SuperDARN 2011 Workshop Schedule

THAYER SCHOOL OF ENGINEERING AT DARTMOUTH

Sunday

18:00 20:00 Reception and Registration (Top of the Hop)

Monday

8:00 9:00 Registration (Thayer School, Great Hall)

9:00 10:30 Welcome and Status Reports

9:00 Welcome	*S. G. Shepherd*
9:15 SuperDARN Radars Status Report 2011	*M. Lester*
10:00 MSI Update	*S. G. Shepherd*
10:20 Scheduling Working Group Report	*T. Yeoman*

10:30 10:45 ***Coffee Break***

10:50 12:10 Programmatic *(Chair: P. Ponomarenko)*

10:50 Zhongshan Radar Update: Year One	*H. Hu*
11:10 SuperDARN in Poland - study of potential scientific benefits	*B. Popielawska*
11:30 A Brief History of the Early Technical Development of SuperDARN	*R. Greenwald*

12:30 13:30 ***Lunch (provided)***

13:30 14:30 Analysis Techniques *(Chair: D. Andre)*

13:30 A comparison of SuperDARN ACF fitting methods	*A. J. Ribeiro*
13:50 Making sense of SuperDARN elevation: Phase offset and variance	*P. Ponomarenko*
14:10 Map Potential 2.0	*E. D. P. Cousins*

14:30 15:00 ***Afternoon Break***

15:00 16:40 Radiation Belt Studies *(Chair: T. Yeoman)*

15:00 Toward prediction of relativistic electron environment in geospace	*T. Nagatsuma*
15:20 RBSP Mission: Understanding Particle Acceleration and Electrodynamics of the Inner Magnetosphere	*A. Y. Ukhorskiy*
15:40 SuperDARN: looking ahead to RBSP	*J. A. Wild*
16:00 Studying Relativistic Electron Precipitation with BARREL	*R. Millan*
16:20 Geospace Exploration Mission: ERG	*Y. Miyoshi*

17:00 ***Dinner (on own)***

18:00 21:00 Working Group Meetings: PI (Dinner provided), Software, Scheduling, Data Distribution

Tuesday

8:00	**9:00**	**Registration (Thayer School, Great Hall)**	
9:00	**10:20**	**Wave Processes** *(Chair: K. B. Baker)*	
		9:00 Phase coherence on open field lines associated with FLRs	*A. Nedie*
		9:20 Properties of Solar Wind ULF Waves Associated with Ionospheric Pulsations	*A. D. M. Walker*
		9:40 Analysis of waves at the magnetopause during a period of FLR activity recorded by the SANAE radar	*J.A.E. Stephenson*
		10:00 A case study of coordinated THEMIS-SuperDARN observations of field line resonances	*E. R. Talaat*
10:30	**10:45**	***Coffee Break***	
10:50	**12:10**	**Wave Processes (continued)** *(Chair: K. Oksavik)*	
		10:50 Comparison of ionospheric azimuthal Pc5 plasma oscillations with geomagnetic pulsations on the ground and in geostationary orbit	*K. Sakaguchi*
		11:10 Upstream Pc3 ULF wave signatures observed near the Earth's cusp	*T.K. Yeoman*
		11:30 Short-period Doppler shift variations in the polar cap: ULF waves or something else?	*P. Ponomarenko*
		11:50 Large-scale irregular undulations of the ionosphere as observed by the Falkland Islands SuperDARN radar	*S. E. Milan*
12:30	**13:30**	***Lunch (provided)***	
13:30	**14:50**	**Wave / Neutral Processes** *(Chair: J.B.H. Baker)*	
		13:30 Medium-scale traveling ionospheric disturbances simultaneously observed with the SuperDARN Hokkaido radar and FORMOSAT/ISUAL	*T. Ogawa*
		13:50 MSTIDs observed with SuperDARN	*E. S. Miller*
		14:10 Solar cycle variability of atmospheric waves and tides as observed by SuperDARN	*E. R. Talaat*
		14:30 On the importance of IMF |BY| on polar cap patch formation	*Q. H. Zhang*
14:50	**15:20**	***Afternoon Break***	
15:20	**17:00**	**Ionospheric Irregularities** *(Chair: R. G. Gillies)*	
		15:20 F-region echo occurrence in the polar cap: A comparison of PolarDARN and Saskatoon data	*A.V. Koustov*
		15:40 Spectral widths of F-region PolarDARN echoes, a statistical assessment	*A.V. Koustov*
		16:00 Auroral high frequency waves: Possible scattering targets?	*J. LaBelle*
		16:20 Sounding rocket measurements of decameter structures in the cusp	*K. Oksavik*
		16:40 Toward Scatter Classification at Middle Latitudes	*E. S. Miller*
17:00	**19:00**	**Poster Session (Thayer School, Atrium)**	
19:00		***Dinner (on own)***	

Wednesday

8:00 9:00 Late Registration (Thayer School, Great Hall)

9:00 10:20 Radio Wave Propagation *(Chair: C. Hanuise)*

9:00	Making sense of SuperDARN elevation: Ionospheric diagnostics	*P. Ponomarenko*
9:20	The radio wave power distribution at HF frequencies as modelled for Radio Receiver Instrument (RRI) investigations on the ePOP satellite mission	*G.C. Hussey*
9:40	Electron density estimates of the radar scattering volume for the Radio Receiver Instrument (RRI)-SuperDARN experiment on the ePOP mission	*R.G. Gillies*
10:00	GPS Phase Scintillation and HF Radar Backscatter Occurrence at High Latitudes	*P. Prikryl*

10:30 10:45 ***Coffee Break***

10:50 11:50 Radio Wave Propagation (continued) *(Chair: S. E. Milan)*

10:50	Characteristics of ionospheric responses to solar flares observed by the SuperDARN Hokkaido radar	*N. Nishitani*
11:10	SuperDARN observation of March 9, 2011 X-class solar flare	*S.G. Shepherd*
11:30	Solar Sector Structure Correlations with SuperDARN Saskatoon Radar and EISCAT Svalbard Radar Data	*D. Huyghebaert*

12:30 13:30 ***Lunch (provided)***

12:30 Afternoon Excursion and Dinner

Thursday

9:00 10:20 Subauroroal Processes *(Chair: A. V. Koustov)*

9:00	A survey of plasma irregularities seen by the mid-latitude Blackstone SuperDARN radar	*A. J. Ribeiro*
9:20	Observations of an evening enhancement in ground backscatter from mid-latitude SuperDARN radars	*S. de Larquier*
9:40	Midlatitude Ionospheric Features in the Plasmasphere Boundary Layer: The View From Millstone Hill	*P. Erickson*
10:00	Study of mid-latitude ionosphere convection during super quiet, quiet, and disturbed period with the SuperDARN Hokkaido radar	*Y.Zou*

10:30 10:45 ***Coffee Break***

10:50 12:10 Subauroroal Processes (continued) *(Chair: L. J. Baddeley)*

10:50	Sub-auroral flow shear observed by King Salmon HF radar and RapidMAG	*T. Hori*
11:10	Large-Scale SuperDARN observations of a Sub-Auroral Polarization Stream at Mid-Latitudes	*L. B. N. Clausen*
11:30	SAPS intensification during substorm recovery: A multi-instrument case study	*R. A. Makarevich*
11:50	Dynamic sub-auroral ionospheric electric fields observed by the Falkland Islands radar during the course of a geomagnetic storm	*A. Grocott*

12:30 13:30 ***Lunch (provided)***

13:30 14:50 Solar Wind - Magnetosphere Interactions *(Chair: J. A. Wild)*

13:30	Magnetopause reconnection rate and cold plasma density: a study using SuperDARN	*M. Lester*
13:50	Magnetotail Disruption Zones and their …	*G. Sofko*
14:10	Ionospheric Convection and Field-Aligned Currents During Strong Magnetospheric Driving: A SuperDARN/AMPERE Case Study	*L. B. N. Clausen*
14:30	Solar wind-magnetosphere coupling, substorms, and ramifications for the ionospheric convection pattern	*S. E. Milan*

14:50 15:20 ***Afternoon Break***

Thursday (continued)

15:20 17:00 Convection Studies *(Chair: L.B.N. Clausen)*

15:20	Magnetometer and radar study of the ionospheric convection response to sudden changes in the interplanetary magnetic field	*R. A. D. Fiori*
15:40	On the relationship of polar cap flow velocities and the IMF/solar wind	*B. Bristow*
16:00	SuperDARN and reversed flow events in the cusp	*K. Oksavik*
16:20	The formation of transpolar arcs	*R. C. Fear*
16:40	Towards an information theory approach for monitoring the ionospheric convection dynamics	*I. Coco*

18:00 Banquet

Friday

9:00 10:40 Interhemispheric Studies & Satellite Studies *(Chair: A. Grocott)*

9:00	Hemispheric Comparison of Signatures of Flux Transfer Events	*K.A. McWilliam*
9:20	Unprecedented observations of a sequence of flux transfer events	*S. E. Milan*
9:40	Testing the Equipotential Magnetic Field Line Assumption Using Interhemispheric SuperDARN Measurements	*J.B.H. Baker*
10:00	Swarm and SuperDARN	*D. Knudsen*
10:20	Active Magnetosphere Polar Electrodynamics Response Experiment (AMPERE): Status and Highlights	*B. J. Anderson*

10:50 11:05 ***Coffee Break***

11:10 12:15 WG Reports and PI Reports *(Chair: J.M. Ruohoniemi)*

11:10	SuperDARN Software	*R.J. Barnes*
11:25	Data Collection and Distribution Report (June 2010 to May 2011)	*D. Andre*
11:35	SuperDARN 2012	*H. Hu*
11:45	Spacecraft Working Group Report	*R. C. Fear*
12:00	PI Report	*M. Lester*

12:30 13:30 ***Lunch (provided)***

13:30 17:00 Radar Operating System Mini-course

17:00 ***Dinner (on own)***

Saturday

9:00 12:00 ROS Mini-course continued

12:30 13:30 ***Lunch (on own)***

13:30 17:00 ROS Mini-course (if needed)

Posters

Convection Studies, Interhemispheric Studies

CS1	High-latitude convection maps derived from AMPERE field-aligned currents and comparisons with SuperDARN line-of-sight velocities	*B. J. Anderson*
CS2	AMPERE and SuperDARN: What's in it for me?	*L. B. N. Clausen*
CS3	Characteristics of spatial variability in high-latitude SuperDARN velocities	*E. D. P. Cousins*
CS4	Convection mapping with Swarm satellite and SuperDARN radar data	*R. A. D. Fiori*
CS5	Symmetry and asymmetry of interhemispheric dayside ionospheric convection seen by the SuperDARN Kerguelen and Hankasalmi radars	*A. Marchaudon*
CS6	The interhemispheric version of the TRANSCAR ionosphere model	*A. Marchaudon*
CS7	Quantitative comparison of cross polar cap potential as derived from AMIE, DMSP, SuperDARN	*E. R. Talaat*
CS8	Interhemispheric comparison of cross-polar cap potentials	*A. S. Yukimatu*

Ionospheric Irregularities, Radio Wave Propagation, Neutral Processes

II1	SuperDARN and EISCAT observations of SPEAR (Space Plasma Exploration by Active Radar) induced sporadic E-region heating at 78N	*L. J. Baddeley*
II2	SPEAR-induced F region heating effects as observed using CUTLASS and EISCAT Svalbard radar	*L. J. Baddeley*
II3	Coincident multi-point observations of the E- and F-region decametre-scale plasma waves at high latitudes	*B. A. Carter*
II4	Gravity waves and their relationship to geomagnetic activity	*A. Grocott*
II5	Analysis of HF radar observations of ionospheric backscatter during geomagnetically quiet periods	*T. A. Kane*
II6	Classifying near-range echoes detected by the mid-latitude SuperDARN radars	*E. A. McCubbin*
II7	Extended observations of decameter scatter associated with the mid-latitude ionospheric trough	*E. R. Talaat*

Hardware Development, Analysis Techniques

HD1	A DDS-based Phasing and Pulse Unit for SuperDARN	*D. Andre*
HD2	Clear frequency search algorithm for twin radar operation	*A. C. Bradley*
HD3	Circular TTFD array design for omni-directional FoV	*J. Devlin*
HD4	FPGA-based cable length phase calibration	*J. Devlin*
HD5	Impedance matching for SuperDARN antennas: An improved technique	*J. Devlin*
HD6	An integrated analysis platform powered by fitacf CDF and the THEMIS tool developed by ERG-Science Center (ERG-SC)	*T. Hori*
HD7	New Operating System Upgrade for the Bruny Island Radar	*K. Kamalakkanan*
HD8	Investigations of cross-channel interference on a stereo SuperDARN radar	*A. McDonald*
HD9	Assessment of control program operation for twin radars	*M. M. McClorey*

Programmatic

SuperDARN in Poland - study of potential scientific benefits

B. Popielawska (1), A. Odzimek (2), I. Stanislawska (1), M. Kubicki (2), A. Wernik (1), G. Góral (1), M. Grzesiak (1), M. Pozoga (1)
(1) Space Research Center PAS, Warsaw, Poland; (2) Institute of Geophysics PAS, Warsaw, Poland

Abstract: Space Situation Awareness program of the European Space Agency includes space weather and is an appropriate frame for Polish space research community to plan new research infrastructure to increase our contribution to global space weather monitoring and development of underlying science. SuperDARN station in Poland seems to be an ideal investment for such a goal. Two research institutes of the Polish Academy of Sciences, the Space Research Centre and the Institute of Geophysics, partners of the Geoplanet consortium, joined efforts to prepare the appropriate scientific program and complete the necessary formalities to apply for funds to build SuperDARN station in Poland. In this paper we will shortly present participating scientists and institutes, their experience and achievements in space weather studies, and their interest in SuperDARN science. Potential scientific benefits of having SuperDARN in Poland will be discussed and present status of the project will be reported. Success of the project will depend strongly on the support of the international SuperDARN and space weather communities and organizations.

