Sodankylä Geophysical Observatory

Reports

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OULUN YLIOPISTO

13th International EISCAT Workshop

Mariehamn, Åland, Finland

6 th – 10 th August 2007

Programme & Abstracts

Edited by Anita Aikio, Thomas Ulich and Anna-Liisa Piippo

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Programme

Monday, 6th August

08:00-09:00 Registration

09:00-09:25 Opening of the 13th International EISCAT Workshop

Session I: Session in Honour of Professor Tor Hagfors: Contribution to science
Conveners: Asgeir Brekke & Tony van Eyken
Pages: 15 – 22

09:25-09:30 Introduction by session chair
Tony van Eyken

09:30-10:00 Tor Hagfors: Contribution to incoherent scatter theory (invited)
John Holt

10:00-10:30 Tor Hagfors: A career in incoherent scatter and planetary radar (invited)
Don Farley

10:30-10:55 Coffee break

10:55-11:25 Tor Hagfors: Contribution to ionospheric modification, pulse coding and novel radar techniques (invited)
Michael Sulzer

Session I: Session in Honour of Professor Tor Hagfors: Legacy

11:25-11:30 Introduction by session chair
Asgeir Brekke

11:30-12:00 World-wide incoherent scatter: Systems, capabilities, and operations (invited)
Tony van Eyken

12:00-13:30 Lunch

13:30-14:00 The next generation of incoherent scatter radars: AMISR, EISCAT_3D, and beyond (invited)
John Kelly

14:00-14:30 EISCAT: Scientific strategy for the next five, ten and thirty years (invited)
Mike Lockwood

Session II: Meteor and Interplanetary Space Studies with Large Aperture Radars
Conveners Asta Pellinen-Wannberg & Diego Janches
Pages: 23 – 34

14:30-15:00 The importance of the meteoroid environment in spacecraft design and operations: How can HPLA radars contribute? (invited)
William J. Cooke

15:00-15:15 Dramatic increase of space depris peak density since 2006 seen at ESR
Jussi Markkanen

15:15-15:30	Modelling the temporal and geographical variability of the micrometeor mass input in the upper atmosphere using HPLA radar measurements **Diego Janches** and J. Fentzke
15:30-16:00	*Coffee break*
16:00-16:15	Extremely long-baseline interplanetary scintillation measurements: A tool for probing solar wind structure A. Breen, **Richard Fallows**, G. Dorrian and M. Bisi
16:15-16:30	Equatorwards expansion of the fast solar wind **Gareth Dorrian**, A. Breen, R. Fallows, M. Bisi, P. Thomasson and G. Wannberg
16:30-17:00	Plasma and EM simulations of meteor head echo reflections (invited) **Lars Dyrud**, D. Wilson, S. Close, S. Boerve, J. Trulsen and H. Pesceli
17:00-17:15	A comprehensive model of electromagnetic scattering from meteor head plasmas M. Light, S. Close, **Patrick Colestock** and J. Zinn
17:15-17:30	The EISCAT Meteor Code **Gudmund Wannberg**, A. Westman, A. Pellinen-Wannberg, J. Kero and C. Szasz
17:30-17:45	3D position determination of small coherent meteor targets with EISCAT UHF **Johan Kero**, C. Szasz, G. Wannberg, A. Pellinen-Wannberg and A. Westman
17:45-18:00	Luminosity of the EISCAT UHF micrometeoroids estimated with an ablation model **Csilla Szasz**, J. Kero, A. Pellinen-Wannberg, D. D. Meisel, G. Wannberg and A. Westman
18:00-18:15	Dusty plasma conditions in meteor trails **Asta Pellinen-Wannberg**, I. Häggström, M. Rosenberg, N. Meyer-Vernet, E. Murad, O. Popova, I. Mann, T. Mukai and M. Rapp
19:00-21:00	**Reception of the Government of Åland in the House of Parliament**

Tuesday, 7th August

Session III: Novel Developments in Radar Techniques and Applications
Conveners: Ian McCrea & John Kelly
Pages: 35 – 48

08:15-08:30	Perfect pulse compression codes and other advances in radar experiment theory **Markku Lehtinen**
08:30-08:45	General radar transmission codes **Juha Vierinen**, M. Lehtinen and M. Orispää
08:45-09:00	FLIPS (Fortran Linear Inverse Problem Solver) **Mikko Orispää**
09:00-09:15	A new method for decoding phase codes **Ilkka Virtanen**, M. Lehtinen, T. Nygrén, M. Orispää and J. Vierinen
09:15-09:45	A Bayesian approach to resolving velocities with the Poker Flat ISR (invited) **Craig Heinselman** and M. Nicolls
09:45-10:15	*Coffee break*

10:15-10:30	AMISR as a tool for studying the generation and propagation of gravity waves at high latitudes **Michael Nicolls**, C. Heinselman, S. Vadas and J. Kelly
10:30-11:00	EISCAT_3D: Background, progress, current status and next steps (invited) **Gudmund Wannberg**
11:00-11:15	Presentation of the Large Aperture Array Radar Simulation Environment (LAARSE), a Matlab simulation tool developed for the EISCAT_3D radar **Gustav Stenberg**
11:15-11:30	Time synchronization in the EISCAT_3D incoherent scatter radar **Tore Lindgren**, G. Stenberg, M. Larsmark, J. Borg and J. Johansson
11:30-11:45	Phase calibration of an aperture synthesis imaging array by means of incoherent scattering T. Grydeland, **Cesar La Hoz** and V. Belyey
11:45-12:00	Data archive and distribution systems for the EISCAT_3D radar **Derek McKay**, I. Finch, S. Crothers and I. McCrea
12:00-12:15	Developments in the use of EISCAT for interplanetary scintillation **Richard Fallows**, A. Breen and G. Dorrian
12:15-13:45	*Lunch*

Session IV: Mesosphere and D-Region Studies
Conveners: *Sheila Kirkwood & Esa Turunen*
Pages: *49 – 58*

13:45-14:00	New PMSE observations with the EISCAT 500-MHz Svalbard Radar and the SOUSY 53.5-MHz Svalbard Radar **Jürgen Röttger**, M. Rapp, L. Qiang, J. Trautner, A. Serafimovich and C. Hall
14:00-14:15	Polar mesosphere winter echoes: Height dependence of spectral widths at 224 MHz and 52 MHz and the infrasound theory **Sheila Kirkwood**, E. Belova and H. Nilsson
14:15-14:45	PMSE/PMWE research using the EISCAT Heating facility: A review of recent results (invited) **Evgenia Belova**
14:45-15:00	Measurements and theory of scattering cross sections of PMSE with the EISCAT VHF and UHF radars **Cesar La Hoz** and O. Havnes
15:00-15:15	Temperature tide at polar mesosphere and lower thermosphere observed by meteor and EISCAT radars **Takehiko Aso**, M. Tsutsumi, C. M. Hall, Y. Ogawa and R. R. Garcia
15:15-15:45	*Coffee break*
15:45-16:15	Sunset transition in the D-region ionosphere during the October 1989 solar proton event (invited) **Pekka T. Verronen**, Th. Ulich, E. Turunen and C. J. Rodger

16:15-16:30 Energy Characteristics of precipitating relativistic electrons as determined from EISCAT, VLF propagation and riometer data using D-region ion chemistry modelling
Esa Turunen, Th. Ulich, C.-F. Enell, A. Kero, T. Raita, J. Manninen and P. T. Verronen

16:30-16:45 Modelling the mesospheric effects of solar short-wave radiation
Carl-Fredrik Enell, P. T. Verronen, A. M. Seppälä, A. Kero, Th. Ulich and E. Turunen

16:45-18:30 **Poster session**
Pages: *59 – 80*

Session III: Novel Developments on Radar Techniques and Applications

The use of long-time EISCAT data series for improving ionospheric corrections models: First results
Rico Behlke, V. Belyey and C. La Hoz

First results of an open-source based program for acquiring long time series of ionospheric parameters from the EISCAT Madrigal database
V. Belyey and **Cesar La Hoz**

Interferometric imaging (WP5) for EISCAT_3D
V. Belyey, T. Grydeland and **Cesar La Hoz**

Statistical analysis of incoherent scatter experiments using the Markov Chain Monte-Carlo method
Juha Vierinen, I. Virtanen, M. Lehtinen and A. Kero

Session IV: Mesosphere and D-Region Studies

Modelling of the ion composition in the lower high-latitude ionosphere during solar proton precipitation
A. Osepian, **Sheila Kirkwood**, P. Dalin and V. Tereschenko

Influence of the concentration of minor neutral (NO, O_3, and O) constituents on the structure of the lower ionosphere during solar proton events
Sheila Kirkwood, A. Osepian, V. Tereschenko and P. Dalin

D-layer electron temperature estimates from Heater-modulated PMSE as observed by the IRIS riometer
Graham Routledge, M. J. Kosch and F. Honary

Overshoot effect and polar mesosphere winter echoes on October 24, 2006
E. Belova, **Maria Smirnova**, M. Rietveld, B. Isham, S. Kirkwood and T. Sergienko

Session V: Magnetosphere-Ionosphere-Atmosphere Coupling Studies

Incoherent scatter radar measurements of field-aligned currents in the polar region
Ingemar Häggström

On meso-scale coupling between ionospheric Joule heating and electrojet activity
Kirsti Kauristie, O. Amm, A. Aikio, L. Juusola, I. Sillanpää and H. Vanhamäki

Influence of the ionosphere F2 layer peak height hmF2 long-term lowering on the mean night variation in the red 630.0 nm line nightglow intensity
G. Didebulidze, N. Gudadze, **Levan Lomidze** and G. Javakhishvili

Comparison and validation studies related to the modeling ionospheric convection and the EISCAT observations in the polar cap
Renata Lukianova, A. Kozlovsky and T. Turunen

Polar cap sporadic E and electric field
Tuomo Nygrén, A. Aikio and M. Voiculescu

Session VI: Auroral Phenomena

The Trans-National Access Program
Lisa Baddeley

Session VIII: Ionospheric Plasma Physics and Scattering Mechanisms

Naturally enhanced ion-acoustic lines and solitary waves
Jonas Ekeberg, K. Stasiewicz, L. Eliasson and T. B. Leyser

Dependence of the ion-acoustic speed on the electron drift in the high-latitude ionosphere
A. Koustov, R. Fiori, J. Gorin and **Mikhail Uspensky**

Session IX: Ionospheric Modification by Radio Waves

HF heater-induced phenomena in the ionospheric F region under the pump frequency above the maximum plasma frequency
Nataly Blagoveshchenskaya, T. Borisova, V. Kornienko, M. Rietveld and A. Brekke

Ionospheric pumping experiments on the second electron gyro-harmonic in Alaska
M. Kosch, B. Bristow, F. Djuth, C. Heinselman, J. Hughes, **Björn Gustavsson**, E. Kendall, B. Marshall, M. McCarrick, E. Mishin, C. Mutiso, K. Nielsen, et al.

Observation of ionosphere response to HF heating at Barentsburg
Alexey Mochalov, A. Pashin and T. K. Yeoman

Previously unreported emissions from ionospheric heating experiments
Charles Mutiso, J. Hughes, M. Kosch and B. Gustavsson

Modification of the natural plasma line during HF heating at Tromsø
Andrew Senior and M. J. Kosch

Wednesday, 8th August

Session V: **Magnetosphere-Ionosphere-Atmosphere Coupling Studies**
Conveners: *Tim Yeoman & Olaf Amm*
Pages: *81 – 94*

08:15-08:45 The Pedersen current carried by electrons: Effects on magnetosphere-ionosphere coupling (invited)
Stephan Buchert

08:45-09:00 Statistical MLT-distribution of conductances, electric fields, and Joule heating rate at high latitudes
Anita Aikio, A. Seppänen and T. Nygrén

09:00-09:15 A comparison of various ground-based methods of estimating ionospheric conductances
Andrew Senior, M. J. Kosch, T. R. Pedersen and F. Honary

09:15-09:30 Investigation of the ground-based signatures of the ionospheric Alfvén resonator (IAR) using the data from EISCAT Svalbard Radar
Nadezhda Semenova and A. G. Yahnin

09:30-09:45 GPS imaging of magnetosphere-ionosphere coupling
Dimitry Pokhotelov, C. Mitchell and P. Spencer

09:45-10:15 *Coffee break*

10:15-10:45 Mesoscale thermospheric structure: Current evidence and future experiments (invited)
Eoghan Griffin, A. Aruliah, I. McWirter, I. Yiu, A. Dobbin, G. Millward, A. Aylward, A. Charalambous, I. McCrea, V. Howells, C. Davis and M. Kosch

10:45-11:00 Physical mechanism to generate vertical motions in the polar lower thermosphere
Shin-ichiro Oyama, S. Maeda, H. Shinagawa and B. J. Watkins

11:00-11:15 Multi-layer structure and its short-period oscillations in the ionosphere F2 layer as a result of the presence of atmospheric vortical perturbation excited in the horizontal shear flow
Levan Lomidze, N. Gudadze and G. Didebulidze

11:15-11:30 Relationship between ion upflows and suprathermal ions observed with the EISCAT Svalbard Radar and Reimei satellite
Yasunobu Ogawa, K. Seki, M. Hirahara, K. Asamura, T. Sakanoi, Y. Ebihara, Y. Obuchi, S. C. Buchert, S. Nozawa and R. Fujii

11:30-11:45 Observations of an auroral streamer in a double oval configuration
Olaf Amm, R. Nakamura, T. Takada, K. Kauristie, H. U. Frey, C. Owen, A. Aikio and R. Kuula

11:45-12:00 Effects of a geomagnetic pulsation on electron precipitation spectra
Andrew Kavanagh, F. Honary and A. Senior

12:00-12:15 Determination of auroral electrons spectra and field-aligned potential differences using simultaneous ground-based optical observations of an auroral arc with ALIS
Hervé Lamy, M. Roth, J. De Keyser, T. Sergienko, B. Gustavsson and U. Brändström

12:15-14:00 *Lunch*

14:00-17:30 **Excursion**

19:00- **Conference Dinner**

Thursday, 9th August

Session VI: Auroral Phenomena
Conveners: *Takehiko Aso & Anita Aikio*
Pages: *95 – 106*

08:15-08:45 Results from ASK observing campaign 2006/7 in Tromsø (invited)
Nickolay Ivchenko, B. Lanchester, H. Dahlgren, D. Whiter, G. Marklund, T. Sergienko and B. Gustavsson

08:45-09:00 Modelling and observations of the energy spectrum of precipitating electrons using joint EISCAT-ASK (Auroral Structure and Kinetics) measurements
Mina Ashrafi, B. Lanchester, D. Whiter, H. Dahlgren and N. Ivchenko

09:00-09:15 Conditionally integrated incoherent scatter radar data and flickering aurora
T. Grydeland, **Björn Gustavsson**, E. M. Blixt, L. Baddeley and J. Lunde

09:15-09:30 A new method to estimate ionospheric electric fields and currents using ground magnetic data from a local magnetometer network
Heikki Vanhamäki, O. Amm and K. Kauristie

09:30-09:45 Observation of ionospheric effects in the aurora zone using CHAMP and COSMIC/Formosat-3 data
Christoph Mayer and N. Jakowski

09:45-10:15 Coffee break

10:15-10:45 Colour imaging of the aurora (invited)
Noora Partamies, M. Syrjäsuo and K. Kauristie

10:45-11:00 Electric fields associated with post-noon auroras
Alexander Kozlovsky, T. Turunen, A. Aikio, T. Pitkänen, K. Kauristie and S. Massetti

11:00-11:15 Coordinated optical and radar observations of enhanced electric fields within auroral arcs
Vladimir Safargaleev, T. Sergienko, A. Kozlovsky, I. Sandahl, S. Osipenko and U. Brändström

11:15-11:30 Coordinated EISCAT and ALIS observations of the active auroral arc system
Tima Sergienko, I. Sandahl, V. Safargaleev, B. Gustavsson and U. Brändström

11:30-11:45 The Trans-National Access Program
Lisa Baddeley

11:45-13:30 Lunch

Session VII: Structures and Dynamics of the Polar Cap and Cusp

Conveners: Jøran Moen & Kirsti Kauristie
Pages: 107 – 120

13:30-14:00 The case for a new process, not mechanism, for cusp irregularity production (invited)
Herbert Carlson, T. Pedersen, S. Basu and J. Moen

14:00-14:15 Ion-dispersion in the cusp: A case study investigated with satellite and radar
J. Lunde, **Stephan Buchert**, Y. Ogawa, M. Hirahara, K. Seki, Y. Ebihara, T. Sakanoi and K. Asamura

14:15-14:30 Cusp density enhancements by Fossil FTEs?
Ian McCrea, J. Davies, M. Hapgood and V. Howells

14:30-14:45 Electron density in the cusp ionosphere: When the ESR confirms TRANSCAR predictions
Frédéric Pitout and P.-L. Blelly

14:45-15:00 Combined CHAMP-EISCAT studies on local thermospheric mass density enhancements in the CUSP
Stephanie Rentz, H. Lühr and M. Rietveld

15:00-15:15 Cluster high altitude observations of oxygen ion outflow, the connection to the ionosphere
Hans Nilsson, M. Waara and H. Rème

15:15-15:30 Effects of the IMF BY inferred from the FAC-based convection model and radar observations
Renata Lukianova, A. Kozlovsky, F. Christiansen and T. Turunen

15:30-16:00 *Coffee break*

16:00-16:30 Dependence of the electromagnetic and precipitating particle energy inputs to the ionosphere upon the sunlit/shade condition of the ionosphere (invited)
Ryoichi Fujii, H. Handa, S. Nozawa and Y. Ogawa

16:30-16:45 Dynamics of the polar cap boundary in the evening sector during a substorm event
Timo Pitkänen, A. Aikio, A. Kozlovsky and O. Amm

16:45-17:00 On the diurnal variability in F2-region plasma density above EISCAT Svalbard Radar
J. Moen, X. C. Oiu, **Herbert Carlson**, R. Fujii and I. W. McCrea

17:00-17:15 Large scale structuring of polar cap plasma in the nightside ionosphere: The influence of the orientation of the interplanetary magnetic field
Alan Wood, E. Pryse, H. R. Middleton and V. Howells

17:15-17:30 Ground based observation of high latitude ULF wave signatures
Carlos Gane, D. Wright and T. Raita

Friday, 10th August

Session VIII: Ionospheric Plasma Physics and Scattering Mechanisms

Conveners: *Anja Strømme & Francois Forme*
Pages: *121 – 126*

08:15-08:45 Zakharov simulations of Langmuir turbulence: Effects on waves observed by incoherent scattering (invited)
Patrick Guio

08:45-09:00 Naturally enhanced radar spectra and low energy auroral emission
J. Sullivan, **Mike Lockwood**, B. Lanchester, E. Kontar and D. Whiter

09:00-09:15 Naturally enhanced ion acoustic lines with the Poker Flat AMISR radar
Anja Strømme and J. Semeter

09:15-09:30 Study of the electron distribution function stability in the edges of auroral arcs
Geraldine Garcia and F. Forme

09:30-09:45 Equatorial ionospheric F region vertical plasma drift variations over Africa
Oyedemi Samuel Oyekola, A. Ojo and J. Akinrimisi

09:45-10:15 *Coffee break*

Session IX: Ionospheric Modification by Radio Waves

Conveners: *Björn Gustavsson & Mike Kosch*
Pages: *127 – 139*

10:15-10:45 Radio wave modification of plasma irregularities associated with mesospheric dust clouds (invited)
Wayne Scales and C. Chen

10:45-11:00	Aspect sensitivity of the first 100 ms HF-modification measured with the MUIR at HAARP **Shin-ichiro Oyama** and B. J. Watkins
11:00-11:15	Observations of aspect sensitive SPEAR-induced enhancements in incoherent scatter spectra **Ranvir Dhillon**, T. Robinson and T. Yeoman
11:15-11:30	Bistatic observations of ULF waves in SPEAR-induced HF coherent backscatter **Tim Yeoman**, T. Robinson, D. Wright and L. Baddeley
11:30-11:45	ULF wave activity from HF pumping experiments at mid and high latitudes **Nataly Blagoveshchenskaya**, T. Borisova, V. Kornienko, M. Rietveld, V. Frolov, M. Kosch, F. Honary and A. Brekke
11:45-12:00	Density of upper atmosphere neutral components and artificial magnetic pulsations in Pc1 range excitation **Alexey Mochalov** and A. Pashin
12:00-13:30	*Lunch*
13:30-14:00	Plans for and progress towards the new Arecibo HF facility (invited) **Michael Sulzer**
14:00-14:15	Heating upgrade **Markku Postila**, G. Wannberg, M. Rietveld, T. Iinatti and A. Westman
14:15-14:30	New diagnostic methods for the D-region ionosphere in a case of EISCAT heating experiments **Antti Kero**, J. Vierinen, I. Virtanen, C.-F. Enell and E. Turunen
14:30-14:45	The registration of the influence effects from SPEAR heating facility operation in observatory Barentsburg in February-March 2007 A. Kotikov, **Eugene Kopytenko** and A. Frolov
14:45-15:00	Aspect angle dependence of top- and bottom-side UHF radar backscatter from ionospheric HF pumping at Tromsø **Mina Ashrafi**, M. Kosch, M. Starks, A. Senior, M. Rietveld and T. Yeoman
15:00-15:15	Altitude distribution of HF-pump enhanced emissions at 6300 and 5577 Å: A comparison between observations and theory **Björn Gustavsson**, B. Bristow, C. Heinselman, J. Hughes, M. Kosch, C. Mutiso, K. Nielsen, T. Pedersen, W. Wang and A. Wong
15:15-15:20	Closing words
15:20	End of the workshop

Abstracts

Session I: Session in Honour of Professor Tor Hagfors

Conveners: Asgeir Brekke & Tony van Eyken

Invited speakers
Don Farley, John Holt, John Kelly, Mike Lockwood,
Mike Sulzer and Tony van Eyken

Monday, 6th August
09:25-14:30

Tor Hagfors: Contributions to incoherent scatter theory

J. Holt

MIT Haystack Observatory, Westford, Massachussets, USA

Following Gordon's prediction of incoherent scattering of radio waves by the ionosphere in 1958 and Bowles' observations of that scattering later the same year, there was a flurry of activity to theoretically describe the observed returns. From 1961 to 1962 over 20 journal articles and technical reports were published, largely completing the theory of incoherent scatter as we understand it today. This period will be discussed from a historical perspective with an emphasis on the contributions of Tor Hagfors. In brief, to quote an unpublished manuscript of Tor's, "In spite of the difference in approaches to the problem, there seems to be a common feature in all of them, viz. they all appear to be sufficiently complicated to make physical interpretation difficult. Since it appears to be of importance to have available simple physical explanations for the different properties of the scattering process, an attempt is made to rederive the expressions for the scattering from first principles and fairly readily understandable pictures."

