intense ionospheric backscatter echo power and moderate Doppler negative velocity in the poleward boundary of the nightside auroral oval, and simultaneous observation by the optical auroral imager did not capture the valid aurora. In the duskside sector, Doppler velocity monitored by the SYE showed irregular plasma structures towards or away from the radar site. Furthermore, ionospheric digisonde at Zhongshan station observed strong spread F during the storm main phase. Concerning this event, coordinated observations suggest that the ionospheric convection dominates the periodical plasma transportation.

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An update on the Svalbard SuperDARN radar

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An update regarding the construction of the new SuperDARN radar on Svalbard will be given. In the last year, progress has been made both on and off site, and the radar is still expected to be operational by late fall 2015. The space physics group at UNIS also now includes a dedicated SuperDARN engineer.

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EISCAT_3D: Next-generation incoherent scatter radar (invited)

I.W. McCrea, on behalf of the EISCAT_3D Consortium
STFC-RAL

In this talk, we will review the plans for EISCAT_3D, covering the science case, system design and the current planning and funding status. We will also discuss the potential for EISCAT_3D to carry out collaborative science with other ground-based instruments, including the SuperDARN radars.

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A unified view of favorable gradients in the lower ionosphere

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The notion of favorable gradients permeated the ionospheric physics field in a sense of those gradients that destabilize the plasma through the gradient-drift instability (GDI). It is well understood what constitutes the most favorable gradient configuration, i.e. mutual vector orientation that results in the maximum GDI growth rate in the linear regime. In the F region, the maximum growth rate is achieved when background gradient vector is parallel to the convection velocity. Relevant examples from the high-latitude region include observations of the strongest plasma waves on the trailing edges of plasma density enhancements such as polar patches and polar cap arcs. In the E region, on the other hand, the maximum growth rate is achieved when gradient is parallel to background electric field. One question that often needs addressing in context of graduate student education is why the direction of the most favorable gradient changes between the E and F regions. Moreover, a related question about similar criteria in the transitional region between the E and F layers does not appear to have a clear general answer. In this talk, I will demonstrate that the two descriptions of favorable gradients that are essentially separate in the E and F regions, while being perfectly adequate for most purposes, may also hide important aspects of electrodynamics and plasma physics that are common to both ionospheric regions, and in fact to the entire lower ionosphere. I will present the altitude-, species- and geometry-independent formulation of the two-fluid theory of the GDI and will show that the GDI growth rate is maximized along the bisector between the electric current and the cross product of the gradient vector and magnetic field. This result holds at all considered altitudes, including a transitional region between the E and F regions. Implications for SuperDARN observations and possible experimental verifications will be discussed.

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Interhemispheric comparison of seasonal mesospheric tdal activity observed by mid-latitude SuperDARN Radars

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Meteor wind measurements obtained by mid-latitude SuperDARN radars are used to study mesospheric tidal behavior in the Northern and Southern Hemisphere from 2010-2013. Our analysis technique builds upon previous work by Hall et al. [1997] in that it employs refined methods to extract meteor scatter from "Grainy Near Range Echoes" and differentiate them from other sources, such as sporadic E-layer and ground scatter. The results are compared with measurements obtained by radars at higher latitudes and the HWM07 model averaged over an altitude range of 85-95 km. We find the tidal amplitudes in the Southern Hemisphere are significantly greater than the amplitudes in the Northern Hemisphere and there are significant differences in seasonal behavior of the semi-diurnal and diurnal tides between the hemispheres. We also see notable model-data inconsistencies such that the model tends to overestimate the zonal and meridional components in both hemispheres. We discuss the various influences that may be responsible for producing these differences.

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Cluster, Polar and SuperDARN simultaneous observations of cusp signatures in the northern and southern hemispheres

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We present preliminary results of an excellent conjunction between the Polar and Cluster spacecraft on 5 April 2004. Both missions were located respectively in the northern mid-altitude cusp and in the southern exterior cusp, almost on the noon MLT meridian. These two spacecraft exhibit very nice ions dispersion allowing to compute, independently from both hemispheres, the distance from the reconnection line, located on the northern dawn magnetopause. The SuperDARN northern hemisphere radars show a nice coverage of the noon-dawn sector allowing to make a precise comparison between Polar and ionospheric observations. Although SuperDARN southern coverage is sparse and does not cover the region conjugated with Cluster observations. The Halley and Sanae radars show nice and intense convection channels on the duskside, suggesting the existence of a duskside active reconnection line. From this very nice set of experiments, we investigate the large-scale geometry of the reconnection on the dayside magnetopause.

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A preliminary study on the polar ionosphere features during periods of radial Interplanetary Magnetic Field

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The orientation of the interplanetary magnetic field (IMF) has an important role in the dynamics of the solar wind - magnetosphere - ionosphere system. When the IMF is nearly aligned with the solar wind velocity, a quasi-parallel shock develops in front of the magnetosphere together with strong turbulent fluctuations both in the upstream and downstream regions. Moreover, for nearly radial IMF the shape of the bow shock and the magnetopause can be atypical with respect to other IMF orientations. Here we present the study of the polar ionospheric response during some prolonged period of radial IMF performed using a comprehensive set of observations by SuperDARN radars, magnetometers and auroral imagers.

