Sodankylä Geophysical Observatory

Reports

2nd VERSIM Workshop 2006

Sodankylä Geophysical Observatory

Sodankylä, Finland

26th – 30th September 2006

Abstracts

Edited by Jyrki Manninen, Thomas Ulich and Anna-Liisa Piippo

Report No 56

Sodankylä 2006

Sodankylä Geophysical Observatory
Reports

ISBN 951-42-6053-8 (paperback)
ISBN 951-42-6054-6 (pdf)
ISSN 0359-3657

Sodankylä 2006

ACKNOWLEDGMENTS

The organisers of the workshop wish to thank those organizations, which kindly supported the meeting financially. The funds made it possible to provide nine participants with full or partial support for travel costs.

IAGA – International Association of Geomagnetism and Aeronomy

URSI – International Union of Radio Science

Academy of Finland

Table of Contents

PROGRAMME

(Table of Contents)

Tuesday, 26th September 2006

14:45—15:45 **POSTER SESSION** (with coffee/tea)

15:45—17:15 **Session 3: PROBING THE EARTH-IONOSPHERE WAVEGUIDE** (Chair: E. Turunen)

19:00 ***Ice breaking party***

Wednesday, 27th September 2006

09:00—10:25 **Session 4: WHISTLER MODE WAVES OBSERVED IN SPACE** (Chair: M. Rycroft)

10:25—10:55 ***Coffee***

10:55—12:00 **Session 5: GROUND BASED OBSERVATIONS OF WHISTLER MODE WAVES AND LIGHTNING** (Chair: J. Lichtenberger)

12:00—13:30 ***Lunch***

13:30—14:45 **Session 6: PROBING THE EARTH-IONOSPHERE WAVEGUIDE** (Chair: M. A. Clilverd)

14:45—15:15 ***Coffee***

15:15—16:45 **Session 7: CONSEQUENCES OF WHISTLER MODE WAVES** (Chair: D. Nunn)

16:45—17:00 ***Break***

17:00—17:45 **Session 8: WHISTLERS** (Chair: U. Inan)

18:00 ***Secret excursion***

Thursday, 28th September 2006

09:00—10:25 **Session 9: PROBING THE EARTH-IONOSPHERE WAVEGUIDE** (Chair: A. Demekhov)

10:25—10:55 ***Coffee***

10:55—12:00 **Session 10: CONSEQUENCES OF WHISTLER MODE WAVES** (Chair: R. Horne)

12:00—13:15 ***Lunch***

13:15—13:45 **SGO's VLF antenna exhibition**

13:45—14:00 Bus to Geological Survey Laboratory, Sodankylä

14:00—16:00 **Geological Survey Laboratory**

16:00—16:15 Stop at hotel (if needed)

16:30—17:00 SGO's measurement station at Pittiövaara

17:30 **Social evening at Mattila's Reindeer Farm**

22:00 Return to the hotel and to Tähtelä

Friday, 29th September 2006

15:15—17:00 **Session 14: GROUND BASED OBSERVATIONS OF WHISTLER MODE WAVES AND LIGHTNING**
(Chair: T. Turunen)

Saturday, 30th September 2006

09:00—10:15 **VERSIM Working group meeting**

10:15—10:45 ***Coffee and snacks***

10:45—11:15 **Discussion and future plans**

11:15—11:30 **Closing of Workshop**

TUTORIAL

(Chair: C. J. Rodger)

Tuesday, 26th September 2006

09:45 — 10:45

Some reflections on whistler-mode probing of the plasmasphere

D. L. Carpenter

Stanford University, Stanford, California, USA

This is a topical overview of studies of the Earth's plasmasphere, with emphasis on the use of radio probing techniques. Among highlights are: Storey's pioneering discovery of the "protonosphere," the discovery of the nose whistler, the recognition of the ducting phenomenon, and the initial identification of the plasmapause phenomenon by Gringauz from Lunik rocket data and by the Stanford group using ground-based whistler methods. Whistlers later provided a global description of the asymmetric plasmasphere with its duskside bulge as well as the ability to track cross-L bulk motions in the plasmasphere during both disturbed and quiet periods. Some more recent achievements include the remarkable equatorial profiles provided by the ISEE, GEOS, and CRRES satellites, followed today by the stunning photos of the Helium + component of the plasmasphere obtained by the EUV instrument on IMAGE. An interesting controversy surrounded the early whistler work on the plasmapause phenomenon, and theories of its formation have been controversial and remain important issues today.

Session 1

CONSEQUENCES OF WHISTLER MODE WAVES

(Chair: C. J. Rodger)

Tuesday, 26th September 2006

11:00 – 12:00

Aspects of the triggered VLF emission problem

D. Nunn

Southampton University, Southampton, UK

The VLF emission triggering phenomenon is a classic problem involving non linear wave particle interactions. We review many aspects of the underlying physics, including particle trapping and the linear and non linear regimes, energy balance and the correct calculation of the resonant particle current. The field equation is derived and expressions given for the frequency sweep rate and non linear growth rates. Using a VHS/VLF code simulations are presented of triggered emissions observed in SGO campaigns with good agreement. It is observed that emissions are generated from stable non linear self consistent structures termed generation regions. These are discussed and the factors influencing sweep rate and emission form (riser, faller, hook) are considered. Of course the simulation code involves approximations and these will be discussed. They are assumption of a 1D system, unknown saturation mechanism and finite bandwidth.

Evolution of pith-angle and energy distribution of energetic electrons related to quasi-periodic ELF/VLF emissions in the Earth's magnetosphere

D. Pasmanik[1], A. Demekhov[1], V. Trakhtengerts[1] and D. Nunn[2]

[1] *Institute of Applied Physics, RAS, Nizhny Novgorod, Russia*
[2] *Southampton University, Southampton, UK*

We study the generation of quasi-periodic ELF/VLF wave emissions in the Earth's magnetosphere due to the whistler cyclotron instability on the basis of self-consistent quasilinear theory taking into account the evolution of 2D distribution of energetic electrons in pitch-angles and energies.

Numerical simulations based on this model confirm that taking into account realistic energy distribution results only in quantitative, but not qualitative, differences in the generation regimes compared with the simplified model assuming monoenergetic energy distribution. Dependence of generation regime and related variation in 2D-distribution of energetic electrons on the parameters of electron distribution in the source is studied.

The updated model allows us to study temporal evolution of energy distribution of precipitated electrons causing auroral pulsations, which is important for comparison of the model with observations.

Some achievements of short-periodic VLF emissions theory

P. A. Bespalov

Institute of Applied Physics, Russian Academy of Sciences, Nizhny Novgorod, Russia

In this work a short-periodic VLF emissions with periods of repetition of a dynamic spectrum 2-6 sec are considered. This type of signals is possible in morning and midday sector of subauroral magnetosphere. The cause of the excitation of short-periodic VLF emissions most likely is connected with the compensation of the dispersion signal transformation and the quasilinear evolution of the cyclotron instability increment as a result of the distribution function modification during the electromagnetic pulse. We took into account both: the linear dispersion in the not uniform magnetospheric resonator and the cyclotron amplification variation during the pulse as a result of the wave-particle interaction. If the energetic electron distribution function has appropriate form, the consolidation of emission in packets reduces the dissipation of electromagnetic energy in the plasma magnetospheric maser, and these processes can give a gain in energy. Consequently, the effective saturation of dissipation leads to excitation of rather short electromagnetic envelope solitary waves. As a result of calculations the expressions for the fundamental characteristics of short-period emissions, including frequency drift within the limits of separate spectral element, are obtained.

Session 2

WHISTLERS

(Chair: J. Lichtenberger)

Tuesday, 26th September 2006

13:30 – 14:45

Automatic Whistler Detector and Analyzer (AWDA) system: first results of fully functional system for mid-latitudes

J. Lichtenberger

Eötvös University, Budapest, Hungary

Whistlers have been regarded as cheap and effective tools for probing plasmasphere since the beginning of whistler research, but it hardly fulfills this expectation mainly due to the enormous and tedious human labour required to obtain plasmaspheric electron density and propagation path from whistler traces. The first AWDA system was installed at Tihany, Hungary in 2002 and the automatic detector collected more than 100.000 whistler traces per year. However, automatic analysis of traces proved to be a difficult task and has come true only recently for mid-latitude whistlers. This paper describes the results from the first three years (2002-2005) of AWDA data from Tihany: dynamics of plasmasphere, including spatial and temporal electron density profiles, short and long term variations of ionosphere-magnetosphere coupling fluxes.

We are working on the extension of automatic analyzer system for high-latitude whistler

Automatic Whistler Detector: operational results from New Zealand

J. Lichtenberger[1], C. J. Rodger[2] and G. McDowell[2]

[1]*Space Research Group, Eötvös University, Budapest, Hungary.*
[2]*Low Frequency Electromagnetic Research, Dunedin, New Zealand.*

Whistlers have been regarded as cheap and effective tools for plasmasphere diagnostic since the early years of whistler research. The Eötvös University Automatic Whistler Detector (AWD) system has been operating in New Zealand since mid-May 2005. An initial examination of the first 115 days of observations found >25,000 whistler events, where each event may include multiple traces, and only ≈6400 "false triggers." Our whistlers probe a very large range of L-shells (including L=2.5-3.7), and include a significant population of whistler observations occurring during local noon. We find that the whistler rate at Dunedin is fairly similar to the whistler rate reported from Tihany, Hungary, despite there being >2000 times more lightning at Tihany's conjugate point. Clearly there is no simple relationship between conjugate lightning activity and whistler rates. In our presentation we present statistics including more than one year's operation in Dunedin, including >55,000 events.

Assigning the causative lightning to the whistlers observed on DEMETER and MAGION-5 satellites

J. Chum[1], F. Jiricek[1], O. Santolik[2, 1], M. Parrot[3], G. Diendorfer[4] and J. Fiser[1]

[1] *Institute Of Atmospheric Physics, Prague, Czech Republic*
[2] *Charles University, Faculty of Mathematics and Physics, Prague, Czech Republic*
[3] *LPCE/CNRS, Orleans, France*
[4] *Austrian Electrotechnical Association (OVE-ALDIS), Vienna, Austria*

We study the penetration of lightning induced whistler waves through the ionosphere investigating the correspondence between the whistlers observed on the DEMETER and MAGION-5 satellites and the lightning discharges detected by the European lightning detection network EUCLID. We compute all the possible differences between the times when the whistlers were observed on the satellite and times when the lightning discharges were detected. We show that the occurrence histogram for these time differences exhibits a distinct peak for a particular characteristic time corresponding to the sum of propagation time and a possible time shift between the clock of the wave record and the clock of the lightning detection network. Knowing this characteristic time, we can search in the EUCLID database for the location, current, and polarity of causative lightning discharges corresponding to the individual whistlers observed on the satellite. The founding of "causative lightning—whistler" pairs is possible both in the night-time and day-time conditions. We demonstrate that the area in the ionosphere through which the electromagnetic energy induced by a lightning discharge enters into the magnetosphere as whistler mode waves is up to several thousands kilometres wide.

POSTERS

Long distance monitoring of the lower ionosphere: the global AARDDVARK sensors

M. A. Clilverd[1] and C. J. Rodger[2]

[1]Physical Sciences Division, British Antarctic Survey, Cambridge, United Kingdom
[2]Physics Department, University of Otago, Dunedin, New Zealand

We have recently developed a global-scale sensor network of sensors which monitor fixed-frequency communications transmitters, where ionospheric modifications lead to changes in the received amplitude and phase. The joint NZ/UK lead Antarctic-Arctic Radiation-belt (Dynamic) Deposition - VLF Atmospheric Research Konsortia (AARDDVARK) is a new extension of a well-establish experimental technique, which provides continuous long-range observations of the lower-ionosphere. Subionospheric VLF propagation allows us to undertake remote sensing of the upper atmosphere over large regions; these signals can be received thousands of kilometres from the source. In contrast, incoherent scatter radar techniques and riometers can make measurements in the D-region and above, but are limited to essentially overhead measurements. At this stage AARDDVARK is essentially unique, as similar systems are only deployed at a regional level (e.g., the HAIL array in the central USA). The AARDDVARK sensor network is well suited to provide observations complementary to other ground based and space-based instruments, operating continuously or in high-resolution campaigns.