Tor Hagfors: A career in incoherent scatter and planetary radar

D. Farley

Cornell University, Ithaca, New York, USA

Tor Hagfors made major contributions to both planetary radar astronomy (theory of scattering from rough surfaces) and to incoherent scatter from the ionosphere (theory of scattering from thermal fluctuations in plasma density) throughout a long and productive career. He played major roles in the leadership of the three largest incoherent scatter radar (ISR) observatories (Jicamarca, Arecibo, and EISCAT) and also of the Max Planck Institute in Lindau, Germany. He was an outstanding theorist, experimentalist, and scientific leader and administrator. He spearheaded the major upgrade of Arecibo in the 1990s and was the founding Director of EISCAT. This talk will review his many contributions to our field and attempt also to give a bit of the flavor of his personality.

Tor Hagfors: Contribution to ionospheric modification, pulse coding and novel radar techniques

M. Sulzer

Arecibo Observatory, Arecibo, Puerto Rico, USA

It is unusual for one individual to make so many original contributions in so many areas including theory and experiment in multiple scientific fields. This talk discusses seemingly unrelated areas, ionospheric modification science and novel radar techniques, and shows how Professor Hagfors in at least one case contributed to both in the same experiment. He first invented the chirp plasma line technique, which allows high signal-to-noise ratio measurements anywhere in the F region. This high sensitivity can be achieved with an unmodulated long pulse only at the F peak. Then he applied this technique to measurements of the enhanced plasma line using both Arecibo and EISCAT radars and HF heaters to help in characterize the the effect of a powerful HF wave on the ionospheric plasma. This technique gives both frequency and range measurements with good resolution and is matched to the characteristics of the plasma. Techniques are very much a product of the technology at the time they were introduced, and so in the rest of the talk we shall try to give some historical perspective on Professor Hagfor's contributions. One example is a brief look a surface wave filters for decoding Barker codes. (He did not invent this, but recognized it early on and brought one to Arecibo from Norway in the early 1970s.) Another is an inverse technique, before the term was even in general use, to extract Arecibo F region ionospheric vectors velocities from a time sequence of line of sight measurements with the azimuth angle continuously changing. This technique was used until recently when it became possible to work with an entire experimental set and thus better allow for changes in the vector with time.

World-wide incoherent scatter: Systems, capabilities, and operations

T. van Eyken

EISCAT Scientific Association, Kiruna, Sweden

Eleven incoherent scatter radars, including the recent addition of the Poker Flat Radar in Alaska, are now in operation around the World. Professor Hagfors made important contributions to many of these facilities, and indeed directed or worked at more than half of them. No two radars are alike, all develop and change with time, and their capabilities, goals and programs vary. This presentation will document, compare and review the existing radars providing an up to date summary of the capabilities of these powerful instruments.

The next generation of incoherent scatter radars: AMISR, EISCAT_3D, and beyond

J. Kelly

SRI International, Menlo Park, USA

Incoherent Scatter Radars (ISRs) have existed for 40 plus years; EISCAT and Sondrestrom for 25 plus years. All of them continue to contribute to knowledge largely through incremental additions. We now better understand plasma convection, dayside aurora, Joule heating and particle energy deposition, substorm phenomena and the response to CME and CIR drivers – all as examples of topics where incremental additions continue to be made. The incremental improvement process varies from the addition of new operational modes, waveforms, adding to long term data bases, combining data sets through assimilation techniques, etc. New knowledge or sizeable incremental steps however, will be achieved with the addition of new techniques, new locations, and new stimuli for the scientific community. We are now in the process of doing just that. The application of modern radar and information technology (in the form of phased array beam steering, distributed solid state transmit/receive modules, and internet protocols) has been utilized in the AMISR design, resulting in an ISR with vast measurement improvements as compared to today's existing radars. The EISCAT_3D is currently underway as a design and prototype study with the goal of producing an even more capable ISR. These advanced systems will enable new discoveries in addition to sizable incremental additions to our knowledge. What is beyond this current thinking? The science will be the driver, but not necessarily the scientists. Imagination is key to what is produced and it will be done with a combination of need and capability. What might Tor have advised?

EISCAT: Scientific strategy for the next five, ten and thirty years

M. Lockwood

Rutheford Appleton Laboratory, Chilton, UK

Looking into the future of EISCAT is, as for any scientific facility or discipline, far from easy. Surprise discoveries can always render the most carefully laid plans obsolete. Nevertheless, it is clear that EISCAT must define a strategy that is closely allied to, and an integral part of mankind's future major scientific themes if it is to maintain its leading position, its scientific community and its funding. This talk will investigate promising strategies aimed at themes that are well beyond the classical "solar-terrestrial physics" and "space weather" studies that have been at the heart of EISCAT research in the past. This talk will attempt to extrapolate some recent applications of EISCAT into potential programmes to develop, for example, the means to study the atmospheres of Earth-like exoplanets, to study the formation of our own solar system, to investigate the role of Langmuir turbulence in the cosmos and the role of middle atmosphere - troposphere coupling in a warming global climate system. To take on such a daunting task, I draw inspiration from Tor Hagfors' vision in founding and nurturing EISCAT.

Session II: Meteor and Interplanetary Space Studies with Large Aperture Radars

Conveners: Asta Pellinen-Wannberg & Diego Janches

Invited speakers
Willam J. Cooke and Lars Dyrud

Monday, 6th August
14:30-18:15

The importance of the meteoroid environment in spacecraft design and operations: How can HPLA radars contribute?

W. J. Cooke

NASA Meteoroid Environments Office, Marshall Space Flight Center, Huntsville, AL, USA

The recent loss of the orbiter Columbia and its crew, while not caused by a meteoroid strike, has resulted in re-evaluations of the current meteoroid models used by NASA and other agencies. The most prevalent of these, that published by Grun et al. in 1985, assumes an isotropic meteoroid background in which all meteors travel at speeds of ^{2}0 km s^{-1}, and is clearly oversimplified. The standard Divine NASA interplanetary model, currently called METEM, is a set of empirical fits to data using distributions that have little or no resemblance to reality; consequently, the model's environment directionality and velocity distributions are in error. The recommendation of the Columbia Accident Investigation Board's (CAIB) report that meteoroid risk to Space Shuttle missions be evaluated in a manner similar to that used for ISS, combined with the insistence that these environment assessments be accompanied by confidence levels or uncertainties, is a driving force behind the development of new, physics-based meteoroid environment models for near-Earth space and elsewhere.

Such models, of course, must be calibrated. In-situ measurements by spacecraft would be ideal, as they can sample throughout the Solar System. However, the small collecting area of current detectors renders them useless for detecting particles with sizes capable of causing spacecraft damage, which is greater than 100 microns. Fortunately, ground-based sensors, such as radar, can, at least in principle, measure the fluxes of particles in the threat regime, thereby providing the necessary calibration points. This paper will discuss the role High Power Large Aperture (HPLA) systems can play in helping to mitigate the meteoroid threat to spacecraft and highlight specific areas, such as velocity measurements, where such data are urgently needed.

Dramatic increase of space debris peak density since 2006 seen at ESR

J. Markkanen

EISCAT Scientific Association, Sodankylä, Finland

In March and July 2006, EISCAT collected about 160 hours of space debris measurements at ESR. The 2006 measurements provide a convenient reference point for the debris measurements to be done during the IPY in 2007 and 2008. The IPY debris measurement commenced in March 12, 2007 at ESR, and immediately revealed a large increase of daily peak debris detection rate. In March 2007, in the altitude zone 780-980 km, during the UT hours 6 and 12, between 70 and 110 events per hour were regularly observed, while in other hours of the day, the event rate typically is between 10 and 20. In 2006, the daily peak hourly event rate in that altitude zone varied between 20 and 30. The enhanced debris density is consistent of being due to the ESR 42m antenna beam crossing the debris cloud originating in a Chinese antisatellite test performed in January 11, 2007. The cloud has been claimed by NASA to be "the most severe orbital debris cloud in history". The EISCAT IPY debris campaign offers a good opportunity to observer the expected gradual spreading-out of the cloud day by day.

Modeling the temporal and geographical variability of the micrometeor mass input in the upper atmosphere using HPLA radar measurements

D. Janches[1], J. Fentzke[2]

[1] NWRA./CoRA Divison, Boulder, USA

[2] University of Colorado, Boulder, USA

It is now widely accepted that microgram extraterrestrial particles from the sporadic background are the major contributors of metals in the Mesosphere/Lower Thermosphere (MLT). It is also well established that this material gives rise to the upper atmospheric metallic and ion layers observed by radars and lidars. In addition, micrometeoroids are believed to be an important source for condensation nuclei (CN), the existence of which is a prerequisite for the formation of NLC particles in the polar mesopause region. In order to understand how this flux gives rise to these atmospheric phenomena, accurate knowledge of the global meteoric input function (MIF) is critical. This function accounts for the annual and diurnal variations of meteor rates, global distribution, directionality, and velocity and mass distributions. Estimates of most of these parameters are still under investigation. In this talk, we present results of a detailed model of the diurnal, seasonal and geographical variability of the micrometeoric activity in the upper atmosphere. The principal goal of this effort is to construct a new and more precise sporadic MIF needed for the subsequent modeling of the atmospheric chemistry of meteoric material and the origin and formation of metal layers in the MLT. The model is constructed based on meteor radar observations obtained with the 430 MHz dual-beam Arecibo (AO) radar in Puerto Rico, the 50 MHz Jicamarca (JRO) radar in Peru and the 1.29 GHz Sondrestrom radar in Greenland, thus utilizing almost the entire NSF ISR chain. The model uses Monte Carlo simulation techniques and includes an accepted mass flux provided by six main known meteor sources (i.e. orbital families of dust) and a detailed modeling of the meteoroid atmospheric entry physics. The results indicate, that although the Earth's Apex centered source, composed of dust from long period comets, is required to be only about ~33% of dust in the Solar System at 1 AU, it accounts for 60 to 70% of the actual dust which enters the atmosphere. These particles are mostly characterized by very high geocentric speeds (~55 km/sec) since they are in retrograde orbits. The reminding 30% of meteoroids entering the atmosphere originate mostly from the Helion and Ant-helion sources. The results of the model are in excellent agreement with observed diurnal curves obtained at different seasons and locations. Based on these results, we calculate the micrometeor global, diurnal and seasonal input in the upper atmosphere.

Extremely long-baseline interplanetary scintillation measurements: A tool for probing solar wind structure

A. Breen[1], R. Fallows[1], G. Dorrian[1], M. Bisi[2]

[1] *University of Wales, Aberystwyth, Ceredigion, UK*

[2] *University of California, San Diego, California, USA*

Two-site measurements of interplanetary scintillation have been used to study solar wind velocities for over 30 years, but recent developments using EISCAT and MERLIN have led to new insights into the large-scale structure of the inner heliosphere. In this presentation we discuss these observations and present highlights from recent results. These include evidence of a distinct change in fast solar wind speed between the polar crown outflow and the flow from the equatorwards extension of a polar coronal hole, observations of super-radial expansion of tte fast wind at heliocentric distances of 25-80 solar radii and evidence for flow rotation in stream interaction regions and in the solar wind perturbed by the passage of a iCME. We compare our results with those obtained from tomographic reconstructions based on lower-frequency IPS observations from the STELab telescoep network in Japan and show that the combination of the two IPS approaches provides a powerful tool for studying solar wind structure.

Equatorwards expansion of the fast solar wind

G. Dorrian[1], A. Breen[1], R. Fallows[1], M. Bisi[2], P. Thomasson[3], G. Wannberg[4]

[1] *University of Wales, Aberystwyth, UK*

[2] *University College, San Diego, USA*

[3] *Jodrell Bank Observatory, Macclesfield, UK*

[4] *EISCAT Scientific Association, Kiruna, Sweden*

We present results from Interplanetary Scintillation (IPS) observations made jointly with the EISCAT system in Scandinavia and the MERLIN system in the UK. These results provide evidence of a small but measureable equatorwards velocity component in the fast solar wind typically of the order of 1° - 2° off radial direction. Possible reasons for this expansion and further investigations are discussed.

Plasma and EM simulations of meteor head echo reflections

L. Dyrud[1], D. Wilson[1], S. Close[2], S. Boerve[3], J. Trulsen[4], H. Pecseli[4]

[1] *Center for Remote Sensing, Fairfax, Virginia, USA*

[2] *Los Alamos National Laboratory, Los Alamos, USA*

[3] *NDRE, Kjeller, Norway*

[4] *University of Oslo, Oslo, Norway*

Every day billions of meteoroids impact and disintegrate in the Earth's atmosphere. Current estimates for this global meteor flux vary from 2000-200,000 tons per year, and estimates for the average velocity range between 10 km/s to 70 km/s. The basic properties of this global meteor flux, such as the average mass, velocity, and chemical composition remain poorly constrained. We believe much of the mystery surrounding the basic parameters of the interplanetary meteor flux exists for the following reason, the unknown sampling characteristics of different radar meteor observation techniques, which are used to derive or constrain most models. We believe this arises due to poorly understood radio scattering characteristics of the meteor plasma, especially in light of recent work showing that plasma turbulence and instability greatly influences meteor trail properties at every stage of evolution. We present our results on meteor plasma simulations of head echoes using particle in cell (PIC) ions, which show that electric fields strongly influence early stage meteor plasma evolution, by accelerating ions away from the meteoroid body. We also present the results of finite difference time domain electromagnetic simulations (FDTD), which can calculate the radar cross section of the simulated meteor plasmas. These simulations have shown that the radar cross section depends in a complex manner on a number of parameters. These include a relatively weak dependence on angle between radar and meteor entry, a large dependence on radar frequency, which shows that for a given meteor plasma size and density, the reflectivity as a function of probing radar frequency varies, but typically peaks below 100 MHz. We present functional forms for the RCS of head echoes as a function of plasma parameters such as peak plasma density and size. Finally, we discuss how this parameterization of head echo RCS can be used to derive, meteoroid, ionization, and plasma properties from HPLA head echo observations.

A comprehensive model of electromagnetic scattering from meteor head plasmas

M. Light, S. Close, P. Colestock and J. Zinn

Los Alamos National Laboratory, Los Alamos, New Mexico, USA

One of the most important aspects of meteor physics that remains to be determined in detail is the distribution of meteor mass and flux, especially for the observed large population of sub-microgram meteors. As these meteors are burned up by entering the atmosphere, they create a plasma which can register a measurable return in large-aperture radar. Although an extensive body of large-aperture radar scattering data from these meteor head plasmas has been accumulated in recent years, the essential physics that relates the measured radar cross-section to meteor mass and velocity has only been partially formulated in the limit of long-wavelength scattering from nominally spherical plasmas. In this work we extend that treatment to include fully electromagnetic scattering from inhomogeneous meteor head plasmas, whose expected density profiles are determined from first-principle fluid or Monte-Carlo simulations. The results indicate that the plasma parameters vary widely with altitude, as expected, and hence with the initial meteor mass. Moreover, we develop a general model for the scattering based on both an exact calculation via the method of moments and the geometrical theory of diffraction which can be used with the markedly non-spherical meteor head plasmas that can occur in some experimentally relevant regions of parameter space. The implications of this scattering model for the interpretation of large-aperture radar scattering data will be described.

The EISCAT Meteor Code

G. Wannberg[1], A. Westman[1], A. Pellinen-Wannberg[2], J. Kero[2], C. Szasz[2]

[1] *EISCAT Scientific Association, Kiruna, Sweden*

[2] *Swedish Institute of Space Physics, Kiruna, Sweden*

The EISCAT UHF system is uniquely well suited to meteor orbit determination through head echo Doppler velocity estimation. Since only a few good Doppler fits from each site are required to determine the orbital parameters, even meteors crossing the beams at very large angles and/or spending very short times in the common volume produce analysable events. The technique can therefore be used to map meteors arriving from arbitrary directions over a very large solid angle.

During 2001/2002, several versions of a radar code optimised for this application were developed, culminating in the code version used for all EISCAT meteor observations since and presented here. In this code, the transmitter is BPSK modulated by a low-sidelobe 32-bit pseudo-random sequence with 2.4 μs baud-length, for a total pulse length of 76.8 μs. Pulses are repeated every 1656 μs. The receiver -3 dB bandwidth is set to 1.6 MHz to accommodate both the modulation bandwidth and the target Doppler shift. The receiver output voltage is sampled at 0.6 μs intervals, corresponding to 90-m range resolution.

First-order target range and Doppler are extracted through a multi-step matched-filter procedure. A signal power vs. range function computed from the complex-amplitude data is convolved with a normalised infinite-SNR echo. This convolution peaks at a fixed offset relative to the start of an echo, whose range is thereby determined to within one or two samples. Next, the power-frequency spectrum of a 128 sample subset of the data vector is convolved with the theoretical spectrum of the transmitted pulse and the center-of-gravity of the convolution taken as the first-order Doppler estimate.

A fine-tuning procedure follows: A complex sinusoid at the first-order Doppler frequency is BPSK modulated with a range-shifted replica of the transmitted code and cross-correlated with the raw data vector. The pulse compression ratio is then computed from the correlation function. A robust gradient-search routine varies range and Doppler until the compression ratio maximises; their values at maximum are taken as best estimates.

For strong (SNR>5) events this code achieves 100-150 m/s Doppler velocity standard deviation. Its effective range resolution of about 30 m also allows very accurate time-of-flight velocity estimates. A statistical analysis of the entire database shows Doppler and TOF velocities agreeing to within about one part in 103. A unique feature is that the code can resolve two or more simultaneous targets separated by < 300 m in range; a beautiful VHF event will be used to exemplify.