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Birkeland currents and the auroral electrojets: observations and modeling

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Magnetospheric currents mediate solar wind-magnetosphere-ionosphere coupling by transmitting stress from the magnetopause to the ionosphere as part of the convection cycle. Different aspects of the current system can be monitored by measuring the associated magnetic perturbations, either on the ground or in space. For instance, ground magnetic perturbations are used to construct the auroral electrojet indices, AU and AL, the cross-polar cap current index, PC, and the ring current indices, SYM-H and ASY-H. Magnetic field perturbations measured by the Iridium satellite constellation are employed to reconstruct the region 1 and 2 Birkeland current distribution using the Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE) technique. In this paper we investigate the relationships between these different aspects of the current system and relate them to magnetospheric/ionospheric convection, using the expanding/contracting polar cap (ECPC) paradigm as a theoretical framework. Simple modelling shows that the currents respond to both dayside and nightside reconnection, and that the substorm current wedge is associated with the nightside driving of convection.

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SuperDARN and GPS observations of Traveling Ionospheric Disturbances

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Abstract

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Coordinated observations of Pc5 pulsation events using SuperDARN and magnetometer data

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HF radars belonging to the SuperDARN network receive backscatter over a very large fan shaped fields of view which, when combined, allows for simultaneous returns over extensive regions of the polar caps and mid-latitudes. This makes them ideal instruments for the observation of global magnetohydrodynamic events such as Pc5 pulsations. However, very few pulsation events using multiple radars have been reported in the literature. Here we present two such events, one with a simultaneous detection in both hemispheres. These events coincide with geomagnetic pulsations observed by magnetometers under or near the radars' fields of view. Complex demodulation revealed low m values, frequently associated with external sources such as those in the solar wind. However, these events also demonstrated phase velocities consistent with sunward flow. A point which we investigate further here.

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Pc5 observations at King Salmon HF Radar during CT-TRIG mode period

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The Pc5 geomagnetic pulsation is one of the causes of enhancement of the relativistic electron enhancement in the outer radiation belt. Radial diffusion and/or drift bounce resonance driven by Pc5 geomagnetic pulsations can accelerate electrons. Therefore, to understand the generation mechanism of Pc5 and current condition for the global distribution of Pc5 is important. Because of the relativistic electron flux are enhanced after the geomagnetic storm, understanding the conditions of Pc5 activities during geomagnetic storm period is also important. For these purposes, special mode of observations (ST-APOG) for the conjunction of Van Allen Probes (VAP), and trigger mode observations (CT-TRIG) that is operated during the Dst index is less than 50 nT period. In these special modes, we use three camping beams for high-time resolution observations for Pc5 and 2-min. scan for the global distribution of plasma convection. Based on these observations, ground-based magnetometer network, VAP, and other satellite data, we can examine the three-dimensional distribution of electromagnetic variations of Pc5. Pc5 activities during CT-TRIG mode observations by King Salmon HF radar will be reported in our presentation.

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Characteristics of ionospheric convection associated with low-latitude aurora observed at Rikubetsu, Hokkaido during the 2015 March storm

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The 2015 March storm (St. Patrick's day storm), which occurred during 17-21 March 2015, is the largest one during Solar Cycle 24. During the storm, optical instruments installed at Rikubetsu, Hokkaido, Japan (geomagnetic altitude: 36.5 degs) registered auroral emissions during 15 to 20 UT on March 17. In addition, both the SuperDARN Hokkaido East and West radars were operating, and they succeeded in obtaining unprecedented set of high-time-resolution ionospheric convection data associated with the low latitude aurora up to below 50 degs geomagnetic latitude. Details of the observation and the data interpretation will be presented.

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Study of ionospheric disturbances using the remote HF wave receiver of the SuperDARN Hokkaido East radar: initial results

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We have been operating the remote HF wave receiver of the SuperDARN Hokkaido East radar in Nagoya (about 1100 km away from the radar) and Rikubetsu (in the vicinity of the HF radar) since 2014 to monitor the ionospheric disturbances. The receiver set consists of USRP-N210 receiver unit, Ubuntu Linux PC and dipole (or loop) antenna. The total cost of 1 set of the receiver system is about 350K Japanese Yen. Using the remote receiver data it is possible to monitor the upward / downward motion of the ionosphere at the ionospheric reflection point of the HF radar backlobe beams emitted torward Nagoya areas. Similar technique has been deployed in the operation of HF Doppler system, but usage of the SuperDARN (backlobe) beams has the following advantages: (1) Backlobe beams also have high directivity, so that the it is possible to observe strong echoes at the remote area more than 1000 km away from the radar. (2) Since the SuperDARN radars emit pulse waves instead of continuous waves, it is possible to identity the travel time from the radar to the receiver. Initial result of the observation of ionospheric perturbations using the remote HF wave receiver of the SuperDARN Hokkaido East radar will be presented.

