IAGA/ URSI Joint Working Group on

# VLF/ELF Remote Sensing of Ionospheres and Magnetospheres Newsletter

**Editor:** Craig J. Rodger No. 19, December 2004

Dear Colleagues,

Normally this would have been a relatively quiet year for the VERSIM working group, as neither IAGA nor URSI held large-scale meetings. However, the *VLF Workshop 2004* which took place in September at the Sodankylä Geophysical Observatory was supported by the VERSIM IAGA/URSI joint working group, and attracted a large part of the VERSIM community. A report on this meeting can be found on the VERSIM website (*www.physics.otago.ac.nz/versim*). At the end of the 2004 Workshop it was felt that the meeting had been a large success, providing a fresh venue for the VLF community to gather and exchange information. After discussions amongst the participants, it was decided to run another workshop in 2006 (as no URSI or IAGA meetings will take place that year), with the possibility of the VLF Workshop becoming a "standard" feature of our scientific community. I hope to see this meeting develop into a regularly held VERSIM Workshop, reflecting the activities and interests of our community.

Last year the VERSIM website and email listing were transferred to New Zealand. Over 2004 we have had a significant problem with spam-email being sent to the mailing list. I apologise for the IT problems which delayed the VERSIM email list becoming moderated (which continue). However, I am pleased to report that the spam-filtering at the University of Otago has vastly improved lately, and you should receive much less junk through our mailing list.

Over 2004 the IAGA newsletter has become a regular feature of communications inside the IAGA community. I'd like to encourage VERSIM members to read these newsletters, which provide a new way of getting information out to scientists in one of the wide groupings we are a part of. The latest IAGA newsletter is placed at the IAGA website (*http://www.iugg.org/IAGA/)*.

2005 will be a big year for VERSIM members, with both the IAGA Scientific Assembly and the URSI General Assembly scheduled for next year. VERSIM business meetings will take place at both meetings, and I hope to see many of you there (travel funding willing for all of us, of course!). The deadline for abstract submissions is early in 2005 for both meetings, so start thinking about your presentations now. Links to the websites for both the IAGA and URSI Assembly's are on the VERSIM website.

There is an important deadline is coming up associated with the URSI General Assembly in New Delhi: URSI Young Scientist Award Applications close on 15 January 2005. Younger members of VERSIM will hopefully be aware that URSI Commission H covers waves in plasmas, while Commission G covers ionosphere and radio. Young Scientists are defined as scientists under the age of 35 years old on 1 September 2005. Award recipients will be entitled to free registration, free lodging and a given amount of money to cover most of their daily expenses in New Delhi. There is also normally a social event for the Young Scientists. More information, application forms, and how to apply can be found on the URSI web site (*http://www.ursiga2005.org/*). I have been lucky enough to be an URSI Young Scientist in the past, and can highly recommend the programme. Would anyone in your group meet the requirements?

I hope the New Year finds you prosperous, productive, and well. Looking forward to seeing you at one of the conferences in 2005! Best wishes to you all.

Craig J. Rodger
IAGA co-chair VERSIM working group

## *Forthcoming meetings*

- *AGU Fall Meeting*, San Francisco, USA, 13-17 December 2004.
- *Workshop on Energetic Electron Radiation Belt Dynamics*, Hermanus, South Africa, 7-11 March 2005.
- ***IAGA 2005* Toulouse, France, 18-29 July 2005. [VERSIM business meeting Thursday 21 July 2005]**
- ***URSI 2005* New Delhi, India, 23-29 October 2005. This meeting is to include a VERSIM session, " ULF, ELF, and VLF impacts on the radiation belts"**
- *AGU Fall Meeting*, San Francisco, USA, 5-9 December 2005.

## Reports from VERSIM research groups 2004

This based on information received by the IAGA co-chairman, Craig Rodger, by email from the VERSIM membership. It has been necessary to trim a number of reports. Where-ever possible the full report is available from the VERSIM website, as listed.

**Czech Republic** Jaroslav Chum (Institute of Atmospheric Physics) reported on the activities taking place in the Department of the Upper Atmosphere. They have primarily focused on obliquely propagating whistler mode waves with experimental data mainly from the MAGION 5 satellite. The recorded wave phenomena have been compared with the results of numerical simulations done by means of ray tracing method. Their interests are both the propagation of lightning induced whistlers that undergo magnetospheric reflection and the properties and propagation of chorus emissions generated in the process of wave particle interaction near the plane of magnetic equator.