Analysis Techniques

A comparison of SuperDARN ACF fitting methods

A. J. Ribeiro (1), P. V. Ponomarenko (2), R. A. Greenwald (1), K. Oksavik (3), J. M. Ruohoniemi (1), J. B. H. Baker (1), L. B. N. Clausen (1)
(1) Bradley Department of Electrical and Computer Engineering, Virginia Tech, Blacksburg, Virginia, USA; (2) Institute of Space and Atmospheric Studies, University of Saskatchewan, Saskatoon, Saskatchewan, Canada; (3) Department of Arctic Geophysics, University Centre in Svalbard, Longyearbyen, Norway

Abstract: The radars of the Super Dual Auroral Radar Network (SuperDARN) employ a multi-pulse sequence in order to simultaneously resolve range and Doppler velocity. A complex autocorrelation function (ACF) is then calculated from the returns, and fitting in a routine known as fitACF is performed on the phases of the ACFs in order to resolve Doppler velocity, and to the amplitude and decay of the ACF to determine backscatter power (signal-to-noise ratio) and spectral width. A second method, called fitex2 has also been used to determine Doppler velocity, spectral width, and backscatter power from the ACFs. The Levenberg-Marquardt method has been shown to be able to correctly identify simultaneous returns from different scatterers (terrestrial surface and plasma irregularities) within the same range gate, known as mixed scatter. This method could also be applied to the fitting of returns from a single target. A comparison of ACF fitting methods) using simulated radar returns is performed to determine which method produces the most accurate results.

Making sense of SuperDARN elevation: Phase offset and variance

P. Ponomarenko, J. Wiid, A. Koustov, and J.-P. St.-Maurice
University of Saskatchewan, Saskatoon, SK, Canada

Abstract: The vertical angle of arrival of HF signals contains very important information about the propagation modes and ionospheric conditions. However, despite being routinely registered by SuperDARN radars, elevation angles are rarely utilised. The main reason for that is the apparent unreliability of these data, which frequently appear to be unrealistic. At SuperDARN 2010 we attributed the problem to an inadequate phase calibration that fails to account for certain phase shifts in the radar hardware. However, a following detailed analysis of the experimental data and statistical modelling revealed that the presence of strange elevation components could be fully explained by accounting for the statistical distribution of phase fitting errors. In essence, a combination of this distribution with the very non-linear phase-elevation relationship leads to a two-pi wrap-around of the phase that results in an artificial population of echoes at very high elevation angles.

Map_Potential 2.0?

E. D. P. Cousins, S. G. Shepherd
Thayer School of Engineering, Dartmouth College, Hanover, NH, USA

Abstract: Global ionospheric convection maps calculated from line-of-sight velocities using the Map_Potential procedure are one of the most widely used SuperDARN data products. We will show that the convection maps can be improved (to better match observed data) by using the International Geomagnetic Reference Field (IGRF) to calculate electric field values from velocities and by using the new SuperDARN dynamical model of Cousins and Shepherd [2010] to constrain the pattern where no data is available. These changes can produce >10% change in the derived convection pattern (as measured by the cross-polar cap potential difference) in time periods with moderate to low data coverage.

Radiation Belt Studies

Toward prediction of relativistic electron environment in geospace

T. Nagatsuma, K. Sakaguchi, S. Saito, M. Kunitake, and K. T. Murata
Space Weather and Environment Informatics Laboratory, Applied Electromagnetic Research Institute, National Institute of Information and Communications Technology

Abstract: Radiation belt dynamics is one of the well known but still unsolved issue of solar terrestrial physics. This is also important for the practical point of view because relativistic electron can penetrate into a satellite body and causes deep dielectric charging. This phenomena is one of the major reason of satellite anomaly. We start developing the prediction of relativistic electron environment using numerical simulation with observation data. The data can be used as some background conditions and also for the empirical parameters, such as diffusion coefficient. We can monitor wide-regions of ULF activities using SuperDARN and ground-based magnetometer data. The plan of predicting relativistic electron environment using numerical simulation with observation are introduced in our talk.

RBSP Mission: Understanding Particle Acceleration and Electrodynamics of the Inner Magnetosphere

A. Y. Ukhorskiy, B. Mauk, N. Fox
Johns Hopkins University Applied Physics Laboratory

Abstract: During past 50 years of space exploration and research our understating of radiation belts considerably evolved. It is now recognized that radiation belt fluxes exhibit highly dynamical nonlinear response to varying geomagnetic conditions with complex spatial and temporal properties. Some profound physical mysteries still remain. Their solution is critical for Space Weather applications at Earth as well as our understanding of fundamental mechanisms of high-energy particle acceleration and transport across the universe. Predictive understanding of dynamic variability of the belts requires a broad range of coordinated measurements of particles and fields that determine particle motions. NASA RBSP two-spacecraft mission in collaboration with other space missions, balloon and ground based observations will provide a complete set of measurements to address complex variability of the belts. We will discuss science goals and objectives of the RBSP mission and collaboration with SuperDARN to understand how global electrodynamics of the inner magnetosphere governs acceleration and variability of energetic particle populations in the belts.

SuperDARN: looking ahead to RBSP

J. A. Wild (1) and R. C. Fear (2)
(1) Physics Department, Lancaster University, Lancaster, Lancashire, UK; (2) Department of Physics and Astronomy, University of Leicester, Leicester, Leicestershire, UK

Abstract: As the launch of the Radiation Belt Storm Probes approaches, it is timely to consider possible synergies between this mission and the international array of SuperDARN radars. Building upon the coordination already underway for the Cluster, THEMIS and Geotail missions, we look at the disposition of the spacecraft relative to radar coverage and consider strategies for maximising collaborative research.

Studying Relativistic Electron Precipitation with BARREL

R. Millan
Dartmouth College, Hanover, NH, USA

Abstract: BARREL (Balloon Array for RBSP Relativistic Electron Precipitation) is a multiple-balloon investigation that will study electron losses from Earth's Radiation Belts. Atmospheric losses of relativistic electrons play an important role in radiation belt dynamics; precipitation into the atmosphere can deplete the radiation belts during the main phase of some geomagnetic storms and is also observed during relatively low geomagnetic activity levels. BARREL will consist of Antarctic balloon campaigns conducted in Austral summers of 2012 and 2013. During each campaign, a total of 20 small (~20 kg) balloon payloads will be launched to an altitude of 30-35 km to maintain an array of payloads extending across up to 8 hours of magnetic local time. Each balloon will carry a NaI scintillator to measure the bremsstrahlung X-rays produced by precipitating relativistic electrons as they collide with neutrals in Earth's atmosphere, and a DC magnetometer to explore the nature of observed Ultra Low Frequency temporal modulations of precipitation. We present an overview of the BARREL investigation which will provide the first balloon measurements of relativistic electron precipitation while in situ measurements of both plasma waves and energetic particle distributions are available. The combination of BARREL with in situ measurements from RBSP and THEMIS, and with ground-based measurements, provides a unique opportunity to study the wave-particle interactions believed to be responsible for the precipitation.

Geospace Exploration Mission: ERG

Y. Miyoshi (1), T. Ono (2), T. Takashima (3), K. Shiokawa (1), K. Seki (1), and V. Angelopoulos(4), ERG-Science Center Task Team, ERG-Working Group
(1) Solar-Terrestrial Environment Laboratory, Nagoya University, Nagoya, Japan; (2) Tohoku University, Sendai, Japan; (3) ISAS/JAXA, Sagamihara, Japan; (4) UCLA/IGPP, Los Angeles, USA

Abstract: In order to investigate acceleration mechanisms of relativistic particles of the radiation belts and dynamics of geospace during space storms, the ERG (Energization and Radiation in Geospace) project is now under preparation. The project consists of satellite observation team, ground-network observation team, and simulation/integrated studies team. The satellite ERG (SPRINT-B) of ISAS/JAXA will be launched around 2014-2015, and is currently designed to have a comprehensive set of plasma/particle sensors as well as field and wave instruments. Coordinated observations with the ground-network observations such as magnetometer networks, SuperDARN HF radar networks, optical imager networks, and VLF wave networks are essential for the comprehensive understanding the dynamic of the inner magnetosphere. For the integrated data analysis using various kinds of data sets, the ERG science center develops the CDF of the project-related data as well as the plug-in tools for the THEMIS data analysis software (TDAS) in collaborating with the THEMIS project. As the pre-launch activity of the ERG-SC, the CDF files and the TDAS procedures for Japanese SuperDARN fitacf data (SYE, SYS, KSR and HOK) have been developed and are now available for Japanese STP researchers for the performance test. In this presentation, we will discuss about the possible collaborations between ERG and SuperDARN radar networks and show examples how the SuperDARN data can be analyzed in the TDAS.

Wave Processes

Phase coherence on open field lines associated with FLRs

Abiyu Nedie, Frances Fenrich, Robert Rankin
University of Alberta, Edmonton, AB, CANADA

Abstract: A wide variety of waves occur in the magnetospheric regions of Earth excited by sources internal to the magnetosphere and external sources in the solar wind. Amongst them are the ULF waves whose direction of propagation is an important indicator of where the source mechanism might be located. For years, ULF field line resonances were known to cause oscillations in the F-region plasma flows, which are detected in SuperDARN's measured line-of-sight Doppler velocities. In this talk, discernible FLR signatures at 0.8-mHz, extended azimuthally along the latitude contour and its associated source in the solar wind using simultaneous measurements from multiple HF radars will be presented. We characterize ULF observations with coordinated simultaneous HF radars, optical instrumentation, ground-based magnetometers and satellite-borne instrumentation. During the time interval of interest, Geotail was on an outbound pass from the dawn side magnetosheath into the upstream solar wind region. In this talk, we present a completely new feature of phase coherence on open field lines at exactly the same resonant frequency. Equally important and new in this study is; our suggestion on how SuperDARN could be used as a potential tool of providing a direct diagnostics on how MHD waves in the solar wind could enter into magnetosphere right at the boundary providing improved understanding of large-scale processes on a time scale of a minute. This potential capability of SuperDARN could enable researchers for the first time to test various theories on how energy is transported into the boundary of the magnetosphere in a global scale view through continuous monitoring of the high latitude ionospheric convection. Results in this study support the hypothesis that the coherent phase on open field lines and the discrete frequency FLR at 0.8-mHz were being driven by an external wave source in the solar wind at the same discrete frequency.

Properties of Solar Wind ULF Waves Associated with Ionospheric Pulsations

A. D. M. Walker, J. A. E. Stephenson, and S. Benz
School of Physics, University of KwaZulu-Natal, Durban, South Africa

Abstract: A number of events in which oscillations in the solar wind plasma are correlated with Pc5 pulsations observed by SuperDARN radars have been identified. Magnetic field, velocity, thermal pressure and density data from the ACE and WIND satellites are analysed using sophisticated multiple taper techniques to provide complex demodulated time series of the oscillations. The energy flux, energy density, and polarization of the signals are used to determine the physical nature of the waves.