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Initial observation with the SuperDARN Hokkaido Pair of (HOP) radars

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Initial results from the SuperDARN Hokkaido Pair of (HOP) radars, consisting of Hokkaido East and Hokkaido West radars, will be presented. The Hokkaido East radar have been operating since Nov 2006. We obtained the funding for installing the Hokkaido West radar in 2013, which is about 1.1 km northwest of the Hokkaido East radar, and completed the installation of the whole system in Oct 2014. Both radars are connected via optical fiber cable to send blanking signal to each other, to avoid damages to the other receiver. The Hokkaido West radar has been operating since 24 Oct 2014 and obtaining important data such as the small storm which started on 4 Nov 2014. In this presentation we will focus on the spatial temporal characteristics of Sub-Auroral Polarization Streams (SAPS) during this event and their relation to the geomagnetic activity at higher latitudes.

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Derivation of ionospheric currents and Joule heating rate in the polar region from IMAGE/FUV and SuperDARN

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In the past studies, it has been tried to model the conductance, the electric field, the currents and the Joule heating rate in the polar ionosphere from a set of observations. However, the availability of the convection electric field and the conductance used for the modeling is not always perfect in time and space due to several limitations in the observations. Hence, the temporal evolution of the response of the magnetosphere-ionosphere-thermosphere coupling system to the energy input from the magnetosphere has still not been understood well. In this paper, we established a method for deriving a large-scale map of the electric currents in the polar ionosphere by combining the Pedersen and Hall conductivities as estimated from the global UV auroral observations of the IMAGE spacecraft and the convection electric field as obtained from Super Dual Auroral Radar Network (SuperDARN). To test the procedure, we estimated ionospheric currents and Joule heating rate for two auroral substorm events identified from the IMAGE spacecraft observations on September 25, 2001 and January 12, 2002, and discuss its temporal evolution in detail. As a result, it was found that there is no remarkable difference in the Joule heating rate between regions of high (due to the auroral substorm) and low conductivities. This implies that the Joule heating rate depends more on the convection electric field than on the conductance. In particular, during the event on September 25, 2001, an auroral substorm occurred in a large area on the nightside, but, the significant enhancement of the Joule heating rate was not seen within the auroral bulges. This suggests that the convection electric field decreases in the regions of bright auroral activity; thus, the Joule heading rate does not increase in the auroral bulges. In addition to the estimation of the Joule heating rate, field-aligned currents (FAC) will also be derived from the IMAGE/FUV and SuperDARN observations and their temporal evolution will be discussed in the framework of magnetosphere-ionosphere coupling system.

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Geolocating HAARP-induced backscatter

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The HAARP ionospheric heater in Gakona, Alaska provides an excellent opportunity to calibrate various geolocation techniques of SuperDARN backscatter for those radars with HAARP in their field of view. Using observations of HAARP-induced backscatter from radars in Kodiak (kod), Christmas Valley (cvw) and Adak (ade), geolocation techniques are compared for all types of observed propagation paths: 1/2-hop E- and F-region, 1-1/2-hop F-region and 2-1/2-hop F-region. It is shown that our current geolocation technique is inadequate for multi-hop scatter. Using elevation angle information from these radars significantly improves positioning of the observed multi-hop scatter, however, some difference remain and may result from an incomplete understanding of the plasma processes associated with HAARP-induced irregularities.

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HF radar for long-range monitoring of ionospheric irregularities in the equatorial region

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Ionospheric instabilities associated with plasma bubbles in the equatorial region are one of the major space weather impacts, creating scintillation that affects satellite communications and navigation as well as spread-F and propagation effects on lower frequency systems. Coherent scatter radars can be used to detect the presence of irregularities at a scale size corresponding to half the wavelength of the radar when the raypaths are perpendicular to the magnetic field. A number of vertical incidence radars operating in the VHF range near the magnetic equator use this effect to map out vertical irregularity structure in bubbles, while at high latitudes in both the northern and more recently southern hemisphere, HF radars in the SuperDARN network have successfully used refraction along near-horizontal paths to reach perpendicularity with the near-vertical magnetic field and map out ionospheric convection and irregularity structure over fields of view thousands of km across. In the equatorial region, perpendicularity can be obtained anywhere within a near-vertical plane even without refraction, although refraction can be used to achieve long ranges after one or more reflections from the earth's surface and bottomside ionosphere. This potentially provides a means of detecting and monitoring equatorial plasma bubbles over the oceans from long ranges using a small number of ground-based sites. We discuss the possible echoes that could be detected by such a system, the likely propagation modes and characteristics, and means of obtaining and utilizing elevation angle information to correctly locate distant plasma bubbles.