3D position determination of small coherent meteor targets with EISCAT UHF

J. Kero[1], C. Szasz[1], G. Wannberg[2], A. Pellinen-Wannberg[1], A. Westman[2]

[1] *Swedish Institute of Space Physics, Kiruna, Sweden*
[2] *EISCAT Scientific Association, Kiruna, Sweden*

The target cross section of the ionized region created by a meteoroid passing through the common volume of the EISCAT UHF receivers can be determined and investigated as a function of scatter angle from the received power at each site. However, since the observed target sizes have proven to be very small, the received power strongly depends on which part of the common volume the target passes through. The true position of the target can be estimated geometrically. We consider each remote receiver as located in one foci of an ellipsoidal surface with the Tromsø transmitter in the other. The Tromsø receiver is located at the focus of a sphere. The range measured in Tromsø gives the radius of the spherical surface and the ranges measured at the remote receivers can in combination with the Tromsø range reveal the geometries of the ellipsoids. The target's location is found by calculating the point where the three geometrical shapes intersect. The accuracy of the position determination is limited by the range resolution of the measurements, which is about 100 m for each receiver and a single radar pulse but considerably smaller when taking into account that most of our events comprise several measurement points that may be combined with least-squares. We have been able to correct the measured ranges for systematic biases by statistically comparing the profiles of the received power of a large number of events with the theoretical beam shapes. The biases are probably caused by group delay in the transmission lines and remote station clock offset. The biases are of the order of one to a few microseconds and may be insignificant for incoherent measurements but of vital importance for the position determination of small coherent targets.

Luminosity of the EISCAT UHF micrometeoroids estimated with an ablation model

C. Szasz[1], J. Kero[1], A. Pellinen-Wannberg[1], D. D. Meisel[2], G. Wannberg[3], A. Westman[3]

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[2] *SUNY Geneseo, Geneseo, New York, USA*

[3] *EISCAT Scientific Association, Kiruna, Sweden*

The purpose of this study is to investigate the conditions for simultaneous meteor observations with the EISCAT UHF radar system and telescopic optical devices. The meteor luminosity is calculated as a part of a meteoroid ablation model using a fifth order Runge-Kutta numerical integration technique. The observed characteristics for 400 tristatic meteoroids are compared with model simulations and their luminosity is estimated. The luminosity of our targets gives us a hint of the necessary requirements of an optical device able to detect them. No simultaneous HPLA (high-power large-aperture) radar head echo and optical observations have hitherto succeeded, due to the low light emission levels of typical HPLA radar meteors. Having both types of observations of the same meteors would be of great importance in further understanding of the meteoroid-atmosphere interaction processes and the physics of the head echo.

Dusty plasma conditions in meteor trails

A. Pellinen-Wannberg[1], I. Häggström[2], M. Rosenberg[3], N. Meyer-Vernet[4], E. Murad[5], O. Popova[6], I. Mann[7], T. Mukai[7], M. Rapp[8]

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[7] *Kobe University, Kobe, Japan*

[8] *Leibniz Institute of Atmospheric Physics, University of Rostock, Kühlungsborn, Germany*

Dusty plasma conditions have been studied in a variety of environments in the outer space as well as upper atmosphere. We are investigating if dusty plasma parameters are applicable even for expanding meteor trails. As a first example we have two events where a structure seems to drift through the EISCAT UHF radar beam in a size and time scale reasonable for a meteor trail. These trails, though observed in 1990, are of the recently discussed high altitude type, observed at 148 and 130-135 km. The first one appeared in the EISCAT long pulse ACF measurement scheme, and the second one even in a Barker-coded alternating code pulse scheme. The ion-acoustic spectra of these events are enhanced in one side consequently with the background plasma drift direction monitored in the tristatic point in F-region. We will discuss how typical ionised atoms and/or molecules from the ablating meteoroids can contribute the observed spectrum and suggest better dedicated observation strategy for further studies.

Session III: Novel Developments in Radar Techniques and Applications

Conveners: Ian McCrea & John Kelly

Invited speakers
Craig Heinselman and Gudmund Wannberg

Tuesday, 7th August
08:15-12:15

Perfect pulse compression codes and other advances in radar experiment theory

M. Lehtinen

Sodankylä Geophysical Observatory, Sodankylä, Finland

Incoherent scatter radar was the main application in the early development of statistical inverse problems research in Finland. This resulted in important advances in radar methods, including alternating codes, proper statistical analysis with the GUISDAP software and radically improved experiment optimization. These early developments were mainly relevant in the case of a low SNR and also somewhat suffered from the need to be compatible with legacy type of data reduction by correlation calculations.

In connection with the Finnish Centre of Excellence in Inverse Problems Research 2006-2011, some significant breakthroughs have recently been made, including complete charaterization of comparison radar experiments of time-coherent distributed targets for any SNR, formulation of proper signal sampling and invention of pulse compression codes with exactly zero sidelobes.

We discuss these new developments, putting emphasis on their technical consequences, including the need for arbitrarily chosen phases in phase codes - and in some cases even amplitudes, and necessity of acces to raw, uncorrelated radar echoes for proper analysis. We also discuss the ways to approximate the best codes by more practical ones (like binary phase codes) and ways to compare these to the perfect codes.

We discuss a stepwise plan to implement these new methods as practically applicable software systems for data analysis. We also shortly introduce efforts towards computer searches for the new kinds of experiments and show some first results of new types of codes with actual data. These particular experiments are designed to replace alternating codes with a significantly simpler code sets, typically using only a sequence of 2 or maybe 4 codes instead of the rather long alternating code cycle. This part is meant to serve as an introduction to a few other talks with more detailed presentation of the various new techniques.

Finally, we discuss the plans of future development of these theoretical developments. This mainly concerns generalizations of the results to the non-time-coherent case and also new planned analysis methods making full use of signal statistics by moving the inversion step from lag profiles to echo amplitudes.

General radar transmission codes

J. Vierinen, M. Lehtinen, M. Orispää

Sodankylä Geophysical Observatory, Sodankylä, Finland

We introduce a modulation principle that in theory performs better than traditional binary phase coding. This is done by allowing a baud to have a freely chosen amplitude and phase. In the case of a static target it is possible to find finite length transmissions that are very close to perfect. We also study the performance of the new modulation principles in the case of lag profile measurements used in incoherent scatter experiments and compare this to alternating codes.

FLIPS (Fortran Linear Inverse Problem Solver)

M. Orispää

Sodankylä Geophysical Observatory, Sodankylä, Finland

We introduce FLIPS, the Fortran Linear Inverse Problem Solver. FLIPS is a Fortran 95 module for solving large scale statistical linear inverse problems. It is meant to be open source and free alternative to (and successor of) GULIPS, the Grand Unified Linear Inverse Problem Solver.

In statistical linear inverse problem the theory (or model) matrix and the measurement data are given. The measurement error is assumed to be Gaussian. Also some statistical properties like variances (or standard deviations) of the errors or the whole error covariance matrix may be known. The unknowns are assumed to be random variables. The inverse problem is then to find the posteriori density of the unknowns. In many cases, however, it is enough to find the MAP (maximum a posteriori) estimate and the posteriori covariance matrix of the unknowns. This is what FLIPS is able to calculate.

FLIPS uses elementary plane rotations (so called Givens rotations) to transform the original linear system into a upper triangular one, which is then easy and fast to solve. Similarly as in GULIPS, it is possible to feed the data into FLIPS in small fragments, even one data row at the time, thus considerably decreasing the computer memory consumption. This makes FLIPS especially suitable for solving large overdetermined linear systems. Another quite unique feature of FLIPS (and GULIPS) is the possibility to marginalize away unknowns or add new unknowns to the problem at any time.

Currently FLIPS has practically the same functionality than GULIPS. FLIPS is however actively developed further and we will also discuss the planned new features of FLIPS that will extend its capabilities beyond GULIPS.

A new method for decoding phase codes

I. Virtanen[1], M. Lehtinen[2], T. Nygrén[1], M. Orispää[2], J. Vierinen[2]

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[2] *Sodankylä Geophysical Observatory, Sodankylä, Finland*

Alternating codes are a standard modulation method in the present-day incoherent scatter measurements. Alternating codes consist of sequences of very specific phase patterns. They are very effective but their drawback is the great number of patterns in the whole code sequence when the number of bits is great.

A phase coded modulation produces range ambiguities, which should be removed by means of decoding. Alternating codes are designed in a way which allows the decoding to be made in power domain. Here we present a new decoding method based on stochastic inversion. The method is capable to decode any phase and/or amplitude modulated radar code (including alternating codes), if both the transmitted signal and the ionospheric echoes are recorded in amplitude domain.

In the new method, both the range ambiguity functions and the lagged products are calculated using the measured data. Because each ambiguous lagged product is a linear combination of the unknown true lag values at a number of range gates, the measurements can be combined to make an overdetermined set of linear equations. Each ambiguous lagged product produces a single equation and the coefficients of the unknowns are determined by the range ambiguity function. By means of stochastic inversion, one obtains the most probable values of the unknowns and their a posteriori variances. The practical solution is made using a special software package (FLIPS) that is suitable for big inversion problems. Finally, the ionospheric plasma parameters are fitted to the decoded autocorrelation functions using iterative methods in the same way as in the GUISDAP analysis package.

The main reason to build a new analysis system is that the method is capable of decoding the next generation radar codes which cannot be decoded with the traditional methods. The method also gives much flexibility to the ISR data analysis, allowing lag profile decoding with different range and time resolutions. The only limiting factors are the sampling frequency at the recording stage and the statistical nature of the measurement itself.

Using real data from an alternating code experiment, we present some comparisons between the inversion method and the standard decoding. Both decoded lag profiles and plasma parameters are presented. We also show some first results of experiments with new kinds of binary codes that contain only few different transmission sequences but are still capable to produce very accurate results.

A Bayesian approach to resolving velocities with the Poker Flat ISR

C. Heinselman, M. Nicolls

SRI International, Menlo Park, California, USA

The Poker Flat Incoherent Scatter Radar, based on AMISR technology, commenced scientific operations in January of this year. This system is the first pulse to pulse steerable phased array ISR operating at high latitudes and, as such, fully exploiting its capabilities requires some new developments in radar techniques. In this presentation, we will discuss an approach to estimating the vector ion velocities from measurements made in multiple simultaneous directions. While the approach is also applicable to other systems, PFISR derives special benefits from it because that system readily supports simultaneous estimates at multiple spatial and temporal scales. In particular, the measurements themselves can help determine what scales are available in the data sets after collection in a very general way, greatly relaxing the need to make critical decisions before or during an experiment.

In addition to discussing the technique, several data sets will be presented to demonstrate its application. In particular, we will show estimates of latitudinal profiles of electric field behavior versus time as well as neutral wind influences on ion motion as a function of altitude.

AMISR as a tool for studying the generation and propagation of gravity waves at high latitudes

M. Nicolls[1], C. Heinselman[1], S. Vadas[2], J. Kelly[1]

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[2] *NWRA/CoRA Divison, Boulder, Colorado, USA*

The tracers of atmospheric gravity waves (AGWs) are observed frequently at high latitudes by examining fluctuations in ionospheric parameters measured by incoherent scatter radars, ionosondes, or HF radars (e.g., SuperDARN), and have been studied for decades. These waves are in general thought to be associated with auroral electrojet activity, which impart momentum and energy into the neutral gas through Lorentz forcing and/or Joule heating. Tropospheric sources may also be a major source of a certain subset of AGWs that reach ionospheric altitudes. The Advanced Modular Incoherent Scatter Radar (AMISR) is a unique tool allowing for the study of the propagation characteristics and source region identification of AGWs. Multi-position measurements with AMISR allow for the direct and nearly unambiguous extraction of AGW parameters, including period, horizontal and vertical wavelengths, and propagation direction and speed. This allows for the explicit evaluation of a recently derived AGW dispersion relation [Vadas and Fritts, 2005] that includes the role of kinematic viscosity and thermal diffusivity, important effects in the upper atmosphere, without assumption about horizontal wavelengths. In addition, AMISR studies will allow for source region identification using observed AGW amplitudes and wavelengths, which could shed light on the major sources of AGWs at high latitudes. We will show some case studies where AMISR data have been used to extract AGW properties and discuss how AMISR can be used, in combination with other instruments, to better understand AGW generation, propagation, and interaction with the ionosphere.

EISCAT_3D: Background, progress, current status and next steps

G. Wannberg

EISCAT Scientific Association, Kiruna, Sweden

In response to user demands for higher temporal and spatial resolution and better basic radar performance, and in an effort to improve the reliability and economics of the mainland operation, in May 2005 the EISCAT Association in co-operation with several other institutions embarked on a four-year, European Union-supported design study for a new radar facility with greatly enhanced performance to replace the existing VHF and UHF systems.

The performance specifications for the new system, EISCAT_3D, have been established in close collaboration with current and future EISCAT user communities. Phased-array technology will be employed throughout and the powerful multi-static configuration of the EISCAT UHF system will be retained. The design goals include a tenfold improvements in temporal and spatial resolution, instantaneous measurements of full-vector ionospheric drift velocities over the entire altitude range of the radar, fully integrated interferometry capability, real-time raw data access and extensive archiving facilities. For optimum performance in low electron density conditions, and in the middle atmosphere, a frequency in the high VHF band (~240 MHz) will be used.

The first half of the study has focussed on establishing the overall system architecture, studying the feasibility of employing new sampling, beam forming and signal processing techniques, and on establishing how much of the needed technology already exists either in the organisation or as commercial off-the-shelf products. The optical performance of different types of phased arrays has been simulated, both in single-beam mode and in interferometer mode, a direct-sampling receiver design has been shown to meet the performance requirements in simulation, trigger criteria for interferometry have been developed and several commercial data storage options have been identified. A 48-element "Demonstrator" array has been constructed at the Kiruna site. It will be used during the coming winter together with the Tromso VHF transmitter to validate the simulation results in practice before proceeding to a grant application/tender process.

The science case, the performance criteria and the envisaged system architecture will be reviewed and the use of novel techniques and technologies (e.g. the fully digital receivers) highlighted. The Demonstrator sub-project will be covered in-depth. Prospects for the time after the end of the study phase may also be briefly discussed.

Presentation of the Large Aperture Array Radar Simulation Environment (LAARSE), a Matlab simulation tool developed for the EISCAT_3D radar

G. Stenberg

Luleå University of Technology, Luleå, Sweden

In order to provide truly instantaneous three-dimensional radar measurements spanning the entire vertical extent of the ionosphere, the planned EISCAT_3D incoherent scatter system includes multiple receive-only antenna arrays, situated at 90-280 km from the main transmitting/receiving core site. These will employ band-pass sampling at ~80 MHz, with the input signal spectrum contained in the 6th Nyqvist zone. Digital beamformers realized in Field Programmable Gate Arrays (FPGAs) will generate five or more simultaneous beams that intersect the transmitter beam at different altitudes. Among key requirements is frequency-independent beam direction over a 30 MHz band with correct reconstruction of pulse-lengths down to 200 ns.

This talk presents simulations and methods used to investigate how well these requirements can be met by a Fractional-Sample-Delay (FSD) system. To reconstruct short pulses the beamforming must be a true time-delay system since the whole array not will be illuminated simultaneously. Subsequent demands are put on this system: The clock jitter from sample-to-sample must be extremely low for the integer sample delays; the FSD must be able to delay the 30 MHz wide signal-band 1/1024th of a sample without introducing phase shifts; and it must all be done in the base-band. The simulation system, LAARSE, is implemented in Matlab to provide cross-platform compatibility and can be applied to any similar system. Performance degrading aspects such as noise, jitter, bandwidth and resolution are included.

The use of Finite Impulse Response (FIR) filters in the base-band of a band-pass sampled signal to apply true time-delay beamforming is shown not only possible but also well behaved. The simulations done with LAARSE have resulted in better knowledge of the necessities of the FIR-filters as well as a relaxation of the preliminary timing demands on the EISCAT_3D system.

Time synchronization in the EISCAT_3D incoherent scatter radar

T. Lindgren, G. Stenberg, M. Larsmark, J. Borg, J. Johansson

Luleå University of Technology, Luleå, Sweden

This presentation will give an overview of possible techniques for the intra-array timing in the planned EISCAT_3D incoherent scatter radar. The challenges related to using GNSS as the timing solution is discussed in more detail with particular focus on modelling the multipath environment.

With the EISCAT_3D radar it will be possible to obtain instantaneous three-dimensional radar measurements spanning the entire vertical extent of the ionosphere. In order to achieve this, the system will include multiple receive antenna arrays situated 90-280 km from the main transmit/receive site. Each site, including the main site, will consist of an antenna array with 2000 to 16000 elements. One of the main challenges when designing the arrays is the timing between the antenna elements. The current requirement for this is that the total timing error must not exceed 150 ps. Several solutions to this are being studied, these are:

Cable solution: A common high-end oscillator can be used to distribute a clock pulse to each element in the array. To compensate for temperature effects in the cables this solution requires that the total propagation time to each antenna element is measured continuously.

External radio source: A signal can be transmitted from e.g. a tower to calibrate the elements in the array. This has a clear advantage since the same signal can be used both to calibrate for timing and amplitude of the antenna elements. Substantial infrastructure will be needed for this solution and there is also a risk that the tower structure inteferes with the scientific measurements.

GNSS timing: Signals from GNSS satellites can be used to time the antenna elements individually or in groups. This solution is slightly more complicated than the ones mentioned above but has the advantage of being robust to changes in temperature. It also also gives absolute timing to UTC which enables synchronization between the sites.

GNSS receivers can be used for timing purposes with very high accuracy requirements. For receivers at short distances almost all external errors on the GNSS signals (i.e. errors affecting the signal before it reaches the GNSS receiver) can be assumed to be identical and hence the accuracy is increased further. The only remaining significant error source is the multipath effects arising when the signal is scattered of structures and the terrain. A tool for modelling the multipath environment in a large antenna array has been developed and will be presented.

Phase calibration of an aperture synthesis imaging array by means of incoherent scattering

T. Grydeland, C. La Hoz, V. Belyey

University of Tromsø, Tromsø, Norway

For a radar interferometer, phase calibration is an important, and often challenging technical step to be completed before further progress, e.g. aperture synthesis imaging, can be achieved. We have found a way to achieve phase calibration by means of regular incoherent scattering from the ionosphere.

As part of the EASI project (ESR aperture synthesis imaging), we have found that regular incoherent scattering over moderate integration periods (a few to a few tens of seconds) result in quite stable phase differences between the signals seen in the different antennas, even when the coherence (normalized cross-spectrum) is below detectability.

Since the transmit beam is the only plausible source of backscattering inhomogeneity which might produce such a cross-correlation, this offers a very simple phase calibration procedure for the interferometer -- the phases of the received signals are adjusted so that the phase differences due to incoherent scattering is zero in all baselines. In the EISCAT_3D project, interferometry is going to be an integral part of the system, and this technique should be of interest.

We present the cross-correlation and phase observations which underlie this calibration procedure, and the resulting enhancement of detected coherence for localized scatterers, including satellites and naturally enhanced ion-acoustic echoes. We also present simulations from synthetic incoherent scatter signals which demonstrate how such stable phase differences can arise, even for very low coherence levels.

Data archive and distribution systems for the EISCAT_3D radar

D. McKay, I. Finch, S. Crothers, I. McCrea

Rutheford Appleton Laboratory, Chilton, UK

This talk will review the progress made within Work Package 8 of the EISCAT_3D design study, which focuses on the data archive and distribution systems for the new radar. In particular, we will report on the proposed topology of the archive system and possible hardware solutions for implementing it. Our conclusion is that, in spite of the very high data rates which we expect to be delivered by the EISCAT_3D system, a data archiving system capable of storing all of the most scientifically important data products is achievable using existing technology. We will also set out our current understanding of the dependences between the archive system design and the other work packages of the design study.