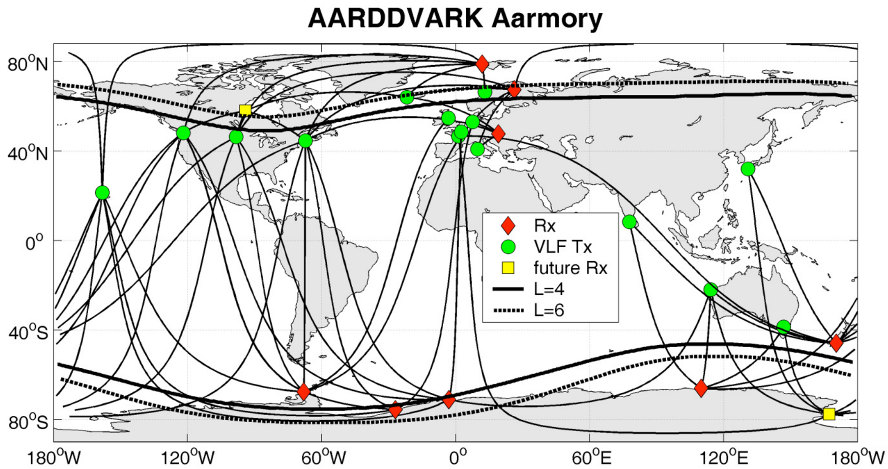


Figure 1: The locations of the current (diamonds) and planned (squares) AARDDVARK receiver (Rx) locations. The great circle paths between the observed VLF communications transmitters (Tx, circles) and the receiver sites are shown.

AARDDVARK members: Mark Clilverd (BAS); Craig Rodger (Otago U); Andrew Collier (Kwa-Zulu Natal U); Janos Lichtenberger (Eötvös U); Fred Menck (Newcastle U); Neil Thomson (Otago U); Thomas Ulich (Oulu U)

Modelling the ionospheric effects of solar proton events using the Sodankylä Ion Chemistry model

M. A. Clilverd[1], A. Seppälä[2], C. J. Rodger[3], N. R. Thomson[3], P. T. Verronen[2], E. Turunen[4], Th. Ulich[4], J. Lichtenberger[5] and P. Steinbach[5]

[1] *British Antarctic Survey, Cambridge, United Kingdom*
[2] *Finnish Meteorological Institute, Helsinki, Finland*
[3] *Physics Department, University of Otago, Dunedin, New Zealand*
[4] *Sodankylä Geophysical Observatory, Sodankylä, Finland*
[5] *Space Research Group, Eötvös University, Budapest, Hungary*

At Ny Ålesund, Svalbard, (78º54'N, 11º53'E, L≈18) a narrow-band VLF receiver was used to monitor the behaviour of the phase and amplitude of several high power transmitters located in the Northern hemisphere under the influence of the solar proton events (SPE) of October/November 2003. We have used Sodankylä Ion Chemistry (SIC) atmospheric model profiles calculated at a single location in the northern wintertime polar region to investigate the radio propagation properties of several high latitude paths. Different paths showed different responses to the proton precipitation, but propagation modelling was able to account for all of these types of behaviour. The same SIC profiles were able to model the SPE response on partial polar cap paths by being applied to only part of the path, leaving normal ionospheric conditions on the remainder of the path. Using the SIC-based electron density profiles we have been able to develop models of ionospheric effective height (h') and sharpness (b) in order to describe the D-region behaviour during SPEs. As a result, our understanding of VLF propagation influenced by SPEs is high, such that VLF observations might be used to predict changes in the ionospheric D-region electron density profiles during other particle precipitation events

SoftPAL

R. L. Dowden[1] and C. D. D. Adams[2]

[1] *Low Frequency Electromagnetic Research, Dunedin, New Zealand*
[2] *ADInstruments, Dunedin, New Zealand*

SoftPAL is a fully software version of AbsPAL (Absolute Phase and Amplitude Logger) which is used to study phase and amplitude variations in the transmission of VLF signals in the Earth-Ionosphere Wave Guide (EIWG). Such variations range from very fast (onsets < 1s for Trimpis), to very slow (periods ≈ 1 year). This is achieved by AbsPAL, and now SoftPAL, by locking to the GPS (Global Positioning System) Pulse-Per-Second (PPS), which is maintained to have zero phase drift in the long term. This requires the VLF transmitters to have similar phase stability (at least one of them is also locked to GPS). Other VLF transmitters controlled by caesium beam standards are suitable for phase variations over several hours (e.g., those produced by solar flares) to several days.

SoftPAL is the latest of a series of instruments (AbsPAL, OmniPAL, and OPAL) designed by Adams over the last 20+ years. It takes advantage of the processing power of modern PCs to provide MSK phase and amplitude measurements with much improved signal to noise ratios, higher time resolution (if desired), and reliable absolute phase measurements with 180° (rather than 90°) phase ambiguity. It provides a powerful and convenient graphical user interface that facilitates data visualization and analysis, in both the real-time sampling mode and the off-line analysis mode.

About 30 of the earlier instruments were made for research in particle precipitation from the radiation belts, sprites and possible earthquake prediction, resulting in some 50 publications.

UWB modelling of guided waves in anisotropic plasmas

O. E. Ferencz[1], P. Steinbach[2], C. Ferencz[2], J. Lichtenberger[1], M. Parrot[3] and F. Lefeuvre[3]

[1]Space Research Group, Eötvös University (ELTE), Budapest, Hungary
[2]MTA-ELTE Res. Group for Geoinformatics and Space Sciences, Budapest, Hungary
[3]LPCE/CNRS, 3A Avenue de la Recherche, 45071 Orleans cedex 2, France;

In this paper a new solving method is presented, using the Method of Inhomogeneous Basic Modes (MIBM), that avoids all the former monochromatic ways of thinking in the description of UWB signals, in order to obtain the complete solution of Maxwell's equations for real impulses. The paper presents new and general solutions for ducted electromagnetic waves in wave-guides filled by vacuum or anisotropic plasma. The theoretical results are presented in comparison with the database measured by DEMETER satellite.

By the application of the new theoretical model exact closed-formed solution of the UWB-problem can be yielded directly from Maxwell's equations, for a rectangular waveguide filled by vacuum, or anisotropic, magnetized plasma, excited by an arbitrarily formed electromagnetic signal (Dirac, or real, short impulse). This method avoids the application of the former assumptions regarding the sinusoidal waveform.

The theoretically deduced results are comparable to measured data registered by DEMETER satellite ("X"-type whistlers with one ore more furcated branches in their dynamic spectra) and some terrestrial data (terrestrial measurements from Agra). Important information can be obtained from the exact description of the propagating signal form, connecting to the circumstances of propagation, the shape of the excitation, etc.

"Early/slow" events: a new category of VLF perturbations observed in relation with sprites

C. Haldoupis[1], R. Steiner[1], A. Mika[1], S. Shalimov[2], R. Marshall[3], U. Inan[3], T. Bösinger[4] and T. Neubert[5]

[1]*Department of Physics, University of Crete, Heraklion, Greece*
[2]*Institute of Physics of the Earth, Moscow, Russia*
[3]*STAR Laboratory, Stanford University, Stanford, USA*
[4]*Department of Physical Sciences, University of Oulu, Oulu, Finland*
[5]*Danish National Space Center, Copenhagen, Denmark*

Analysis of subionospheric VLF transmissions, observed in relation with sprites, led to the identification of a new category of VLF perturbations caused by the direct effects of tropospheric lightning on the overlying lower ionosphere. They constitute a subset of the so called "early/fast" events where now the term "fast," which implies rapid onset durations less than ≈20 ms, is not applicable. In contrast with early/fast, the perturbations have a gradual growth and thus "slow" onset durations ranging from about 0.5 to 2.5 s, thus these events are labelled herein as "early/slow." Analysis of broadband VLF sferic recordings, made with a two-channel receiver near the sprite producing storms, shows that the growth phase of an early/slow event coincides with the occurrence of complex and dynamic lightning action. This is comprised of a few sequential cloud-to-ground lightning strokes, and clusters (bursts) of sferics which are attributable to intra-cloud lighting.

We postulate that the long onset durations are due to secondary ionization build-up in the upper D region below the nighttime VLF reflection heights, caused mainly by the impact on sprite-produced electrons of sequential electromagnetic pulses radiated upwards from horizontal in-cloud discharges.

Preliminary setup of a VLF prototype receiver for the South American VLF NETwork (SAVNET)

A. C. V. Saraiva[1], J.-P. Raulin[2], R. Rhadano[3] and A. Dal Lago[1]

[1] *Instituto Nacional de Pesquisas Espaciais, Sao Jose dos Campos, Brazil*
[2] *Centro de Radio-Astronomia e Astrofísica Mackenzie, São Paulo, Brazil*
[3] *Radio-observatório de Itapetinga, Atibaia, Brazil*

The South America VLF NETwork (SAVNET) project is a proposed network of VLF receivers to be deployed in the South-America continent and to be operated in 2007. The main scientific goals of the SAVNET are the long-term monitoring of the solar activity and the study of ionospheric perturbations in the South Atlantic Magnetic Anomaly (SAMA). In this work we present the preliminary setups for a SAVNET prototype receiver, and discuss the hardware and engineering involved. The first prototype consists of a vertical antenna, a pre-amplifier made on site and a "loop" antenna. The two antennae are connected in a soundcard were the signal is sampled and directed to a computer. We use the new Software Phase and Amplitude Logger (SoftPAL) algorithm (Dowden et al., 2006) to retrieve the amplitude and the phase of the incoming wave. At VLF the signal can be shielded by obstacles, like trees, mountains, and is very sensitive to local noise, like reactors of light bulbs, power lines, local AM/FM radio stations. We present and compare day-night time amplitude and phase variations obtained on different long propagation paths.

Session 3

PROBING THE EARTH-IONOSPHERE WAVEGUIDE

(Chair: E. Turunen)

Tuesday, 26th September 2006

15:45 – 17:15

Atmospheric precipitation during storm-time relativistic electron flux drop outs

M. A. Clilverd[1], C. J. Rodger[2], R. M. Millan[3] and Th. Ulich[4]

[1] *British Antarctic Survey, Cambridge, United Kingdom*
[2] *Physics Department, University of Otago, Dunedin, New Zealand*
[3] *Dept. of Physics and Astronomy, Dartmouth College, Hanover, NH, USA*
[4] *Sodankylä Geophysical Observatory, Sodankylä, Finland*

During the sudden decrease of geosynchronous electron flux (>2 MeV) of 17:10-17:20 UT, January 21, 2005 large-scale precipitation into the atmosphere was observed by the VLF AARDDVARK network (the joint NZ/UK lead Antarctic-Arctic Radiation-belt (Dynamic) Deposition VLF Atmospheric Research Konsortium) and the MINIS balloon experiment. Estimates from ground-based radio propagation experiments at L≈5 in the northern and southern hemispheres suggest that the atmospheric precipitation was less than 1/10 of the flux apparently lost during this 10-minute period. However, continuing precipitation losses from 4<L<6, observed for the next 2.7 hours, provides about 1/2 of the total relativistic electron content lost. Similarities and differences in the phenomena observed by MINIS and the AARDDVARK network during this event will be explored.