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First results from coordinated studies between SuperDARN and e-POP

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The enhanced Polar Outflow Probe (e-POP) is a suite of instruments onboard the CAScade, Smallsat and IOnospheric Polar Explorer (CASSIOPE) satellite launched into a 1500 km by 325 km elliptical polar orbit on September 29, 2013. One component of e-POP is the Radio Receiver Instrument (RRI) designed to study both artificially and naturally generated radio emissions in the 10 Hz to 18 MHz regime. One experimental objective of e-POP is to coordinate RRI with SuperDARN radars to study HF radio propagation and investigate the source of coherent backscatter in the ionosphere. We present the first results from these coordinated studies including the observation of the effects of the polarization of SuperDARN pulses propagating directly to the spacecraft from SuperDARN, and scattered signals propagating indirectly to the spacecraft. In addition, we report on the radiation patterns of a solitary SuperDARN Rankin Inlet beam, and the back-beams of the SuperDARN Saskatoon radar.

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Swarm and ESR observations of the ionospheric response to a field-aligned current system in the high-latitude midnight sector

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We present a conjunction between the Swarm fleet and the EISCAT Svalbard Radar (ESR) on 9 January 2014. The Swarm orbit in the early phase of the mission gives us the unique opportunity of sequencing the temporal evolution of the observed field-aligned current system in the nightside, near magnetic local midnight. These field-aligned currents are seen to move poleward through the radar field of view and to affect the observed ionosphere. The upward FAC is responsible, at least in part, for the heating of the ionospheric electrons. It is less clear whether the downward FAC cools the ionosphere. We use the TRANSCAR model of the ionosphere, with SuperDARN convection map as an input, to quantify the thermoelectric effect that comes into play. Finally, we compare the plasma parameters measured by the Langmuir probe on board Swarm and the ESR, and conclude on an agreement within the errors.

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On monitoring HF propagation conditions at high latitudes

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In contrast to low and mid latitudes, the high-latitude ionosphere is highly variable due to the presence of energetic precipitating particles, strong electric fields and irregular patches of enhanced ionisation. As the result, HF propagation conditions at these latitudes are much more dynamic and complex so that an acceptably accurate forecast is currently unachievable. From this prospect, owing to its extensive spatial coverage and sufficiently high sampling rate, SuperDARN represents a potentially ideal instrument for real-time monitoring HF propagation in the auroral and polar cap regions. The most important propagation information can be obtained from elevation angle, which allows for unambiguous identification of the propagation modes and for determination of plasma density at the scatter/reflection point. While SuperDARN radars routinely generate elevation data, the latter are generally considered to be unreliable due to the complexity of the phase calibration and an apparently unphysical behaviour of some echo populations. As a result, the previous attempts to extract propagation information from SuperDARN data rely on additional assumptions on the modal structure of the echoes and the background plasma density. The above problem can now be resolved by utilising an extensive expertise in calibrating and interpreting SuperDARN interferometry data gained by the Saskatchewan group in recent years. In this work, we make a first step in developing an empirical model of HF propagation at high latitudes by analysing statistics of seasonal-diurnal elevation patterns observed by Canadian SuperDARN radars and relating the observed echo populations to different propagation modes. Furthermore, we are working on optimal ways of extracting propagation information (skip distance, MUF, electron density distribution) from both ground and ionospheric returns.

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Calibration of historic interferometry data

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Information on the vertical angle of arrival (elevation) is crucial in determining propagation modes of high-frequency (HF, 3-30 MHz) radio waves travelling through the ionosphere. The SuperDARN radars rely on interferometry to measure elevation, but this information is rarely used due to intrinsic difficulties with phase calibration as well as with the physical interpretation of the measured elevation patterns. In this work, we propose an empirical calibration method which is based on comparison of the observed and expected dependencies of elevation on range for ground scatter returns. "Fine tuning" of the phase is achieved based on a detailed analysis of its statistical fluctuations at very low elevation angles. While the proposed technique has been successfully applied to data from the mid-latitude Hokkaido East SuperDARN radar, it can also be used at any other installation that utilises HF interferometry.

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Quantifying self-cutter in SuperDARN correlation functions

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The multiple-pulse measurement technique used by SuperDARN radars introduces unwanted interference into estimates of the radar auto-correlation function (ACF). The uncertainty in estimates of the ACF is increased by both noise and self-clutter (cross range interference), however only the former is currently quantified. Without quantification of self-clutter it is not possible to account for all the uncertainty in estimates of the ACF. Voltage sample IQ data-based self-clutter estimators will be presented and discussed along with two maximal self-clutter estimators. The application of the self-clutter estimates in processing ACF data will be explored, with a focus on how these may be used in determining error bars for SuperDARN measurements.

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An improved SuperDARN data fitting algorithm enabling signal-derived error bars

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Current SuperDARN fitting techniques are not able to completely account for measurement errors in the parameters (velocity, spectral width, etc.) extracted from SuperDARN autocorrelation functions (ACFs). A new error-weighted fit to the functional form of the ACF, that includes error estimates for each lag of the ACF, has been developed. The fitting technique has been successfully tested with both simulated and measured SuperDARN ACFs. The technique is computationally intensive, but with modern computing capabilities easily viable for operational implementation. Extracted parameters from the new algorithm have been compared with those from the FITACF algorithm. The new algorithm is capable of producing self-consistent signal-derived error bars for SuperDARN extracted parameters.