Developments in the use of EISCAT for interplanetary scintillation

R. Fallows, A. Breen, G. Dorrian

University of Wales, Aberystwyth, Wales, UK

Decreased bandwidth and increased interference from GSM networks has led to novel developments in the use of EISCAT for interplanetary scintillation (IPS) studies. The main science found from these studies is obtained through the cross-correlation of signals from antennas having the longest baseline. With 1.4GHz receivers now installed at the remote sites, and the necessity for their use at Sodankyla in particular, the cross-correlation of different observing frequencies is required. This has allowed the use of the EISCAT Svalbard Radar for IPS, increaseing the available baselines further. Increasing the sampled bandwidth is highly desirable to raise the sensitivity of IPS observations. Methods of achieving this, and the results of trials, are discussed.

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Session IV: Mesosphere and D-Region Studies

Conveners: Sheila Kirkwood & Esa Turunen

Invited speakers
Evgenia Belova and Pekka T. Verronen

Tuesday, 7th August
13:45-16:45

New PMSE observations with the EISCAT 500-MHz Svalbard Radar and the SOUSY 53.5-MHz Svalbard Radar

J. Röttger[1], M. Rapp[2], L. Qiang[2], J. Trautner[2], A. Serafimovich[3], C. Hall[4]

[1] *Max-Planck-Institut, Northeim, Germany*
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[3] *Leibniz-Institut für Atmosphärenphysik, Germany, now at Bayereuth University, Germany*
[4] *University of Tromsø, Norway*

A campaign was carried out between 6 and 30 June 2006 to compare observations of Polar Mesosphere Summer Echoes with the SOUSY Svalbard Radar (SSR)and the EISCAT Svalbard Radar (ESR), which are almost collocated near Longyearbyen on Svalbard (78 deg N). The EISCAT Svalbard Radar was operated in a special complementary code mode which for the first time allowed this radar to be used with the high range resolution of 300 meters for D-region/mesosphere studies. This resolution is equal to the range resolution of the SOUSY Svalbard Radar. For the first time we are now able to compare spectra of PMSE obtained on the two different Bragg scales of 2.8 m (SSR) and 0.3 m (ESR) with the same range resolution, although both radars have different antenna beam widths.

First we present some statistics of PMSE observed with the EISCAT Svalbard Radar during the month of June 2006, and compare it with observations of the SSR.

Then we present spectrum analyses with both radars. We can demonstrate that the spectra of SSR are much wider and show less structure than the ESR spectra. This is likely due to the wider beam width of the SSR (5 deg) as compared to that of the ESR (1.6 deg). We will also describe one particular structure which is characterized by a layer of less than 300 m thickness which show clear features of Kelvin-Helmholtz-Instability. This feature is more clearly recognized in the narrower beam width observations of the ESR. We will also discuss potential implications which these observations have on the interpretation of PMSE observed with wide beam radars.

We kindly acknowledge the assistance of Assar Westman and Ingemar Häggström of EISCAT and his colleagues for preparing the EISCAT Svalbard Radar code and doing the operational oversight.

Polar mesosphere winter echoes: Height dependence of spectral widths at 224 MHz and 52 MHz and the infrasound theory

S. Kirkwood, E. Belova, H. Nilsson

Swedish Institute of Space Physics, Kiruna, Sweden

Thin layers of strongly enhanced radar echo power are often seen from mesospheric heights. At high latitudes, in summer, these are the well known Polar Mesosphere Summer Echoes, PMSE, at ~80-90 km height. Slightly weaker scattering layers also appear at high latitudes in winter, whenever the electron density is enhanced above the quiet level by energetic particle precipitation. These are Polar Mesosphere Winter Echoes, PMWE. When such winter echoes were first observed (in the 1980's) they were assumed to be caused by thin layers of turbulence in the neutral atmosphere. Recent studies have found two characteristics of PMWE which are incompatible with this explanation. The first is that the scatterering features at 52 MHz move horizontally at very high speeds of several 100s of m/s. The second is that the spectral width of the echoes at 224 MHz is just the same inside the PMWE as it is from the adjacent background plasma. This has led to a proposed explanation of PMWE as scatter by enhanced ion-acoustic waves caused by partial reflection of infrasound at windshears or temperature gradients. This presentation will focus on spectral widths. We examine the height dependence of PMWE spectral widths at 52 MHz (ESRAD, Kiruna) and 224 MHz (EISCAT VHF, Tromsø) during the solar proton event 10-13 November 2004 and compare to theoretical expectations.

PMSE/PMWE research using the EISCAT Heating facility: A review of recent results

E. Belova

Swedish Institute of Space Physics, Kiruna, Sweden

Polar Mesosphere Summer Echoes (PMSE) are very strong radar backscatters from 80-90 km altitude which are seen in the summer time at polar latitudes. They have been observed by radars operating over a wide variety of frequencies including the EISCAT VHF and UHF radars. All features of PMSE are far from being completely understood despite of many years of intensive studies. Chilson et al. (2000) introduced a new method for investigation of PMSE using ionospheric heating by powerful ground-based HF transmitter - the EISCAT Heating facility. They showed that PMSE were modulated by heating impulses in the way that their power dropped immediately when the heater was turned on and returned to the initial level when the heater was switched off. From a series of similar experiments deductions were made about the role of ambipolar diffusion and charged aerosol/dust particles in PMSE generation. Then Havnes et al. (2003) proposed theoretically (and confirmed experimentally) an 'overshoot' effect on PMSE whereby they are influenced by specially modulated heating so that a strong enhancement in PMSE strength occurs at the moment of heater switch-off compared to its initial level prior to heating. The behavior of PMSE power during the course of the heating cycle can provide us with information about the size and concentration of charged aerosol particles, and about enhanced electron temperature.

Recently one more polar mesospheric phenomenon, similar to PMSE but occurring in wintertime (whenever D-region ionisation is enhanced) has been re-examined and termed PMW(inter)E (e.g. Kirkwood et al., 2002; Kirkwood et al., 2006). PMWE have been observed by 50 MHz MST radars as well as by the EISCAT VHF radar (Belova et al., 2005). Different mechanisms such as very strong neutral turbulence with or without presence of charged dust particles, or highly-damped ion-acoustic waves generated by infrasonic waves have been suggested for explanation of the phenomenon. PMWE- heating experiments might serve as diagnostic tool for charged particles in the winter mesosphere.

I will present an overview of the recent results in PMSE/PMWE research using ionospheric heating experiments and models.

Measurements and theory of scattering cross sections of PMSE with the EISCAT VHF and UHF radars

C. La Hoz, O. Havnes

University of Tromsø, Tromsø, Norway

Simultaneous and collocated measurements of PMSE and electron density in the D- and E-regions of the ionosphere with the EISCAT radars have allowed to make accurate absolute calibrations of the PMSE scattering cross sections at 224 MHz (Bragg wavelength of 67 cm) and at 930 MHz (Bragg wavelength of 16 cm). These measurements give volume scattering cross sections of 5250×10^{-18} and 3.5×10^{-18} m^{-1} for the VHF and UHF radars respectively. These unprecedented measurements allow to make a crucial test to the theory of PMSE that asserts that electron turbulence induced by neutral air turbulence can be maintained at the necessary scale lengths by an extension of the Kolmogorov spectrum due to the presence of charged nanometer size ice particles which causes an enhancement of the Schmidt number. Using a model of of the Kolmogorov spectrum proposed by Hill that incorporates the Schmidt number, it has been possible to fit to the model the Schmidt number and the dissipation rate of electron density variance, given the two measurements of the volume scattering cross sections. In particular, the Schmidt number turns out to be of the order of a thousand. This number implies charge numbers of the ice particles from the order of ten to several tens, depending on the width of the PMSE spectrum, namely, the intensity of the turbulence. Since reliable models of charged ice in the mesosphere indicate very low charge numbers, of the order of a few charges, it is unlikely that this theory can explain these measurements.

Temperature tide at polar mesosphere and lower thermosphere observed by meteor and EISCAT radars

T. Aso[1], M. Tsutsumi[1], C. M. Hall[2], Y. Ogawa[1], R. R. Garcia[3]

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Meteor radars in Longyearbyen and Tromso measure the temperature of the neutral atmosphere around 90km from the decay rate of fading, underdense echo returns. Temperature values from meteors are almost continuously available over several years, although the absolute temperature value depends on the assumed atmospheric pressure model and has some uncertainty, on the order of 10K, as estimated from a comparative study with optical measurements. The EISCAT radar can also estimate the neutral temperature from the ion temperature, with some uncertainties caused by frictional heating, especially under disturbed conditions. The ion temperature at lower heights is also subject to ambiguity due to the dominant collisional effects on the incoherently scattered spectrum at these heights. Taking these factors into consideration, temperature fluctuations are analysed to extract features of the temperature tide and are compared with those suggested by linearized steady and time-dependent GCM models of the atmospheric tide at polar latitudes.

Sunset transition in the D-region ionosphere during the October 1989 solar proton event

P. T. Verronen[1], Th. Ulich[2], E. Turunen[2], C. J. Rodger[3]

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[3] *University of Otago, Dunedin, New Zealand*

The solar proton event of October, 1989 and especially the sunset of October 23 is examined in this study of negative ion chemistry which combines measurements of nitric oxide, electron density, and cosmic radio noise absorption with ion and neutral chemistry modelling. Model results show that the negative charge transition from electrons to negative ions during the sunset occurs at altitudes below 80 km and is dependent on both ultraviolet and visible solar radiation. The ultraviolet effect is mostly due to rapid changes of neutral oxygen species, while the decrease of electron photodetachment from negative ions plays a minor role. The effect driven by visible wavelengths is due to changes in photodissociation and subsequent electron photodetachment from negative ions. The relative sizes of the ultraviolet and visible effects vary with altitude, the visible effects increasing in importance at higher altitudes, and are also controlled by the nitric oxide concentration. These modelling results are in good agreement with EISCAT incoherent scatter radar and Kilpisjärvi riometer measurements.

Energy characteristics of precipitating relativistic electrons as determined from EISCAT, VLF propagation and riometer data using D-region ion chemistry modelling

E. Turunen[1], Th. Ulich[1], C.-F. Enell[1], A. Kero[1], T. Raita[1], J. Manninen[1], P. T. Verronen[2]

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[2] *Finnish Meteorological Institute, Helsinki, Finland*

The temporal variability of the relativistic electron population is reasonably well characterized with numerous satellite measurements. However, implications of the precipitation of the relativistic electrons (REP) into the atmosphere are not well known. A major deficiency is a missing global picture of the precipitation. The EISCAT radars can record the excess ionisation due to REP partly in the lower ionosphere, but supporting information from other ground -based measurements is needed for interpretation of the REP characteristics. One of the experimental techniques which can probe the atmosphere for the presence of REP uses the propagation of very low-frequency (VLF) electromagnetic radiation in the Earth-ionosphere waveguide. VLF signals can be recorded thousands of kilometres from their sources. The variability of the received signals is mostly due changes at and below the lower ionosphere. In this paper we show how the temporal features seen in the VLF signals, with necessary supporting information from EISCAT and riometer measurements, can be used to estimate the energy characteristics of the precipitating electrons, using detailed ion-chemistry modeling of the lower ionosphere.

Modelling the mesospheric effects of solar short-wave radiation

C.-F. Enell[1], P. T. Verronen[2], A. M. Seppälä[2], A. Kero[1], Th. Ulich[1], E. Turunen[1]

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[2] *Earth Observation unit, Finnish Meteorological Institute, Helsinki, Finland*

Although the mesosphere is almost neutral, coupling between ion and neutral chemistry affects the concentrations of species determining its structure and radiative balance, such as odd nitrogen and ozone. This is especially the case during events of high ionisation, such as solar flares.

The Sodankylä coupled Ion-neutral Chemistry model (SIC) has been developed specifically for modelling these processes, including reactions of negative ions and water cluster ions. This talk presents case studies of the effect of solar X rays and extreme UV radiation. The SIC results are compared with local measurements by EISCAT and riometers.

Poster Session

Tuesday, 7th August
16:45-18:30

The use of long-time EISCAT data series for improving ionospheric corrections models: First results

R. Behlke, V. Belyey, C. La Hoz

University of Tromsø, Tromsø, Norway

Plasma turbulence in the ionosphere is considered of significant importance for communication, navigation, and surveillance systems based on trans-ionospheric radio links, since radio scintillation caused by electron density irregularities in the ionosphere may result in signal degradation and outage. In addition, some remote sensing techniques may also experience severe disturbances. With the help of ionospheric models it is possible to correct for these disturbances up to certain levels. However, these models do not represent very well the real ionosphere at high latitudes, since the models have been built with the use of empirical data obtained at mid- and low-latitudes. Thus, one of the purposes of Work package 10 of the EISCAT_3D project is to investigate the feasibility and utility of employing long incoherent scatter radar data time series to improve the integrity of trans-ionospheric radio communication signals, especially athigh latitudes. One critical area in which this contribution can be important is in improving the ionospheric models used by the GPS and the future Galileo global navigation satellite systems. We present the first results of comparisons between ionospheric models and long-time EISCAT data series and suggest ways for further progress of this part of work package 10.

First results of an open-source based program for acquiring long time series of ionospheric parameters from the EISCAT Madrigal database

V. Belyey, C. La Hoz

University of Tromsø, Tromsø, Norway

A software package has been designed and implemented to retrieve and process data from the EISCAT Madrigal database. The software package is an important tool to achieve the objectives of the EISCAT_3D Work Package 10, namely to explore the potential of the new radar to carry out climatic studies based on examination of long-time data series and to construct models of ionospheric electron density relevant to improving the accuracy of navigation and positioning parameters produced by the GPS and Galileo satellite constellations. Included are examples produced by the tool that show daily, seasonal and solar cycle variations of electron density measured by the EISCAT radars over two solar cycles. Work is already under way to use the data acquired and processed by the tool to assess current ionospheric models, including those used to make corrections to positioning parameters produced by the Galileo and GPS satellite constellations.

Interferometric imaging (WP5) for EISCAT_3D

V. Belyey, T. Grydeland, C. La Hoz

University of Tromsø, Tromsø, Norway

The magnetic field geometry at high latitudes means that there are no inherent symmetrical directions in the brightness distribution of potential ionospheric targets for radar imaging. Thus, it is recommended that full 2-dimensional imaging be incorporated into the EISCAT _3D design form the start. Measurements in range provides the 3rd dimension, ergo 3D. The adopted two-level architecture for antenna beam forming is an optimum global solution that also satisfies the requirements of interferometric imaging, as the module antennas of the second level constitute the antenna units upon which antenna baselines can be constructed with great flexibility. Thus it is not necessary to adopt a fixed module configuration since it can be synthesized in software on demand. The visibility function (the observable) and the brightness distribution (the image) are Fourier transforms of each other. The former is defined in baseline space and the latter in angle space subtended by the image. They are reciprocal of each other. Therefore, the size of the image is determined by the shortest baseline and the image resolution by the longest baseline. Thus, the shortest spacing (or length for dense packing) of the modules will determine the size of the image. In order to obtain a resolution of 10-20 m it will be necessary to have baselines of the order of a kilometer. Thus outlying receive-only modules separate from the core transmitting array will be necessary to achieve this resolution. Simulations of module antenna configurations with advantageous geometric patterns consistent with these conditions have been carried out. Real time monitoring of a selected subset of baselines to identify events worth of imaging is recommended. The detection of a pre-programed threshold will trigger the saving of the full set of baselines for on- or off-line imaging.

A useful condition on the accuracy of the visibility function phases — which determine the quality of the measured image — is that the timing system random variations (time jitter) should be a small fraction of the period of the radar wave. The choice of 1/40th of the period implies that the timing system has to be accurate to within 100 ps for a 250 MHz radar. Since the module beam-forming algorithms include add/multiply operations on the signals over the tens (possibly more) of antenna elements of a module, the timing accuracy can be relaxed accordingly, since the signal's timing fluctuations are random and independent. An important and useful (global) calibration of the baseline phases of radar imaging has been discovered. The nature of incoherent scattering implies that the phases of the visibility function averages to zero over the image, a consequence of incoherent scattering signals having (locally) uniform brightness distribution and being spatially uncorrelated. The measured non-zero phases of the visibility function of pure incoherent scatter are the calibration values for each baseline.

Statistical analysis of incoherent scatter experiments using the Markov Chain Monte-Carlo method

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The analysis of incoherent scatter measurements is currently mostly done by finding a maximum of the posterior distribution of the plasma parameters. In this study we use the Markov Chain Monte-Carlo method to study the full distribution of the plasma parameters. As an example, we show how the method can be applied to D and F-layer measurements. We conclude that examining the full distribution of the estimated parameters yields more information than the traditional method and makes the inversion more stable.

Modelling of the ion composition in the lower high-latitude ionosphere during solar proton precipitation

A. Osepian[1], S. Kirkwood[2], P. Dalin[2], V. Tereschenko[1]

[1] *Polar Geophysical Institute, Murmansk, Russia*

[2] *Swedish Institute of Space Physics, Kiruna, Sweden*

The height profiles of the main positive ions (O_2^+ and NO^+ intermediate cluster ions of the form of $O_2^+(X)$ and $NO^+(X)$, combined into a family Cluster1+, proton hydrated family Cluster2+) and negative ions (O_2^-, O^-, NO_3^-, CO_3^-), electron density and effective recombination coefficient are calculated for quiet conditions and at the time of the solar proton event (SPE) on 17 January 2005 based, on a theoretical ionization-recombination model of the D-region. The different height profiles of the minor neutral constituents (NO, O, O_3), which are the tracers for quiet and SPE conditions, are incorporated into the theoretical model as input parameters. Since the atomic oxygen plays a dominant role in processes controlling the ionization balance, the experimental data on the electron density obtained with the incoherent scatter technique as well as with partial reflection technique are used as a criterion for choosing the O-profile during SPE from available theoretical O-models at mesospheric altitudes. Variations of the ionic composition, associated with extra ionization by the solar proton fluxes, and variations of the minor neutral constituents during the SPE are considered.

This work is partly supported by the RFFI grant No. 07-05-00012.

Influence of the concentration of minor neutral (NO, O_3, and O) constituents on the structure of the lower ionosphere during solar proton events

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[2] *Polar Geophysical Institute, Murmansk, Russia*

Solar energetic proton events (SPE) produce extra ionization and change the neutral composition of the lower high-latitude ionosphere. One important aspect of SPE is the enhancement of concentration of the nitric oxide, NO, and odd hydrogen constituents, H and OH which leads to changes in ozone, O_3, and atomic oxygen, O. Theoretical estimates show that during the SPE event the NO concentration can increase by 1-2 orders of magnitude and the concentration of O_3 and O is decreased during daytime by a factor of 2 or 2-10, respectively. In this study, based on a theoretical model of the D region, we investigate the influence of the NO, O_3, and O concentrations on the following parameters of the lower ionosphere: the f^+ parameter which describes the ratio of the positive cluster ions to positive molecular ions O^+_2 and NO^+; the λ parameter which represents the ratio of the total negative ion density N^- to the electron density Ne; the transition heights $h_{f+=1}$ and $h_{\lambda=1}$; the electron density defined as $Ne = N^+ - N^-$; and effective recombination coefficient α_{eff}.

We use the SPE on 17 January 2005 as a case study and show that each minor neutral component has its unique input into ionization balance which depends on altitude. Increasing [NO] inside the height range 55-90 km up to [NO] $\approx 10^8$ cm^{-3} does not effect the negative ion chemistry and does not change the transition height $h_{\lambda=1}$. The f^+(h)-profile depends on [NO] in the height range 67-85 km and the transition height $h_{f+=1}$ is decreased by 3 km compared to low concentration of the [NO]. Enhancement of the [NO] up to $\approx 10^9$ cm^{-3} leads to increasing of the transition height $h_{\lambda=1}$ by ~1 km and decreasing the $h_{f+=1}$ by ~6 km compared to low concentration of the [NO]. This results in a decrease of the effective recombination coefficient in the height range 67-82 km and an increase of the electron density by about 1.5 times.

Variations in the ozone concentration at the altitudes below 70 km affect the negative ion chemistry. However, as it is known, depletion of the [O_3] due to SPE does not exceed 50%. The effect of such a decrease in ozone on the ion composition and electron density is very small.