Ground based observations of relativistic electron precipitation from the radiation belts

C. J. Rodger[1], M. A. Clilverd[2], D. Nunn[3], P. T. Verronen[4], J. Bortnik[5] and E. Turunen[6]

[1] *Physics Department, University of Otago, Dunedin, New Zealand*
[2] *Physical Sciences Division, British Antarctic Survey, Cambridge, United Kingdom*
[3] *School of Electronics and Computer Science, Southampton University, United Kingdom*
[4] *Earth Observation, Finnish Meteorological Institute, Helsinki, Finland*
[5] *Department of Atmospheric and Ocean Sciences, UC Los Angeles, CA, USA*
[6] *Sodankylä Geophysical Observatory, University of Oulu, Sodankylä, Finland*

Small changes in the solar wind can result in very large increases in the population of relativistic electrons stored in the Van Allen belts. Various electromagnetic waves have been identified as influencing these electrons, associated with both the acceleration and loss of relativistic radiation belt electrons. For example, Hiss, Chorus, and EMIC waves all interact with, and precipitate, electrons into the middle and upper atmosphere (30-90 km), producing significant increases in the local ionisation levels. One of the few experimental techniques that can probe these altitudes uses very low-frequency (VLF) electromagnetic radiation, trapped between the lower ionosphere (≈85 km) and the Earth; these signals can be received thousands of kilometres from the source. The nature of the received radio waves is determined by propagation inside the waveguide, with variability largely coming from changes at and below the lower ionosphere. We have recently developed a global-scale network of sensors that monitor fixed-frequency communications transmitters. The joint NZ/UK lead Antarctic-Arctic Radiation-belt (Dynamic) Deposition – VLF Atmospheric Research Konsortium (AARDDVARK) provides continuous long-range observations of the lower-ionosphere. Here we look for evidence of these processes in AARDDVARK data and model the precipitation processes using balloon and satellite electron spectra measurements.

Differences in amplitude behaviour on a single VLF trace during flare events

D. Grubor[1], D. Šulic[2] and V. Žigman[3]

[1]*Faculty of Mining and Geology, Physics Cathedra, University of Belgrade, Serbia*
[2]*Institute of Physics, Belgrade, Serbia*
[3]*University of Nova Gorica, Nova Gorica, Slovenia*

The signal GQD/22.1 kHz, amplitude and phase data on the VLF path from Anthorn (54° 53' N, 3°17' W) to Belgrade (44° 51' N, 20° 23' E) have been recorded during summer 2004 and 2005, by the AbsPAL system situated at the Institute of Physics (Belgrade). The data have been analyzed in coincidence with solar flare X-ray irradiance taken from GOES 12 data lists.

It was found that on the Anthorn-Belgrade trace flares from class C to class X affect the amplitude of the GQD/22.1 kHz signal in distinctly different ways even at similar diurnal ionospheric conditions. The events classified according to the type of effect produced on the VLF propagation in the Earth-ionosphere waveguide, will be presented. These will be employed, along with the corresponding GOES X-ray data, to discuss the time delay in the amplitude response and the possible mechanisms of absorption/reflection of the VLF signal in the D-region of the Earth's ionosphere.

The flare effects resulting on the GQD/22.1 kHz trace will be paralleled with the ones obtained on the NAA/24.0 kHz, for which an amplitude-enhancement pattern is found as a unique response to the flare occurrence.

Determination of D-region electron density during solar flares from VLF data from three transmitters

V. Žigman[1], D. Grubor[2] and D. Šulic[3]

[1]*University of Nova Gorica, Nova Gorica, Slovenia*
[2]*Faculty of Mining and Geology, Physics Cathedra, University of Belgrade, Serbia*
[3]*Institute of Physics, Belgrade, Serbia,*

The VLF data, i.e. amplitude perturbation and amplitude time delay (ΔA, Δt) of three VLF signals: NAA/24.0 kHz, NWC/19.8 kHz and GQD/22.1kHz, all recorded at Belgrade, have been used to determine the D-region electron density enhancement during solar flares.

The continuity equation for electrons has been solved, by taking the time varying rate of electron production in accordance with the 1-minute GOES-12 Solar X-ray data lists, in the range 0.1 to 0.8 nm. For each flare event examined, independent evaluations with the VLF data pertaining to each of the signals considered have been performed.

Comparison of maximum electron densities resulting in a single flare, as registered by the VLF data of the three signals, yields good agreement. Moreover, fair agreement is found with the traditional Wait (LWPC) ionosphere parameters, at perturbed conditions: the reflection height *H'* and the sharpness β. This evidence is likely to set the estimate of the uncertainty in the applied method for determining flare induced electron densities below 20%.

Solar cycle dependence of ionospheric Sudden Phase Anomalies at VLF

A. A. Pacini[1], J.-P. Raulin[2], P. Kaufmann[3] and E. Correia[1]

*[1]Centro de Radio-Astronomia e Astrofisica Mackenzie (CRAAM) /
Instituto Nacional de Pesquisas Espaciais (INPE), Sao Paulo, Brasil*
[2]Centro de Radio-Astronomia e Astrofisica Mackenzie (CRAAM), Sao Paulo, Brasil
*[3]Centro de Radio-Astronomia e Astrofisica Mackenzie (CRAAM) /
Centro de Componentes Semicondutores (CCS/UNICAMP), Sao Paulo, Brasil*

We present an analysis on ionospheric ionization excesses produced by enhancements of X-ray emission during solar flares, measured as Sudden Phase Anomalies (SPA) at Very Low Frequency (VLF) propagation signals. Nearly 1300 and 200 SPAs were analysed during solar maximum and solar minimum periods, respectively. It has been shown that the low ionosphere has a sensitivity response to flare ionizing radiation dependent on the solar activity cycle, being more sensitive during low solar activity period, when the probability of SPA occurrence due to weak solar flares becomes higher. A quantitatively investigation of the spectral properties of selected solar flares has shown that: (i) the minimum X-ray energy input to produce a detectable SPA increases with increasing solar activity; (ii) a given solar flare will produce a greater SPA during solar minimum by about 2.8°/Mm. These results also indicate the feasibility of long-term monitoring of the solar radiations, which originate and maintain the undisturbed low ionosphere, by using continuous observations of VLF propagation signals.

Session 4

WHISTLER MODE WAVES OBSERVED IN SPACE

(Chair: M. Rycroft)

Wednesday, 27th September 2006

09:00 – 10:25

Variability of amplitudes, polarization and propagation of whistler-mode chorus emissions measured by the Cluster and Double Star spacecraft

O. Santolik[1], E. Macusova[1], D. A. Gurnett[2], J. S. Pickett[2], M. Parrot[3], N. Cornilleau-Wehrlin[4], Y. de Conchy[5], K. H. Yearby[6] and P. W. Daly[7]

[1]*Charles University / IAP , Prague, Czech Republic*
[2]*University of Iowa, Iowa City, USA*
[3]*LPCE/CNRS, Orleans, France*
[4]*CETP/IPSL, Velizy, France*
[5]*LESIA, Observatoire de Paris-Meudon, Meudon, France*
[6]*University of Sheffield, Sheffield, UK*
[7]*MPS, Lindau, FR Germany*

Using five years of measurement by the four Cluster spacecraft and two years of measurement of the Double Star TC-1 spacecraft we systematically investigate properties of whistler-mode chorus emissions. We analyze variability of wave amplitudes as a function of position and level of geomagnetic activity. Close to its perigee, the Cluster orbit scans different magnetic latitudes in a narrow range of radial distances around 4 Earth radii. To complement this analysis we also use a data base of systematic measurements of the Double Star TC-1 spacecraft which has a low-inclination orbit with an apogee of 13.4 Earth radii. Additionally, a correlation of wave amplitudes with fluxes of energetic electrons is investigated using the Cluster data. We also systematically analyze average properties and variability of wave polarization and propagation properties from multicomponent measurements onboard Cluster. This leads to a very clear and statistically significant localization of the chorus source in a narrow region close to the geomagnetic equator.

Variations of chorus source location: comparison of CLUSTER data and the backward-wave oscillator model

B. Kozelov[1], A. Demekhov[2], E. Titova[1], V. Trakhtengerts[2], O. Santolik[3] E. Macusova[3], M. Parrot[4] and N. Cornilleau-Wehrlin[5]

[1] Polar Geophysical Institute, Apatity, Russia
[2] Institute of Applied Physics, Nizhny Novgorod, Russia
[3] Charles University, Prague, Czech Republic
[4] CNRS/LPCE, Orleans, France
[5] CETP/UVSQ, Velizy, France

We study the motion of the source region of magnetospheric chorus emissions using multi-point measurements of VLF wave emissions and geomagnetic field onboard Cluster spacecraft. The wave data from STAFF instrument are used to obtain the energy flux in chorus waves, and the chorus-source region is found as the region where the energy flux is bi-directional. The geomagnetic-field data are matched to a parameterized model of local magnetic field, and the spatio-temporal dynamics of the magnetic field is obtained on this basis. Comparison of these data shows that the chorus-source location remains related to the magnetic-field minimum, while the position of this minimum can vary rather strongly during periods of enhanced geomagnetic activity. These results support the backward-wave oscillator (BWO) model of chorus emissions, which attributes chorus generation to an absolute instability of whistler-mode waves in the presence of a step-like velocity distribution of energetic electrons. Such an instability takes place in a small vicinity of the local “magnetic equator” of a magnetic flux tube. Quantitative agreement between the data and the model is demonstrated by the results of numerical simulations of self-consistent equations of magnetospheric BWO in which the experimentally obtained time-varying profile of the geomagnetic field is used.

Survey of ELF/VLF waves observed by DEMETER above Finland

M. Parrot

LPCE, Orléans, France

DEMETER is an ionospheric micro-satellite launched on a polar orbit at an altitude of 710 km. Its main scientific objectives are to study the ionospheric perturbations in relation with the seismic activity and the anthropic activity. Therefore, it allows a survey of the electromagnetic environment of the Earth. Its scientific payload allows to measure electromagnetic waves and plasma parameters in the ionosphere. There are two modes of operation: i) a survey mode where data with low time and frequency resolution are recorded around the Earth (except in the auroral zones) and ii) a burst mode where high-resolution data are recorded above the main seismic zones. Burst zones can be also implemented in other regions, and Finland has been selected as a non-seismic zone at high latitudes. This paper will present observations of natural ELF/VLF waves and of man-made waves above Finland from October 2004 until February 2006. Among the natural waves, DEMETER has shown that quasi-periodic emissions are frequently observed. Concerning the man-made waves, DEMETER has registered emissions associated with the VLF ground-based transmitters and with the Power Line Harmonic Radiations.

DEMETER observations of Power Line Harmonic and Magnetospheric Line Radiation

F. Nemec[1], O. Santolik[1], M. Parrot[2] and J.-J. Berthelier[3]

[1]Charles University / IAP , Prague, Czech Republic
[2]LPCE/CNRS, Orleans, France
[3]CETP/CNRS, Saint-Maur des Fosses, France

We present a systematic survey of Power Line Harmonic Radiation (PLHR) and Magnetospheric Line Radiation (MLR) observed by the DEMETER spacecraft. An automatic identification procedure has been developed and implemented in the DEMETER control center in Orleans, France, as a part of the Level 3 data processing. This procedure has been applied to 2 years of VLF Burst mode data. The events which are identified by this procedure form two distinct groups: 1) PLHR: Events with frequency spacing of 50/100 or 60/120 Hz. These emissions are electromagnetic, although the magnetic component is often too weak to be observed. They most probably propagate in the right-hand polarized whistler mode along the magnetic field lines. Their artificial origin from power systems is demonstrated by tracing magnetic field lines to the possible regions of generation. We present a detailed study of their properties. 2) MLR: Events with frequency spacing different from frequencies of power systems. These emissions usually occur at lower frequencies, in many cases allowing us to use the ELF Burst mode data, containing measurement of all field components. MLR events also occur during periods of higher geomagnetic activity. There is no evidence for their artificial origin. We classify these events and perform a detailed analysis.