Analysis of waves at the magnetopause during a period of FLR activity recorded by the SANAE radar

J.A.E. Stephenson
School of Physics, University of KwaZulu-Natal, Durban, South Africa

Abstract: In the past, we have identified events which show that coherent waves observed in the solar wind near the libration point are phase locked with field line resonances of the same frequency observed by the Sanae radar. We now apply the same techniques to CLUSTER data to obtain the wave behaviour near the magnetopause. Previous analysis of solar wind observations for one event demonstrated that the wave was transverse Alfven. This same method, whereby components of the thermal pressure, density and vector components of the velocity and magnetic field are analyzed, is employed here once more. Complex demodulation is applied to a multiple taper spectrum of each of these components and the resulting waves are examined to determine which of them was the major contributor to the energy flux vector. In addition, comparison of the phase and amplitude allows for the determination of the polarization of the wave. This analysis is intended to provide more evidence, and increase understanding, of the mechanism by which pulsations in the solar wind may drive field line resonances.

A case study of coordinated THEMIS-SuperDARN observations of field line resonances

E. R. Talaat (1), Theodoros Sarris (2)
(1) The Johns Hopkins University Applied Physics Laboratory; (2) University of Colorado

Abstract: The THEMIS mission, consisting of a five probe constellation, was launched in 17 February 2007 to study substorms; however its instrumentation and the alignment at close distances among some of the THEMIS probes, particularly in the first period of its mission, provides unique opportunities to characterize ULF pulsations in the magnetosphere. At the same time, the SuperDARN radar network provides measurements of ionospheric convection at high temporal and spatial resolution, that are not bounded by the rotation and attenuation that the ionosphere inflicts to the magnetic signatures detected on the ground. In this presentation, we show a case study of coincident measurements of ULF waves using in-situ magnetic and electric field measurements at multiple L-shells near the equator using the THEMIS spacecraft and remotely sensed convection with SuperDARN during February 2008.

Comparison of ionospheric azimuthal Pc5 plasma oscillations with geomagnetic pulsations on the ground and in geostationary orbit

K. Sakaguchi (1), T. Nagatsuma (1), T. Obara (2), and O. A. Troshichev(3)
(1) National Institute of Information and Communications Technology (NICT), Koganei, Tokyo, Japan; (2) Japan Aerospace Exploration Agency (JAXA), Tsukuba, Ibaraki, Japan (3) Arctic and Antarctic Research Institute (AARI), St. Petersburg, Russia

Abstract: The oscillations of azimuthal Doppler velocity in the ionosphere that had been observed in 2007 with a westward beam No.3 of SuperDARN King Salmon radar were analyzed in this study for the Pc5 frequency range. The local time distributions of the ionospheric oscillations showed peculiar asymmetric characteristics, that is the occurrence rate is maximum at the pre-midnight sector. The echos of 30-40 % contained Pc5 velocity oscillations from dusk to midnight, whereas the echos observed from dawn to noon hardly contained the oscillations. These ionospheric Pc5 events were compared with magnetic fields variations on the ground of Pebek and King Salmon under the beam, and the ETS-8 satellite orbiting at almost conjugate longitude in geostationary orbit. As a result, we identified only a few events that magnetic fields behaved sinusoidal variations in agreements with ionospheric oscillations. After statistical spectral analysis, on the other hand, we found that there were positive correlation between integrated Pc5-range spectral power of velocity oscillations and geomagnetic pulsations on the ground and in geostationary orbit. These results indicate that azimuthal Pc5 plasma velocity oscillations observed by the radar affect ground and geostationary magnetic-field spectral power. However, the local time distributions of ionospheric Pc5 events were different from previously reported Pc5 geomagnetic pulsations on the ground and in the magnetosphere. We examined in addition, the relation between ionospheric Pc5 power and solar-wind parameter, and found no linkage with neither solar wind velocity nor pressure variation. Therefore, ionospheric azimuthal Pc5 oscillations might not monitor well-known type of toroidal MHD waves driven by solar wind change, and Pc5 power distributions obtained by radar observations provide different features from magnetic field observations.

Upstream Pc3 ULF wave signatures observed near the Earth's cusp

T.K. Yeoman (1), M. J. Engebretson (2), M. R. Lessard (3), and H. Kim (3)
(1) Department of Physics and Astronomy, University of Leicester, Leicester LE1 7RH, UK; (2) Augsburg College, Minneapolis, MN, USA; (3) University of New Hampshire, Durham, NH, USA

Abstract: Pc 3-4 pulsations (f ~ 10-100 mHz) which originate in the ion foreshock upstream of the Earth's bow shock due to the interaction between reflected ions and the solar wind are frequently observed in ground-based pulsation magnetometer data. Previous studies have noted increased Pc 3-4 wave power in the vicinity of the dayside cusp and inferred that the upstream waves gained entry via the cusp, although more recent studies have revealed a more complex picture. Here, we examine Pc3-4 wave power near local noon observed by search coil magnetometers at three closely-spaced stations on Svalbard, during times when an extended interval of HF radar backscatter indicative of the cusp is detected by the Hankasalmi SuperDARN radar. The location of the equatorward edge of the HF radar cusp may then be directly compared with the Pc3-4 wave power measured at three latitudes as the cusp migrates across the stations on a statistical basis. These observations are not consistent with wave entry into the magnetosphere via the cusp proper, but rather along closed field lines equatorward of the cusp, which map to the low-latitude boundary layer or outer magnetosphere.

Short-period Doppler shift variations in the polar cap: ULF waves or something else?

G. Scoular, P. Ponomarenko, and J.-P. St.-Maurice
University of Saskatchewan, Saskatoon, SK, Canada

Abstract: Daytime Pc3-4 waves (10-50 mHz) are generated at the bow shock and propagate through the inner magnetosphere to the ground as Alfven waves in the closed field line geometry. These waves have also been detected in the polar cap, but their propagation mode for the open field lines remains largely unknown. To address this issue, we ran a pilot study of ionospheric ULF wave signatures in the northern polar cap. For this purpose we analysed Doppler shift variations in the HF ground scatter echoes across the 5-60 mHz frequency range as measured by the PolarDARN radars at Rankin Inlet and Inuvik. Previous ground magnetometer studies showed that the high-latitude Pc3-4 waves exhibit relatively long spatial coherence, distinct band-limited spectral shape, and occurrence/power maximum near MLT noon. In contrast, our observations revealed a dominance of Doppler shift variations that exhibit low spatial coherence, a featureless power-law spectrum and no connection to the ground magnetic field variations, while their power has two diurnal peaks before and after 12 MLT. This rather unexpected outcome of our studies has forced us to look for alternative explanations of the observed Doppler shift variations.

Large-scale irregular undulations of the ionosphere as observed by the Falkland Islands SuperDARN radar

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Abstract: The Falkland Islands SuperDARN radar observes large-scale undulations of the ionosphere. These manifest themselves as motions of the ground scatter region towards or away from the radar, associated with positive or negative Doppler-shifts, respectively. The motions are sometimes isolated in time, or appear quasi-periodically with time-scales of several hours. At present it is unclear what causes these undulations. This presentation will summarize the characteristics of the undulations and discuss possible causes.

Wave / Neutral Processes

Medium-scale traveling ionospheric disturbances simultaneously observed with the SuperDARN Hokkaido radar and FORMOSAT/ISUAL

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Abstract: Medium-scale traveling ionospheric disturbances (MSTID) have been observed with various instruments like radar, airglow imager, GPS satellite, etc. SuperDARN HF radars having a wide field-of-view (FOV) in the horizontal plane have also contributed to MSTID observations at high- and mid-latitudes, though these radars cannot clarify vertical MSTID structures. MSTID observations with a SuperDARN radar combined with an optical instrument capable of imaging MSTID in the vertical plane are required to know three-dimensional MSTID structures. We present some results from simultaneous observations of nighttime MSTID with the Hokkaido SuperDARN HF radar and a limb imager, called ISUAL (Imager for Sprites and Upper Atmospheric Lightning), on the FORMOSAT-2 satellite. The radar observed MSTID propagating southwestward in the horizontal plane, and ISUAL did two-dimensional OI 630-nm airglow structures in the vertical plane along the N-S satellite track. The observations were made during the night on 20 and 21 December 2006 and 29 December 2008. On 20 and 21 December, the radar FOV was separated by a few hundred kilometers or more from the ISUAL observation area, while on 29 December, the ISUAL observation area was inside the radar FOV. Analyses of data from both instruments and simultaneous total electron content data from a dense GPS network in Japan suggest that spatial MSTID structures observed with the HF radar are well identified as airglow intensity enhancements at altitudes of 200-300 km observed with ISUAL.

MSTIDs observed with SuperDARN

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Abstract: The term "Medium Scale Traveling Ionospheric Disturbance" (MSTID) can refer to at least two distinct proposed phenomena: 1. a thermospheric acoustic gravity wave that causes density and height variations in the ionosphere via collisional and density/ionization effects; or 2. an electrified structure due to a plasma instability related to the model presented by Perkins. In this work, we present examples of the signatures of both kinds of structures in SuperDARN backscatter data. Finally, we comment on observational support for the recent theory of Kelley that the so-called "Perkins orientation" of electrified MSTIDs is due to minimization of Joule damping as gravity waves reach the middle latitudes.

Solar cycle variability of atmospheric waves and tides as observed by SuperDARN

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Abstract: We have analyzed the occurrence of mesospheric tides and planetary wave activity in the meteor wind data over a solar cycle at several radar stations in both hemispheres. Understanding the behavior of planetary waves and tides is not only crucial to characterizing mesopause variability but also transport in the mesosphere and lower thermosphere. We examine the variability in tidal and planetary wave activity over the past solar cycle and correlations with lower atmospheric phenomena. We further investigate the seasonal and inter-annual variations of the diurnal, semidiurnal and terdiurnal tides, and planetary waves. We find possible connections to the quasi-biennial oscillation and to sudden stratospheric warming (SSW) events. Additionally, we present examples of intensified planetary wave activity that occurred during SSWs.

On the importance of IMF |BY| on polar cap patch formation

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Abstract: A number of poleward-moving events were observed between 1130-1300 UT on 11 Feb 2004, during periods of southward interplanetary magnetic field (IMF), while the steerable antenna of the EISCAT Svalbard Radar (ESR) and the Tromso VHF Radar pointed nearly northward at low elevation. In this interval, simultaneous SuperDARN CUTLASS Finland radar measurements showed poleward-moving radar aurora forms (PMRAFs) which appeared very similar to the density enhancements observed by the ESR northward-pointing antenna. These events appeared quasi-periodically with a period of about 10 minutes. Comparing the observations from the above three radars, it is inferred that there is an almost one-to-one correspondence between the Poleward-Moving Plasma Concentration Enhancements (PMPCEs) observed by the ESR and the VHF radar, and the PMRAFs measured by the CUTLASS Finland radar. These observations are consistent with the interpretation that the polar cap patch material was generated by photo-ionisation at sub-auroral latitudes, and that the plasma was structured by bursts of magnetopause reconnection giving access to the polar cap. There is clear evidence that plasma structuring into patches was dependent on the variability in IMF |BY|. The duration of these events implies that the average evolution time of the newly opened flux tubes from the sub-auroral region to the polar cap was about 33 minutes.

Ionospheric Irregularities

F-region echo occurrence in the polar cap: A comparison of PolarDARN and Saskatoon data

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Abstract: F-region echoes in the polar cap can be detected by both the auroral zone and PolarDARN radars. In this presentation, we assess Rankin Inlet, Inuvik and Saskatoon echo occurrence rates at various magnetic latitudes and seasons. We show that the overall echo detection for MLAT=75-90 decreases from winter towards summer by a factor of 2. However, for MLAT=80-85, there are clear equinoctial maxima that occur mostly because the echoes are frequently observed not only near noon but also on the nightside. We discuss inferred variations in the echo occurrence rates in terms of various factors influencing echo detection.

Spectral widths of F-region PolarDARN echoes, a statistical assessment

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Abstract: In this report, we investigate the spectral width of F-region PolarDARN echoes as a parameter of auroral backscatter. We show that, overall, the echoes are broader in the pre-noon sector and winter time. Scatter plots of the width versus velocity show presence of narrow (< 10 Hz) and broad echoes. We show that broad echoes dominate at relatively short ranges of ~ 800-1000 km. As range (magnetic latitude) increases, narrow-width echoes become more and more frequently detected and they dominate at ranges > 1500 km. The echoes detected simultaneously by the Inuvik and Rankin Inlet radars over Resolute Bay have comparable widths with somewhat smaller values for Inuvik, consistent with slightly larger ranges of observations. By comparing the width data with the Resolute Bay CADI measurements of the electric field we show that the spectral width does not change much with the azimuth of the flow, both for simultaneously detected RKN and INV echoes, and for separate statistics. The width slightly increases with the ExB magnitude, consistent with previous reports.