The biggest changes are caused by variations in [O]. With decreasing of the [O] concentration in the height range 55-75 km from [O] $\approx 2\times 10^{10}$ -5×10^9 cm^{-3} till [O]$\approx 10^9$ cm^{-3}, the transition heights $h_{f+=1}$ and $h_{\lambda=1}$ rise, the effective recombination coefficient below 70 km is increased and variations in the electron density can be as much as a factor of 2-5.

This work is partly supported by the RFFI grant No. 07-05-00012.

D-layer electron temperature estimates from Heater-modulated PMSE as observed by the IRIS riometer

G. Routledge, M. J. Kosch, F. Honary

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HF pumping of the ionosphere causes the electron temperature in the D-layer to rise, which increases electron diffusivity and therefore modulates the polar mesospheric echoes (PMSE), as seen in the VHF radar, virtually destroying them. It is thought that the heated electrons attach themselves to the dust and/or aerosol particles within the PMSE. The IRIS riometer is sensitive to the free electron density and electron collision frequency, which is temperature dependent. Despite pump-induced changes in both these parameters in the D-layer, the riometer, in this case study, detects no significant change in the background absorption. This suggests that the absorption increase due to electron temperature increasing is cancelled out by the absorption decrease due to electron density decreasing. The increase in electron temperature in the D-layer has never been measured directly. We use the riometer observation, in conjunction with the VHF radar data of electron density and absorption models, to estimate the pump-enhanced electron temperature within the D-layer.

Overshoot effect and polar mesosphere winter echoes on October 24, 2006

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Polar Mesosphere Winter Echoes (PMWE) are strong radar backscatter from altitudes between 50 and 80 km observed by VHF radars in the polar latitudes during winter time. They are seen when there is extra D-region ionization due to e.g. energetic solar protons or magnetospheric electron precipitation. Because PMWE are somewhat similar to Polar Mesosphere Summer Echoes (PMSE) there were attempts to explain them in the same way as PMSE: by neutral turbulence with the high Schmidt numbers. This assumes the presence of charged aerosol particles at PMWE heights. So far convincing evidence for the presence such particles has not been found when using radar, lidar or rockets experiments.

Havnes (2004) proposed an original experimental method for detecting aerosol particles at the summer mesopause which was called the PMSE overshoot effect. It is based on artificial heating of electrons in the PMSE region with a particular scheme of heater modulation. We have applied the same method to test PMWE for the presence of aerosols.

On October 24, 2006 PMWE were initially detected with the Esrad MST radar located at Esrange, northern Sweden and then at about 11 UT with the EISCAT VHF radar located near Tromsø, Norway. At the same time we started to run the EISCAT heating experiment using a modulation pattern of 20 s heater on and 160 s heater off. Preliminary analysis shows a modulation of PMWE at about 68 km altitude with heating such that their strength was decreased during intervals when the heater was turned on. We did not found any 'recovery' of PMWE strength during the 20 s of heating. This is not enough to prove or disprove the presence of charged particles. We will present the results of further analysis of this experiment.

Incoherent scatter radar measurements of field-aligned currents in the polar region

I. Häggström

EISCAT Scientific Association, Kiruna, Sweden

During the long runs carried out at EISCAT, plasma line are regularly measured. They are mainly used for calibration of the ion line analysis, but give also information on the suprathermal electrons in the ionosphere. By monitoring both the upshifted and downshifted lines simultaneously, one can from differences in power and frequency shift deduce currents along the radar line-of-site. From the long run in March-April 2006 and the present one year IPY run, started 1 March 2007, the daily and day-to-day variations of direction and strength of field aligned currents over the EISCAT Svalbard Radar are presented.

On meso-scale coupling between ionospheric Joule heating and electrojet activity

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With a data set of ~17 hours of EISCAT-based estimates of ionospheric conductances and MIRACLE observations of equivalent currents and electric field we investigate the relationship between ionospheric currents and Joule heating. The events selected for the analysis are roughly homogeneous in the longitudinal direction and thus can be studied with the 1-dimensional method of characteristics and with data collected along the central meridian of our instrumentation. The alpha-parameter (Hall to Pedersen conductance ratio) which the method needs as an input is derived from EISCAT data. Hall conductance estimates fix the boundary conditions of the differential equations that the method solves. The latitudinal variations of alpha can be estimated with recently published empirical formulas linking this parameter with equivalent current intensities. Our analysis will yield new information about the relationship between ionospheric currents (or ground-based magnetic activity) and energy dissipation in meso-scale phenomena. These results will be discussed in the context of previously published formulas suggesting simple linear relationship between the global energy dissipation and the AE-index.

Influence of the ionosphere F2 layer peak height hmF2 long-term lowering on the mean night variation in the red 630.0 nm line nightglow intensity

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The long-term variations in the ionosphere F2 layer peak height (hmF2) for day- and night-time conditions and for different seasons is investigated using Tbilisi (41.65 N, 44.75 E) ionosonde data obtained in 1963-1986. The revealed lowering of hmF2 is compared with the oxygen red 630.0 nm line total nightglow intensity seasonal and night long-term variations at Abastumani (41.75 N; 42.82 E) in 1957-1993. The long-term increase in the 630.0 nm intensity observed after astronomical twilight for most seasons and its decrease during midnight is considered as a result of the lowering of the ionosphere hmF2 peak height. The different values of the red line intensity long-term change (increasing trend after twilight and decreasing at midnight) in different seasons may result from the meridional wind velocity long-term changes. By using a simple Chapman type (damping in time) layer for the ionosphere F2 region electron density height distribution, which takes into account a meridional wind velocity, an estimation of the lowering of the ionosphere peak height for any month and corresponding red line intensity nighttime behaviour is done.

Comparison and validation studies related to the modeling ionospheric convection and the EISCAT observations in the polar cap

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We use the ionospheric velocity measurements obtained by the European incoherent scatter (EISCAT) Svalbard radar (ESR) for comparison with the electric field distribution predicted by new ionospheric convection model based on realistic maps of field-aligned currents [Lukianova and Christiansen, 2006].

The velocity vector at high latitudes (>75 deg. MLAT) can be obtained only in the cases when the antenna is pointed northward and swings between two directions. Altogether, 110 hours of such observation during 2000-2002 have been selected from the MADRIGAL database. In 2004, two campaigns have been performed to observe the azimuthal plasma flow. During these campaigns the ESR steerable antenna was directed to the east or west along the corrected geomagnetic latitude at an elevation angle of 45. The measurements were made in the dayside during 60 hours, altogether. These data which include only the east-west flow component are also used in the present study.

Thus, the comparative analysis of model' output and observations is based on the data contained both the north-south and east-west components of the ionospheric electric field. First, a comparison provides an independent check of the model. It is shown that the model represents accurately the large-scale features of statistical electric field inferred from the ion velocity measured by the ESR. Also, from observations and modeling we quantitatively determine the dependence of the ionospheric electric field strength on the IMF conditions and how this varies with MLT. Such dependence are clearly seen by contrasting the results for two magnitudes of the IMF strength (BT=1 and 5 nT), for two opposite directions of the IMF BZ, and for BY+, BY-. For specification of the dependence we derive average convection patterns for sorting by the magnitude and direction of the IMF. The magnitude of the IMF has the main impact on the average flows under BZ- conditions. We calculated coefficients characterizing a linear increase of the electric field strength with BT and obtained a good consistency between simulation and observations with regard of this parameter. The sign of IMF BY is the most important factor influenced the convection system under BZ+ conditions. For BY- the northward component of the electric field is negative during ¾; part of the day indicating clockwise plasma flow around the pole. For BY+, the electric field is directed poleward and the plasma rotate anticlockwise. These are confirmed nicely by the ESR observations.

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Polar cap sporadic E and electric field

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It is now well known that electric fields of the order of tens of millivolts per metre are capable of producing sporadic-E layers, provided the field points in a proper direction. The polar cap electric field has a sufficient intensity and the field direction has a diurnal variation which predicts a diurnal variation in the Es occurrence as well. Since the polar cap convection pattern strongly depends on the IMF, an IMF dependence of Es occurrence is also expected.

In two earlier papers, a statistical study on the relation of the IMF, the polar cap convection pattern and the Es occurrence was made. The data consisted of two years of ionosonde observations from Longyearbyen and Thule and simultaneous satellite-based IMF observations. A convection model was used in calculating the polar cap electric field from the IMF observations. As expected, the diurnal variations of the Es occurrence at the two sites were different, but their mean features could be explained by the electric field theory. The study has revealed a mechanism for an IMF control of the polar cap ionosphere.

In the present study, an effort will be made to check the IMF connection to Es occurrence in individual cases. Examples of ESR observations of sporadic E have been selected and IMF observations will be used in calculating the time dependent electric field at the radar site. This electric field will then be used in calculating the vertical plasma convergence and the layer growth and the results will be compared with the observed Es layers.

The Trans-National Access Program

L. Baddeley

EISCAT Scientific Association, Kiruna, Sweden

The EU funded Trans-National Access program is designed to allow scientists from the EU and EU related countries who aren't members of EISCAT to use the radar facilities for their own experiments. The funding covers experimental time on any EISCAT radar as well as scientific and other financial support for travel to and from the radar sites, accommodation and subsistence at EISCAT.

There will be an accompanying oral presentation regarding the Trans-National Access program in session 6 of the workshop. This poster will provide further details about this program currently in place at EISCAT.

Naturally enhanced ion-acoustic lines and solitary waves

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Since the identification of naturally enhanced ion-acoustic lines in incoherent radar spectra, there have been several suggestions of generation mechanisms. These generation mechanisms include current-driven instabilities, ion-ion two-stream instabilities and parametric decay of Langmuir waves. In spectra from the EISCAT Svalbard Radar (ESR), naturally enhanced ion-acoustic lines are often seen around local noon. Using ESR spectra and a two-fluid plasma description, we have investigated the possibility that these lines are caused by solitary waves.

Dependence of the ion-acoustic speed on the electron drift in the high-latitude ionosphere

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The ion-acoustic speed Cs at electrojet heights is an important parameter for understanding physics of small-scale irregularity formation at high latitudes. It is known that the mean Doppler shift of VHF coherent echoes, observed roughly along the electrojet direction, is close to Cs, but how much close is less clear, especially in view that Cs changes drastically with the intensity of the ExB plasma drift. In this study EISCAT measurements of the electron and ion temperatures at a number of electrojet heights are considered to establish analytical equations describing the relationship between Cs and the velocity of plasma of ExB drift, V. A simple quadratic dependence of the form $Cs=A+BV^2$ is accepted. Numeric values for the coefficients A and B are presented for a large number of EISCAT measurements spanning ExB magnitudes of 400-1500 m/s. Obtained expressions are applied to compare trends in Cs and the velocity of VHF and HF coherent echoes increase with ExB.

HF heater-induced phenomena in the ionospheric F region under the pump frequency above the maximum plasma frequency

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It is known that the excitation of artificial small-scale field-aligned irregularities (AFAI), HF-induced electron heating and optical emissions, anomalous absorption and other phenomena related to upper-hybrid waves occurs in HF heating experiments when the HF pump wave with an O-mode polarisation is reflected from the ionosphere. Nonetheless, experimental results from Tromsø heating experiments have shown that AFAIs were excited in the F-region as well as in the auroral E-region when the pump frequency exceeded the maximum plasma frequency. It is assumed that despite of the pump frequency was larger than the critical frequency, it was comparable to the maximum plasma frequency. We present experimental result from Tromsø heating experiment on 13 October 2006 in the evening hours when the critical frequencies in the F-region was gradually decreased from 4.1 to 3.3 MHz. The HF heating facility at Tromsø was operated at 4040 kHz, using O-mode polarization. The HF transmission scheme of 2 min on, 2 min off was used with the HF antenna beam pointed in the magnetic field-aligned direction. In the course of the experiment bi-static HF Doppler radio scatter observations were carried out on the London – Tromsø – St. Petersburg path in the conjunction with the EISCAT UHF radar observations. It was found that strong signals scattered from AFAIs were observed when the pump frequency was up to 0.5 MHz larger than the critical frequency. In these conditions very strong electron temperature enhancements (in 2-3 times) closely related to the heater-on periods took place. They were accompanied by the increase of the electron density from the EISCAT UHF radar observations.

Ionospheric pumping experiments on the second electron gyro-harmonic in Alaska

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Results are reported from the night-time "artificial aurora" ionospheric pumping experiments on the second electron gyro-harmonic (2.85 MHz) at the HAARP (Gakona) and HIPAS (Fairbanks) facilities in Alaska. Diagnostics include the Kodiak HF SuperDARN radar, which scans over HAARP and HIPAS, the MUIR UHF radar at HAARP, the new Poker Flat AMISR UHF radar near HIPAS, and a variety of optical instruments. Some novel results include: (1) An asymmetric response maximum for pump frequencies just above the second gyro-harmonic as opposed to the minimum at higher gyro-harmonics, (2) The co-existence of the parametric decay and thermal parametric instabilities, (3) The first observation of pump-induced lower-hybrid waves, (4) The first optical observation of the temporal evolution of the pump beam self-focusing effect, and (5) Incoherent scatter measurements of plasma temperature within the heated ionospheric volume when pumping on the second gyro-harmonic.

Observation of ionosphere response to HF heating at Barentsburg

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A series of heating experiments have been carried out on 2006 at SPEAR heating facility at Svaldbard. The experiments on modulated ionosphere heating were mainly aimed on injection of the artificial MHD waves into upper ionosphere. Ground based observations of the artificial magnetic pulsations near heating site provided by Polar Geophysical Institute at Barentsburg show some interesting features. Probability of their excitation is rather small (~10%) and independent from k-index of magnetic activity. Density of ionospheric current estimated from magnetic disturbances during intervals of the artificial emission generation being in the range 100 – 200 mA/m corresponds to a moderate disturbances. The pulsation intensity does not vary significantly, only one case shows amplitude exceeded others by the order. Numerical modeling of the ground based artificial emissions could solve a problem of their effective generation.

Previously unreported emissions from ionospheric heating experiments

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We present observations of the O+ 732 nm multiplet emission (excitation energy ~5.00 eV) generated during an ionospheric heating campaign conducted in March 2007 at HIPAS, Alaska. The emission, which to the best of our knowledge has not been previously observed during ionospheric heating experiments, was detected along the local magnetic zenith during cycles of O-mode heating at the second gyro harmonic (2.85 MHz). In addition to the brighter OI 557.7 nm (4.17 eV) and 630.0 nm (1.96 eV) features, other emissions of interest observed were the OI 777.4 nm and 844.6 nm lines, both with excitation energies of ~11 eV.

The primary instrumentation used was a modified Czerny-Turner CCD spectrometer observing from 500 to 860 nm. In addition, there were several co-located all sky cameras. Radar diagnostics were provided by the Kodiak Island HF SuperDARN radar, and the AMISR VHF radar located at Poker Flat. Optical, radar, model and ionosonde data will be analyzed in an attempt to characterize this previously undetected emission.

Modification of the natural plasma line during HF heating at Tromsø

A. Senior, M. J. Kosch

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The F-region "cutoff" of the natural (photoelectron-enhanced) plasma line was observed with the EISCAT UHF radar during O-mode HF heating with the EISCAT HF facility near Tromsø, Norway. The F-region critical frequency was slightly above the HF pump frequency of 4.544 MHz during the daytime in January 2006. Large electron temperature enhancements (~2000 K) were observed. The natural plasma line cutoff frequency was observed to increase by ~200 kHz coincident with the increases in electron temperature, but the cutoff spectrum also became weaker and less well-defined while the pump wave was switched on. The shift of the cutoff appears to be consistent with the shift in Langmuir frequency estimated from the electron density and temperature derived from the analysis of the UHF ion line spectrum. This suggests that the large temperature enhancements observed by the UHF radar during heating can be correctly interpreted in terms of a Maxwellian plasma and non-Maxwellian effects due to electrons accelerated by plasma turbulence play only a minor role. The weakening and spreading of the plasma line during heating is probably due to the formation of density irregularities in the plasma.

Session V: Magnetosphere-Ionosphere-Atmosphere Coupling Studies

Conveners: Tim Yeoman & Olaf Amm

Invited speakers
Stephan Buchert and Eoghan Griffin

Wednesday, 8th August
08:15-12:15

The Pedersen current carried by electrons: Effects on magnetosphere-ionosphere coupling

S. Buchert

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Irregularities in the auroral electrojet occur when the electric field imposed by the large scale plasma convection exceeds a threshold, and the Farley-Buneman instability is excited. Then significant heating manifests itself by enhancements of the electron temperature seen in incoherent scatter radar data. The heating is powered by large scale plasma convection transfering electromagnetic energy via field-aligned currents (FACs) into the lower E region where the FACs are closed by a dissipative current. Theory shows that first order correlations between variations of charge density and electron velocity in the presence of irregularities affect the direct current, mainly its direction, turning it partially from a Hall into a Pedersen current.

The effect may be parameterized by an anomalous electron-ion collision frequency and corresponding effective conductivities. Thus Ohm's law for the lower ionosphere becomes non-linear, locally strongly, and integrated over height only slightly. Models to calculate values for the anomalous collision frequency under given conditions have been proposed, also methods to estimate them from observations. I review these works and compare the predictions and results for a selected event where a relatively sustained high electric field is seen. Birkeland currents and electric field are coupled together on large scales by a ionosphere-magnetosphere coupling equation that results from the current continuity and Ohm's law. Thus different estimates of Birkeland currents are obtained depending on whether classical or effective ionospheric conductivities are assumed. I compare estimates of the current for the high electric field event.

Statistical MLT-distribution of conductances, electric fields, and Joule heating rate at high latitudes

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The continuous one-month EISCAT UHF radar measurement in Tromsø (cgmLat 66.1°) in March-April 2006 is analysed with a 2-min resolution to get reliable estimates of the ionospheric electric field. The same resolution is utilized in the calculation of height-integrated conductivities. The ionospheric Joule heating rate is then estimated from ΣpE^2. In this work, we have no measurements of the neutral wind velocity, so neutral gas dynamics is not taken into account. The calculated parameters in the pre-noon, post-noon, pre-midnight, and post-midnight sectors show very different characteristics. The characteristics reflect the different magnetospheric properties at different MLT sectors as well as variable ionospheric response. These effects will be discussed.

A comparison of various ground-based methods of estimating ionospheric conductances

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A knowledge of the spatial distribution of ionospheric conductances is important for estimating field-aligned currents from ground-based measurements. Optical emissions and cosmic noise absorption recorded by auroral imagers and riometers can be used to deduce the conductances since they are both related to particle precipitation from the magnetosphere. Magnetometers and coherent scatter radars give measurements of currents and electric fields from which the conductances can also be deduced. The results of deriving conductances by various different methods are compared.

Investigation of the ground-based signatures of the ionospheric Alfvén resonator (IAR) using the data from EISCAT Svalbard Radar

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The spectra of the electromagnetic noise in frequency range of 0.1-10 Hz are sometimes exhibit a resonance structure with frequency scale of few tenths to 1-2 Hz. This spectral resonant structure (SRS) is believed to be an observable signature of the ionospheric Alfvén resonator (IAR). According to the IAR theory, characteristics of SRS depend on parameters of the upper ionosphere, particularly on the electron density in the F-layer maximum, altitudinal scale of the density decay above the maximum, and the conductivity in the E-layer. The morphology of SRS have been studied at low, middle, and auroral zone latitudes and showed a general agreement with the theory. Recently the SRS observations were performed at high latitudes, in Barentsburg on Svalbard using the search coil magnetometer of the Polar Geophysical Institute. An advantage of this location is in closeness with the EISCAT Svalbard radar that provides information on the height distribution of the ionospheric parameters. In the cases when radar data are available during SRS observations we performed calculations of the IAR eigenfrequencies on the basis of measurements of the electron density altitudinal profiles. Obtained values are in a good agreement with frequencies and frequency scale of SRS. This confirms IAR as the origin of SRS. We also compared statistical properties of SRS in Barentsburg with predictions made on the basis of the IAR theory and the electron density altitudinal profiles revealed from the Incoherent Scatter Radar Ionospheric Model (ISRIM). As the result, some disagreement between calculations and observations is found. Thus, the observations show very low occurrence of SRS in the daytime, while calculations suggest almost equal occurrence during day and night. This disagreement is explained by enhanced changeability of the ionosphere in the daytime, when the ionosphere above the station is undergone an influence of transient precipitation, fields, and currents related to the cusp and various boundary layers, in comparison with night conditions, when the station is situated well poleward of the auroral oval. The changeability is not accounted by ISRIM, but affects the SRS magnetic observations, which require a stability of the ionospheric parameters at least for some tens of minutes.