Session 5

GROUND BASED OBSERVATIONS OF WHISTLER MODE WAVES AND LIGHTNING

(Chair: J. Lichtenberger)

Wednesday, 27th September 2006

10:55 – 12:00

Sudden short duration power line harmonics enhancements

T. Turunen and J. Manninen

Sodankylä Geophysical Observatory, Sodankylä, Finland

In September-October 2005 campaign a few cases were recorded when power line harmonics level suddenly increases in several harmonic frequencies. After sudden onset the event decays in a few seconds or tens of seconds. At least in one case the event seems to be connected to a strong sferics, which evidently triggers it. In one case enhanced power line harmonics triggered emissions. In other cases the event were seen only in harmonics without any detectable relation to anything else. These events are the only ones so far noticed in the VLF recordings of Sodankylä Geophysical Observatory but there should be such events in other data, too, because they appeared at least once in 2-3 days. It is not clear if the events are produced directly in power line system or if they are power line harmonics, which have experienced amplification in the magnetosphere. The case, when triggered emissions are seen, seems to indicate quite strongly that at least the harmonics propagat ed in the magnetosphere even if one cannot prove that they were generated there. We present the empirical properties of the enhanced power line harmonics and the general geophysical conditions during all the events so far noticed.

Preliminary analysis of the ELF-VLF campaign in September-October 2005: Plasmaspheric ELF hiss and magnetic storms and substorms

N. G. Kleimenova[1], O. V. Kozyreva[1], J. Manninen[2] and T. Turunen[2]

[1] *Institute of the Physics of the Earth, RAS, Moscow, Russia*
[2] *Sodankylä Geophysical Observatory, Sodankylä, Finland*

The ELF-VLF campaign was carried out between 26 September and 13 October 2005 at Siiselkä (67.82° N, 26.08° E, L=5.47), Finland. The obtained data showed that the main typical whistler mode emissions there were hiss-like broadband, structureless ELF emissions, which occurred in the daytime in the frequency range usually less than 2 kHz. We attribute these emissions to typical plasmaspheric hiss [e.g., Thorne et al., 1973; Meredith et al., 2004]. This hiss was observed at the daytime between the sunrise and sunset at 100 km (≈06-18 MLT, i.e. ≈04-16 UT). At this time the observation point was located deep inside of the plasmapause. The ELF hiss practically did not occur under quiet magnetic conditions with $K_p<2$ (e.g., on 5-6 and 12 October). As a rule the enhanced daytime hiss was observed under negative values of B_z IMF and after strong solar wind density enhancement. Typically there were substorms observed at Sodankylä (SOD) in the previous night, and simultaneously with daytime ELF hiss there was substorm development at the night side of the magnetosphere at College (CMO), Fort Churchill (FCC) and others. We suppose that wave intensification was associated with a substorm injection of plasma sheet electrons into the inner magnetosphere.

The strongest ELF hiss was observed on 8 October during the main phase of small magnetic storm with $D_{st} \approx -90$ nT. This is contrary to VLF chorus generated outside of plasmasphere, which intensity according to Smith et al. (2004) typically decreases in the storm main phase. The ELF hiss event on 8 October was accompanied by large amplitude Pc5 geomagnetic pulsation generation, observed outside of plasmapause. The Pc5 pulsations did not modulate the ELF hiss intensity.

On the generation of LHR waves in the upper ionosphere

D. L. Pasmanik[1], A. G. Demekhov[1], V. Y. Trakhtengerts[1], E. E. Titova[2], M. J. Rycroft[3], J. Manninen[4] and T. Turunen[4]

[1] Institute of Applied Physics, RAS, Nizhny Novgorod, Russia
[2] Polar Geophysical Institute, Apatity, Russia
[3] CAESAR Consultancy, Cambridge, UK
[4] Sodankylä Geophysical Observatory, Sodankylä, Finland

Generation of LHR waves in the upper auroral ionosphere by protons with energies above 1 keV is analysed. The ray-tracing technique is used to study the properties of LHR wave propagation in inhomogeneous ionospheric plasma. Path-integrated amplification along obtained ray trajectories is calculated taking into account variation of wave parameters along the ray.

It is shown that in the case of protons having transverse anisotropic distribution with respect to the magnetic field the most effective generation of LHR waves occurs near points of double resonance: $\omega=\omega_{LHR}=n\omega_H$, where ω_{LHR} is the local lower-hybrid resonance frequency, ω_H is the local gyrofrequency of energetic protons, and n is an integer. It is found that in this case large amplification ($\Gamma\approx10$ dB) of LHR waves is possible for reasonable values of energetic proton flux ($E_p\approx10$ keV, $S\approx10^7$ cm^{-2} s^{-1} ster^{-1}) in the auroral region. The results obtained are discussed in relation to ground-based observation of VLF hiss with banded spectral structure.

Session 6

PROBING THE EARTH-IONOSPHERE WAVEGUIDE

(Chair: M. A. Clilverd)

Wednesday, 27th September 2006

13:30 – 14:45

Ground- and satellite-based observations of electron precipitation induced by lightning discharges and VLF transmitters

U. Inan[1], D. Piddyachiy[1], M. Parrot[2], J.-A. Sauvaud[3], W. Peter[1] and R. Marshall[1]

[1] Stanford University, Stanford, California, USA
[2] LPCE, Orelans, France
[3] CESR, Toulouse, France

We present a review of recent observations of precipitation of energetic radiation belt electrons by whistler-mode waves injected by lightning discharges and VLF transmitters. Ionospheric effects of burst precipitation induced by the injected signals are observed via associated subionospheric VLF signal perturbations, while direct measurements of the injected waevs and precipitating electrons are carried out on board the DEMETER satellite. We concentrate on the comparative analysis of the ground- versus satellite-based observations, from the point of view of bringing out the various factors involved, in terms of detectability of precipitation bursts, and how these sparse observations may be used to deduce globally meaningful information about the loss rates of radiation belt electrons. The dependence of observations on geomagnetic conditions and on the geographic longitude is specifically focused upon.

What if we knew the energy characteristics of precipitating relativistic electrons using VLF recordings and D-region ion chemistry modelling?

E. Turunen[1], C. J. Rodger[2], P. T. Verronen[3], A. Seppälä[3], Th. Ulich[1], M. A. Clilverd[4], K. Kaila[5], C.-F. Enell[1], T. Raita[1], J. Manninen[1] and T. Turunen[1]

[1] *Sodankylä Geophysical Observatory, Sodankylä, Finland*
[2] *Dept of Physics, University of Otago, Dunedin, New Zealand*
[3] *Finnish Meteorological Institute, Helsinki, Finland*
[4] *British Antarctic Survey, Cambridge, U.K.*
[5] *Dept of Physical Sciences, University of Oulu, Oulu, Finland*

Satellite measurements on radiation belt electrons are numerous and the temporal variability of the relativistic electron population is reasonably well characterized. However, actual atmospheric implications of the precipitation of the relativistic electrons are not well known. A major deficiency is missing global picture from atmospheric measurements. One of the experimental techniques, which can probe the relevant altitudes, 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. Systems such as the Antarctic-Arctic Radiation-belt (Dynamic) Deposition — VLF Atmospheric Research Konsortium (AARDDVARK) should prove to be very useful tools in global, continuous monitoring of the lower ionosphere.

Model estimates of possible neutral composition and chemistry effects due to excess ionisation by the precipitating relativistic electrons need information on temporal and spatial variations of the energy and flux of the electrons. In this paper we show how temporal features seen in the VLF signals, with assumptions, can be used to estimate the energy characteristics of the precipitating electrons, using detailed ion-chemistry modelling of the lower ionosphere.

Comparison of the performances of the OmniPAL and Stanford VLF receivers

A. Mika[1], C. Haldoupis[1], J. Lichtenberger[2] and U. Inan[3]

[1] University of Crete, Heraklion, Greece
[2] Eotvos Lorand University, Budapest, Hungary
[3] Stanford University, Stanford, USA

The research in the area of early VLF perturbations has been mainly persued by two research groups, at Stanford University and at the University of Otago. There are many experimental observations available from both groups. However, there is some controversy in the published findings, especially in the area of detection of VLF perturbations caused by backscatter at near distances from red sprite formations. It was proposed that the discrepancies may be due to differences in instrumentation and in the methods of identification of early VLF events.

Since August 2005, and for the first time ever, the two types of VLF receivers are operated at the same location, on the island of Crete. This gives an opportunity to examine the possible differences in the performance of the two instruments. Preliminary results of comparison of data gathered using the two receivers are presented. General differences and similarities in the recorded time series are shown, and case studies comparing observations of early VLF perturbations are presented and discussed.

Session 7

CONSEQUENCES OF WHISTLER MODE WAVES

(Chair: D. Nunn)

Wednesday, 27th September 2006

15:15 – 16:45

Electron acceleration and loss by whistler mode chorus waves in the Earth's radiation belts during magnetic storms

R. B. Horne[1], S. A. Glauert[1], N. P. Meredith[1], A. Varotsou[2], D. Boscher[2], R. M. Thorne[3] and R. R. Anderson[4]

[1]British Antarctic Survey, Madingley Road Cambridge, England
[2]ONERA/Department of Space Toulouse, France
[3]Department of Atmospheric and Oceanic Science, UCLA, USA
[4]Department of Physics, University of Iowa, USA

Variations in the flux of radiation belt electrons (few MeV) are a result of an imbalance between acceleration, transport and loss processes. Here we use quasi-linear theory to show that during storms whistler mode chorus waves contribute to electron loss at energies up to a few hundred keV, but can also accelerate electrons up to MeV energies, which remain trapped in the radiation belts. Wave acceleration is most efficient in low-density regions, and can account for the observed timescale for flux increase of 1-2 days during very large magnetic storms. We compare diffusion rates for different types of whistler mode and electromagnetic ion cyclotron waves. We discuss how wave acceleration can be incorporated into a global radiation belt model and show that storms with a long recovery phase, such as those associated with corotating interaction regions, provide sustained supply of electrons to continually enhance chorus wave activity and thereby produce effective electron acceleration. We suggest that the storms, which produce an enhancement in the relativistic electron flux, are more likely to be associated with a long recovery phase, and or have a very strong compression of the plasmapause, which enables very efficient wave acceleration.

A self-consistent particle simulation of VLF triggered emission

Y. Katoh[1] and Y. Omura[2]

[1] Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University, Sendai, Miyagi, Japan
[2] Research Institute for Sustainable Humanosphere, Kyoto University, Uji, Kyoto, Japan

We carry out a self-consistent particle simulation with a dipole magnetic field to study the generation mechanism of VLF triggered emissions.

The evolution of a wave packet propagating along a reference magnetic field line is solved by Maxwell's equations while the bounce motion of energetic electrons in the non-uniform magnetic field is taken into account.

Simulation result shows that a triggered emission with a rising tone is generated at the trailing edge of the triggering wave packet.

The generation process is explained by roles of resonant currents JE and JB in association with an electromagnetic electron hole in the phase space produced through the nonlinear interaction.

We find that these resonant currents in the simulation result are formed by untrapped electrons through the nonlinear wave-particle interaction and suggest that the phase bunching of untrapped electrons plays an essential role in the triggering mechanism.