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The effect of different ionospheric electrodynamic patterns on the thermospheric state in a global model

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We have attempted to validate the Global Ionosphere Thermosphere Model (GITM) to measurements of thermospheric winds by Fabry Perot Interferometers (FPIs) and mass density by different satellites. We have found that the comparisons, especially of the winds, are extremely sensitive to the drivers of the model. For one study, comparing winds over Alaska, we ran GITM using 16 different combinations of electric field models and auroral precipitation patterns. We found that the model was able to capture the overall neutral wind pattern a portion of the time, but with different electrodynamic models, the results varied dramatically. There was no clear "best driver" combination, even when using SuperDARN convection patterns. We will present model results and comparisons between different measurements to show how the model is dependent on the drivers.

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Effect of ray and speed perturbations on ionospheric tomography by over-the-horizon radar: A new method, probably useful for SuperDarn too.

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Most recent methods in ionospheric tomography are based on the inversion of the total electron content measured by ground-based GPS receivers. As a consequence of the high frequency of the GPS signal and the absence of horizontal raypaths, the electron density structure is mainly reconstructed in the F2 region (300 km), where the ionosphere reaches the maximum of ionization, and is not sensitive to the lower ionospheric structure. We propose here a new tomographic method of the lower ionosphere, based on the full inversion of over-the-horizon (OTH) radar data. Previous studies using OTH radar for ionospheric tomography inverted only the leading edge echo curve of backscatter ionograms. The major advantage of our methodology is taking into account, numerically and jointly, the effect that the electron density perturbations induce not only in the speed of electromagnetic waves but also on the raypath geometry. This last point is extremely critical for OTH radar inversions as the emitted signal propagates through the ionosphere between a fixed starting point (the radar) and an unknown end point on the Earth surface where the signal is backscattered. We detail our ionospheric tomography method with the aid of benchmark tests. Having proved the necessity to take into account both effects simultaneously, we apply our method to real data. This is the first time that the effect of the raypath deflection has been quantified and that the ionospheric plasma density has been estimated over the entirety of Europe with an OTH radar. Today, we wish to apply our method to the more ambitious SuperDarn network and interact with the users community.

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Dynamics of polar cap plasma convection during periods of northward IMF

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Under conditions of sustained northward IMF the site for anti-parallel merging on the dayside magnetopause is known to shift tailward of the cusp and to drive 'reverse connection', i.e., sunward plasma flows, deep in the polar cap. These flows reach to auroral latitudes on the dayside and then rotate to return along the flanks, forming reverse convection cells that were first imaged directly by the Kapuskasing-Saskatoon SuperDARN radar pair. The manner in which the flows in the polar cap respond to northward turnings of the IMF and to variations under predominantly northward IMF is not clear. For example, how quickly does the plasma convection respond to northward turnings and to their reversals, how closely coupled is the convection response to increases in IMF magnitude, and do the flow velocities saturate if the driving conditions become extreme? A solar coronal mass injection (CME) in late September 2014 brought initially large (> 20 nT) and variable northward IMF to Earth that was followed by days of more moderate but sustained northward IMF. The polar cap was observed during this time by a suite of instruments including the Resolute Bay Incoherent Scatter Radar (RISR), PolarDARN, and DMSP satellites. Dramatic effects were observed in the polar cap flow which indicate, that, at times, the coupling between solar wind IMF and polar cap flow is very direct, even quasi-linear. In this talk we describe the dynamics of the polar cap flow observed under northward IMF conditions and examine the connections to solar wind drivers and to the physics of dayside reconnection.

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Growth signature of omega band auroras

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We examined omega band auroras observed with the THEMIS ground based all-sky imagers. We found several events that showed almost whole processes of the generation of omega band aurora from the initial growth phase to the declining phase through expansion phase. The interesting features for the growth of omega band aurora are as follows; the omega band aurora grew from a faint seed, not via distortion of pre-existing east-west band aurora. The aurora did not show any shear motion during the growth of auroral activity. The omega band auroras occur in the morning sector auroral zone during the recovery phase of magnetospheric substorms. They drifted eastward with a speed of a few hundred meter/sec. Ps6 magnetic pulsations were observed in association with the occurrence of omega band aurora, most apparent for the Z component. A black hole-like dark aurora was found during growth and expansion phase just at the eastside of omega band aurora. In this study we examine generation and growth signatures of omega band auroras with referring ionospheric convection obtained by SuperDARN radars.

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A new algorithm for determining SuperDARN elevation angles

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SuperDARN radars with interferometer arrays use the observed phase delay relative to the main array in order to determine the arrival direction of backscattered signals. For many radars the interferometer array is simply offset from the main array along the boresight direction and the current algorithm works well. Some radars, however, have interferometers that are also offset in the vertical direction and/or the direction along the arrays. For these more complicated geometries the current algorithm is an approximation that works poorly or not at all in some situations.

A new algorithm is presented that is more intuitive and accurate for general array geometries. The new algorithm solves the equation for the distance between plane waves passing through the main and interferometer arrays. This simple equation gives the same answer as our current algorithm for the simple array geometries and can be applied to general geometries. Using the new algorithm it is shown that our current algorithm gives results that are not correct for these more complicated geometries. It is suggested that this new algorithm be adopted for determining elevation angles from SuperDARN radars.