GPS imaging of magnetosphere-ionosphere coupling

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The global pattern of the ionospheric plasma convection can be deduced from characteristics of GPS signals acquired by ground-based network of GPS receivers. The tomographic inversion of these GPS data in a three-dimensional time-dependent inversion algorithm based on Kalman filtering can reveal the spatial and temporal distribution of ionospheric electron density. This algorithm has been applied to reconstruct the 4D dynamics of ionospheric plasma content (TEC) and density during some major magnetic storms of the recent solar maximum. Comparison between the results of GPS tomography and in-situ measurements of plasma bulk motion by LEO satellites allow conclusions to be made about the degree at which the ionospheric convection flow expands during the major storms and the efficiency of electromagnetic magnetosphere-ionosphere coupling at sub-auroral latitudes.

Mesoscale thermospheric structure: Current evidence and future experiments

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The experiments and model results that have revealed the extent of mesoscale thermospheric structure are presented and discussed in the context of the consequences for ion-neutral coupling studies.

The view of the upper thermosphere as a passive, slowly changing medium has evolved in recent years thanks to the combination of innovative experimentation and advances in numerical modelling. More specifically the issue of ion-neutral coupling, at all scales, has been addressed in a more fundamental manner than previously possible. The implications of the structure evident at mesoscales within the thermosphere are significant not just for the accurate representation of the thermosphere itself but also to establish a realistic view of the fully coupled magnetosphere-ionosphere-thermosphere system.

In recent years the development of advanced CCD technology has allowed an order of magnitude improvement in time resolution for the standard Fabry-Perot Interferometer measurements of upper thermosphere neutral winds and temperatures. Structure on the time scale of a few minutes has been evident in many datasets. In parallel, radar studies of ionospheric behaviour has revealed structure in ion velocities at timescales an order of magnitude smaller than the neutrals.

Combined tristatic experiments have been undertaken using the EISCAT radar and FPI measurements from Northern Scandinavia. The results have demonstrated the importance of considering the mesoscale structure in neutral winds and ion velocities when calculating accurate Joule heating rates.

Modelling studies have often underestimated neutral temperatures while overestimating neutral wind velocities in comparison to measurements. Within the self-consistent numerical models improvements have been shown when the small scale influence of electric field variations are properly considered, a possible source of the mesoscale thermospheric structure.

In order to address both the temporal and spatial aspects of the thermosphere at mesoscales a new generation of neutral measurement instrumentation, the scanning doppler imagers, have been developed and are now being deployed at several locations globally. These instruments deliver a simultaneous extended field of detailed spatial samples at relatively high time resolution and thus represent a major improvement in neutral measurement capability and also extend the scope of combined ion-neutral coupling studies.

Physical mechanism to generate vertical motions in the polar lower thermosphere

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An important aspect of the coupled thermosphere-ionosphere system at high latitudes is to know various temporal and spatial relationships in the dynamic interaction between the thermosphere and the ionosphere. While much is already known about the average characteristics of these systems, this subject has not yet been adequately investigated, in particular mesoscale phenomena. One of the most curious examples is the vertical wind in the lower thermosphere at high latitudes. Ground-based observations with Fabry-Perot Interferometers (FPI) have reported large amplitudes of the vertical wind in association with auroral activity. More recent rocket measurements at the Poker Flat Research Range in Alaska also showed considerably larger vertical thermospheric winds. Now there is no doubt in presence of the vertical wind larger than a few tens m/s. The current controversy in the field is then the physical mechanism to generate such large vertical motions. We conducted many experiments with the incoherent-scatter radars (ISR) in order to find the answer. Our recent experiments suggested that the thermospheric wind is accelerated obliquely upward/downward in association with Joule and/or auroral particle heating, and that the wind blows on the isothermal layer, which can be tilted by localized heating or climatological effects from the lower atmosphere. The paper will present the physical explanation using observational results.

Multi-layer structure and its short-period oscillations in the ionosphere F2 layer as a result of the presence of atmospheric vortical perturbation excited in the horizontal shear flow

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It is found that the mid-latitude nighttime ionosphere F2 region electron density height distribution under the influence of a vortical perturbations excited in the horizontal shear flow (horizontal wind with horizontal linear shear) is characterised with a multi-layer structure. The atmospheric shear wave (vortical perturbations excited in the horizontal shear flow) property to transform into short-period atmospheric gravity waves (AGWs) is reflected in the oscillations of the peak heights of the ionosphere F2 region electron density. The analytical description for the ionosphere F2 region electron density height distribution was obtained by solving the ambipolar diffusion equation taking into account the presence of atmospheric shear waves. The peak height and the corresponding multi-layer F2 region electron density depend on the values of the meridional wind zonal shear and the shear wave vertical wavenumber. The oscillation of the atomic oxygen red 630.0 nm line total nightglow intensity with two different short-period AGW frequencies (observed mostly on magnetically disturbed days) is considered as a possible result of the appearance of a secondary maximum in the ionosphere F2 region electron density under the influence of atmospheric shear waves.

Relationship between ion upflows and suprathermal ions observed with the EISCAT Svalbard Radar and Reimei satellite

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The relationship between bulk ion upflows and suprathermal ions was investigated using data simultaneously obtained from the European Incoherent Scatter (EISCAT) Svalbard radar (ESR) and the Reimei satellite. Simultaneous observations were conducted in November 2005 and August 2006, and 14 conjunction data have been obtained at approximately 630 km in the dayside ionosphere. In the dayside cusp region, suprathermal ions with energies of a few eV were present, and the ion velocity distribution changed from an isotropic Maxwellian to tail heating at energies above a few eV. The velocity distribution of the suprathermal ions has a peak perpendicular or oblique to the geomagnetic field, and the temperature of the suprathermal ions was 0.9-1.4 eV. An increase in the phase space density (PSD) of the suprathermal ions, measured from Reimei data, was correlated with bulk ion upflow observed at the same altitude using EISCAT, and the energy flux of precipitating electrons with energies of 50-300 eV. The PSD also has a good correlation with the electron temperature, which was increased by precipitation, but not with the ion temperature (0.1-0.3 eV) at the same altitude measured with EISCAT. These results suggest that rather than anisotropic heating due to O+-O resonant charge exchange, plasma waves such as broadband low frequency electric (BBELF) wave fields associated with precipitation are connected to the bulk ion upflows in the cusp and effectively cause the heating of suprathermal ions.

Observations of an auroral streamer in a double oval configuration

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During the late evening and night of September 14, 2004, the nightside auroral oval shows a distinct double oval configuration for several hours after a substorm onset at ~ 1845 UT. This is observed both by the IMAGE satellite optical instruments, and by the MIRACLE ground-based instrument network. While the two auroral regions are otherwise disconnected and slowly drifting equatorward with comparable speeds, at ~ 2117 UT an auroral streamer is detected by IMAGE over northern Fennoscandia, which connects the two regions for a few minutes. This streamer causes a distortion in the equivalent current patterns seen by the MIRACLE network which indictates that also current is transferred between the two regions. Further, the streamer moves over the EISCAT beams which allows us to deduce the electron density structures and conductances associated with it in detail. The magnetic footprints of the Cluster satellites are located at the streamer's eastern flank, where Cluster measures a bursty bulk flow in the magnetotail. We will compare in detail the electrodynamics and the ionosphere-magnetosphere coupling of this late recovery phase streamer with previously studied expansion phase and early recovery phase streamer cases.

Effects of a geomagnetic pulsation on electron precipitation spectra

A. Kavanagh, F. Honary, A. Senior

Lancaster University, Lancaster, UK

Electrons with energies in excess of 30 keV form a potential source population for relativistic electrons in the outer radiation belt. One loss mechanism of these sub-relativistic electrons from the magnetosphere is precipitation linked to substorm activity, whether directly or following gradient-curvature drift of the freshly injected electron population. This can be observed using cosmic noise absorption measurements from a riometer. The precipitation is caused by the scattering of electrons into the loss cone by VLF whistler-mode waves; however, the precipitation can itself be modulated on timescales of seconds to tens of minutes. Using EISCAT data we investigate the change in energy spectra within a Pc5 pulsation (260 seconds) to determine the effect on the different levels of particle energy. The Coroniti-Kennel theory of ULF wave-electron interaction predicts a change in the shape of the high energy tail; alternatively, a shift in the whole spectrum would indicate that the pulsation in the precipitation is caused by acceleration in a parallel electric field such as that caused by kinetic Alfvén wave.

Determination of auroral electrons spectra and field-aligned potential differences using simultaneous ground-based optical observations of an auroral arc with ALIS

H. Lamy[1], M. Roth[1], J. De Keyser[1], T. Sergienko[2], B. Gustavsson[2], U. Brändström[2]

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With the Auroral Large Imaging System (ALIS) located near Kiruna, the three-dimensional structure of an auroral arc can be reconstructed by use of a tomographic inversion of optical observations of the arc obtained simultaneously at several ground-based stations. By inverting the forward model described in Janhunen et al (2001) or Semeter and Kamalabadi (2005), the discrete two-dimensional (2D) spatial distribution of the energy spectrum of electrons precipitating into the ionosphere can be obtained from the vertical distributions of auroral arc emissions obtained at those wavelengths corresponding to the most prominent auroral emissions (i.e. blue, red and green emission lines). If we use for example the Knight (1973) assumptions and if realistic values for electron densities and temperatures in the magnetosphere are considered, the discrete 2D field-aligned potential difference can be inferred from the non-linear relationship between the total energy flux (obtained from the energy spectrum) and the field-aligned potential difference, used by Lundin & Sandahl (1978). An example of such a complete inversion will be presented as well as future improvements and complementary analyses planned for the model.

Session VI: Auroral Phenomena

Conveners: Takehiko Aso & Anita Aikio

Invited speakers
Nikolay Ivchenko and Noora Partamies

Thursday, 9th August
08:15-12:00

Results from ASK observing campaign 2006/7 in Tromsø

N. Ivchenko[1], B. Lanchester[2], H. Dahlgren[1], D. Whiter[2], G. Marklund[1], T. Sergienko[3], B. Gustavsson[4]

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[4] *University of Tromsø, Norway*

ASK (Auroral Structure and Kinetics) is a multispectral auroral instrument, consisting of three narrow field of view imagers and two photometers. The imagers are based on the iXon EMCCD detectors, and are fitted with custom made f=150mm, F/1 lenses, resulting in 3x3 degree field of view. Narrow passband filters are used in each of the imagers and photometers, providing simultaneous measurements in different emissions, with frame rates of up to 32 fps. Sets of imager filters include combinations of 777.4 nm (OI), 732.0 nm ([OII]), 562.0 nm (O2+), 673.0nm (N2), and 427.8 nm (N2+). Using these filters allows to estimate the energies and energy flows of auroral electrons, and potentially - by observing the afterglows in the forbidden oxygen ion line - ionospheric plasma flows. Since September 2006 until March 2007 ASK was operated at the mainland EISCAT site in Ramfjorden, Norway. Several coordinated campaigns were carried out, with both ASK and EISCAT pointing to the magnetic zenith. We present selected results on the morphology and time development of the fine structure in the aurora, and its effects in the ionosphere, as measured by the EISCAT radar.

Modelling and observations of the energy spectrum of precipitating electrons using joint EISCAT-ASK (Auroral Structure and Kinetics) measurements

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A time-dependent ion chemistry model is used to derive the energy spectrum of precipitating electrons in dynamic structured aurora, using multi-spectral measurements from the ASK instrument combined with radar electron density profiles. During the winter season of 2006/7 the ASK instrument was deployed at the EISCAT Tromsø site. Events from 22 October 2006 with fast moving filamentary auroral structures on sub-kilometre, sub-second scales have been analysed in conjunction with EISCAT radar measurements, in particular the tristatic measurements of electric fields in the region of the dynamic aurora. These measurements are discussed in terms of the possible physical auroral acceleration mechanisms.

The ASK instrument consists of three narrow field of view imagers, each operating with a narrow passband filter to image auroral emissions in different spectral bands. Each camera has a 3 degree field of view centred on the magnetic zenith (corresponding to 5 km at 100 km altitude) and sub-second integration time. These features make ASK an ideal instrument for studying dynamic and structured aurora. The possible combinations of observed emissions (N2 1PG 6730, [OII] 7320, OI 7774) provide a unique dataset for optical studies of spectral ratios and variations in different auroral features.

Conditionally integrated incoherent scatter radar data and flickering aurora

T. Grydeland[1], B. Gustavsson[1], E. M. Blixt[1], L. Baddeley[2], J. Lunde[3]

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[3] *currently at Solar-Terrestrial Environment Laboratory, Nagoya University, Nagoya, Japan*

Flickering aurora is characterized by optical emissions varying in intensity with frequencies typically between 5 and 20 Hz. The horizontal scale size of flickering columns are typically 1-10 km, while the vertical extent is 10-40 km. At times the flickering appears as a whirling motion. Here we use high-speed narrow field-of-view imaging in white light to determine the intensity variation in the field aligned direction, which is also the direction of the beam of the EISCAT Svalbard Radar (ESR).

Incoherent scatter radar data is noise-like, and must be integrated over multiple pulses to reduce the variance to useful levels, even for high signal to noise ratios. Usually, this means integrating over several seconds to some tens of seconds of observation, which is not very useful with respect to flickering aurora. In the experiment presented here, we have taken data at the voltage level, before any integration. By doing so, we are free to define integrations which are not necessarily contiguous in time.

We have used the intensity variation of flickering aurora within the area of the radar beam to define local temporal origins, and have integrated together pulses at the same time offset from the nearest origin to investigate whether radar backscatter varies in a way which is correlated with the variation in optical emission intensity. We present the technique and preliminary results of this investigation.

A new method to estimate ionospheric electric fields and currents using ground magnetic data from a local magnetometer network

H. Vanhamäki, O. Amm, K. Kauristie

Finnish Meteorological Institute, Helsinki, Finland

Determination of ionospheric electric parameters from direct or indirect measurements is a fundamental task in ionospheric physics. In this study we present a new method to estimate ionospheric electric fields and currents using ground magnetic recordings and measured or modelled ionospheric electric conductivity as the input data. This problem has been studied extensively in the past, and the standard analysis technique for such a set of input parameters is known as the KRM method (developed by Kamide et al. in 1981).

The new method presented in this study makes use of the same input data as the traditional KRM method, but differs significantly from it in the mathematical approach that is used. In the KRM method one tries to find such a potential electric field, that the resulting current system has the same curl as the ionospheric equivalent currents. In the new method we take a different approach, so that we determine such a divergencefree current system that, together with the equivalent currents, it is consistent with a potential electric field. This approach results in a slightly different equation, that makes better use of the information contained in the equivalent currents.

In regional studies the (unknown) boundary conditions at the borders of the analysis area play a significant role in the KRM solution. In order to overcome this complication, we formulate a novel numerical algorithm to be used with our new calculation method. This algorithm is based on the cartesian elementary current systems (CECS). With CECS the boundary conditions are implemented in a natural way, making regional studies less prone to errors. We compare the traditional KRM method and our new CECS-based formulation using realistic models of typical meso-scale phenomena in the auroral ionosphere, including the westward traveling surge and Omega-bands.

Observation of ionospheric effects in the aurora zone using CHAMP and COSMIC/Formosat-3 data

C. Mayer, N. Jakowski

German Aerospace Center/ Institute of Communication and Navigation, Neustrelitz, Germany

We present observations of the auroral ionosphere combining radio occultation data from the CHAMP and from the COSMIC/Formosat-3 satellite missions. The CHAMP radio occultation measurements with about 150 vertical electron density profiles per day enables us to study solar-cycle dependencies since the beginning of observations in April 2001. With more than 2500 profiles per day the COSMIC/Formosat-3 offers an unprecedented temporal and spatial data coverage since April 2006.

The developed algorithms for analyzing the shape of the vertical electron density profiles up to 800km height fit an empirical Ansatz to the data. This approach consists of Chapman functions for the E- and F-layers and of an exponential decay for the topside. Using this technique, we select profiles with pronounced ionization at E-Layer height in the range of about 90-150 km for studying the geophysical conditions and characteristics of the related ionospheric processes.

In particular we show that profiles with enhanced E-layer ionization are closely related to the location and shape of the auroral zone. Thus, we are able to study the local-time, seasonal, and space-weather dependence of enhanced ionization prozesses in the auroral zone, e.g. related electron precipitation processes of magnetospheric origin. Furthermore, we present a statistical analysis of the F-layer parameters and the plasmasphere scale height at 600-800 km height for both auroral zones.

Colour imaging of the aurora

N. Partamies, M. Syrjäsuo, K. Kauristie

Finnish Meteorological Institute, Helsinki, Finland

Most of the auroral imaging nowadays is performed by using either white light imagers or cameras with narrow band-pass filters centered at the most common auroral emission lines: green at 557.7nm, blue at 427.8nm and red at 630.0nm. Imagers utilising the filters provide quantitative information on emissions at each wavelength, but they are also very expensive and replacing worn-out parts can be costly. White light (panchromatic) imagers, on the other hand, lose all the spectral information but can provide high temporal resolution of the evolution of the aurora at a lower cost.

Colour imaging has been investigated as an option by University of Calgary to help the automatic detection of the aurora from the growing amount of imager data. A prototype imager called Rainbow was run during a Finnish optical and EISCAT campaign at the auroral station on Svalbard in February, 2004. In our preliminary study of these colour data, we show the results of fitting the four Rainbow channels (cyan-magenta, cyan-green, yellow-magenta, yellow-green) to reconstruct the traditionally filtered auroral wavelengths: green (557.7nm), red (630.0nm) and blue (427.8nm) which were simultaneously recorded by the Meridian Scanning Photometer (MSP) at the same station. This fit is qualitatively surprisingly good and almost linear. We show that using colour imagers instead of white light cameras provides us with a possibility to reconstruct some spectral information in addition to the great public outreach component. At the moment, six all-sky colour cameras are operating continuously in the Northern auroral zone, and more are being deployed.

Electric fields associated with post-noon auroras

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In November 2006, a special EISCAT campaign was performed on Svalbard to investigate electric fields associated with the post-noon (12-17 MLT) auroral arcs observed by the all-sky cameras in Longyerbyen and Ny-Alesund. The most important is the northward (perpendicular to auroral arcs) electric field component, which was inferred from the EISCAT Svalbard Radar (ESR) measurements with the radar beam directed to west. The observed auroras are poleward moving auroral forms (PMAF) occurring during different IMF conditions (southward, northward, and near-zero IMF Bz). The auroral arcs and associated electric field patterns are discussed in connection with possible mechanisms for the aurora formation. The discussed mechanisms are the dayside reconnection driven by southward IMF, the interchange instability which likely occurs during northward IMF, and the flow shear created due to magnetospheric eigenmode toroidal oscillations. The electric field (plasma flow) patterns are shown to be important indicator of the arc generation mechanisms.

Coordinated optical and radar observations of enhanced electric fields within auroral arcs

V. Safargaleev[1], T. Sergienko[2], A. Kozlovsky[3], I. Sandahl[2], S. Osipenko[1], U. Brändström[2]

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The first theoretical models of the auroral arc were based mainly on optical observations. The further progress was connected with radar measurements, which confirmed, in particular, the theoretical prediction that the arc itself is a region of enhanced conductivity. For this reason, the electric field within the arc should be smaller than outside. But there were some events reported where the electric field inside the arc increased and as appeared to be correlated with the conductivity (de la Beaujardiére at al., 1981). Although a theoretical interpretation was suggested (Marklund, 1984), the observations were questioned by Lanchester et al. (1996). After that no clear cases of the "correlating arcs" were reported and the field decrease is regarded now as the only possibility for the change of the electric field within the arc. Our paper is a case study of coordinated EISCAT and ALIS observations of a series of auroral arcs. The vector of the ionospheric electric field was inferred from tristatic measurements. The observations showed that the electric field was enhanced every time when the arc crossed the EISCAT beam. Due to high temporal and spatial resolution, the discussed observations do not suffer from disadvantages indicated by Lanchester and verify the presence of "correlating arcs". A possible interpretation of the observations is suggested.