Ray tracing of penetrating chorus and its implications for the radiation belts

J. Bortnik

UCLA, Atmospheric and Oceanic Sciences, Los Angeles, USA

Chorus is an electromagnetic whistler mode wave, and ranks as one of the most intense natural waves in the ELF/VLF frequency range. Recent work shows that chorus can serve a dual role in controlling the dynamics of the Earth's outer radiation belt, dominantly acting as either a loss process in the main phase, or as an acceleration process in the recovery phase of storms. In either role, the propagation characteristics, evolution of the chorus wave normal angle, and damping of the wave play key roles in the interaction of the chorus wave with the energetic radiation-belt particles. In the present work, we use numerical raytracing combined with a Landau damping calculation to infer the complete propagation characteristics of the chorus wave. We use suprathermal flux measurements from the CRRES satellite parameterised by L-shell, MLT, and AE to construct realistic distribution functions, which we use in the calculation of Landau damping. While typically chorus is seen to damp at mid-latitudes, we show that under specific conditions, the Landau damping can be dramatically reduced and the chorus waves can penetrate to very high latitudes. The implications of this so-called "penetrating chorus" are discussed in the context of the radiation belts.

Electron acceleration in the magnetosphere by whistler-mode waves with varying frequency

A. Demekhov[1], V. Trakhtengerts[1], M. Rycroft[2] and D. Nunn[3]

[1] *Institute of Applied Physics, Nizhny Novgorod, Russia*
[2] *CAESAR Consultancy, Cambridge, UK*
[3] *Southampton University, Southampton, UK*

We consider acceleration of relativistic electrons in an inhomogeneous magnetic field due to their resonant interaction with longitudinally propagating whistler-mode waves of varying frequency. Specific features of acceleration of electrons trapped by the wave field are studied. Estimates of efficiency of such acceleration, performed earlier, are generalized with relativistic effects taken into account, and a simple formula describing the energy gain in a wide range of initial energies is obtained. It is shown that the energy gain during a single interaction of an electron with a whistler-mode wave packet having typical parameters of a chorus element in the Earth's magnetosphere can reach several kev. Conditions of realization of this acceleration mechanism are discussed. In particular, it is obtained that in the case of chorus emissions in the Earth's magnetosphere, it can efficiently operate for electrons whose perpendicular energy is several times higher than that of electrons generating the chorus.

Session 8

WHISTLERS

(Chair: U. Inan)

Wednesday, 27th September 2006

17:00 – 17:45

An homage to Chung Park, pioneer of remote sensing using whistlers

D. L. Carpenter

Stanford University, Stanford, California, USA

Chung Park's research career lasted only from 1970 to 1981, but in that short period he made contributions to Space Physics that resonate in the community today. He used whistlers to demonstrate for the first time results that we now take for granted, namely that: (1) day-side upward plasma fluxes are sufficient to allow the plasmasphere to serve as a reservoir for the nighttime ionosphere; (2) following a disturbance, the inner plasmasphere reaches an equilibrium state in terms of interchange fluxes with the ionosphere, while the outer region continues to fill; (3) the post storm recovery of the plasmasphere lags that of the underlying ionosphere. Park was a pioneer on the topic of thunderstorm coupling to the ionosphere, offering ideas on how the electric fields of thundercloud charge centers could give rise to whistler ducts. He and a student pushed aside traditions according to which thunderstorm electricity was confined to the electrosphere, a spherical shell below the ionosphere with a conducting upper limit that precluded meaningful electrostatic or dynamic coupling to the ionosphere. Park also made notable contributions to the study of non-linear wave particle interactions in the magnetosphere, finding evidence that the development of sidebands on VLF signals transmitted from Siple, Antarctica was inconsistent with theories in which sideband frequency was dependent upon the carrier amplitude.

Performance of low noise ultra linear 24-bit VLF receiver system UEV2300 developed at Sodankylä Geophysical Observatory

T. Turunen, T. Rantala and J. Manninen

Sodankylä Geophysical Observatory, Sodankylä, Finland

The frequency band of 1-20000 Hz contains signals from sferics, power line harmonics, power line control signals, VLF transmitters and various types of natural VLF emissions, which in data appear together with the system noise. The strongest signals arise from sferics, which thus dictate the highest possible gain in linear receiver systems, and the thermal noise level of the receiver limits the detection of the weakest VLF-emissions. The spectral characteristics of the signals are very different. The difference between the peak signal level and the system noise varies strongly as a function of frequency and the final analysis bandwidth, but as a practical design parameter one can use 120 dB dynamic range as a design goal. This immediately rules out tape recorders and 16 bit AD-converters, because those limit the dynamic range to about 90 dB and in practice even less. Design demands components having noise levels low enough and no components having distortion level above -120 dBc in the band are allowed in the amplifier and filter chain. In practice, 120 dB dynamic range cannot be realized in every respect because even the fast 24-bit AD-converters cannot meet the demand, but 105-110 dB range seems to be possible. The 2-channel receiver was designed using 10-pole analog linear phase filters having -3 dB frequency at 5 kHz, 24-bit AD-converters containing digital filters and sampling was 39062.5 Hz (10 MHz/256). Loop antennae having turn-area product 2300 m2 and 0.54 H inductance were either tuned to 1500 Hz with Q-value at 0.7 or coupled to amplifier via 2-pole LC matching circuit forming a band pass LC-filter.

The timing and frequency is controlled by GPS-system and the data written to computer disks contains also GPS time code. The system performs as designed and it is linear. For example the night time band just below mode 1 cutoff occurring around 1.8-2.0 kHz does not contain any indications of sferics because distortion products are not produced at detectable level. At lower frequencies the mode 0 rises above the system noise level.

Session 9

PROBING THE EARTH-IONOSPHERE WAVEGUIDE

(Chair: A. Demekhov)

Thursday, 28th September 2006

09:00 – 10:25

Modelling of red sprites as a set of interacting column segments in the Earth-ionosphere waveguide

A. Mika[1], D. Nunn[2] and C. Haldoupis[1]

[1] *University of Crete, Greece*
[2] *University of Southampton, UK*

Preliminary results of modelling of the scattering of VLF waves from the ionised bodies of red sprites are presented. The ionisation associated with sprites is modelled as a set of conducting columns inside the Earth-ionosphere waveguide. In some previous studies sprites were represented as sets of spritelets, infinite long interacting columns with height-independent characteristics. Scattered fields were computed analytically without accounting for VLF propagation effects inside the waveguide. In other studies spritelets were defined as regions of electron density perturbations (with altitude-dependent characteristics), covered by a 3-D spatial grid. VLF propagation theory was used to find the scattered field at the receiver. Interactions between grid elements were not taken into account explicitly, only through parameterization. In the present approach sprites are modelled as sets of columns having a finite length. The columns are broken up into segments having different, altitude-dependent characteristics. The VLF propagation code MODEFNDR is used to determine the incident field from the transmitter on each segment. The currents induced in the individual segments are calculated, taking into account the interaction between them. Finally, the field at the receiver is again calculated using MODEFNDR. Scattering patterns are produced and compared to experimental results and past studies.

VLF evidence of thermosphere-to-stratosphere descent of polar NOX

M. A. Clilverd[1], A. Seppälä[2], C. J. Rodger[3], P. T. Verronen[2], N. R. Thomson[3], J. Lichtenberger[4] and P. Steinbach[4]

[1] *British Antarctic Survey, Cambridge, United Kingdom*
[2] *Finnish Meteorological Institute, Helsinki, Finland*
[3] *Physics Department, University of Otago, Dunedin, New Zealand*
[4] *Space Research Group, Eötvös University, Budapest, Hungary*

During the northern hemisphere winter of 2003-2004 significant levels of stratospheric odd nitrogen (NOX) were observed descending from the polar mesosphere. Here we study subionospheric radio wave propagation data from Ny Ålesund, Svalbard, Norway to determine the origin of the mesospheric NOX. A clear change in VLF radio wave diurnal variation is observed, starting on January 13, 2004, lasting for 37 days. The behaviour is consistent with the ionization, by Lyman-alpha, of thermospheric NOX descending into the mesosphere from altitudes above 85km. Estimates of the concentration of NOX required to produce the observed ionization changes are consistent with the levels of previously published stratospheric mixing ratios after the NOX has descended into the stratosphere. The radio wave data shows that no significant proton or electron precipitation events into the mesosphere occurred at this time, and the mesospheric effects of the large storms in October/November 2003 had abated by late December 2003. Similar analysis of the VLF data during 2004-05 and 2005-06 contrasts the roles of NOX production and vertical middle-atmosphere transport.

Importance of proton spectral hardness in the atmospheric effects of solar proton events - the Jan 2005 events

A. Seppälä[1], P. T. Verronen[1], M. A. Clilverd[2], C. J. Rodger[3], E. Turunen[4], Th. Ulich[4], C.-F. Enell[4], V. Sofieva[1], J. Tamminen[1] and E. Kyrölä[1]

[1] Finnish Meteorological Institute, Helsinki, Finland
[2] British Antarctic Survey, Cambridge, UK
[3] Physics Dept. University of Otago, Dunedin, New Zealand
[4] Sodankylä Geophysical Observatory, Sodankylä, Finland

On January 20, 2005, the giant sunspot 720 produced a powerful X-class solar flare. From this flare began an extraordinary solar proton storm: the flux with the highest energies was of the same order as in the well known October 1989 SPE, whilst the lower energy fluxes remained at moderate levels, making this event the hardest and most energetic proton event of Cycle 23 so far. The high-energy protons ionize the polar atmosphere and following ion chemistry leads to increased production of NOx and HOx, which, in turn, participate in catalytic, ozone destroying reaction cycles.

We have used the SIC model and VLF subionospheric propagation observations and modelling as well as atmospheric measurements by the GOMOS instrument to study the conditions in the polar atmosphere during the January events. The SIC model was used to predict the response of the NOx, and HOx constituents to the high proton fluxes, and the subsequent effect on ozone. SIC also produces the ionospheric D-region electron densities, which are further used as an input to a VLF subionospheric propagation modelling for comparison with experimental observations. We will present these results from the January 2005 solar proton storms, contrasting the effects of different levels of proton spectral hardness.

Relationship of VLF chorus with electron precipitation observed by IRIS and TV camera

E. Titova[1], B. Kozelov[1], J. Manninen[2], F. Honary[3], S. Marple[3] and T. Turunen[2]

[1] *Polar Geophysical Institute, Apatity, Murmansk region, Russia*
[2] *Sodankylä Geophysical Observatory, Sodankylä, Finland*
[3] *Dept of Communication Systems, Lancaster University, Lancaster, United Kingdom*

Relationship between VLF chorus and electron precipitation were analysed using simultaneous observations of VLF antenna, IRIS riometer array, and TV camera located at Kilpisjärvi (69.05° N, 20.79° E) and Porojärvi (69.16° N, 21.47° E), Finland. Morning ELF/VLF chorus was observed simultaneously with riometer bay, when amplitude of absorption was less then 0.5 db. The amplitude of chorus correlate better with riometer absorption bay (linear Pearson correlation coefficient reaches ≈0.9), than with TV aurora data. Up frequency of the chorus emissions corresponded to half equatorial gyrofrequency of south boundary of electron precipitation. Aurora pulsations (5-15 sec) on the south boundary corresponded sometimes to groups of chorus elements for weak VLF signal and aurora. When intensity of VLF waves and electron precipitation increased, anticorrelation between VLF chorus groups and aurora/riometer absorption was observed. The height distribution of electron concentration in E-region is calculated from the energy spectrum of incoming electrons with energy <30 keV as measured by DMSP satellite during considered events. Altitude profiles of absorption for high frequency (38 MHz) and low frequency (VLF range) waves were calculated using estimated electron density profiles. Calculated integral high-frequency wave absorptions agree with IRIS data; the estimations for low-frequency waves explain qualitatively the variations of chorus amplitude.