Auroral high frequency waves: Possible scattering targets?

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Abstract: From the early years of space physics, rocket- and satellite-borne wave experiments probing auroral regions detected electrostatic waves between the plasma and upper hybrid frequencies. These high frequency waves are most prevalent at high altitudes, above about 600 km, but they occur down to or even below the F-peak. One consequence is two types of mode-conversion radiation observable at ground level: Auroral roar originates from upper hybrid waves at the matching condition between the upper hybrid frequency and cyclotron harmonics, most commonly near 275 km altitude; and auroral MF burst is of unknown origin but proposed to come either from Langmuir waves extending from the F-peak up to about 600 km or from electron sound waves. The upper hybrid waves, with wave vectors perpendicular to the magnetic field and wavelengths from a few meters to tens of meters, might be effective scatterers of SuperDARN frequencies, although a bistatic system may be needed to receive the scattered wave which would refract differently from the upgoing wave due to its significant (several MHz) frequency offset. However, experiments suggest that much of the time the upper hybrid waves form standing wave structures in pre-existing field-aligned density enhancements, in which case there may sometimes be no significant frequency offset of the scattered wave. In such cases it seems possible for SuperDARN to detect the scatter. The other high-frequency wave, MF burst, associated either with Langmuir waves or electron sound waves, either of which has parallel wave vectors, are targets for radars that look up the magnetic field line; they may be related, for example, to enhanced ion lines (NEIALs) detected with incoherent scatter radars pointed directly up the magnetic field, but they seem less likely targets for SuperDARN radars than do the upper hybrid waves. A search for scatter from field-aligned upper hybrid waves near 275-375 km altitude, possibly offset by about 3 MHz, could add significant contributions to knowledge of HF waves and open another type of regular SuperDARN diagnostic measurement.

Sounding rocket measurements of decameter structures in the cusp

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Abstract: In this paper we use in-situ measurements from a sounding rocket to investigate the fine-scale structures in polar cap patches and the growth of F-region plasma irregularities in the cusp ionosphere. The Investigation of Cusp Irregularities (ICI-2) sounding rocket was launched from Nylesund, Svalbard, on 05 December 2008. The high-resolution rocket data is combined with ground-based data; an all-sky camera, the EISCAT Svalbard Radar, and the SuperDARN Hankasalmi radar. These datasets are used to characterize the spatial structure of the observed F-region irregularities and to derive instability growth rates at various spatial scales. We find the gradient-drift (GD) mechanism to be dominating the production of the observed F-region irregularities. The growth rate of the Kelvin-Helmholtz (KH) mechanism was too slow to explain any of the observed plasma irregularities.

Toward Scatter Classification at Middle Latitudes

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Abstract: We present an update on on-going work at JHU/APL to understand the sources of backscatter observed with the new middle latitude radars. Notably, we propose classifying backscatter from: auroral convection FAIs (traditionally called "ionospheric scatter"), non-convection FAIs (e.g., those found in the trough/plasmapause region in the evening), the ground via F region, the ground via sporadic E, specular meteor echoes, E-region FAIs (so-called "quasi-periodic echoes"), and specular sporadic-E echoes. These classifications are vital to the extension of SuperDARN science to middle- and lower-latitude phenomena.

Radio Wave Propagation

Making sense of SuperDARN elevation: Ionospheric diagnostics

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Abstract: The elevation angle of HF signals contains information about ionospheric conditions affecting radio wave propagation. Unfortunately, this parameter has rarely been utilised in SuperDARN experiments due to the apparent bias attributed to some unaccounted-for phase offset. However, in the accompanying presentation we demonstrated that this effect, in fact, reflects the statistical variability of the phase measurements, and the majority of the elevation data can be trusted. Ray tracing modelling of the HF backscatter characteristics reveals the presence of two possible propagation modes related to Pedersen and low-angle rays. The first mode is characterised by very little variation in elevation with range and contains information about the refractive index (i.e. electron density) in the vicinity of the ionospheric maximum. Careful analysis of elevation data from the Rankin Inlet PolarDARN radar has shown that the Pederesen regime is regularly observed in daytime hours during the spring-summer-autumn months. Applying Snell's law for the spherical geometry and the simplest form of the Appleton-Hartree equation to these data, we have attempted to reconstruct seasonal-diurnal variations of the maximum electron density near 70LAT.

The radio wave power distribution at HF frequencies as modelled for Radio Receiver Instrument (RRI) investigations on the ePOP satellite mission

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Abstract: The Cascade Demonstrator Small-Sat and Ionospheric Polar Explorer (CASSIOPE) satellite is scheduled to be launched as early as December 2011. The scientific payload on this satellite will consist of a suite of eight scientific instruments comprising the enhanced Polar Outflow Probe (ePOP). One instrument, the Radio Receiver Instrument (RRI), will be used to receive HF transmissions from ground transmitters such as SuperDARN. Magnetoionic polarization and propagation theory has been used to model the relative power that SuperDARN will deliver to the Ordinary (O) and Extraordinary (X) modes of propagation, with reference to the RRI/ePOP orbit. The geometry of the ground-based radars and the Earth's magnetic field results in the X-mode dominating the transmitted signal when a radar wave propagates northward, where it is nearly perpendicular to the geomagnetic field lines. Other propagation directions (i.e., above or southwards of the radar) results in propagation which is anti-parallel to the geomagnetic field lines and an equal splitting of transmitted power between the O- and X-modes occurs. For either high transmitting frequencies or low ionospheric electron densities, the range of latitudes that signal will be received at the satellite is significant (up to ~90 degrees of latitude). Conversely, for lower transmitting frequencies or higher ionospheric electron densities, the latitudinal range that signal will be received by the RRI is smaller. This modelling work will be used as a basis for interpretation of the signal received by the RRI when the ePOP satellite is operational.

Electron density estimates of the radar scattering volume for the Radio Receiver Instrument (RRI)-SuperDARN experiment on the ePOP mission

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Abstract: The upcoming launch of the Cascade Demonstrator Small-Sat and Ionospheric Polar Explorer (CASSIOPE) satellite, as early as December 2011, has a number of scientific objectives, one of which is to study the micro-physics of the coherent scattering process. The CASSIOPE satellite will contain a suite of eight scientific instruments comprising the enhanced Polar Outflow Probe (ePOP) mission. One instrument, the Radio Receiver Instrument (RRI), will be used in conjunction with the Saskatoon SuperDARN radar for high resolution measurements of the scattering volume. Two specific objectives are to study the coherent radar scatter Doppler velocity measurements and the corresponding electron density in the scattering volume. In the scattering volume it turns out these parameters are related. It has been found that measurements of ionospheric velocities made by HF coherent radars, such as SuperDARN, are underestimated because the refractive index, which is determined by the electron density in the scattering volume, has not been taken into account. Large-scale, background estimates of refractive index from incoherent scatter radar measurements, empirical models such as the International Reference Ionosphere (IRI), or a proxy using elevation angle measurements, have improved comparisons between SuperDARN and other instruments. Nonetheless, the velocities measured by SuperDARN were statistically lower than velocities measured by other instruments. This underestimation is likely a consequence of HF coherent scatter preferentially occurring in regions of the ionosphere with small-scale structures where higher-than-average background electron densities are present. A technique to estimate the electron density in the actual SuperDARN scattering volume (instead of larger-scale background values) has been developed. This technique uses routine shifts in the radar operating frequency to directly measure the electron density at the location of scatter. Results from this frequency shifting method have indicated that the average electron density in the scattering volume of the SuperDARN radars is appreciably higher than the background densities. Validation and confirmation of this by the RRI-SuperDARN experiment and other instruments on the ePOP satellite will allow for an unprecedented examination of the nature of the scattering structures.

GPS Phase Scintillation and HF Radar Backscatter Occurrence at High Latitudes

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Abstract: The Canadian High Arctic Ionospheric Network (CHAIN) consists of ten dual-frequency receivers, configured to measure amplitude and phase scintillation from L1 GPS signals and ionospheric total electron content (TEC) from L1 and L2 GPS signals. One-minute amplitude and phase scintillation indices and TEC are computed from data sampled at 50 Hz. Maps of GPS phase scintillation at high latitudes have been constructed for the first three years of CHAIN operation during the 2008-2010. As a function of magnetic local time and geomagnetic latitude, the phase scintillation predominantly occurs in the cusp and the nightside auroral oval. The auroral phase scintillation shows an expected semiannual oscillation with equinoctial maxima known to be associated with aurorae, while the cusp scintillation is dominated by an annual cycle maximizing in autumn-winter. Depletions of the mean TEC are identified with the statistical high-latitude and mid-latitude troughs. Scintillation-causing irregularities may coexist with small-scale field-aligned irregularities detected as HF radar backscatter. The statistical occurrence of phase scintillation and ionospheric backscatter observed by SuperDARN Saskatoon radar are compared.

Characteristics of ionospheric responses to solar flares observed by the SuperDARN Hokkaido radar

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Abstract: Solar flares emit X-rays onto the earth's ionosphere and causes a variety of changes such as abnormal ionization, which lead to absorption of HF waves. In this paper characteristics of ionospheric responses to solar flares observed by the SuperDARN Hokkaido radar will be presented. We use mainly ground / sea scatter (GS-scatter) echoes, which are commonly observed by the Hokkaido radar in the daytime region. The change of the echoes are characterized by the disappearance / weakening of GS-scatter echoes, preceded by short (a few minutes) periods of positive Doppler velocities corresponding to downward motion of the ionospheric reflection point, indicating increased ionization rate in the E and F region ionospheres. We also observe horizontal asymmetry of reappearance of echoes in the recovery phase probably due to the horizontal non-uniformity in the chemical reaction rate. Details of ionospheric responses to solar flares and their physical interpretation will be presented.

SuperDARN observation of March 9, 2011 X-class solar flare

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Abstract: Enhanced x-ray flux resulting from an X-1 class solar flare on March 9, 2011 had a rapid and dramatic effect on the Earth's ionosphere that was observed by many of the SuperDARN radars. The x-ray flux, recorded by the GOES spacecraft, caused a rapid increase in ionization which, in turn, was seen by many of the SuperDARN radars as a positive (toward the radars) Doppler velocity on all beams, combined with a reduction in backscattered power, and a slower recovery to quiescent conditions. Although seen mostly in Doppler spectra from ground or sea scatter the effects were also seen in Doppler measurements from ionospheric scatter. Observations show enhanced ionization causing D-region absorption of HF transmissions during the most intense period of x-ray flux and recovery beginning shortly after the x-ray-induced ionization begins declining from its maximum level. The observed effects are mostly consistent with expectations, with the radars closest to the sub-solar point recording the strongest response and radars located on the night-side, where they are shielded from the impinging x-rays, seeing little to no response. There are, however, differences from the expected behavior and SuperDARN appears to be well-suited to contribute to a better understanding of the complicated ionospheric response to x-ray events.

Solar Sector Structure Correlations with SuperDARN Saskatoon Radar and EISCAT Svalbard Radar Data

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Abstract: The Sun produces an electromagnetic plasma (the solar wind) and a magnetic field that permeates the solar system. This interplanetary magnetic field (IMF) has a large radial component that influences processes in the Earth's space environment. During its orbit the Earth finds itself in sectors of IMF that are predominantly towards or away from the Sun. The solar sector structure (structure of the IMF) has been shown in previous studies to be correlated with atmospheric weather phenomena (Wilcox 1979). By finding connections between the solar sector structure and the magnetosphere/ionosphere, we can better understand the coupling mechanism between the space environment and the Earth's atmosphere. Fairfield and Scudder (1985) have shown previously a process by which the solar wind plasma can directly reach the Earth's upper atmosphere. The plasma is injected into the northern or southern hemisphere, depending on the solar sector structure (aways or towards). In a previous study, a very clear correlation in the number of HF radar echoes measured in the ionosphere by the Super Dual Auroral Radar Network (SuperDARN) radars and the solar sector structure was found. During toward sectors, more echoes were received, and during away sectors, fewer echoes were received. The present study includes IMF and solar wind information from the Advanced Composition Explorer (ACE) satellite and ionospheric data from a SuperDARN radar and the Svalbard Incoherent Scatter Radar (ISR). A periodic correlation was found between the solar sector structure and the electron density measured by the Svalbard ISR during the International Polar Year, as well as between the solar sector structure and the amount of groundscatter detected by the SuperDARN radar. These results could be important in finding a link between space weather and atmospheric weather.