Coordinated EISCAT and ALIS observations of the active auroral arc system

T. Sergienko[1], I. Sandahl[1], V. Safargaleev[2], B. Gustavsson[3], U. Brändström[1]

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[2] *Polar Geophysical Institute, Apatity, Russia*

[3] *University of Tromsø, Tromsø, Norway*

High time and space resolution optical (ALIS) and EISCAT UHF radar measurements have been used to study the ionospheric electrodynamics of system of the active auroral arcs. 3D distribution of volume emission rate of the auroral "blue" (427.8 nm) line obtained by tomography-like reconstruction from the multi station ALIS images was used for deducing the spectra of precipitating auroral electrons. Obtained spectra were used to calculate the 2D map of the ionospheric conductances. Ionospheric electric field obtained from the three static EISCAT measurements combined with the 2D conductance distribution allowed us to reconstruct the electric current system associated with the multiple auroral arc structure. Temporal evolution of the current system is discussed.

The Trans-National Access Program

L. Baddeley

EISCAT Scientific Association, Kiruna, Sweden

The EU funded Trans-National Access program is designed to allow scientists from the EU and EU related countries who aren't members of EISCAT to use the radar facilities for their own experiments. The funding covers experimental time on any EISCAT radar as well as scientific and other financial support for travel to and from the radar sites, accommodation and subsistence at EISCAT.

The exact details regarding the program as well as the application procedure will be discussed. There will also be an accompanying poster presentation at the meeting with further details of the program.

Session VII: Structures and Dynamics of the Polar Cap and Cusp

Conveners: Jøran Moen & Kirsti Kauristie

Invited speakers
Herbert Carlson and Ryoichi Fujii

Thursday, 9th August
13:30-17:30

The case for a new process, not mechanism, for cusp irregularity production

H. Carlson[1], T. Pedersen[2], S. Basu[2], J. Moen[3]

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[2] *AFRL/VSB, Massachusetts, USA*

[3] *University of Oslo/UNIS, Norway*

Two plasma instability mechanisms are currently thought to dominate formation of plasma irregularities in the F region high latitude and polar ionosphere: the gradient-drift driven instability, and velocity-shear driven instability. The former mechanism is accepted as accounting for structuring plasma in polar cap patches, the latter for structuring plasma in polar cap sun aligned arcs. This structuring, studied intensively for both scientific and practical reasons, leads to phase and amplitude scintillation capable of disrupting satellite communications and navigation signals. Here we introduce not a new mechanism, but a needed new process of orthogonal mixing of these two instability mechanisms, which drives severe structuring and scintillation in plasma entering the polar cap through the cusp. Correct modeling of cusp and early polar cap patch structuring will not be accomplished without allowing for this compound process. This compound process also explains previously unexplained characteristics of cusp and early polar cap patch irregularities.

Ion-dispersion in the cusp: A case study investigated with satellite and radar

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[6] *IAR, Nagoya University, Nagoya, Japan*

[7] *PPARC, Tohoku University, Sendai, Japan*

[8] *ISAS/JAXA, Japan*

We present results from a joint Norwegian-Japanese-Swedish campaign, ESR/REIMEI, which was carried out in the winter 2006 on Svalbard. The aim was to conduct coordinated temporally and spatially highly resolving observations of structured aurora, electron precipitation and ion-outflow with the ESR (EISCAT Svalbard Radar) and the low altitude REIMEI satellite. The results are mainly from the daytime cusp. Clear signatures of so-called ion-dispersion are seen in the satellite data, meaning that the energy of precipitating ions decreases over time continuously or in steps. In particular fast variations of the electron flux and energy in these events have been found and studied.

In one event, on the 1st February of 2006, the REIMEI satellite flew at ~ 610 km height close past the ESR facility (75.27° N and 111.65° E CGM). The ESR 32m antenna was pointed 233.8 in azimuth and 78.7° in elevation, corresponding to the satellite shortest range direction (~ 628 km at ~ 09:27 UT). In the satellite data, a continuously decreasing ion energy was clearly seen, followed by a step-like decrease. The downward ion-precipitation was in the range between 100 – 1000 eV. Additionally, during the ion-dispersion, the REIMEI data show quasi-periodic fluctuations in the electron energy and flux while the interplanetary magnetic field (IMF) had been relatively steady the 2 hours before. Features of the ion dispersion agree relatively well with previously published observations of satellites at various altitudes. These had been interpreted as effects of the magnetic reconnection process occurring at the dayside magnetopause. The much faster electron variations seen here might be caused by fine spatial structures in the reconnection region that map down onto the ionosphere, or by temporal oscillations arising in the ionosphere-magnetosphere coupling.

Cusp density enhancements by Fossil FTEs?

I. McCrea, J. Davies, M. Hapgood, V. Howells

Rutheford Appleton Laboratory, Chilton, UK

We will present data taken dring the interval from 06 to 10 UT on April 23 2006, when the Cluster spacecraft were moving from the nightside to the dayside through the magnetic cusp. The magnetic footprint of Cluster was close to conjugacy with the VHF and ESR radars, which were both running in support of Cluster operations.

IMF Bz was initially southward, turning to northward later in the interval. During the period of Bz south, strong density signatures were observed by both the EISCAT radars and by Cluster, and we seek to interpret these events in terms of FTE signatures, possibly generated at the sub-solar magnetopause before being convected into the cusp region.

Electron density in the cusp ionosphere: When the ESR confirms TRANSCAR predictions

F. Pitout[1], P.-L. Blelly[2]

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[2] *LPCE, Orléans, France*

The ionosphere beneath the polar cusp has been extendedly studied until now in order to understand the processes leading to IS radar observations. In a previous work, Pitout and Blelly (2003), using the TRANSCAR ionospheric model, predicted the response of the ionospheric plasma parameters, especially focusing on the electron density, in response to intense magnetosheath particles precipitation and strong convection electric field. One of their conclusions was that the electron density in the cusp is primarily ruled by its initial electron content, i.e. by the origin of the flux tubes. We present ESR data that clearly show this trend. Moreover, we have run a series of ESR experiments to verify another prediction: in certain conditions, the electron density should decrease almost immediately after the opening of the field line. The ESR 32m-antenna was used to scan the dayside polar ionosphere alternatively in azimuth and elevation in order to have 2D views of the ionosphere in two planes. Again, our observational results agree well with the simulations.

Combined CHAMP-EISCAT studies on local thermospheric mass density enhancements in the CUSP

S. Rentz[1], H. Lühr[1], M. Rietveld[2]

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[2] *EISCAT Scientific Association, Tromsø, Norway*

Using onboard-measured accelerometer data the neutral atmospheric density and wind distribution at orbit altitudes of the CHAMP satellite (ca. 400km) can be examined both on global scale and on local scale. A prominent investigated local phenomenon is the thermospheric mass density anomaly in the cusp region. CHAMP frequently records air drag peaks during cusp overflights. In case studies, the arising density variations were discussed. The results initiated a multi-instrumental satellite-EISCAT-campaign called SIRCUS, where incoming magnetosheath plasma was supposed to be a possible driving mechanism. It can penetrate down to lower altitudes in the cusp region and cause ionospheric currents which may fuel Joule heating. In the meantime, several years of CHAMP data are available. Hence, the investigation of the local phenomenon was extended to a statistical analysis, using three years of accelerometer measurements. The study reveals dependences on solar activity, season and solar zenith angle. The amplitude of the density enhancement strongly depends on the level of solar EUV radiation. It decreases by a factor of 3 between 2002 (average yearly F10.7 = 179) and 2004 (average yearly F10.7 = 107). In the northern hemisphere, the density distribution displays a clear seasonal variation with weakest amplitudes in summer and largest amplitudes during autumn and winter (mean ratio autumn/summer = 1.1). Whilst the density enhancement is confined to the noon sector during high solar zenith angles, it is shifted by about 1.5 hours towards the afternoon during low solar zenith angles. The statistical analysis was complemented by a combined CHAMP-EISCAT campaign in October 2006. While the CHAMP spacecraft maps the thermospheric responses, the ESR32, ESR42, and the Tromsø VHF radar simultaneously measure the ionospheric parameters, which are used to calculate conductivities, electric field, and Joule heating rates. The measurements will help to identify the altitude range of the heated area and the driving processes. Therefore the combined studies contribute to a better understanding of the coupling processes between ionospheric plasma and thermospheric neutral gas.

Cluster high altitude observations of oxygen ion outflow, the connection to the ionosphere

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[2] *CESR, Toulouse, France*

We present Cluster observations of oxygen ion outflow at high altitudes above the polar cap. At altitudes of 5 - 12 Earth radii the oxygen ions are transversely heated by waves as well as accelerated in the parallel direction, mainly by the centrifugal acceleration mechanism. Much of the transverse heating is transient and occur in bursts. The number flux of the oxygen ions also shows clear transients. We have developed a method to automatically detect such transients. We will show statistical results on the distribution of such transients in three year of Cluster data. Initial results show that sudden increases of number flux are typically about 5 minutes apart when observed by Cluster at high altitude. Superposed epoch and multi-spacecraft measurements will be used to relate the transients to surrounding conditions, in particular convection changes in space and time. The robustness of the transient detection technique and the effect of using different thresholds in the detection algorithm will be discussed. Finally we will discuss what this tells us about the ionospheric source. Can we tell whether the main number flux modulation occur in the ionosphere (large upflow) or in a second stage in the upper ionosphere/ lower magnetosphere where transverse heating or other mechanisms provide enough energy for the ions to overcome gravity, by comparing with statistical EISCAT results on ion upflow?

Effects of the IMF BY inferred from the FAC-based convection model and radar observations

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We present the results of modeling and radar observations of the ionospheric electric fields in the polar cap, where the electrodynamic processes are strongly controlled by the IMF BY component. The polar-orbiting satellites such as the Orsted, Magsat, Champ, Iridium detect intense field-aligned currents (FAC) above ±75° MLat which depends on a sign of BY. These current density numbers are comparable with the density of the corresponding pair of R1 currents. The near-pole FAC imply large and variable electric fields in the polar cap, which is not presented adequately in the statistical convection models published up to now. Recently, a new approach for modeling the global distribution of ionospheric electric potentials utilizing high-precision maps of FACs derived from measurements by the Orsted, Magsat and Champ satellites as input to a comprehensive numerical scheme has been developed. We show that the FAC-based convection model reproduces nicely the polar cap effects. We combine the model' predictions with the European IS Svalbard radar (ESR) and SuperDARN observations for specific cases of strong interhemispheric asymmetry caused by the sign of BY, season, universal time (UT) to adress the following questions. To what degree the FAC-based model does reproduce the radar observation? How does the difference in electric potential between the near-pole region and the auroral zone depend on the magnitude of BY? Are the observed peculiarities of plasma flow controlled by FAC, ionospheric conductance or both? What can be the reason of observed variability of the polar cap potential? Also, the simulation in frame of the FAC-based model as well as observations shows that the solar zenith angle (both seasonal and UT variation) should be linked to the IMF clock angle to fully characterize the convection patterns. That confirms the necessity to link season with the sign of IMF BY to fully characterize the dependence of the convection patterns on season. Finally, we show that when the seasonal interhemispheric asymmetry in conductivity and in FAC intensity is amplified with the BY–related redistribution of FACs, the plasma flow at middle latitude is also modified. Specifically, the flow is strongly affected by the corresponding summer polar cap convection pattern.

Dependence of the electromagnetic and precipitating particle energy inputs to the ionosphere upon the sunlit/shade condition of the ionosphere

R. Fujii[1], H. Handa[1], S. Nozawa[1], Y. Ogawa[2]

[1] *STEL/Nagoya University, Nagoya, Japan*
[2] *National Institute of Polar Research, Tokyo, Japan*

Based on an analysis of EISCAT CP-1 data obtained from January 1987 to November 2004, we have statistically determined the dependence of the electromagnetic energy and the kinetic energy of precipitating particles from the magnetosphere into the ionosphere and then thermosphere upon the sunlit/shade condition of the ionosphere. The energy deposition by precipitating particles can be derived from the ion-electron pair production rate that is obtained from the recombination rate using measured electron density in the E-region. Since the neutral atmosphere is ionized not only by particle precipitation but also by solar irradiation, however, in order to obtain the electron density due to particle precipitation, we have first estimated the electron density due to the solar irradiation and expressed it as a function of solar zenith angle by using data where we do not see any significant ionizations by particle precipitation. We have thus successfully estimated the precipitating particle energy deposition even in the sunlit ionosphere on all available CP-1 data. The present study shows that not only the electromagnetic energy but also the precipitating particle energy deposition in the dark ionosphere tends to be larger in the sunlit ionosphere, indicating that ionospheric conditions actively control the magnetosphere-ionosphere (M-I) coupling.

Dynamics of the polar cap boundary in the evening sector during a substorm event

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Plasma flow through the polar cap boundary (PCB) in the ionosphere can be utilized for estimating the reconnection electric field as a measure of the energy transfer from the open magnetic field lines to the closed field line region. In this study, we calculate the ionospheric reconnection electric field in the nightside for a substorm period on November 25, 2000. The plasma flow vectors are determined by the dual-beam measurement of the EISCAT VHF radar and the location of the PCB is estimated from the EISCAT measurements on the mainland and on Svalbard. In addition, the convection reversal boundary is determined from the EISCAT data. The PCB is compared with optical satellite measurements by Polar UVI and equivalent east-west electrojets calculated from MIRACLE magnetic measurements by 1D upward continuation.

On the diurnal variability in F2-region plasma density above EISCAT Svalbard Radar

J. Moen[1], X. C. Oiu[1], H. C. Carlson[2], R. Fujii[3], I. W. McCrea[4]

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Two separate months of continuous operation of the EISCAT Svalbard Radar (ESR) in the common program mode, looking up along the magnetic field line, have been analysed with respect to variability in the F2 region peak density. In order to characterize the diurnal variation, 2 minute resolution data were binned in 30 minute averages, and then averaged over all days of observations within each month; February 2001 and October 2002. The analysis resulted in a characteristic diurnal variation in the F2 region peak density, with one maximum located almost exactly at 12 MLT and one around 23 MLT. The ESR is sitting inside the polar cap most of the time for moderate and high activity. The peak near noon is consistent with transport of solar EUV ionized plasma into the polar cap in the cusp inflow region. The peak near magnetic midnight indicates that on average, the path of exit of high density plasma from the polar cap is shifted slightly towards pre-midnight, i.e. entirely consistent with a recent statistical study on the occurrence of airglow patches by Moen et al. (submitted to Geophys. Res. Lett, 2007). In February 2001 (October 2002), about 50% (17 %) of the 2 minute data dumps had F2 region peaks larger than 1012m-3, referred to as extreme densities. This high density plasma represents patches or source material for polar cap patches. The occurrence of extreme densities in the 10-11 MLT sector occur predominantly for IMF BY positive, and the occurrence of extreme densities in the 13-14 MLT sector occur predominantly for IMF BY negative. This is entirely consistent with the IMF control of zonal motion near noon. However, this represents the strongest evidence to date for no IMF BY preference in patch formation. Comparison with the international reference ionosphere model (IRI) demonstrates that the model value F2 peak is representative of solar EUV production of plasma, but not of long distance transport of F2 region plasma. Time continuous measurements by the ESR during IPY will constitute an important basis for empirical modelling of the polar cap ionosphere.

Large scale structuring of polar cap plasma in the nightside ionosphere: The influence of the orientation of the interplanetary magnetic field

A. G. Wood[1], E. Pryse[1], H. R. Middleton[1], V. Howells[2]

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The polar ionosphere is a highly structured medium comprising electron density enhancements on a large range of horizontal spatial scales. On the larger scales high density dayside plasma may be drawn antisunward within the high latitude convection pattern. This plasma can form regions of enhanced ionisation known as polar cap patches which may be drawn into the nightside ionosphere. It is well established that the occurrence and subsequent evolution of these patches can be influenced by the interplanetary magnetic field, season and solar cycle. To date most studies have focussed on either the dayside or the central region of the polar cap, but this presentation focuses on nightside observations.

Modelling predicts that the offset of the geographic and geomagnetic poles will introduce a UT dependence on the ionisation drawn from the dayside. Therefore it is predicted that patches in the night sector will be most clearly observed over Northern Europe. The EISCAT TOI/NIGHT UK special programme was designed to investigate nightside patch morphology under a range of geophysical conditions. Results are presented from case studies illustrating the influence of the orientation of the interplanetary magnetic field.

Ground based observation of high latitude ULF wave signatures

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The island of Spitsbergen, at a latitude of 78 deg north spends a significant amount of its time at either side of the open-closed field line boundary and within the cusp region. The ULF wave spectrum at these latitudes still remains little understood and the unique dynamic processes which occur here leave characteristic wave signatures, which may be resolved using a number of techniques.

A new induction coil magnetometer system located at Barentsburg has been employed to identify these phenomena. Combining these measurements with those obtained using the CUTLASS radars and spacecraft provides new insight into the wave modes present in this dynamic region.

This presentation focuses on a number of observations of high latitude ULF wave signatures including those which are associated with the cusp. CUTLASS radar measurements will be compared with those from the ground-based magnetometer to identify common features in the data and these observations will be considered in the context of current theories of ULF wave generation.

Session VIII: Ionospheric Plasma Physics and Scattering Mechanisms

Conveners: Anja Strømme & Francois Forme

Invited speaker
Patrick Guio

Friday, 10th August
08:15-9:45

Zakharov simulations of Langmuir turbulence: Effects on waves observed by incoherent scattering

P. Guio

University College London, London, UK

We present a numerical study of the effect of Langmuir turbulence on incoherent scatter spectra. The Langmuir turbulence is driven by low energy beams of electrons in the Earth's upper ionosphere above 300 km. The nonlinear coupling between Langmuir waves and ion-acoustic waves is governed by the Zakharov system of equations. The model is enhanced with stochastic forcing in order to estimate by how much over the thermal level the spectrum seen by an incoherent scatter radar will be enhanced. This also allows to compare directly the modelled spectra to the observed spectra collected by the incoherent scattering technique, as well as to investigate statistically the signature of the modelled spectra through an exploratory data analysis. Results for different beam energies are presented, covering the regimes of weak as well as strong turbulence. The incoherent scatter spectra signature is discussed in light of these regimes. It is shown that incoherent scatter radar observations of enhanced ion-acoustic and/or Langmuir waves compared to thermal level can provide good estimates of the beam parameters and of the type of turbulent regime. The cascade regime leads to strongly asymmetric spectra with enhancements over a limited range of wavenumbers. The cavitation regime leads to marginally asymmetric spectra, with enhancement over a wide range of wavenumbers, and features a central peak for a limited range of wavenumbers. Finally, it is shown that the Langmuir turbulence should be preferentially observed for scattering wavelengths large compared to the Debye length.

Naturally enhanced radar spectra and low energy auroral emission

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We present a study of EISCAT Svalbard radar data in which many examples of anomolous spectral events known as naturally enhanced ion-acoustic lines, or NEIALs, were observed. NEIAL activity occurred in the polar cusp region under lobe-reconnection conditions during an extended period of low solar wind density within an extremely high speed solar wind stream.

The Andor imager, fitted with a narrow passband filter around 7325 Å and primarily sensitive to the forbidden [OII] doublet emission, and the SIF imager, responding mainly to N2 1PG emissions, were both set up as part of the Spectrographic Imaging Facility in Adventdalen during this period. Using these two imagers we show a direct link between the occurrence of multiple NEIAL events and co-located auroral emissions caused specifically by extremely low-energy electron precipitation i.e. less than about 100eV. This observation is consistent with the parametric instability model for NEIAL generation, where beam excited langmuir waves decay down to ion-acoustic wave modes through a 3 wave interaction.

In selected events studied, where a clear brightening in the aurora is associated with the occurrence of a NEIAL, processed images show field aligned auroral filaments, seen in the sub-100eV imager, passing through the centre of the radar beam. Possible links with low energy electrons observed at the open-closed boundary by a DMSP satellite passing near the ESR are discussed.