Session 10

CONSEQUENCES OF WHISTLER MODE WAVES

(Chair: R. Horne)

Thursday, 28th September 2006

10:55 – 12:00

Simulation of non linear Landau resonance with a Vlasov Hybrid Simulation code

D. Nunn[1] and D. Shklyar[2]

[1]Southampton University, Southampton,UK
[2]IZMIRAN, Moscow, Russia

This work considers the development of a lightweight efficient simulation code for the numerical modelling of non linear Landau resonance. The method uses the simple Vlasov Hybrid Simulation technique. The VHS method is first described and its many advantages over PIC and other Vlasov methods are underlined are underlined. The 1D electrostatic code is then described and tests for energy and particle conservation are conducted. It is found that unresolved fine structure results in energy and particle number increase. Simulation results are presented for various hot beam strengths and beam temperatures. The linear growth rates are computed from the globally averaged distribution function and compared to non linear growth rates. It is found that the quasi linear result does not hold.

On a mechanism forming the dynamic spectrum of VLF chorus elements and its verification using Cluster data

V. Trakhtengerts[1], A. Demekhov[1], E. Titova[2], B. Kozelov[2], O. Santolik[3], E. Macusova[3], D. Gurnett[4], J. Pickett[4], M. Rycroft[5] and D. Nunn[6]

[1] *Institute of Applied Physics, Nizhny Novgorod, Russia*
[2] *Polar Geophysical Institute, Apatity, Russia*
[3] *Charles University, Prague, Czech Republic*
[4] *University of Iowa, Iowa City, IA, USA*
[5] *CAESAR Consultancy, Cambridge, UK*
[6] *ECS, Southampton University, Southampton, UK*

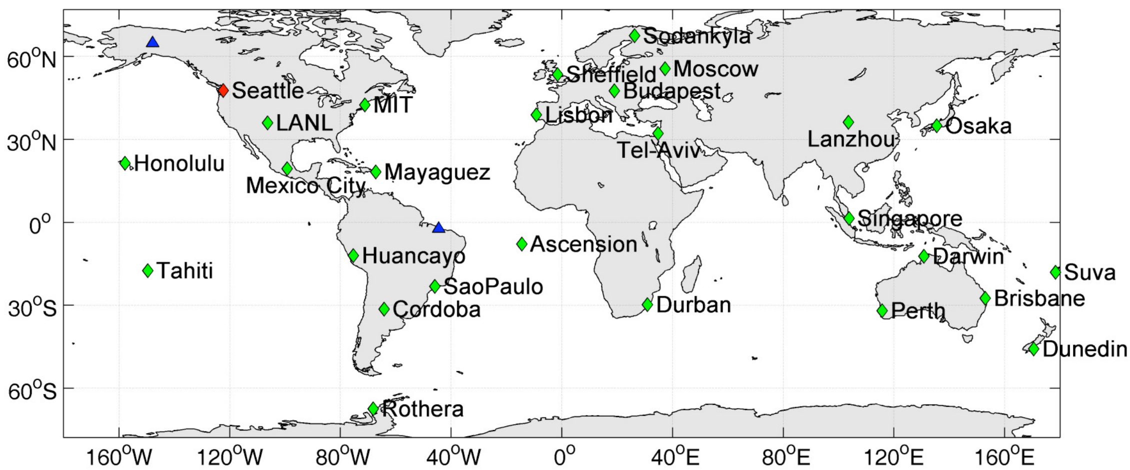
Formation of VLF chorus spectrum is considered on the basis of a Backward Wave Oscillator (BWO) model of chorus generation. The theory yields the spectral form dependence of a separate chorus element on the wave energy flux direction and on the position of observation point inside the generation region. In particular, it predicts that only a part of a chorus element is visible inside the source region. For the typical case of rising-tone chorus elements, the lower frequencies are generated downstream with respect to the chorus propagation and, hence, become invisible as a receiver is moved upstream within the source region. These spectral features are verified on the basis of Cluster data. The chorus source is localized using multicomponent measurements of the electric and magnetic fields. The analysis confirms that, in agreement with the theoretical model, the spectrum of detected chorus lacks the lower frequencies at the center of the source region.

The World Wide Lightning Location Network (WWLLN): Rapid global observations of the worlds "big" lightning

C. J. Rodger[1], E. H. Lay[2], A. R. Jacobson[2], R. H. Holzworth[2], J. B. Brundell[3] and R. L. Dowden[3]

[1] *Physics Department, University of Otago, Dunedin, New Zealand*
[2] *Dept. Earth and Space Sciences, University of Washington, USA*
[3] *Low Frequency Electromagnetic Research, Ltd, New Zealand.*

Powerful lightning flashes with large return stroke peak currents induce energetic and electrical coupling between the troposphere and the upper atmosphere via the quasi-electrostatic and/or the radiated electromagnetic pulse (EMP). In particular, a single lightning EMP can affect a large area (≈10^5 km^2) at ionospheric D-region altitudes, and the decay rate for the ionization produced at these altitudes can be less than the rate at which a large thunderstorm generates lightning EMP bursts. Several researchers have suggested that the lightning EMP which drives ELVES may be a significant source of variation in the upper atmosphere at regional and global scales. In addition, "big" lightning is more loosely associated with other Transient Luminous Events (TLEs). Panned space-based TLE observing missions will benefit from rapid access to global lightning locations, uniquely available through the experimental lightning detection network, the World Wide Lightning Location Network (WWLLN). This is being developed to provide low-cost, real-time global lightning coverage. While still growing, the network currently consists of 27 stations, which measure the very low frequency (VLF; 3-30 kHz) radiation from lightning discharges. Propagation at these very long electromagnetic wavelengths (up to 100 km) allows lightning strokes to be located in real time at up to 10,000 km from the receivers with a location accuracy that is estimated to be a few kilometres. True global mapping of lightning from widely spaced (a few Mm) ground-based receivers requires the use of frequencies <30 kHz. Lightning impulses in this frequency range suffer low propagation attenuation, and hence propagation in the Earth-ionosphere waveguide is possible over global distances.



Locations and hosts of the 27 VLF receiving stations currently operating in the WWLLN. The location of the central processing computer plus receiver is shown as a red diamond, while planned locations of future WWLLN sites are shown as blue triangles.

Session 11

WHISTLERS

(Chair: O. Santolik)

Friday, 29th September 2006

09:00 – 10:25

Whistler wave experiments on large "KROT" device

M. Gushchin, A. Kostrov, S. Korobkov, A. Strikovsky, D. Yanin, M. Starodubtsev, V. Gundorin and A. Mochalov

Institute of Applied Physics, RAS, Nizhny Novgorod, Russia

Current status of activities performed on "KROT" device (IAP RAS, Nizhny Novgorod) in whistler frequency range is reported. "KROT" facility was specially designed to model VLF wave excitation, propagation and interaction in near-Earth plasma, it represents a vessel in which an extremely very large (5 m × 1.5 m) plasma column is generated. During the last decade whistler research program is of primary concern. The key topics are whistler interactions with time-varying plasma density and magnetic field perturbations, and also with plasma density and magnetic field irregularities of various scales. The two main problems are considered: (i) whistler propagation in magnetically disturbed areas and accompanying parametric effects, and (ii) excitation and propagation of whistlers in density and, foremost, magnetic field duct-like structures. Applications of our results to magnetosphere processes are discussed.

The work is supported by RFBR (grants #04-02-17188 and #05-08-50020) and by Federal Agency for Science and Innovations.

Oblique whistler propagation in the ionosphere: Results of the first application of a full-wave propagation model on DEMETER burst recordings

P. Steinbach[1], O. E. Ferencz[2], Cs. Ferencz[2], J. Lichtenberger[2], D. Hamar[2], J. J. Berthelier[3], F. Lefeuvre[4] and M. Parrot[4]

[1]Research Group for Geoinformatics and Space Sciences, Hungarian Academy of Sciences, Budapest, Hungary
[2]Space Research Group, Institute of Geography and Earth Sciences, Eötvös University, Budapest, Hungary
[3]CETP/CNRS St Maur, France
[4]LPCE/CNRS Orleans, France

The dispersion values of whistlers recorded on board of LEO satellites appear to fall into distinct clusters. The largest of these dispersion values correspond to one-hop whistlers, thought to be excited in the magnetic conjugate region and reached the satellite position after long plasmaspheric propagation along geomagnetic field lines. Whistlers exhibiting the smallest dispersion ($D_0 < 8$ s½) are widely accepted as fractional-hop ones reaching the LEO satellite. As a still unexplained phenomenon a large number of whistlers, forming a clear cluster in the dispersion distribution ($D_0 \approx 10 - 40$) have not been classified into any of these categories.

Fractional-hop whistlers recorded on board the DEMETER satellite were possible to model and interpret applying our full-wave impulse propagation model describing obliquely propagating signals on a basis of ionospheric and magnetic field standard models (IRI and IGRF). The results yielded a basically new picture of ionospheric whistler propagation. Dispersions of fractional-hop whistlers themselves exhibit bimodal distribution; the values vary regularly with magnetic latitude of the satellite. The diverse dispersion values correspond to different propagation directions from the lower ionosphere to the satellite and thus different angles between the direction of the propagation and the geomagnetic field along the path. Realistic, UWB modelling of a great number of whistlers appeared on the DEMETER ICE VLF recordings, acquired at large latitudinal range proved that the angle of oblique propagation is responsible for diverse dispersions of fractional-hop whistlers. The most probable 3D propagation directions of fractional-hop whistlers in the ionosphere in the vicinity of the satellite can be determined at a given magnetic latitude.

Towards a new whistler 'inversion' model

J. Lichtenberger

Eötvös University, Budapest, Hungary

Probing plasmasphere by whistlers a consistent model is required. A model that can be used to obtain plasmaspheric electron densities and propagation paths deduced from measured whistler data (this is what we call 'inversion') consists of three main components. These components used most widely even nowadays are:

1. A longitudinal whistler-wave propagation model: travel-time integral using an approximate group velocity deduced from Appleton-Hartree dispersion relation (neglecting ions and "+1" in group-refractive index).

2. Dipole field approximation of Earth's magnetic field.

3. Electron-density distributions along field lines: DE-1...4, R4 and Hybrid models.

This model was developed in a consistent way for nose whistlers by Park (1972) and is enhanced by 'nose extensions' (e.g. Ho and Bernard, JATP, 1973; Tarcsai, JATP, 1975).

The choice of these components was based on available information and/or on computational constrains. In this paper we describe a new inversion model based on up-to-date versions of the above listed elements:

1. Travel-time integral from Appleton-Hartree dispersion relation without approximations.

2. Combination of dipole field and DGRF-IGRF models.

3. Empirical or quasi-empirical models of electron density distribution (e.g. Carpenter and Anderson, JGR, 1992; Denton et al., JGR, 2004).

Session 12

WAVES IN SPACE AND GROUND

(Chair: N. G. Kleimenova)

Friday, 29th September 2006

10:55 — 12:00

Proton gyro-harmonic (PGH) echoes stimulated by the radio sounder on the IMAGE satellite

D. L. Carpenter[1], T. F. Bell[1], D. Chen[1], D. Ng[1], I. Galkin[2] and B. Reinisch[2]

[1] *Stanford University, Stanford, California, USA*
[2] *University of Massachusetts Lowell, Lowell, Massachusetts, USA*

Within the Earth's plasmasphere between ≈2000 and 20,000 km altitude, the Radio Plasma Imager (RPI) instrument on the IMAGE satellite regularly detected discrete echoes that arrived at delays equal to multiples of the local proton gyro-period. Similar phenomena were observed at ionospheric altitudes during the ISIS satellite era, and were interpreted as manifestations of a proton memory process wherein the rf of a pulse is impressed on the protons in the vicinity of an electric antenna and is then radiated back to the satellite after one or more proton gyro-periods. PGH echoes on RPI were found: (1) at various frequencies near and above 10 kHz in the whistler-mode domain; (2) above and near the electron gyro-frequency in a nominally non-propagating domain; (3) near 300 kHz, just below and within the Z-mode domain. Echoes in the whistler-mode domain were particularly strong near 10 kHz, close to the local proton plasma frequency, and on occasion as many as 20 additional echoes near 10 kHz were observed at multiples of the proton gyro-period. A PGH echo form not previously found in the ISIS-series data is a resonance centered at a frequency ≈15% above the local electron gyro-frequency. We suggest that energy to support the echo process comes from the gradual collapse of the plasma sheath around the antenna in the aftermath of a pulse and from frequency-dependent energization of thermal protons during the pulse.