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Large-scale observations of ULF pulsations in the subauroral region associated with a moderate substorm

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We report on some interesting ultra-low frequency (ULF) pulsations observed by North American mid-latitude SuperDARN radars associated with an auroral substorm on 25 September 2014. These pulsations are similar to ones analyzed by Frissell et al. [2011] but observations of extended spatial and temporal scales were shown using multi-radars throughout the substorm course. Three mid-latitude SuperDARN radars operating in THEMIS mode observed ULF pulsations right after substorm onset around 06:04 UT and also during an auroral intensification that followed at 06:20 UT. The amplitude of the pulsations reached 500 m/s in the subauroral polarization stream (SAPS) channel equatorward of the auroral oval and inside the ionospheric footprint of the mid-latitude density trough as mapped by GPS/TEC measurements. Of particular note is the fact that prior to onset, Pc4 waves were recorded by the Fort Hays East radar and ground magnetometers. Observations made by THEMIS ground magnetometers further illustrate the extended spatial scale and high spatial coherence of the pulsations. The fact that all pulsations were observed in conjunction with auroral brightenings observed by THEMIS all-sky imagers suggests that the ionospheric electric field was modulated by particle precipitation. We examine the amplitude and phase variations of the pulsations across various data sets and discuss the mechanisms for coupling particle precipitations, currents, and electric fields during substorms.

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Bayesian inference algorithm for SuperDARN rawACF fitting.

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Bayesian inference is a generally applicable probabilistic technique for inverse problems and provides a number of advantages over frequentist approaches such as linear regression fitting which forms the basis of the fitACF algorithm. In particular, the Bayesian approach can incorporate a concept unknown noise sources directly into the fitting model as a set of additional unknown parameters. This makes the Bayesian parameter estimation more robust especially when data is contaminated with complicated noise sources. The major disadvantage to Bayesian techniques is that they are generally computationally expensive to perform in practice. However, modern consumer computing advances make it possible to use Bayesian inference for SuperDARN ACF fitting in real time at an affordable price point in hardware. In this poster we will present the details of a Bayesian analysis algorithm suitable for near real-time rawACF processing using commercially available computer graphics processing hardware. The performance of the new algorithm will be compared directly with fitACF using both synthetic rawACF data as well as rawACF data from active SuperDARN radars.

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Ionospheric scattering observations using extended SuperDARN pulse sequences with multi-frequency Bayesian inference methods

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A new dual frequency Bayesian technique for generating real-time refractive index corrected Doppler velocities at the McMurdo radar was presented last year. A subsequent investigation has found that the the previously reported estimated plasma frequency precision was limited by the available spectral information of the traditional 8-pulse SuperDARN pulse sequence. In order to better resolve plasma frequency estimates, a novel 16 pulse SuperDARN sequence was constructed. This extended pulse sequence forms a ACF comprised of 121 lags and provides significant more spectral information. This extended sequence is well suited for use with multi-frequency Bayesian technique while still being compatible with single frequency fitACF algorithm. When employed at the McMurdo radar, the extended pulse sequence leads to much improved resolution of plasma frequency compared to the standard 8-pulse sequence.

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Spacecraft Working Group Report

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The Spacecraft Working Group (ScWG) will review the progress over the past year including issues with footpoint plots, scheduling requests and new satellites to consider. One of the bigger issues is updating the satellite footpoint plots to show several new satellites including the NASA Magnetospheric Multiscale (MMS) mission which will begin its science mission in September. The group will review operations of the radars including the Van Allen probe conjunction periods, the storm time triggered mode and the new-moon THEMIS mode. Also included will be discussions on upcoming experiments with satellites such as MMS, Canada's Enhanced Polar Outflow Probe (ePOP), and the yet to be launched Exploration of energization and Radiation in Geospace (ERG) satellite from Japan.

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Characterizing the spatio-temporal response of high latitude convection

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High latitude convection is a highly variable system in time influenced by multiple processes, presenting a significant challenge when trying to isolate the response to only one of these inputs. 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 over an 11 year solar cycle. 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 producing an estimate of convection at all locations ever measured by SuperDARN or DMSP and at all times over the solar cycle.

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Application of adaptive optics to scintillation correction in phased array high-frequency radar

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At high-frequency (HF), diffraction during ionospheric 4 propagation can yield wavefronts whose amplitude and phase fluctuate over the physical dimensions of phased array radars such as those of the Super Dual Auroral Radar Network (SuperDARN). Distortion in the wavefront introduces amplitude and phase scintillation into the geometric beamformed signal while reducing radar performance in terms of angular resolution and achieved array gain. A scintillation correction algorithm based on adaptive optics (AO) techniques is presented. An experiment conducted using two SuperDARN radars is presented that quantifies the effect of wavefront distortion and demonstrates a reduction in observed scintillaton and improvement in radar performance post scintillation correction.