Subauroroal Processes

A survey of plasma irregularities seen by the mid-latitude Blackstone SuperDARN radar

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Abstract: The Super Dual Auroral Radar Network is a chain of HF radars that monitor plasma dynamics in the ionosphere. In recent years, SuperDARN has expanded to mid-latitudes in order to provide enhanced coverage during geomagnetically active periods. However, once the radar was built, a new type of plasma irregularity with low Doppler velocity was observed on a very frequent (> 50% of nights) basis. Using three years of data from the Blackstone, VA radar, we have implemented a method for automatically identifying this new type of irregularity. This has allowed for some statistical analysis, which has revealed some interesting features. Specifically, these irregularities are confined to local night, are almost entirely subauroral, and are equatorward of the plasmapause boundary.

Observations of an evening enhancement in ground backscatter from mid-latitude SuperDARN radars

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Abstract: Under geomagnetically quiet conditions, the daytime mid-latitude ionosphere is mainly influenced by solar radiation: typically, electron densities in the ionosphere peak around solar noon. Previous observations from the Millstone Hill Incoherent Scatter Radar (ISR) have evidenced the presence of evening electron densities higher than daytime densities during the summer. The recent development of mid-latitude Super Dual Auroral Radar Network (SuperDARN) radars over North America and Japan has revealed an evening enhancement in ground backscatter during the summer. SuperDARN observations are compared to data from the Millstone Hill ISR, confirming a direct relation between the observed evening enhancements in electron densities and ground backscatter. Statistics over a year of data from the Blackstone radar show that the enhancement occurs during sunset for a few hours from April to September. The evening enhancement observed by both SuperDARN and the Millstone Hill ISR is shown to be related to recent satellite observations reporting an enhancement in electron densities over a wide range of longitudes in the Northern hemisphere mid-latitude sector during summer time. Finally, global results from the International Reference Ionosphere (IRI) and the Horizontal Wind Model (HWM07) are presented in relation with previously published experimental results and proposed mechanisms of the evening enhancement, namely thermospheric horizontal winds and geomagnetic field configuration. It is shown that the IRI captures the features of the evening enhancement as observed by SuperDARN radars and satellites.

Midlatitude Ionospheric Features in the Plasmasphere Boundary Layer: The View From Millstone Hill

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Abstract: For over 5 decades, the Millstone Hill UHF large aperture radar system, located in Westford, MA, has made extensive measurements of the mid-latitude /sub-auroral ionosphere as a NSF supported Upper Atmosphere Facility, using the powerful technique of incoherent scatter radar (ISR). The measurements allow direct E, F and topside region ionospheric profiles of electron density, electron and ion temperature, scalar and vector velocity, and derived neutral parameters such as horizontal neutral winds and exospheric temperature. Spatial coverage of the system was greatly augmented in 1978 with the addition of a 46 meter fully steerable antenna to complement the existing 68 meter zenith profiler antenna and megawatt class UHF transmitters. The subauroral location of Millstone Hill (L ~ 3.5) allows access to a full range of ionospheric features and plasma instabilities in the very dynamic plasmaspheric boundary layer, a term introduced by Carpenter and Lemaire (2004) to describe the region where the cool, dense plasma of the inner plasmasphere overlaps the hot, tenuous plasma associated with the ring current / region 2 and plasma sheet footprints. Energy exchange in this layer forms part of the critically important mesoscale stormtime plasma redistribution circuit which brings large storm enhanced density (SED) plumes from tropical latitudes across continental North America. Large westward subauroral polarization stream electric fields, part of the region 2 current closure system, overlap the edges of SED plumes and help to supply substantial cold O+ flux to the high latitude cusp region where it can participate in the creation of tongues of ionization ,cross-polar cap transport, and heavy ion outflow which mass loads the plasmasheet. During large disturbances, the Farley-Buneman two stream instability provides coherent scatter structures with radar cross sections up to 90 dB over incoherent scatter levels, allowing microscale probing of electric fields in the SAPS/sub-auroral region. In this presentation, we will review the types of mid-latitude features seen in Millstone Hill observations. In particular, we will highlight those processes in the upcoming solar maximum which will benefit from synergistic satellite, HF and ISR measurements using Millstone and DMSP with the extended American sector mid-latitude and polar coverage of the SuperDARN network. These topics form ideal opportunities for collaborations with the SuperDARN science community.

Study of mid-latitude ionosphere convection during super quiet, quiet, and disturbed period with the SuperDARN Hokkaido radar

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Abstract: Characteristics of the ionospheric convection in the mid-latitude and subauroral regions have been studied by various kinds of observation instrument and computer experiments in the last few decades. A presence of westward flow around midnight at mid-latitude has been extensively discussed. This kind of flow can be generated by so-called disturbance dynamo mechanisms working at mid-latitudes (Blanc et al., JGR, 1980). We tested the disturbance dynamo theory by using ionospheric echo data obtained by the SuperDARN Hokkaido radar for 4 years. The SuperDARN Hokkaido radar has been measuring line-of-sight velocities of ionospheric irregularities, which can be regarded as line-of-sight velocities of ionospheric convection. The radar can monitor ionospheric convection at mid-latitude (geomagnetic latitude: 40 to 60 degrees), which could not be monitored by using preexisting SuperDARN radars. In the previous study we found the presence of westward flows around midnight at about 40 to 55 degrees geomagnetic latitude, which intensified with increasing geomagnetic activity. On the other hand, Gonzales et al. (1978, JGR) showed that the ionospheric convection flow just before midnight becomes eastward when the geomagnetic activity level is very quiet (1-day sum of Kp index less than or equal to 14) using the Millstone Hill radar data. This tendency was not found from our previous study using SuperDARN Hokkaido radar. Kumar et al. (2010, JGR) reported using the data from Digisonde drift measurements made at Bundoora (145.1 degrees E, 37.7 degrees S geographic, 49 degrees S magnetic), Australia, that the effects of major storms (minimum Dst < -60nT) in the nighttime mid-latitude ionosphere were observed to last up to 50 hrs after storm onset. In order to understand the effects of the disturbance dynamo on the mid-latitude nighttime ionosphere, we reanalyzed the SuperDARN Hokkaido radar data using only the data under very quiet geomagnetic condition for preceding 48 hours. However, the tendency reported by Gonzalez et al. (1978) was not found even when geomagnetism index Kp was less than or equal to 0+ and the influence from previous geomagnetic storms has been removed. We are studying the dependence of mid-latitude ionosphere convection observed by the SuperDARN Hokkaido radar on Dst index defined storm, using Superposed Epoch Anaysis (SEA). Details of the analysis will be presented.

Sub-auroral flow shear observed by King Salmon HF radar and RapidMAG

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Abstract: We examine in detail the evolution of ionospheric flow shears found in the sub-auroral region. Flow shear structures are often observed in the dusk sector by the SuperDARN King Salmon (KSR) HF radar. Interestingly, some of those show the eastward (westward) flow on the lower (higher) latitude side, respectively, opposite to the typical polarity of the dusk convection cell. In some of those flow shear events, the IMF has a weak but persistent southward component (~ -1 to -3 nT) before onset of flow shears and following decreases of the southward IMF or even northward turning appear to cause the flow shears. The radar observations also show that those changes of convection structure take place rather quickly (~several min). The ground magnetograms provided by the Russian Auroral and Polar Ionospheric Disturbance Magnetometers (RapidMAG) show gradual increases (abrupt declines) of the H-component in association with the increases (decreases) of the merging electric field, respectively, derived from the simultaneous solar wind-IMF observations. The fairly coherent increases (decreases) of the H-component over the wide range of local time (afternoon to evening) indicate development (decay) of the large-scale DP2 current system. We also made statistical studies on this kind of flow shear events. It is found that some of flow shears are formed upon changes of the DP2 current system, while more flow shears occur during substorms and do not necessarily show clear temporal correlation with DP2 variations. Comparison of flow shear positions with simultaneous satellite observations revealed that flow shears are formed in the region of the trapped ring current or plasma sheet ions. This fact suggests that the diverging electric field at a flow shear is brought in the ionosphere by a field-aligned current from the ring current and/or the plasma sheet.

Large-Scale SuperDARN observations of a Sub-Auroral Polarization Stream at Mid-Latitudes

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Abstract: On April 9th 2011 six SuperDARN radars located at mid-latitudes observed a sub-auroral polarization stream (SAPS) during a period of moderately disturbed conditions (Kp = 3+, Bz = -2 nT). The observations span about 10 hours of magnetic local time and lasted from 0400 UT to 1100 UT. We present POES and DMSP measurements of precipitating particles which allow for the dynamic localization of the auroral oval during the event. These observations show that the SAPS was located just equatorward of the equatorward boundary of the auroral oval and that the location of the flow channel moved with the boundary as the oval expanded due to continuous solar wind driving. Due to the extensive local time coverage we are able to study for the first time the longitudinal variation of flow velocities inside the SAPS channel. Our observations again highlight that the mid-latitude SuperDARN radars provide invaluable scientific data even during non-storm periods.

SAPS intensification during substorm recovery: A multi-instrument case study

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Abstract: A case of the major intensification of the subauroral polarization stream (SAPS) during the substorm recovery phase is presented. The continuous high-time-resolution Doppler velocity measurements in the subauroral and auroral regions were conducted with the Unwin HF radar, and these are analyzed in the context of the simultaneous and coincident measurements of the auroral luminosity and the total electron content by the IMAGE and GPS satellites. Additional information was provided by other SuperDARN radars, DMSP F15 satellite crossing the fully-developed SAPS region, ground-based measurements near the location of the substorm onset, and GOES and LANL satellites in the inner magnetosphere. The strong association between the SAPS region and the electron density trough is further substantiated at relatively short time scales and in two horizontal dimensions, with some evidence of the relationship breaking during substorm recovery. It is also demonstrated that the positive feedback processes between the electric fields and electron densities were probably not responsible for the observed strong SAPS intensification. Moreover, it is proposed that the strong and steady plasma acceleration within SAPS may be triggered by a burst of auroral activity, rather than accompanied by a similarly steady variation in other observed parameters either in the ionosphere or in the inner magnetosphere. It is argued that the SAPS major intensification occurring during the recovery phase is not necessarily expected from the current models of the SAPS formation and evolution, but is consistent with the observationally-based view of a fully-developed SAPS as a substorm recovery phenomenon.

Dynamic sub-auroral ionospheric electric fields observed by the Falkland Islands radar during the course of a geomagnetic storm

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Abstract: We present an analysis of ionospheric electric field data observed during a geomagnetic storm by the recently deployed Falkland Islands SuperDARN radar. On 3 August 2010 at ~1800 UT evidence of the onset of a geomagnetic storm was observed in ground magnetometer data in the form of a decrease in the Sym-H index of ~100 nT, indicative of an enhancement in the strength of the ring current. The main phase of the storm was observed to last ~24 hours before a gradual recovery lasting ~3 days. On 4 August, during the peak magnetic disturbance of the storm, a high velocity (>1000 m/s) channel of ionospheric plasma flow, which we interpret as a sub-auroral ion drift (SAID), located between 53 and 58 degrees south and lasting ~6.5 hours, was observed by the Falkland Islands radar in the pre-midnight sector. Coincident data from the magnetically near-conjugate northern hemisphere Blackstone HF radar confirm the existence of a similar feature located at the equivalent northern latitude. In this paper we discuss the influence of the storm on the ionospheric conditions and describe a detailed investigation of the high velocity flow channel. We find that variations in latitude and magnitude of the flows in the channel are related to both the ring current dynamics and variations in the inferred size of the polar cap, suggesting that the electrodynamics of the nightside sub-auroral region are driven by a combination of solar wind driving and processes occurring in the inner magnetosphere.