Naturally enhanced ion acoustic lines with the Poker Flat AMISR radar

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The study of Naturally Enhanced Ion Acoustic Lines (NEIALs) have become one of the key studies for EISCAT both in the polar cusp using the EISCAT Svalbard Radar (ESR), and in the auroral zone, using the EISCAT UHF and VHF systems. Still many questions regarding the temporal and spatial extent of the NEIAL events remain unanswered. The new Advanced Modular Incoherent Scatter Radar (AMISR) in Poker Flat, Alaska is the first phased array Incoherent Scatter Radar at high latitudes, and by taking advantage of its possibility of (almost) simultaneous looking directions, we can resolve some of the space time ambiguity associated with NEIALs. During the night of the 23rd March 2007, a period of NEIALs occurred. The radar ran in a 10 position mode with 9 beams in a narrow quadratic grid spaced by 3 degrees, plus a 10th position up B - slightly offset from the grid. Raw voltage data were sampled to allow for very high time resolution ACFs and spectra. Combining high time resolution data from multiple positions, we have the opportunity for the first time to look at the space-time ambiguity in the development of NEIALs.

During the campaign a narrow field of view imager from university of Boston were operational at the Davis science center close by the AMISR array. The night of the 23rd March, the imager was pointed field aligned, and at around 11:20 UT - at the time of the radar NEIALs - a field of dynamic rays occurred at and near the zenith.

High time resolution multi position data from AMISR will be shown to follow the space and time development of the NEIAL event. This will also be correlated with high time resolution data from the imager.

Study of the electron distribution function stability in the edges of auroral arcs

G. Garcia, F. Forme

CETP, Velizy, France

Thanks to satellites such as FAST or FREJA, we know that large field-aligned currents are commonly observed in the ionosphere. We know that the better the spatial resolution, the higher the downward current densities. These large parallel current densities imply the presence of a parallel electric field. So, we can wonder if this parallel electric field could modify the electron distribution functions. These current densities could be the cause of many phenomena such as tall red rays or triggering of unstable ion acoustic waves.

All the studies of this region were made with fluid model supposing that the kinetic perturbations could be neglected. The aim of our work is to study the dynamic of collisionnal plasma under a parallel electric field with a kinetic model. We consider the issue of electrons moving through an ionospheric gas of positive ions and neutrals under the influence of a parallel electric field. We developed a kinetic model of collisions, including electron/electron, electron/ion and electron/neutral collisions. We use a Fokker-Planck approach to describe binary collisions between charged particles with a long range interaction. We present the essential elements of this collision operator: The Langevin equation for electron/electron and electron/ion collisions and the Monte-Carlo and null collision methods for electron/neutral collisions. We calculate a self-consistent electric field.

The Kinetic model shows that for large field-aligned current densities, the electron distributions are non-Maxwellian. The electron distributions have a suprathermal tail due to runaway electrons. Therefore the threshold for e.g. the ion-acoustic instability is modified. We will compare the stability thresholds obtained with our kinetic model and with a fluid model.

Equatorial ionospheric F region vertical plasma drift variations over Africa

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The ionosphere structure at low and equatorial latitudes is heavily dependent on electrodynamic drift. Eastward electric fields at the magnetic equator cause plasma to drift vertically and subsequently diffuse downward in the direction of the inclined magnetic field lines. As a result, the equatorial ionosphere is the tremendously interesting object of research. We present quiet time F region equatorial ionospheric vertical plasma drifts inferred from 1 year of ionosondes h'F and hmF2 data at Ibadan (7.4°N, 3.9°E; dip 6°S), Nigeria (Africa) during 1957/58 International Geophysical Year (IGY) from sunset-evening hours (1700-2200 LT) for high solar activity conditions. Except for the amplitude differences, our results indicate excellent behavior with equatorial vertical drift model [Scherliess and Fejer, 1999] and with Kwajalein (Pacific) incoherent scatter (ISR) radar winter data. The seasonally averaged absolute value of dusktime vertical velocity at Ibadan is appreciably smaller than that of empirical model and ISR observations with a value of approximately 13, 20, and 22 m/s for ionosonde, model, and ISR drifts, respectively. The prereversal maximum ExB drift velocity (PRE) occurs near 1900 LT for all methods. The model and ISR prereversal peak velocities values are almost a factor of two greater than the PRE velocities derived from hmF2 data, but grossly underrate the postsunset peaks in vertical drifts inferred from h'F data. Ibadan winter results consistently indicate later evening reversal times. In addition, a comparison of Ibadan drifts with AE-E satellite data [Fejer et al., 1995] for four longitudinal zones at similar local time interval clearly show reasonable agreements with the evening patterns of vertical drifts, although ionosondes measurements exhibits a latter reversal times. Ionosonde postreversal ExB downward drifts are in the range of about 5-17 m/s. Our observations confirmed that the dusktime equatorial F region vertical velocity show large longitudinal variations during the winter months.

Session IX: Ionospheric Modification by Radio Waves

Conveners: Björn Gustavsson & Mike Kosch

Invited speakers
Wayne Scales and Mike Sulzer

Friday, 10th August
10:15-15:15

Radio wave modification of plasma irregularities associated with mesospheric dust clouds

W. Scales, C. Chen

Viriginia Tech, Blacksburg, Virginia, USA

Polar mesospheric summer echoes PMSEs are radar echoes, typically in the 50 MHz to 1.3 GHz range, produced by scattering from electron irregularities in the earth's summer polar mesosphere. The electron irregularities believed to produce PMSEs result from electron charging on subvisible dust that exists in the mesosphere. This dust consists of ice particles created due to the cold temperatures in this region of the atmosphere. Experimental observations have shown that PMSEs may be modulated by radio wave heating the irregularity source region with a ground-based ionospheric heating facility. Early experiments showed that the PMSE strength may be initially suppressed after the turn-on of the radio wave heating. It was also recently predicted and verified that the PMSE strength may be enhanced above the undisturbed level for a period of time after the turn-off of the radio wave heating. This has been termed the 'PMSE overshoot effect'. An understanding of the temporal behavior of PMSE strength during radio wave heating shows great promise as a diagnostic of the mesospheric dust layer. Early theoretical modeling work considered what is thought to be the two primary physical processes causing the PMSE modulation, electron diffusion and dust charging, separately. The successful prediction of the overshoot effect incorporated Boltzmann electrons and ions as well as dust charging effects. However, incorporation of Boltzmann electrons neglects finite diffusion time effects. Since the relative timescales for dust charging and ambipolar diffusion may be comparable depending on the mesospheric conditions and irregularity scale-size, important temporal behavior is not incorporated in recent models. This work describes a new model that incorporates both finite diffusion time effects as well as dust charging. The model utilizes fluid ions described by continuity and momentum equations, electrons whose behavior is determined from quasi-neutrality, and the charged dust grains are described by the a Particle-In-Cell PIC method. The model has been used to investigate temporal behavior of electron irregularities during electron temperature enhancement associated with radio wave heating over a range of dust and plasma parameters. The model predicts that the temporal behavior of the irregularities during radio wave heating depends on the ratio of the electron-ion ambipolar diffusion time to the dust particle charging time. Due to the dependence of this ratio on irregularity scale-size, these results have important implications for observations of PMSE modification at different observing radar frequencies. Therefore, new possibilities may exist for diagnosing the dust layer with radio wave modification.

Aspect sensitivity of the first 100 ms HF-modification measured with the MUIR at HAARP

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In this paper we present results of new height-resolved observations of F-region Langmuir turbulence measured with the MUIR (Modular UHF Ionospheric Radar; 446 MHz) at HAARP (High frequency Active Auroral Research Program) in Alaska, USA. The scientific objective of this paper is to study aspect sensitivity of the first 100 ms of HF modification. An outstanding advantage of the MUIR is the phased array system, which enables us to change the beam direction every IPP (interpulse period). The HAARP HF transmitter system was operated on 25-26 March 2006 during geomagnetically quiet conditions. HF pulses of O-mode polarization at 4.95 MHz were periodically transmitted in duration of 100 ms at 8 degree off from the geographic vertical to the geomagnetic south. The duty cycle is 1 % (IPP = 10 s). Three MUIR beam directions were selected for the experiment; geographical vertical, up B (elevation angle = 75 degree), and between them (elevation angle = 82 degree). The coded long-pulse technique was employed with 10 ms IPP, 998 micro-second pulse length, and 1 micro-second baud length, which gives approximately 150 m range resolution. The radar backscatter spectrum was obtained every IPP of 10 ms; but the spectrum at each beam position was derived every 30 ms because the beam direction was sequentially changed every IPP among three directions mentioned above. Thus three HF-pulse sequences or 30 s provide a series of the spectra during HF-on period (100 ms) with time resolution of 10 ms at each MUIR beam position. The radar backscatter spectra along the geomagnetic field line were characterized by well-developed parametric decay instability and the Langmuir decay instability cascade features. While a few cascade lines were identified in the spectra at the middle beam position, number of the cascade line was smaller than that for the field-aligned spectra. The cascade feature was not seen in the vertical-beam spectra. These results are consistent with spectral features predicted by the modern Langmuir turbulence theory. The temporal growth and saturation of the spectra during heating and the decay of the spectra after the HF turn-off are also studied.

Observations of aspect sensitive SPEAR-induced enhancements in incoherent scatter spectra

R. Dhillon, T. Robinson, T. Yeoman

University of Leicester, Leicester, UK

RF-induced plasma instabilities excited by the Space Plasma Exploration by Active Radar (SPEAR) facility give rise to characteristic spectral enhancements in incoherent scatter spectra recorded by the EISCAT Svalbard Radar (ESR), which is collocated with SPEAR. The SPEAR-induced ion and plasma line enhancements are consistent with excitation of both the purely growing mode and the parametric decay instability. The aspect sensitivity of these enhancements provides valuable information regarding the physical processes that occur within the SPEAR-affected ionospheric patch. We present observations of spectral enhancements from several directions in the magnetic meridian plane, centred on field-aligned. These direction-dependent signatures exhibit significant variability and help shed light on possible coupling between artificial field-aligned irregularities generated at the upper-hybrid height and SPEAR-induced instabilities excited near the reflection height for O-mode-polarized radio waves.

Bistatic observations of ULF waves in SPEAR-induced HF coherent backscatter

T. Yeoman, T. Robinson, D. Wright, L. Baddeley

University of Leicester, Leicester, UK

Recent experimental campaigns with the SPEAR high power system on Svalbard have succeeded in generating heater-induced backscatter simultaneously on the Finland and Iceland CUTLASS HF radars. The high-power, high time resolution, low spectral width backscatter has been used to generate vector measurements of the wave's ionospheric electric fields, which enable the determination of the characteristics of such naturally-occurring ULF wave activity over Svalbard. Both large-scale field line resonances, and small scale wave activity associated with magnetospheric wave-particle interactions have been observed. The characteristics of such waves at the very high latitudes of Svalbard will be compared with predictions.

ULF wave activity from HF pumping experiments at mid and high latitudes

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Experimental results from Tromsø and SURA heating experiments in 2005-2006 related to the HF heater-induced and natural ultra low frequency (ULF) waves in the Pc3-5 range (30-300s) are examined. The combination of HF-induced scatter target and bi-static HF Doppler radio scatter remote observations at St. Petersburg is used to examine the ionospheric signatures of a ULF wave. It was found that the amplitude modulated heating by using the HF transmission scheme of 30s on, 30 s off gave rise to the wave variations of Doppler frequency shift, fd, and spectral power of signals scattered from artificial field-aligned irregularities (AFAIs). These waves with period of 1 min were observed from Tromsø heating experiment on 12 October 2005 as well as from SURA experiments on 5 and 7 September 2006. It is interesting that on 12 October 2005 together with an artificial ULF wave with 1 min period there was a ULF wave of natural origin with a period of about 5 min. For this event we have analysed the magnetic field variation data recorded near Tromsø at Kilpisjarvi from SAMNET network of ground-based magnetometers. The correlation between magnetic and Doppler data was found. In the course of SURA heating experiments the period of amplitude modulated heating was close to the eigenperiod for the SURA magnetic flux tube. Here more pronounced fd wave variations as compared with the Tromsø case were observed especially in the evening hours. Natural ULF waves at high latitudes were examined from UK MAZE heating experiment on 3 October 2006. Bi-static HF Doppler radio scatter observations were simultaneously performed at two diagnostic paths allowing to reconstruct two-dimensional vector of plasma velocity in the scattering volume. Ray tracing and Doppler shift simulations were made for this experiment. ULF waves with periods of 3 - 5 min were observed above Tromsø in the morning hours. It was found that the phase velocities of magnitude of about 40-80 m/s were directed to the north-west. The magnitude and direction of the velocity exhibits the wave variations.

Density of upper atmosphere neutral components and artificial magnetic pulsations in Pc1 range excitation

A. Mochalov, A. Pashin

Polar Geophysical Institute, Apatity, Russia

During last decade series with the EISCAT Heating Facility were carried out with the purpose to produce artificial magnetic pulsations in the 0.1 – 3 Hz frequency range. For several experiments the EISCAT radar provided measurement of ionospheric electric field and electron density. Numerical model of artificial pulsation excitation has been verified. Predicted amplitude of the pulsation is in accordance with the measured values, however model could not explained sporadic nature of the artificial signals. Disturbances of neutral components are a possible way to explain this feature. Numerical modelling shows that variation of the pulsation amplitude can be around 20%. For artificial emissions with intensity being comparable with background noise these variations could lead to disappearance of the artificial pulsations at spectrogram.

Plans for and progress towards the new Arecibo HF facility

M. Sulzer
Arecibo Observatory, Arecibo PR, USA

The previous Arecibo HF facility was located near the north coast of Puerto Rico on low-lying flat land. It was seriously damaged by Hurricane Georges in 1998. At the time, the implementation of Government policy to return the entire surrounding area to its original state as the largest wetland in the Caribbean was in its initial stages, and so it was not possible to consider rebuilding at that site. Lack of other available sites in heavily populated Puerto Rico and the need to design a very cost effective facility drove the decision to use the Arecibo 305 m as the HF reflecting antenna for the new facility. We are now in the process of obtaining the final funding for this project and are in the initial stages of implementation.

The design uses a unique Cassegrain screen, supported from the three main towers, as a secondary. It is driven from an array of three crossed dipoles located just above the the 305 m dish near its center. The computer antenna modeling for the design was performed at the Pennsylvania State University. The screen reflects HF, but is nearly transparent to the higher frequencies used for the incoherent scatter radar and radio astronomy. Six 100 KW transmitters (obtained as Federal excess property from a decommissioned over the horizion radar) feed the six elements of the dipoles. The coax lines that connect the transmitters to the dipole elements were also obtained through Federal excess property. In order to keep the cost of building and operating the facility low and to avoid impact on other observatory operations low, we have avoided designs that require supporting a heavy, high-power feed over the dish as some previous designs have. The parts of the facility that need to handle high power are on the ground or mounted on solid low towers, simplifying construction and maintenance.

Heating upgrade

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A major upgrade of the EISCAT Heating facility is currently underway. The thirteen HP analogue synthesizers that are the key part of the Heating modulator are getting quite old, are slow and have a major drawback of starting with a random phase, which makes setting them up a tedious manual procedure. In addition of replacing them by direct digital synthesizers (DDS), another aim in the Heating upgrade is to add proper receiving capability to the system, by converting one of the transmission antenna fields for reception and building a complete receiver unit for it. A key requirement has been to keep the upgrade costs to a minimum, by using as much as possible existing leftover and spare parts from all over the EISCAT system.

Planning for the upgrade started in the spring 2004; in January 2006, first proof-of-concept tests of the new DDS-based modulation unit were performed at the Heating facility. Apart from revealing some lack of driving power in the prototype synthesizer, the initial test was successful and showed that the prototype synthesizer was working well in the noisy environment. In 2006, a dedicated VME-crate was constructed to house the synthesizer board and other equipment needed for the transmission control, such as a radar controller. In 2006, also the UNIX software needed to create and download the amplitude-modulation waveform to the synthesizer was much improved.

In January 2007, a second test period at the Heating site confirmed that the integrated prototype system was now capable of driving the Heating power amplifiers without problems, with freely selectable amplitude modulation. At the time of writing (April 2007), the DDS design is being finalized so that it can be sent out to a vendor for replication. A major job that is still in an early phase is to arrange UNIX control for all the 100+ analog signals needed to handle the various parts of the Heating transmitter. Nevertheless, it is hoped that the upgrade can be taken into operational use before the end of 2007.

New diagnostic methods for the D-region ionosphere in a case of EISCAT heating experiments

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According to present models the EISCAT Heater Facility is capable of increasing the electron temperature by a factor of ten in the D-region ionosphere. However, this maximum effect has not been verified by any radar observation yet. This is mostly due to lack of appropriate incoherent scatter data analysis package for the heated D region. Here we introduce a new nonlinear MCMC fitting of the theoretical autocorrelation function to detected lag profiles. Prior estimates for the fitting parameters are obtained by using the Sodankylä Ion Chemistry (SIC) model. This method is applied for the previous Finnish EISCAT campaign in November 2006, where three dedicated heater and radar experiments were carried out in order to quantify the active heating effect. The standard EISCAT ARC-D program and a newly designed SIPPI experiment, which is based on the direct sampling of the backscattered signal, were used in turns for the VHF radar. All the three experiments were successful technically and in terms of geophysical conditions. Preliminary results are shown in this presentation.

The registration of the influence effects from SPEAR heating facility operation in observatory Barentsburg in February-March 2007

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The first results receiving by ULF magnetic gradiometer with the base near 5km and riometer 38.2 MHz deployed around Barentsburg (arch. Spitzbergen) are presented in this work. The observatory of Polar Geophysical Institute (PGI) was chosen as the base. The two other points of observations were spaced to the East and to the South and formed equilateral triangle. The special constructed narrow-beam riometer aerial for the registration of local disturbances in ionosphere mounted in PGI observatory was directed to the volume probable activated by heating transmitter beam of the SPEAR heating facility. The difference in ionospheric reaction on X or O mode of the heating transmitter operation was detected. The original data were compared with the standard geophysical observation from other nearest observatories. We are indebted to the staff of PGI for placing the equipment at Barentsburg observatory.

Aspect angle dependence of top- and bottom-side UHF radar backscatter from ionospheric HF pumping at Tromsø

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The EISCAT high-frequency transmitter facility near Tromsø has been used to inject an O-mode wave into the ionosphere with the pump beam dipped 9-degrees south of zenith and 106 MW effective radiative power at 4.544 MHz. Due to the beam width (-6 dB), zenith angles of 0-16 degrees were illuminated, with the transmitters modulated 1-s on 29-s off. A low duty cycle at a pump frequency far removed from any electron gyroharmonic encourages Langmuir turbulence and suppresses the formation of striations (upper-hybrid resonance). The latter is confirmed by CUTLASS radar observations at 11 MHz. The UHF radar scanned in 0.5 or 1-degree steps in angular subsets of 0-20 degrees zenith angle south. Ion-line enhancements, corresponding to Langmuir turbulence, were observed in the UHF backscattered power at the O-mode bottom-side reflection height (~220 km) and the Z-mode top-side ionosphere (~310 km). The meridian scanning UHF backscatter show bottom-side enhancements at all angles, except in a narrow window ~8-10 degrees south. Within the so-called radio window top-side echoes appear. These observations confirm theory by Mjølhus and Flå [1984]. When changing the pump frequency, the top-side UHF backscatter is only observed when the ionospheric peak frequency is ~15% higher than the modifying pump frequency, as predicted by theory. The results are consistent with HF ray trace modeling.

Altitude distribution of HF-pump enhanced emissions at 6300 and 5577 Å: A comparison between observations and theory

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We present bi-static observations of radio-wave induced optical emissions at 6300 and 5577 Å from the night-time "artificial aurora" ionospheric pumping experiments at the HIPAS (Fairbanks) facility in Alaska. The optical observations were made at HIPAS and from HAARP located 285 km away. From these observations the altitude distribution of the emissions is estimated with tomography-like methods. These estimates are compared with theoretical models. Other diagnostics used to support the theoretical calculations include the Kodiak HF SuperDARN radar, which scans over HIPAS, and the new Poker Flat AMISR UHF radar near HIPAS.

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