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Superposed epoch analysis of midlatitude plasma density variations driven by geomagnetic storms

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Total electron content (TEC) is a commonly-used parameter for characterizing the Earth's ionosphere. By collecting data from the thousands of stationary GPS receiver sites around the world, globally-gridded maps of GPS TEC allow for imaging of large-scale ionospheric electron density structures at high spatial and temporal resolution. Strong gradients associated with the edges of density structures such as the midlatitude trough, storm enhanced density plume, and tongue of ionization have been increasingly related to small-scale irregularity formation observable by SuperDARN HF radars. In this study, we present a superposed epoch analysis of ionospheric GPS TEC variations at midlatitudes over North America driven by geomagnetic storms during a 13-year interval (2001 – 2013). Measurements of vertically-integrated GPS TEC are organized by storm phase according to the Sym-H index to calculate the deviation from 27-day average and model quiet-time values. The resulting maps of TEC variations are then presented for comparison with similar distributions of ionospheric irregularities and airglow as seen by ground-based networks of HF radars and all-sky imagers.

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Ionospheric signatures of Kelvin-Helmholtz waves at Earth's dayside magnetopause

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Waves on the magnetopause can be observed in situ with spacecraft and in their ionospheric projection by ground-based radar. Ionospheric signatures of these waves may be identified from ultra-low frequency (ULF) oscillations in the E×B plasma drift associated with electric field disturbances mapped along magnetic field lines. We present observations of ULF waves with a peak period of oscillation near 145 s (6.9 mHz) measured equatorward of the high-latitude spectral width boundary by the SuperDARN HF radar in Saskatoon, Canada near 02:00 UT on 21 September 2010. This spectral width boundary is believed to be a good proxy for the boundary between open and closed geomagnetic field lines in the 18:00-02:00 MLT sector, suggesting the wave signatures were associated with closed field lines just inside the dusk flank of the magnetopause. During this time period multiple THEMIS spacecraft also measured boundary waves along the dayside magnetopause near 15:00 MLT which, in addition to the corresponding ionospheric signatures, indicate the presence of tailward propagating Kelvin-Helmholtz waves.

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Are steady magnetospheric convection events prolonged substorms?

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Steady magnetospheric convection events (SMCs), substorms, and sawtooth events are different modes of behaviour by which the magnetosphere responds to the opening of terrestrial magnetic flux via dayside reconnection with the interplanetary magnetic field. Substorms and sawtooth events are explosive episodes of magnetic flux closure in the magnetotail, releasing open flux that has previously accumulated, whereas SMCs are thought to be periods when the magnetotail reconnection rate grows to equal the dayside rate such that flux is transported steadily through the system. It is still a matter of controversy why the magnetosphere responds differently in each case, though it is certain that sawtooth events occur during periods of extreme solar wind-magnetosphere coupling. Classic substorms occur after the magnetospheric driving has enlarged the polar cap and loaded energy into the tail of the magnetosphere in the form of increasing polar cap flux. Some SMCs take place after a substorm has occurred but the magnetosphere does not recover until after the SMC has concluded.

This study focuses on the different magnetospheric behaviours exhibited during substorms and SMCs. We distinguish between SMCs that are disguised within the substorm-cycle and SMCs that are stand-alone events and compare their associated behaviour of magnetospheric and solar-wind parameters to that of substorm signatures. We show the average behaviour of solar wind and magnetospheric parameters before and during these events. We demonstrate that for SMCs occurring independently of substorms, the event-preceding solar wind-magnetospheric coupling is considerably stronger and prolonged than for SMCs that occur as part of the substorm-cycle.

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A test of ionospheric convection predictions from the expanding/contracting polar cap paradigm

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The expanding/contracting polar cap (ECPC) paradigm, or the time-dependent Dungey cycle, provides a theoretical framework for understanding solar wind-magnetosphere-ionosphere coupling. The ECPC describes the relationship between magnetopause reconnection and substorm growth phase, magnetotail reconnection and substorm expansion phase, associated changes in auroral morphology, and ionospheric convective motions. Despite the many successes of the model, there has yet to be a rigorous test of the predictions made regarding ionospheric convection, which remains a final hurdle for the validation of the ECPC. In this study we undertake a comparison of ionospheric convection, as measured by ion driftmeters on board DMSP (Defense Meteorological Satellite Program) satellites, with motions predicted by a theoretical model (Milan, 2013) coupled to measurements of changes in the size of the polar cap made using global auroral imagery from the IMAGE FUV (Imager for Magnetopause to Aurora Global Exploration Far Ultraviolet) instrument. The results are discussed in the context of our understanding of magnetic reconnection at the magnetopause and in the magnetotail.