Generation of Pc1 pulsations in the regime of backward wave oscillator

V. Trakhtengerts and A. Demekhov

Institute of Applied Physics, Nizhny Novgorod, Russia

Satellite data (Loto´aniu et al., 2005) show that EMIC Pc-1 waves demonstrate, in a wide range of L values, bidirectional energy flux propagation at low magnetic latitudes $|MLat| < 11°$ and unidirectional (downward) propagation for $|MLat| > 11°$. Loto´aniu et al. suggested that this fact can be due to generation of Pc-1 waves in the regime of Backward Wave Oscillator (BWO) suggested earlier for ELF/VLF chorus generation. We give a quantitative consideration of this idea. According to the BWO model, waves are generated in the vicinity of the equatorial cross-section of a magnetic flux tube, and the MLat width of the generation region is estimated as $|MLat| = (R_0\ k_A\ L)^{-1/3}$, where R_0 is the Earth radius and k_A is the wave number. In the case of Pc1 waves, for reasonable values of $k_A \approx 0.01\ km^{-1}$, $|MLat| = 9°$ and depends only weakly on L. This is in close agreement with observations. We discuss the dynamical features of Pc 1 pulsations generated in the BWO regime and estimate the threshold energetic-ion flux for BWO generation.

South America VLF NETwork (SAVNET)

J-P. Raulin

CRAAM-UPM, São Paulo, Brazil

Based on recent results on the varying sensitivity of the low ionospheric D-region as a function of the solar cycle, we propose the "South America VLF NETwork (SAVNET)." The main scientific objectives of this network are to monitor short and long-term trends in solar activity, as well as to study the influence on space weather of the South Atlantic Magnetic Anomaly (SAMA). SAVNET is part of the larger programmes International Heliophysical Year 2007 (IHY2007) and United Nations Basic Space Science Initiatives (UNBSSI). SAVNET will be deployed within the South America region at strategic locations (Peru, Argentina and Brazil) relative to the SAMA, increasing the relatively poor instrumental facilities existing at these frequencies. Along with the existing receivers at Atibaia, SP, Brazil and at the Antarctic Brazilian station EACF, the new network of VLF receivers will provide a set of measurements on a large scale, and therefore may provide new insights in space sciences and geophysics. In this paper we will discuss the specific scientific objectives of SAVNET and present the actual status of its construction.

Session 13

PROBING THE EARTH-IONOSPHERE WAVEGUIDE

(Chair: J.-P. Raulin)

Friday, 29th September 2006

13:30 – 14:45

Amplitude and phase perturbations on subionospheric VLF signals produced by LEP observed at Belgrade

D. Šulic[1], D. Grubor[2] and V. Žigman[3]

[1]Institute of Physics, Belgrade, Serbia,
[2]Faculty of Mining and Geology, Physics Cathedra, University of Belgrade, Serbia
[3] University of Nova Gorica, Nova Gorica, Slovenia

Amplitude and phase perturbations on subionospheric VLF signals, known as lightning-induced electron precipitation (LEP) effect, are produced by the scattering of VLF radiation from localized ionization enhancement in the nighttime D-region. Variations in amplitude and phase of the VLF signals NAA/24.0 kHz, and GQD/22.1 kHz, due to this effect have been observed and monitored at the Institute of Physics, Belgrade.

We study mid-latitude ionospheric D-region perturbations as detected by VLF signal variations associated with two geomagnetic storms. Three days after the onset of severe geomagnetic storm on 24 August 2005, high number of LEP events (>0.5 dB) has been detected on the GQD/22.1 kHz signal recorded at Belgrade. Fluctuations in the amplitude of VLF signals were first observed in the pre-midnight sector and persisted through the period of few hours after midnight. Unusually high number of LEP events has been detected during nights from 28 August to 04 September 2005. In the same period sporadical LEP events have been detected on the NAA/24 kHz signal as well. A day after the onset of the geomagnetic storm on 10 September 2005 high number of LEP events was detected on GQD/22.1 kHz. During the next three nights numerous LEP events occurred on both paths, GQD-Belgrade and NAA-Belgrade.

By using the numerical program LWPCv21, and by adapting in successive approximations the disturbed ionospheric profiles, we seek to detect the region of enhanced ionization along the GCP.

Probing of night-time lower ionosphere and plasmasphere using lightning generated sferics recorded in the South Pacific Region

S. Kumar, A. Kishore, A. Deo and V. Ramachandran

School of Engineering and Physics, Faculty of Science & Technology, The University of the South Pacific, Suva, Fiji

The lightning generated Extremely Low Frequency (ELF) and Very Low Frequency (VLF) radio signals called tweeks and whistlers are recorded using the lightning detection system under *Word Wide Lightning Location* (WWLL) *Network* at Suva (18.2º S, 178.3º E), Fiji, a low latitude ground wave station in the South Pacific region. These have been used to determine the lower ionospheric electron content and plasmaspheric parameters. A total of 500 tweeks recoded in the time period of 1800-0600 hrs FST during 2003-2004 have been analysed. The value of ionospheric reflecting height (*h*) calculated using waveguide mode theory of electromagnetic wave propagation in the spherical cell Earth-ionosphere waveguide having perfectly conducting boundaries is found to vary from 80-95 km in the night-time. To estimate the electron density at the ionospheric reflection heights i.e. lower ionosphere, we perform a qualitative analysis based on the propagation theory of radio waves in an infinite, collisionless, anisotropic ionospheric plasma (Shvets and Hayakawa, *J. Atmos. Sol.-Terr. Phys.*, *60*, 461, 1998). The electron density (*n)* at the ionospheric reflecting heights is found to vary from 25-110 cm^{-3} in the altitude range of about 4 km over 88 km which agrees quite well with experimental data. This corresponds to a scale height of 1.3 km in terms of usually used exponential electron density profile. The whistler activity at Suva, in general, is rare and sporadic and mostly short dispersion whistlers are observed. We present some of the results on the plasmaspheric parameters derived from exploitation of whistler spectra and discuss possible propagation mechanism of whistlers to this low latitude station.

Session 14

GROUND BASED OBSERVATIONS OF WHISTLER MODE WAVES AND LIGHTNING

(Chair: T. Turunen)

29th September 2006

15:15 – 17:00

The observed polarisation of the ELF-VLF waves in the frequency range of 0.1-8.0 kHz

J. Manninen and T. Turunen

Sodankylä Geophysical Observatory, Sodankylä, Finland

In September-October 2005 a VLF receiver having orthogonal loop antennae was used at L=5.5 in Northern Finland. The receiver was adjusted to pass even the strongest sferics without saturation. High dynamic range was arranged by 24-bit AD conversions and direct digital recording. The polarisation behaviour of ELF-VLF waves becomes accurately measured over a wide frequency band and different propagation modes appear very clearly. Especially the mode-1 cutoff near 1.7 kHz is interesting. At frequencies above 5 kHz the polarisation of sferics is highly linear, but between 1.7 kHz and ≈5 kHz left-hand polarised component appears. Just above the mode-1 cutoff the sferics are almost purely circularly left-hand polarised and the difference between left and right-hand polarised components can exceed 20 dB.

The sferics offer an easy way to check the effects of Earth-ionosphere wave-guide on the propagating ELF-VLF waves. The propagation path is often very long exceeding several thousands of kilometres.

It is not common to consider Earth-ionosphere wave-guide propagation effects for waves entering to this wave-guide from the ionosphere i.e. whistlers, chorus, auroral hiss, magnetospheric line radiation (MLR), certain phenomena relating to power line harmonics, and triggered emissions of various kind. Those waves propagate in the magnetosphere in right-hand polarised whistler mode. In general they are received as right-hand polarised waves having varying level of ellipticity. However, certain phenomena like MLR and power line triggered emissions measured on the ground show left-hand polarisation. In this study examples are shown, which indicate, that in detailed studies the effects of Earth-ionosphere wave-guide must be taken into account when considering the detailed amplitude and polarisation behaviour of waves entering to the ground after magnetospheric and ionospheric propagation. The effects are quite similar to those seen in sferics.

Polar cusp ELF emissions in the initial phase of intense magnetic storms

N. G. Kleimenova and O. V. Kozyreva

Institute of the Physics of the Earth, RAS, Moscow, Russia

The brief revue of the main properties of the polar cusp ELF emissions (known also as "polar chorus") is presented. The daily variations of cusp ELF emissions occurrence, measured by both the polar-orbiting satellites and the ground-based instruments, showed the maximum near local magnetic noon (09-18 MLT). The possible ELF generation mechanisms including the cyclotron instability of quasi-trapped electrons in the so called "minimum B-pockets" are discussed. We analyzed the peculiarity of the polar cusp ELF emissions at South Pole station (Antarctica, $\Phi \approx -75^\circ$, magnetic noon near 14 UT) during several magnetic storms, caused by the interplanetary magnetic cloud. It was found that the ELF cusp emission enhancement is the typical signature of an initial phase of magnetic storms (e.g., the sheath region of a magnetic cloud impact). During the considered intervals the South Pole station was located inside of the auroral oval. Its position was defined by using the OVATION plots [http://sd-www.jhuapl.edu/Aurora/ovation/ovation_display .html]. The ELF emissions suddenly disappeared if the IMF Bz turned to the negative values demonstrating the magnetic cloud leading edge impact (e.g., a main phase of a magnetic storm beginning). As usually, in such intervals the South Pole station location shifted to the polar cap border or into the polar cap. We found the cusp ELF emission enhancement as well in the recovery phase of the magnetic storms after the IMF Bz turning to the positive direction.

This research was supported by the RFBR grant 05-05-64495 and partly by INTAS grant No 03-51-5359.

Dayside polar cusp ELF emissions suppression and night side substorm onset

O.V. Kozyreva and N.G. Kleimenova

Institute of the Physics of the Earth, RAS, Moscow, Russia

The ground ELF data at polar cusp latitudes (South Pole station, Antarctica, Φ´≈-75˚, magnetic noon near 14 UT, 1999 data) have been analyzed. Our results showed that the ELF intensity enhancement was usually observed in the daytime if this station was located inside the auroral oval. For each given time interval we defined the auroral oval position by using the OVATION plots [http://sd-www.jhuapl.edu/Aurora/ovation/ovation_display .html]. We have found that the intensity of the daytime ELF bursts could be suddenly suppressed if a substorm onset started at the night side of the Earth. The Tixi station (Φ´≈65˚, magnetic midnight near 15 UT) was used as an auroral station. This station is located at the night side when the South Pole station is located at the dayside. The observations showed that the polar border of the day time auroral oval may shift to the lower geomagnetic latitudes after the magnetosphere substorm onset, thus the South Pole station position may fall outside of the closed magnetosphere or near its border. We present here several examples of such effects in details. The quasi-periodical variations of the ELF intensity have been studied.

The similar ELF intensity suppression we found also comparing the ELF records at New Ålesund station (Spitzbergen, Φ´≈75˚, magnetic noon near 09 UT, 1977 data) with simultaneous night-side geomagnetic disturbances development at obs. College (Φ´≈65˚, magnetic midnight near 11 UT).