Solar Wind - Magnetosphere Interactions

Magnetopause reconnection rate and cold plasma density: a study using SuperDARN

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Abstract: It has been suggested that cold plasma associated with cold dense plasma plumes from the plasmasphere can decrease the reconnection rate at the magnetopause as the cold plasma convects towards the magnetopause. This paper reports a study using SuperDARN of the cross polar cap potential and the convection flows in the ionosphere which are generated by the reconnection at the magnetopause and therefore are a direct measure of the reconnection rate. Cold plasma density are taken from LANL measurements and have been used in earlier studies of the impact of cold plasma on the reconnection rates. A super posed epoch analysis of northern hemisphere SuperDARN data has been undertaken during some 350 cold density events. The results indicate that during these events the cross polar cap potential increases in the two hours prior to the event onset time while remaining approximately constant after the onset time. Random selections of events demonstrate that this result is not due to radar data coverage nor due to changes in the solar wind conditions.

Magnetotail Disruption Zones and their

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Abstract: The stretched magnetic field region of the magnetotail has, at its center, the neutral sheet (NSh). THEMIS observations show that a deep minimum of a few nT in field strength B occurs there. The NSh is bordered on the north and south by closed stretched field line regions, which we call Disruption Zones (DZs), for which a new interpretation of Cluster data reveals several important features, namely: (i) an outward field gradient from the NSh; (ii) an outward curvature also pointing away from the NSh. As a result, the curvature-gradient drift of the ions is eastward in the DZs, opposite to the westward drift of the essentially unmagnetized ions in the NSh. There are two important consequences of these adjacent oppositely directed ion drifts. First,the strong momentum shear across the interfaces between the NSh and DZs drives Alfvenic wave activity by means of the Kelvin-Helmholtz Instability (KHI), first in the kink mode, then in the sausage mode and finally the sausage-tearing mode. The latter drives reconnection, likely at multiple X-line locations, and causes substorm onset and field line dipolarization. Secondly, a double-celled current system forms in which eastward current in the DZs is closed with westward current in the NSh. This is a positive-feedback system that creates more stretched line flux in the DZs north and south of the NSh, and this in turn drives faster curvature-gradient drifts, which in turn lead to more current, and so on. Thus, the KHI progression from kink to sausage-tearing mode and the double-current system are strongly correlated. Although external triggering can perturb the highly inductive double-cell current system and lead to onset, the above model does not require triggering and shows that the magnetotail NSh-DZ field topology on its own can quite naturally lead to substorm onset. The DZs also act to deflect earthward the westward curvature-gradient drift plasmasheet flows on the quasi-dipolar field lines between the dawn and dusk LLBL regions and the stretched field region in the middle plasmasheet (~ -8 < Y < ~ +8 RE). This convective deflection leads to the Substorm Current Wedge and the associated FACs that link the magnetospheric substorm to the auroral substorm.

Ionospheric Convection and Field-Aligned Currents During Strong Magnetospheric Driving: A SuperDARN/AMPERE Case Study

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Abstract: We present a detailed case study of the dynamic response of ionospheric convection and field-aligned currents (FACs) to abrupt changes in the interplanetary magnetic field (IMF) on December 12th 2010. Between 1900 and 2000 UT the IMF was strongly northward (Bt > 6 nT) and the SuperDARN radars in the northern hemisphere observed characteristic reverse convection cells on the dayside typically associated with high-latitude reconnection. However, the FACs measured by the AMPERE project during this time show no signature of the expected NBZ current system. Around 2000 UT the IMF turned southward (Bt ~ 10 nT) and following this reversal, the ionospheric convection changed into the typical two-cell pattern associated with dayside reconnection. As the IMF continued to stay southward for 2 hours, the increased solar wind-magnetosphere coupling manifested itself as higher convection velocities observed by SuperDARN radars, higher cross polar cap potential, increasing FAC intensity and an equatorward motion of the FAC location. We interpret the motion of the FACs as a signature of increasing open magnetic flux within the polar cap consistent with dayside reconnection due to southward IMF. The spatial patterns of DMSP satellite observations of auroral boundaries support this claim. Ionospheric convection and the FAC intensity are found to be in good agreement, specifically we find that intense FACs are co-located with strong velocity shears. The combined AMPERE-SuperDARN dataset allows us to study the response of ionospheric convection and FACs to solar wind driving on an unprecedented time scale of minutes.

Solar wind-magnetosphere coupling, substorms, and ramifications for the ionospheric convection pattern
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Abstract: We describe the general characteristics of the evolution of the auroral, ionospheric, and magnetotail signatures of magnetospheric substorms and geomagnetic storms. We present results of superposed epoch analyses of 2000 substorms, identified by Frey et al. (2004), of Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) auroral images, Super Dual Auroral Radar Network (SuperDARN) ionospheric flows, and other measures of magnetospheric disturbance. In particular we examine the effect of the onset latitude of the subsequent evolution of the substorms and geomagnetic storms. The results are interpreted within the expanding/contracting polar cap paradigm (ECPC), and the ramifications for the ionospheric convection pattern are discussed.

Convection Studies

Magnetometer and radar study of the ionospheric convection response to sudden changes in the interplanetary magnetic field
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Abstract: Both magnetometer and SuperDARN data sets are examined in detail for two separate events to investigate the ionospheric response to the sudden southward turning of the interplanetary magnetic field (IMF). Initially, the IMF perturbation wavefront impinges the magnetosphere near noon, dragging field lines across the front-side magnetosphere into the magnetotail over a period of 5-6 minutes. This translates into a noon-to-midnight progression of the ionospheric onset of the observed magnetic and electric field response to the transition wavefront. Once the southward oriented field lines reach the magnetotail, the ionospheric convection pattern responds simultaneously across the entire high-latitude region. The reverse convection cells established on the dayside due to the period of northward IMF prior to the transition break down, and the foci of the new dawn and duskside convection cells begin a progression from their nightside location toward the dayside which lasts for a periods of 8-10 minutes. These results support an idea that convection reconfiguration associated with a southward turning of the IMF is a two-stage process.

On the relationship of polar cap flow velocities and the IMF/solar wind
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Abstract: At nearly 80° magnetic latitude, the SuperDARN radar at McMurdo is the highest latitude radar in the network. The distance from the radar to the magnetic pole is about 1000 km, which is an ideal range for observations of F-region irregularities. The high incidence of irregularities in the polar cap has yielded an excellent database of polar cap velocity observations. This study draws from this database to examine the relationship between the observed Earth-Sun component of the flows and the IMF and solar wind. Line-of-sight velocity observations from latitude greater than 85 degrees magnetic were used when the dot product of the radar k-vector and the Earth-Sun direction exceeded 0.9. Time series of the velocities were correlated with the IMF z-component and found that on average the correlation is about 50%. In some intervals the correlation exceeded 80% while in others there was virtually no correlation. Scatter plots of the observations show a roughly linear relationship between Bz and the velocity, however the spread about the line was significant.

SuperDARN and reversed flow events in the cusp
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Abstract: We present several examples of reversed flow events (RFEs) from the cusp ionosphere. RFEs are 100-200 km wide flow channels opposing the background plasma convection. RFEs were discovered a few years ago by the EISCAT Svalbard Radar. In this paper we show that SuperDARN can also see RFEs. We use the location of distinct auroral signatures to test the standard range finding algorithm, and we find that it overestimated the ground range of the SuperDARN echoes by 140 km. We report a close relationship between RFEs and the development of HF backscatter power and spectral width. Wide spectra were seen near the edges of the RFEs (i.e. associated with the flow shear), and there was a significant increase in SuperDARN HF backscatter power when the RFE expanded, much faster than anticipated from the gradient drift (GD) instability alone, suggesting that RFE flow shears may foster rapid growth of Kelvin-Helmholtz (KH) instabilities. However, the cusp ionosphere is a complex region and other modes of instability growth may also be relevant.

The formation of transpolar arcs

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Abstract: Transpolar arcs are auroral features which form on the night side of the auroral oval, and extend into the polar cap. They occur predominantly during intervals of northward IMF (Berkey et al., 1976), and there is some evidence for IMF BY control of the local time at which the arc initially forms (Gussenhoven, 1982; Elphinstone et al., 1990; Makita et al., 1991; Kullen et al., 2002). Milan et al. (2005) proposed that transpolar arcs might be related to magnetotail reconnection following lengthy periods of dayside reconnection with a significant IMF BY component. Such intervals of dayside reconnection lead to the presence of a cross-tail component of the magnetic field in the magnetotail (Cowley, 1981), and subsequent magnetotail reconnection results in fast eastward or westward ionospheric flows which are asymmetric across midnight MLT (Grocott et al., 2003, 2004). Milan et al. argued that transpolar arcs might be formed by the build-up of closed magnetic flux near midnight MLT, where closed magnetic field lines have one foot in the pre-midnight hemisphere, and the other post-midnight, and therefore their flow back toward the dayside magnetosphere is frustrated. If the Milan et al. (2005) hypothesis is correct, then an anticorrelation should be observed between IMF BY and the local time at which transpolar arcs form, and fast ionospheric flows should be observed directed away from the arc and across the midnight meridian. In this presentation, we show the results of a statistical study of 131 transpolar arcs observed by the FUV cameras on the IMAGE satellite between June 2000 and September 2005. Most of the events occur when the IMF has a northward component. There is an anticorrelation between the magnetic local time at which the arcs form and the IMF BY component in the time leading up to the start of the arc; the anticorrelation is strongest when the IMF is averaged over the 4 hours prior to the start of the event. Examination of SuperDARN data also reveals that most of the events for which there is good ionospheric scatter are also associated with fast eastward or westward ionospheric flows. These observations are consistent with the mechanism proposed by Milan et al. (2005).

Towards an information theory approach for monitoring the ionospheric convection dynamics

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Abstract: Some features, such as vortex structures often observed through a wide spread of spatial scales, can lead to think ionospheric convection is turbulent and complex in nature. Here, applying concepts from information theory and complex system physics we firstly evaluate the Shannon entropy, S, associated with the polar cap potential obtained from the Super Dual Auroral Radar Network (SuperDARN) and, then, estimate the degree of complexity of ionospheric convection in different solar wind and interplanetary magnetic field conditions. The aforementioned quantities have been computed starting from time series of the coefficients of different orders spherical harmonics expansion of the polar cap potential, and in different conditions of radar coverage in both hemispheres in order to understand if and when the global entropy variations in the auroral and polar regions can be viewed as a proxy of the energy drivers in the solar wind and the magnetosphere. Some preliminary results are shown using both superposed epoch data sets and particular time series.

Interhemispheric Studies & Satellite Studies

Hemispheric Comparison of Signatures of Flux Transfer Events

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Abstract: A previous statistical study of flux transfer events (FTEs) observed by spacecraft during magnetopause crossings has noted that FTEs were observed only in the winter hemisphere (Korotova & Sibeck, GRL, 2008). It was expected that, since an open field line is created in both the summer and the winter hemispheres, FTE signatures would be observed in both hemispheres. The present study is an investigation of the SuperDARN signature of FTEs. Ten years of northern hemisphere data were inspected to assess the seasonal occurrence rate of poleward moving radar auroral forms (PMRAFs). The occurrence of PMRAFs follows very closely the overall occurrence of ionospheric echoes. In addition to this, simultaneous and magnetically conjugate observations of PMRAFs do occur. These ground-based results suggest that the assymmetry in FTE occurrence at the magnetopause is not indicative of a lack of reconnected flux tubes in the winter hemisphere; rather it indicates that the commonly used 'bipolar' magnetic field oscillation that is used to identify reconnected flux tubes is not present.

Unprecedented observations of a sequence of flux transfer events imaged by SuperDARN and the FUV instrument of the Imager for Magnetopause-to-Aurora Global Exploration mission

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Abstract: We present a sequence of flux transfer events observed by SuperDARN in the northern hemisphere and their counterpart signatures in southern hemisphere auroral images taken by the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) spacecraft on 31 August 2005. The observations indicate that auroral features associated with each FTE are entrained within a relatively narrow convection throat, with east-west convection flow in the northern hemisphere and west-east auroral motion in the southern hemisphere, consistent with the By > 0 nT orientation of the IMF. We compare and contrast these observations with previous FTE studies and discuss the conclusions that can be drawn for reconnection geometries at the magnetopause.

Testing the Equipotential Magnetic Field Line Assumption Using Interhemispheric SuperDARN Measurements

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Abstract: An important assumption often made in space physics is that magnetic field lines can be treated as electrostatic equipotentials. This assumption tells us that electrodynamic processes occurring at both ionospheric ends of a closed magnetic field line should be very similar, even when there might be substantial interhemispheric differences in ionosphere-thermosphere conditions (e.g. seasonal effects). The net result is to produce a common electrostatic potential structure for the entire magnetic flux tube that includes averaged effects of electrodynamic influences at both ends. In this presentation we examine the validity of the equipotential magnetic field line assumption using SuperDARN radars in both hemispheres. We examine event intervals in which north-south pairs of SuperDARN radars with nominally conjugate fields of view observed simultaneous measurements of ionospheric convection. We use empirical magnetic field models to map the radar measurements between the hemispheres to rigorously examine the consistency between the flows. A particular emphasis is placed on examining the conjugacy of subauroral features observed simultaneously by the mid-latitude Wallops and Blackstone radars in the northern hemisphere and the Falkland Islands radar in the southern hemisphere.