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Electric field mapping in the IGRF

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A method of comparing ionospheric electric fields measured by conjugate SuperDARN radars or by a radar and a conjugate spacecraft is applied to the IGRF. The method was previously briefly outlined at a SuperDARN meeting but was only applied to elementary field models. The usual method of estimating the electric field involves tracing magnetic field lines from one location to a conjugate point and to use their potential difference and their calculated separation to estimate the electric field. This is a crude numerical differentiation and inherently inaccurate. Our method finds analytic expressions for the spatial derivatives of the magnetic field. These form a second rank tensor which is used to deduce three simultaneous first order differential equations for the components of the elementary field separation. These can be integrated simultaneously with the field tracing equations. The electric field can thus be calculated at each point along the field line trace. Python code has been developed to carry out this process for the IGRF. Since the second derivatives of the magnetic potential are required, the standard Fortran GEOPACK routines are not suitable, so new Python routines are used. A variety of tests have been carried out to confirm the accuracy of the method. The next stage will be to add routines to incorporate the Tsyganenko model of the external field. The validity of using external field models for electric field mapping at times of high magnetic activity will be discussed. It is intended that a Python package for the complete model will eventually be made available to the SuperDARN community.

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A new European mid-latitude high frequency SuperDARN radar

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We present an overview of a new, multi-purpose, HF radar capability in mid- latitude Europe to provide measurements of the ion velocity in the upper atmosphere. This radar will also routinely measure mesospheric winds, and atmospheric gravity waves with sources in the troposphere and thermosphere. Currently, the only SuperDARN radars in Europe operate at auroral latitudes, in Iceland and Finland, but recent observations in the USA and Japan demonstrate that such mid-latitude radars are essential to provide coverage of the ion velocity during major space weather disturbances. We describe a mid-latitude radar overlooking the UK to fill this observational gap, which will also link with the recently-constructed SuperDARN mid-latitude radars across central USA and Japan, completing a similar mid-latitude chain of radars to the one at auroral latitudes.

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AgileDARN: Overview and Development Schedule

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SuperDARN is an international radar network surrounding the Arctic and the Antarctic poles. At the Arctic pole, the network is well deployed along the Western Hemisphere, while it is still to be filled up along the Eastern Hemisphere. With this background the Chinese Initiated Meridian Project (Meridian Space Weather Monitoring Project) is going to build 3 HF radars at northern China in its second stage, afterwards SuperDARN network will make its full coverage at both poles. The first step of the schedule is to develop an advanced demonstrator, namely AgileDARN, which is sponsored by China's National High-tech R&D Program (863 Program).

As compared to traditional SuperDARN radar, AgileDARN will be implemented as an active digital phase array and composed of 20 T/R units, among them 16 units are placed in a linear array, and the other 4 units are 100m behind the main array in order to determine the angle of arrival with interferometry. The element antenna is TTFD and the distance between the adjacent antennas is 12.8m. Like some modern radars the AgileDARN benefits from the advances of modern digital electronics and software controlled signal generation and processing. A dedicated pre-processor is designed and cooperate with each T/R unit. Each pre-processor is composed of high speed ADC, DAC, DSP and FPGA. During pulse transmitting, one DAC read digital waveform from each FPGA and converts it into analog waveform. Therefore the phase and amplitude of each transmitter is configurable by software, thus the antenna beam will scan digitally and tapering over the antenna array is applicable. In the receiving stage, echo from each T/R unit is simultaneously sampled by independent ADC. Beam forming is done in digital domain. This advantage results in agile beam forming in the transmitting stage and receiving stage. Multiple beam forming technique and intereferometry within the main array are also applicable to enhance the performance of radar detection. Each pre-processor receives the synchronous clock from the central synchronizer. High performance crystal oscillator is implemented in the synchronizer to keep all the elements work with accurate timing. GPS timing unit is included to ensure well synchronization with other SuperDARN radars. Basically, AgileDARN is a combination of 20 independent small radars. Each element is reconfigurable and works synchronously with software control.

Due to reconfigurability of the AgileDARN design, it will be a testbed for new techniques. AgileDARN will open to SuperDARN community not only the measurements in Eastern Hemisphere, but also a demonstrator for new ideas from its member institutes.

AgileDARN project is formally approved late 2014 and will goes into operation late 2017.

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Direct observations of the full Dungey convection cycle in the polar ionosphere for southward interplanetary magnetic field conditions

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Tracking the formation and full evolution of polar cap ionization patches in the polar ionosphere, we directly observe the full Dungey convection cycle for southward interplanetary magnetic field (IMF) conditions. This enables us to study how the Dungey cycle influences the patches' evolution. The patches were initially segmented from the dayside storm enhanced density plume (SED) at the equatorward edge of the cusp, by the expansion and contraction of the polar cap boundary (PCB) due to pulsed dayside magnetopause reconnection, as indicated by in-situ THEMIS observations. Convection led to the patches entering the polar cap and being transported antisunward, whilst being continuously monitored by the globally distributed arrays of GPS receivers and SuperDARN radars. Changes in convection over time resulted in the patches following a range of trajectories, each of which differed somewhat from the classical twin-cell convection streamlines. Pulsed nightside reconnection, occurring as part of the magnetospheric substorm cycle, modulated the exit of the patches from the polar cap, as confirmed by coordinated observations of the magnetometer at Tromsø and EISCAT Tromsø UHF Radar. After exiting the polar cap, the patches broke up into a number of plasma blobs, and returned sunward in the auroral return flow of the dawn and/or dusk convection cell. The full circulation time was about three hours.

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