This research was partly supported by INTAS grant No 03-51-5359. We are grateful to Dr. U. Inan for ELF-VLF data at South Pole station.

CANCELLED CONTRIBUTIONS

VLF emissions

R. A. Helliwell

Stanford University

This discussion deals with VLF emissions from the magnetosphere and their spectral properties along with their relations to other features of the magnetosphere and the ionosphere. Although many data have been acquired on emissions, several critically important properties are still the subject of controversy. Of particular interest in this context are the intensities of such emissions, which play a critical role in their function as sources of particle scattering into the ionosphere. Using a sounding rocket frrom Siple Station during the injection of VLF waves into the ionosphere and magnetosphere from the Siple Station VLF transmitter, measurements of both E and B of the injected waves were recorded on the rocket in the F- layer, thus calibrating for the first time the injection efficiency of the Jupiter transmitter. These results were in good agreement with the calculated efficiency of the dipole transmitting antenna. Extrapolating these data from the F-layer (about 300 km in altitude), a reliable estimate of the triggered-emission intensity in the equatorial plane of the magnetosphere could be made. This result provided the calibration factor for the recordings analyzed by E. Paschal in his thesis. From this kind of analysis a comparison can be made for various models including those based on computer simulations. Such a comparison has been made on a preliminary basis and the discrepancies are well beyond what we might regard as reasonable statistical variations. These results provide a new basis for discussing in this meeting the discrepancies noted above.

Extra low frequency electron whistler dispersion law above the hydrogen gyrofrequency

B. Lundin[1] and C. Krafft[2]

[1] *IZMIRAN, Troitsk, Russia*
[2] *University Paris 11, Orsay, France*

An approximate expression for the electron whistler wave dispersion law is derived which is suitable for the frequency domain extending in its lower frequency part almost till the gyrofrequency of the lightest ion. Actually this dispersion law at higher frequencies merges with the modified electron whistler dispersion law which is in turn applicable in the range stretching from the LHR frequency domain in its lower part (where the ion's contributions reduce to a single parameter, the LHR frequency value) and extending up to a much higher frequency domain where the contribution of ions is negligible. The law is applicable when a displacement current component parallel to the background magnetic field can be neglected, i.e. in the frequency band much lower than the electron plasma frequency; however, the electron gyrofrequency can even exceed the plasma frequency. This case particularly can be realized in the near Earth plasma at altitudes of transition domain from the lightest ions' to more heavy ions' prevalence, i.e. typically at altitudes of few thousand kilometres above the Earth.

The new dispersion law uses as input the four background plasma parameters: the electron gyrofrequency, the electron plasma frequency, the LHR frequency and the relative content of the lightest ion. The data of upward ray-tracing governed by the total cold plasma dispersion law for the wave frequency of 300 Hz starting at the altitude of 1400 km have been fitted well using the extra low frequency dispersion law. The relative hydrogen content varies here from 0.02 at the altitude of 1400 km till almost 1 at 2500 km.

Upper hybrid resonance waves versus VLF chorus as possible drivers of relativistic electron precipitations

D. Shklyar[1] and B. Kliem[2]

[1] IZMIRAN, Troitsk, Moscow Region, Russia
[2] AIP, Potsdam, Germany

Relativistic electron precipitations from the magnetosphere observed on low-orbiting satellites are discussed, and a new mechanism for these precipitations is suggested. It consists in energetic electron scattering into the loss cone due to higher-order cyclotron resonance interaction with intense narrow-band upper hybrid waves frequently observed outside the plasmapause. We compare this mechanism with previously considered scattering of relativistic electrons by whistler-mode chorus and show that the new mechanism is more efficient. A new aspect in the developed theory is the calculation of particle diffusion coefficient in the case of a wide wavenumber spectrum, with the account of plasma inhomogeneity and relativistic effects. Calculations include the determination of the effective resonant spectral width and the time of resonant interaction for relativistic particles. We show that relativistic electrons have a preference over lower energy electrons from the viewpoint of the number of cyclotron resonances that a particle crosses during each bounce period. This factor competes with the larger inertia of more energetic particles. As the result, electron scattering peaks in the range of near-relativistic to relativistic energies. We discuss other features of the proposed mechanism, and compare the results with observations, which reveals pro and con of suggested model.

The influence of 3D inhomogeneities on an underlying surface calculation in the problem of point source field in the Earth-ionosphere waveguide

O. V. Soloviev and V. I. Ivanov

St. Petersburg State University, St. Petersburg, Petrodvoretz, Russia

The study is concerned to development of methods of calculation VLF and LF electromagnetic field at presence of 3D inhomogeneities on the Earth's surface or in the lower ionosphere. The surface impedance concept is used to model non-uniform Earth-ionosphere waveguide and a parallel-plate model is adopted whose boundaries for transmitter receiver path lengths less than 2000 km. The electro-dynamical problem to be considered is radiation of electric dipole in the three-dimensional domain bounded by the surfaces S_g and S_i characterized by impedance δ_g and impedance tensor $\hat{\delta}_i$, respectively. One of the walls is considered as inhomogeneous, when the problem is reduced to integral equation for Hertz's vector component over this unbounded surface. Using asymptotic ($kr >> 1$) high-precision integration along the transverse to the propagation path direction, we evaluate the contribution in the full field of the surface areas situated beyond some number (ten and more) of Fresnel zones, in the form of one-dimensional integral over external boundary of greatest Fresnel zone. As a result of transformation we obtain the combination of surface and contour integral equation over spatially limited domain (not infinite integral). This last one may be evaluated numerically. The results of VLF point source field diffraction in different waveguide models will be presented.

List of participants (preliminary)

Prof. Peter Bespalov
email: peter@appl.sci-nnov.ru
Institute of Applied Physics,
Russian Academy of Sciences
Nizhny Novgorod
Russia

Dr. Jacob Bortnik
email: jbortnik@gmail.com
University of California
Los Angeles
USA

Dr. Tilmann Bösinger
email: tilmann.bosinger@oulu.fi
University of Oulu
Oulu
Finland

Prof. Donald Carpenter
email: dlic@nova.stanford.edu
Stanford University
Stanford
USA

Dr. Jaroslav Chum
email: jch@ufa.cas.cz
Institute of Atmospheric Physics
Prague
Czech Republic

Dr. Mark Clilverd
email: macl@bas.ac.uk
British Antarctic Survey
Cambridge
UK

Dr. Andrei Demekhov
email: andrei@appl.sci-nnov.ru
Institute of Applied Physics, RAS
Nizhny Novgorod
Russia

Dr. Carl-Fredrik Enell
email: carl-fredrik.enell@sgo.fi
Sodankylä Geophysical Observatory
Sodankylä
Finland

Prof. Davorka Grubor
email: davorkag@rgf.bg.ac.yu
Faculty of Mining and Geology,
University of Belgrade
Belgrade
Serbia

Mr. Mikhail Gushchin
email: mguschin@appl.sci-nnov.ru
Institute of Applied Physics, RAS
Nizhny Novgorod
Russia

Dr. Richard Horne
email: R.Horne@bas.ac.uk
British Antarctic Survey
Cambridge
UK

Prof. Umran Inan
email: inan@stanford.edu
Stanford University
Stanford
USA

Dr. Yuto Katoh
email: yuto@pparc.geophys.tohoku.ac.jp
Tohoku University
Sendai
Japan

Mr. Manfred Kerckhoff
email: kerckhoff@uni-bremen.de
Institute of Adult Education
Bremen
Germany

Mr. Antti Kero
email: Antti.Kero@sgo.fi
Sodankylä Geophysical Observatory
Sodankylä
Finland

Prof. Natalia Kleimenova
email: kleimen@ifz.ru
Institute of the Earth Physics, RAS
Moscow
Russia

Dr. Boris Kozelov
email: kozelov@pgi.kolasc.net.ru
Polar Geophysical Institute
Apatity
Russia

Dr. Olga Kozyreva
email: kozyreva@ifz.ru
Institute of the Earth Physics, RAS
Moscow
Russia

Mr. Johannes Kultima
email: Johannes.Kultima@sgo.fi
Sodankylä Geophysical Observatory
Sodankylä
Finland

Dr. Sushil Kumar
email: kumar_su@usp.ac.fj
School of Engineering and Physics
Suva, NA
Fiji Islands

Dr. János Lichtenberger
email: lityi@sas.elte.hu
Eötvos University
Budapest
Hungary

Dr. Jyrki Manninen
email: Jyrki.Manninen@sgo.fi
Sodankylä Geophysical Observatory
Sodankylä
Finland

Ms. Agnes Mika
email: agnes@physics.uoc.gr
University of Crete
Heraklion
Greece

Mr. Frantisek Nemec
email: nemec@matfyz.cz
Charles University
Praha
Czech Republic

Prof. David Nunn
email: dn@ecs.soton.ac.uk
University of Southampton
Southampton
UK

Dr. Michel Parrot
email: mparrot@cnrs-orleans.fr
CNRS, LPCE
Orleans
France

Dr. Dmitry Pasmanik
email: pdl@aurora.appl.sci-nnov.ru
Institute of Applied Physics, RAS
Nizhny Novgorod
Russia

Mrs. Anna-Liisa Piippo
email: anna-liisa.piippo@sgo.fi
Sodankylä Geophysical Observatory
Sodankylä
Finland

Mr. Tero Raita
email: Tero.Raita@sgo.fi
Sodankylä Geophysical Observatory
Sodankylä
Finland

Dr. Jean-Pierre Raulin
email: raulin@craam.mackenzie.br
Presbyterian Mackenzie University
São Paulo SP
Brazil

Dr. Yuval Reuveni
email: yuval_edna@yahoo.com
Tel-Aviv University
TEL-AVIV
Israel

Dr. Craig J Rodger
email: crodger@physics.otago.ac.nz
University of Otago
Dunedin
New Zealand

Prof. Michael Rycroft
email: michael.j.rycroft
@caesarconsultancy.com
CAESAR Consultancy
Cambridge
UK

Dr. Ondrej Santolik
email: os@matfyz.cz
Charles University
Prague
Czech Republic

Ms. Antonio Saraiva
email: antonio@craam.mackenzie.br
Instituto Nacional de Pesquisas
EspaciaisSao Jose dos Campos
Brazil

Ms. Annika Seppälä
email: annika.seppala@fmi.fi
Finnish Meteorological Institute
Helsinki
Finland

Dr. Sergei L. Shalimov
email: shalimov@ifz.ru
Institute of Physics of the Earth
Moscow
Russia

Mr. Péter Steinbach
email: steinb@sas.elte.hu
Eötvos University
Budapest
Hungary

Dr. Desanka Sulic
email: dsulic@phy.bg.ac.yu
Military Academy, Physics Cathedra
Belgrade
Serbia

Dr. Elena Titova
email: lena.titova@gmail.com
Polar Geophysical Iinstitute
Apatity, Murmansk region
Russia

Prof. Igor Tolstikhin
email: tolstikin@yahoo.com
Geological Institute
Apatity, Murmansk region
Russia

Dr. Esa Turunen
email: esa.turunen@sgo.fi
Sodankylä Geophysical Observatory
Sodankylä
Finland

Prof. Tauno Turunen
email: Tauno.Turunen@sgo.fi
Sodankylä Geophysical Observatory
Sodankylä
Finland

Dr. Thomas Ulich
email: Thomas.Ulich@sgo.fi
Sodankylä Geophysical Observatory
Sodankylä
Finland

Dr. Pekka Verronen
email: pekka.verronen@fmi.fi
Finnish Meteorological Institute
Helsinki
Finland

Prof. Vida Zigman
email: vida.zigman@p-ng.si
University of Nova Gorica
Nova Gorica
Slovenia

ISBN 951-42-6053-8 (paperback)
ISBN 951-42-6054-6 (pdf)
ISSN 0359-3657