Swarm and SuperDARN

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Abstract: The European Space Agency's Swarm mission will include three satellites in circular polar orbits at altitudes between 400-530 km. Swarm is planned for launch in July 2012, and will make precision measurements of the geomagnetic field using a design similar to that of CHAMP. However, each Swarm satellite will also carry a new-generation of ion drift meter that records 2-D images of low-energy (<10 eV) ion distribution functions at a rate of two per second. From these distributions ion drift and temperature will be derived. Each satellite will also carry dual Langmuir probes capable of measuring electron density and temperature, also twice per second. This presentation is meant to introduce Swarm and its capabilities, and to stimulate planning for joint experiments with SuperDARN. Also, we wish to explore the possibility of joining Swarm and SuperDARN data together to produce regional and global convection maps.

Active Magnetosphere Polar Electrodynamics Response Experiment (AMPERE): Status and Highlights

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Abstract: The Active Magnetosphere Polar Electrodynamics Response Experiment (AMPERE) is a facility to provide global measurement of the field-aligned Birkeland electric currents that link the Earth's magnetosphere and ionosphere. This is accomplished using the existing >70 low Earth orbiting (LEO) satellites of the Iridium Communications Inc. satellite constellation. The avionics of each satellite includes a vector magnetometer which is sensitive enough to detect the Birkeland currents. New flight software and ground data systems were developed to send 10 to 100 times more magnetometer data to the ground than previously possible. The higher magnetic field samples yield continuous, near real-time measurement of the global Birkeland currents with a re-visit interval of just nine minutes corresponding to the inter-satellite spacing within a given orbit plane. Continuous AMPERE data have been acquired since June 2010 and test data were acquired starting in October 2009. Inversions of magnetic perturbations and field aligned currents from these data are derived as standard data products supported by various display tools. The status of subsequent data releases, high-rate AMPERE operation plans, real-time development, as well as science highlights are discussed. Combinations of AMPERE field aligned currents with simple models of ionospheric conductance and comparisons with SuperDARN bi-static flow results are used to illustrate the application of AMPERE as a powerful constraint on ionospheric electrodynamics.

Poster Abstracts

Convection Studies, Interhemispheric Studies

High-latitude convection maps derived from AMPERE field-aligned currents and comparisons with SuperDARN line-of-sight velocities

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Abstract: We present preliminary results from a procedure reconstructing high-latitude ionospheric convection from the Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE) field-aligned currents. The basis for the procedure is the solution of the ionospheric Ohm's law derived from current continuity. Three models of ionospheric conductance are used: an empirical model of Extreme Ultraviolet (EUV) ionization; the above with particle precipitation added; and the third where the conductance is modified by anomalous electron heating resulting from Farley-Buneman instability. The precipitation model used includes two contributions: the diffuse aurora is determined from a plasma sheet specification obtained from a global magnetospheric simulation; and the discrete aurora is obtained from the AMPERE currents through the Knight relation. The Farley-Buneman turbulence contribution results in conductances amplified by a factor roughly proportional to the local convection electric field. Once the ionospheric conductance tensor is determined, it is used, along with the AMPERE currents, to derive the ionospheric potential and corresponding electric fields and convection velocities. The latter are compared with SuperDARN line-of-sight velocities. Generally, very good agreement is observed between AMPERE-inferred and SuperDARN velocities, but the result, not-surprisingly, depends strongly on the conductance magnitude and gradients. We discuss similarities and discrepancies between AMPERE and SuperDARN velocities and demonstrate how strong a constraint the superposition of the two provides on the possible conductance distributions. This suggests that such techniques, combined with other ionospheric electrodynamics measurements, are feasible for reconstruction of realistic conductance distributions.

AMPERE and SuperDARN: What's in it for me?

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Abstract: The AMPERE project has recently started to produce and make publicly available global measurements of field-aligned currents (FACs) derived from measurements of horizontal magnetic perturbations observed by the 66 satellites of the Iridium constellation. In this paper we present a number of case studies highlighting how these global observations of currents can be combined with global and local observations of ionospheric convection as provided by the SuperDARN radars. Specifically, we present case studies during strongly northward and strongly southward interplanetary magnetic field (IMF), focusing on the direction and location of both the observed currents and ionospheric flows. For each interval we present estimates of the Poynting flux into the polar ionosphere by combining the electric and magnetic field measurements. Furthermore we present long term (~months) estimates of the integrated energy flux and relate these to solar wind conditions. The AMPERE data set provides, for the first time, global continuous estimates of FACs on the time scale of minutes which, when combined with SuperDARN convection observations, provide a formidable resource for characterizing the state of the polar ionosphere during multiple levels of solar wind-magnetosphere coupling.

Characteristics of spatial variability in high-latitude SuperDARN velocities

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Abstract: Small-scale variability in high-latitude ionospheric plasma drifts can contribute to the total energy deposited through Joule heating but it is typically not accounted for in statistical models of high-latitude convection. In this study, SuperDARN line-of-sight velocity data from both hemispheres are analyzed to determine the statistical characteristics of velocity fluctuations on scales up to ~500 km. It is found that the overall distributions of fluctuations observed during eight months of the years 2000 and 2001 are the same in both hemispheres. Several interplanetary and geophysical parameters such as IMF, AE, and dipole tilt are found to influence the distribution of fluctuations. These parameters are not seen to have the same influence in both hemispheres.

Convection mapping with Swarm satellite and SuperDARN radar data

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Abstract: In 2012 the European Space Agency (ESA) will launch the Swarm mission to provide the best ever survey of the geomagnetic field and the first global representation of its variation on time scales from hours to years (Friis-Christensen et al., 2006; 2008). The Swarm satellites will make continuous observations of the ionospheric plasma drift, making it an ideal instrument for mapping the ionospheric convection pattern. In this report, the spherical cap harmonic analysis (SCHA) technique developed for mapping the magnetic field based on observations covering a cap-like region of the spherical Earth (Haines 1985; 1988; 2007) has been adapted for mapping convection based on ion drift measurements from the Canadian Electric Field Instrument onboard the Swarm satellites. In a previous internal study, convection maps were generated based solely on Swarm measurements. Although it was possible to create such maps, the region of the map constrained by data was limited to a narrow track surrounding the footprints of the satellite trajectory, and it was not possible to create a global picture of the plasma flow based on a single pass of the Swarm satellites. To increase the mapping region, measurements from the SuperDARN radar array are added to the Swarm data set. It is shown that the combination of the Swarm and SuperDARN data sets increases both the region of convection constrained by measurements, and the accuracy of the resultant convection maps that could be generated based on data from either instrument alone.

Symmetry and asymmetry of interhemispheric dayside ionospheric convection seen by the SuperDARN Kerguelen and Hankasalmi radars

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Abstract: We have identified excellent conjugated observations in the cusp regions by Hankasalmi (Northern Hemisphere) and Kerguelen (Southern Hemisphere) SuperDARN radars. First, we have investigated the location of the boundary between low and high spectral width in both hemispheres, studied their relative positions with respect to interplanetary conditions, focusing on periods where the boundaries behave differently in both hemispheres, and finally, we have compared the location between the northern spectral width boundary and the open-closed magnetic field boundary obtained from particles precipitation measured by low-altitude spacecraft. Second, we have identified conjugated pulsed ionospheric flows characteristics of sporadic magnetopause reconnection events (Flux Transfer Events, FTE). These observations were perfectly conjugated, suggesting a unique subsolar magnetopause reconnection line. However, the number, the velocity, and the shape of these ionospheric structures are very different in both hemispheres. We have investigated the causes for these different properties, with respect to season and interplanetary conditions.

The interhemispheric version of the TRANSCAR ionosphere model

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Abstract: In order to study the impact of coupling between hemispheres on the dynamics of the ionospheric and magnetospheric plasma, a new interhemispheric ionospheric model has been developed with a dipolar geomagnetic field geometry. This new model is based on a multi-fluid approach for ions and thermal electrons and a kinetic approach for suprathermal electrons, already used in the TRANSCAR model (Blelly et al., 2005). However, substantial developments have been made, in order to cover high altitudes, low- and mid- latitudes with a single model. The mathematical fluid approach has been extended to a 16-moments to take into account possible temperature anisotropies at high altitudes, in collisionless region. The model also integrates inertial forces, corotation at all latitudes and convection at mid and high latitudes and possible electrons precipitation at auroral latitudes. Convection and precipitation can be deduced from empirical models or from observations such as SuperDARN global maps for convection. We will present the main characteristics of this new model and shows the first simulation results.

Quantitative comparison of cross polar cap potential as derived from AMIE, DMSP, SuperDARN

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Abstract: More than a decade of Cross Polar Cap Potential (CPP) obtained from the SuperDARN radar network is compared to the same parameter derived from the Assimilative Mapping of Ionospheric Electrodynamics technique and calculated from measurements by the Defense Meteorological Satellite Program's Special Sensor-Ions, Electrons, and Scintillation instrument. CPP is a shorthand index used as a measure of the energy flux of the solar wind/magnetospheric energy flux into the ionosphere. We examine the correlations between the different measurements as a function of UT, season, and solar cycle.

Interhemispheric comparison of cross-polar cap potentials

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Abstract: Cross polar cap potentials in the polar ionospheres are important physical parameters showing magnetospheric conditions depending on solar wind energy input, energy dissipation in the magnetosphere and strength of plasma convection in the magnetosphere, etc. The potential drop at northern hemisphere and one at southern hemisphere is thought to be identical in the zero's order approximation. However, it is not clear whether they are always completely the same values or not because of the existence of difference in ionospheric conductivity in both hemispheres due to seasonal differences, the effect of dipole tilt angle, and asymmetries in phenomena in a variety of spatial scales between both hemispheres. In the past, some possible seasonal differences have been discussed with statistical analyses mainly using satellite data, and a recent study using SuperDARN data pointed out that an effect of dipole tilt angle on the differences, but no comprehensive physical understanding has been made yet. We here use SuperDARN data simultaneously obtained at both hemispheres from 1999 to 2006 and try to obtain essential physical understanding of this potential differences especially on dependencies on interplanetary magnetic fields, geomagnetic activities, seasons, dipole tilt angle, and substorm phases, and so on. We first show the initial results of this interhemispheric comparison this time particularly on whether the two simultaneous values show any statistical differences, and whether there exist any examples where large differences exist and discuss the possible reasons if any in detail.

Ionospheric Irregularities, Radio Wave Propagation, Neutral Processes

SuperDARN and EISCAT observations of SPEAR (Space Plasma Exploration by Active Radar) induced sporadic E-region heating at 78N

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Abstract: We present the 1st high resolution observations of sporadic E-layer heating at high latitudes (78N) using the SPEAR heating facility, the EISCAT Svalbard Radar (ESR) the SuperDARN HF radars. During the experiment the SPEAR heating facility was transmitting with O-mode polarization in a field aligned direction. Results from the co-located ESR show distinct heating enhancements in the plasma line spectra, corresponding to the SPEAR heater frequency of 4.45MHz. High spatial resolution (100m) plasma line data indicate simultaneous enhancements at both the top and bottom side of the layer respectively (located at ~107.5 and 109km altitude respectively). The observed enhancements disappear completely during a SPEAR on period, during which time the SuperDARN radars observe a patch of artificial field aligned irregularities (AFAIs) co-located with the SPEAR system. It is postulated that the results represent evidence of O to Z-mode conversion of the heater wave occurring at the bottom of the E-layer, allowing propagation through the layer resulting in simultaneous topside enhancements. When this layer disappeared completely it allowed the beam to propagate to a higher altitude, reaching the F-region, where conditions were suitable for the generation of AFAIs.

SPEAR-induced F region heating effects as observed using CUTLASS and EISCAT Svalbard radar

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Abstract: In this study, results obtained from a recent heating experiment conducted using the SPEAR heating facility on Svalbard are presented. During this campaign, the CUTLASS Finland and Iceland radars made observations using a high spatial resolution scan mode. We show artificial backscatter measurements from both CUTLASS radars which were observed simultaneously with EISCAT Svalbard Radar (ESR) observations of SPEAR-enhanced ion lines. In particular, the ion lines are found to exhibit the Purely Growing Mode (PGM) feature at the centre of the spectrum which persists at varying amplitudes throughout the SPEAR heating, unlike observations made using the Tromso heating facility which is outside the polar cap. The presence of this feature is known to give rise to unreliable estimates of the electron temperature when incoherent scatter spectra are analysed using conventional analyses methods. The focus of this study is on an alternative estimation of the SPEAR-modified electron temperatures, which are obtained by applying a recently developed method that removes the PGM from ESR spectra before they are analysed. We present some initial results which highlights important differences between artificial heating experiments performed using SPEAR and those conducted at lower latitudes.

Coincident multi-point observations of the E- and F-region decametre-scale plasma waves at high latitudes

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Abstract: Presented is a detailed analysis of the E-region backscatter observed by the PolarDARN component of the Super Dual Auroral Radar Network (SuperDARN). The statistical occurrence characteristics of the short-range echoes reveal significant differences from those of the auroral and sub-auroral SuperDARN radars. In particular, most backscatter is detected in the midnight sector in the closest range gates where the geometric aspect angles are quite large. One explanation offered is that layers of intense plasma density significantly refract the radar waves allowing the regular detection of plasma waves in the very short ranges. An analysis of the statistical echo types within the PolarDARN dataset showed similarities with the other SuperDARN radars, with the low-velocity echoes dominating both PolarDARN radar datasets. The high-velocity echoes were observed rather sporadically throughout the morning sector, during which the flow and aspect angles are expected to be small enough for routine backscatter to occur. The locations of the PolarDARN radars relative to the more-equatorward SuperDARN radars results in a new experimental setup that has coincident and simultaneous HF radar coverage of the E and F regions along connecting magnetic field lines. In this radar configuration, the SuperDARN plasma flow measurements are employed to investigate the E-region phase velocity dependence on the electric field strength and the flow angle at multiple locations. By employing elevation angle estimates, a marked decrease in the observed phase velocity with decreasing altitude is observed and is attributed to an increased number of collisions between the charged particles and the neutrals. It is also shown that the measured phase velocity normalised to the background plasma flow is smaller for higher electric fields, compared to that for smaller electric fields. This result is interpreted as being due to a change in the contribution of the convective effects on the plasma wave growth.

Gravity waves and their relationship to geomagnetic activity

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Abstract: We inspect ground backscatter data from the Falkland Islands, Wallops Island and Blackstone radars for evidence of gravity wave activity. We comment on the interhemispheric nature of the gravity waves and their relationship to geomagnetic activity as inferred from the AL, AU, and Sym-H indices.

Analysis of HF radar observations of ionospheric backscatter during geomagnetically quiet periods

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Abstract: Coherent HF backscatter detected by the TIGER SuperDARN radar (Bruny Island, 43.38 S, 147.23 E, geographic) during geomagnetically quiet periods is analysed statistically in order to identify the controlling factors of backscatter occurrence in the F-region ionosphere. The occurrence of F-region backscatter is shown to exhibit distinct diurnal, seasonal and solar cycle variations. The backscatter data is compared to values of F-region peak electron density (NmF2) from the IRI-2007 model and with data from nearby ionosondes for validation. Pedersen conductance values of the underlying E region are also modelled and compared with the backscatter data. During the night, the amount of backscatter is shown to vary directly with the magnitude of NmF2. During the day, occurrence minima are shown to be associated with large E-region conductances. This suggests that solar illumination restricts the production of F-region irregularities during the day.

Classifying near-range echoes detected by the mid-latitude SuperDARN radars
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Abstract: Dartmouth College led the build of two coherent backscatter radars with 24 beams near Christmas Valley, Oregon in November as part of the collaboration to develop a network of mid-latitude radars known as the Super Dual Auroral Radar Network (SuperDARN). Currently research on near-range backscattering drifts are analyzed on determining the classification of meteors trail echoes from other backscattering echoes such as E-region irregularities and background noise occurring at mid-latitudes. With two radars in close proximity, a comparison on derived velocities show different results that may be caused from E-region plasma drifts that have similar characteristics of meteor trail echoes. A clear distinguish on classifying meteor trail echoes can be used to develop a global analysis of neutral winds with multiple SuperDARN radars around the mid-latitude region.

Extended observations of decameter scatter associated with the mid-latitude ionospheric trough
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Abstract: We present extended scatter observations that are associated with the nighttime ionospheric mid-latitude trough. Using data from five mid-latitude SuperDARN HF radar sites, including two radars with greater than 4 years of observations, we are able to compare with trough observations derived from electron density occultation measurements obtained from the COSMIC suite of satellite. We examine the scatter characteristics with respect to trough depth and location. Additionally, we examine longitudinal differences between sites and climatology as a function of seasons and local time.

Hardware Development, Analysis Techniques

A DDS-based Phasing and Pulse Unit for SuperDARN
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Abstract: We have developed a direct-digital-synthesis and micro controller based phasing and pulse unit, that generates the pulsed transmit signals and the constant wave receive signals with the correct phases; necessary to operate the steerable beam of a SuperDARN radar. It replaces timing computer, interface box and phasing matrix. The first of these systems has been in operation at Inuvik since December 2010, the other three Canadian radars will be upgraded during 2011.

Clear frequency search algorithm for twin radar operation
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Abstract: In SuperDARN radar operation a Clear Frequency Search is performed in each beam direction to pick a clear, low noise frequency at which to transmit for that period of integration. For the Christmas Valley MSI radars (cvw and cve), the search algorithm is further complicated by picking a clear frequency for two radars that do not interfere with each other. The current algorithm does not always effectively pick legal, low-noise frequencies, however, "handpicking" acceptable frequencies seems relatively straightforward. This work investigates a technique for identifying "clear frequencies" for two radars by analyzing FFT data from both radars. In this algorithm the selected frequency corresponds to the minimum of a sum of power data from the FFT with several additional constraints including smoothing power over a frequency band, biasing, and artificially boosting the power at frequencies prohibited by FCC regulations. Smoothing the power measurements prevent frequencies close to those with high noise from being selected. Biasing the twin radars towards higher and lower ranges of frequencies allow the algorithm to reliably pick two unique frequencies from corresponding FFT datasets.

Circular TTFD array design for omni-directional FoV
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Abstract: With the enhanced capabilities of the TIGER-3 platform, and a vastly superior signal to noise ratio, the latest TIGER transceivers have the potential to be utilised effectively to study sea-state conditions, in addition to regular SuperDARN operations. A circular design allows great flexibility in the use of the system. For instance the RADAR could provide 3 or more beams from a central east coast location, (ie. Effectively 3 or more radars) with one beam looking poleward overlapping the FoV of the current RADARs, one beam looking equatorward to monitor low latitude activity, and a third beam looking eastward over the Pacific Ocean. The operation of the RADAR with the enhanced sensitivity would allow common mode operations to be interspersed with the sea-state measurements in a versatile operational sequence.

FPGA-based cable length phase calibration

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Abstract: With the new FPGA-based transceivers for TIGER-3, we have the ability to perform a wider range of operations than previously available. One of these is digital compensation for variations in cable length, which can be adjusted at any time after installation, making possible a nominal phase precision of better than one degree TIGER 3 utilises ?? inch solid feeder coax, which has a nominal loss of 0.67dB/100m. Typically, SuperDARN RADARs have used matched length cabling, meaning that cables for antennas closest to the equipment hut can be up to 100m longer than required. This feature enables cable lengths to be set to a physical minimum, decreasing cabling costs, and an increasing both transmit and receive power ?? with the only downside being a 0.1 or less of beam spreading.

Impedance matching for SuperDARN antennas: An improved technique

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Abstract: In recent years we have witnessed the development of the Twin Terminated Folded Dipole (TTFD) antenna which has replaced the deployment of the bulky LPDA [1]. Never the less, the TTFD has been a work in progress and the SuperDARN community is continually optimising the original design to extract maximum performance characteristics [2]. It is evident that the TTFD antenna impedance varies heavily with frequency and in a linear array arrangement antennas near the end of the array will have a different impedance due to its surrounding environment. Also, current SuperDARN radars with TTFD antennas utilise toroids for impedance matching which can be quiet lossy and are not easily tweaked for the desired impedance. Therefore, for maximum performance, each antenna impedance must be individually tweaked using a matching LCR network. With our research and development we would like to present an improved antenna matching technique. References: [1] Custovic, E., Devlin, J., Whittington, J., Console, A., Three-wire Twin Terminated Folded Dipole array for SuperDARN Radars, Proceedings of 12th Australian Symposium on Antennas, pp 33-34, Sydney, Australia, 16 - 17 Feb. 2011 [2] Custovic, E., and Console, A. TTFD Array Variations for TIGER 3, International SuperDARN Conference Proceedings, Hermanus, South Africa, June 2010

An integrated analysis platform powered by fitacf CDF and the THEMIS tool developed by ERG-Science Center (ERG-SC)

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Abstract: The Energization and Radiation in Geospace (ERG) mission seeks to exploring dynamics of the radiation belt in the Earth's inner magnetosphere with a space-borne probe (ERG satellite) in coordination with the related ground observations and simulations/modeling studies. For this mission, the ERG-Science Center (ERG-SC) will provide a useful data analysis platform based on the THEMIS Data Analysis software Suite (TDAS) which has been widely used by researchers and thus had a great success in producing many conjunction studies with the THEMIS spacecraft and ground data. To import SD data to this highly useful platform, ERG-SC developed the CDF design suitable for SD fitacf data and actually has applied it for SD data obtained by Japanese groups. We have also been developing IDL procedures to load the SD data in CDF and to generate various kinds of plots, not only R-T-I-type plots but also 2-D map plots with other data, such as all-sky images of THEMIS-GBO and orbital footprints of various satellites. So far we have completed the CDF conversion of Japanese SD radar data (HOK, KSR, SYE, SYS), which have already been made available freely to the Japanese community. ERG-SC is going to release to the international community the generated CDF files with the associated IDL procedures for use in TDAS during this year (2011). We are ready and quite positive to collaborate with the other radar groups to get more data involved in this data analysis platform. Hopefully the CDF-TDAS scheme by ERG-SC will make SD data more easily accessible and analyzable for researchers and thereby facilitate collaborative studies with other data in the upcoming era of the great exploration for the inner magnetosphere, carried out by the ERG(Japan)-ORBITALS(Canada)-RBSP(U.S.A.)-THEMIS(U.S.A.) fleet.

New Operating System Upgrade for the Bruny Island Radar

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Abstract: This poster presents recent work on the installation and testing the current release Radar Operating System (ROS) for the Tasman International Geospace Environment Radar (TIGER) Bruny Island system. Due to hardware limitations of the computing platforms and old ADC card (DT2828), the Bruny Island radar has been operating using a significantly older version of the ROS. The older ROS does not allow the radar to be operated in an optimal way, particularly for sea state measurements. Key elements of the upgrade include the use of a new ADC card (DT301), replacement of the Main and Timing computing platforms, and a move to a real-time Linux OS. This upgrade should allow the radar to be used in a more effective manner, particularly for Sea State campaigns, and be compatible with new ROS developments.

Investigations of cross-channel interference on a stereo SuperDARN radar

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Abstract: Interference between channels while operating in two channel 'stereo' mode is investigated for the TIGER Unwin SuperDARN radar. A discretionary mode was run in which channel A cycles sequentially over a number of pre-set frequencies while channel B remains fixed. It was found that for certain values of the channel A and channel B frequencies and for certain beams, the number of echoes received on the fixed frequency channel B depends strongly on the frequency on channel A at the time. For a stereo radar to be operating properly there should be no such correlation effects between channels. This cross-channel interference is observed not to depend on ionospheric conditions, only on the particular frequencies used. Spurious channel B echoes resulting from cross-channel interference exhibit low velocities, an absence of low spectral widths and occur at intermediate ranges. Results of a number of tests will be presented which provide insight into this issue currently under investigation.

Performance of control programs on Oregon MSI radars

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Abstract: With the adoption of the new QNX6-based radar operating system as the platform for running the new MSI twin radars, several changes to existing control programs were necessary in order to realize some of the expanded capabilities of these radars. This work describes changes made to normalscan and themisscan to accommodate the expanded number of beams used on the Oregon radars (cvw and cve). New versions of these control programs were run on the Oregon radars and results are compared with the original versions.