They are going to continue the investigation of the wave propagation in the inner magnetosphere based on satellite measurements and numerical simulations. The Czech group also wishes to renew the use of ground-based ELF/VLF. The two magnetic component receiving station is currently under development, with data processing planned in collaborations with Hungarian colleagues from Eötvös University. Examples of the recent main results of their work on Magnetospherically Reflected (MR) lightning-induced whistlers, nonducted propagation of chorus emissions, and references to recent publications can be found in full report, which contains additional details, research conclusions available here (*www.physics.otago.ac.nz/versim/ Czech_report_2004.pdf*).

D.R. Shklyar, J. Chum, and F. Jiricek. Characteristic properties of Nu-whistlers as inferred from observations and numerical modeling. *Annales Geophysicae*, V. 22, N10, pp. 3589-3606, 2004.

Chum J., Jiricek F., Smilauer J., and Shklyar, D.: Magion 5 observations of chorus-like emissions and their propagation features as inferred from ray-tracing simulation, Annales Geophysicae (2003) 21: 2293-2302, European Geosciences Union

**France** Michel Parrot (LPCE/CNRS) provided the following report:

The DEMETER micro-satellite has been launched on June 29, 2004 by a Dnepr rocket from Baïkonour. The plate-form is under the CNES responsibility and the scientific payload was provided by scientific laboratories. The scientific objectives of the DEMETER micro-satellite are related to the study of ionospheric perturbations in relation with the seismic and volcanic activities. These perturbations are interesting because they can be considered as short-term precursors (they occur between a few hours and a few days before a quake). The same payload will allow a survey the ionospheric perturbations in relation with man-made activities. The scientific payload of the DEMETER micro-satellite has several experiments:

-A set of electric sensors to measure the 3 components of the electric field from DC to 3.5 MHz,

-A three orthogonal search coil magnetometer to measure the magnetic field from a few Hz up to 18 kHz,

-Two Langmuir probes to measure the density and the temperature of the electrons,

-An ion spectrometer to measure ion composition,

-An energetic particle analyzer.

The orbit of DEMETER is polar, circular with an altitude of 710 km. DEMETER record data in two modes: a survey mode all around the Earth with low resolution, and a burst mode with high resolution above main seismic zones.

Following an AO from CNES, about thirty scientific teams throughout the world (Greece, India, Italy, Japan, New Zealand, Russia, USA, …) will participate to the DEMETER mission. Their main interests are:

-to compare ground-based data and DEMETER data,

-to search for anomalies in a multi-parameter data set by artificial intelligence method,

-to perform active experiments.

Concerning the former point, attempts have already been done with the HAARP transmitter in Alaska and with the electrical network of Dunedin (NZ).

**Greece** Christos Haldoupis and Ágnes Mika (University of Crete) have made use of data from a fully automatic narrow-band VLF receiver installed in Crete as part of the 'Coupling of Atmospheric Layers" (CAL) Research Training Network (RTN), supported by the European Union. This is a 4-year project that started in 2002, in which there are 11 members from various European Research Institutes and Universities (http://www.dsri.dk/cal/). The purpose of CAL-network is to pursue basic research and train young scientists, both at post- and pre-doctoral level, on the physics of thunderstorm related phenomena observed in the upper atmosphere and ionosphere.

In 2004 their research effort focused on the analysis and interpretation of narrow- and broad-band VLF recordings in relation with sprite occurrences detected during *EuroSprite-2003*. In this campaign, various instruments were deployed in southern Europe and at magnetically conjugate locations in South Africa, which collected data concurrently with the detection of more than 130 sprites during 10 different storms. A summary of their findings from *EuroSprite-2003*:

The receiver in Crete observed early VLF perturbations in nearly one-to-one association with the sprites arriving over a great circle path that cut through the storms to the southeast. While part of the sprite-related VLF perturbations were of the early/fast type, many classified as "early/slow" having onset durations up to ~2 s and thus suggesting a new mechanism at work which may cause a slow build up of ionization after a sprite. The only elve in the data set was found to associate also with an early/fast VLF perturbation. No early VLF events occurred in relation to the numerous ±CG discharges that did not lead to sprites. Bandpass filtering of a broadband VLF signal from a receiver located to the northwest of the sprite producing storms, revealed that only 10% of the sprites showed wide-angle scatter, concurrently with the much stronger Crete VLF events caused by forward scatter. Finally, a limited number of early VLF perturbation events relating to sprites were also associated with whistler-induced electron precipitation events, or classic Trimpi perturbations, undoubtedly produced by the precipitation of electrons due to whistler-mode waves injected into the magnetosphere by the same lightning flash that led to the production of the sprite.

The full report, containing a more detailed account of their efforts, conclusions and the publications in which they are reported is available from (*www.physics.otago.ac.nz/versim/ VERSIM_UCrete_2004.pdf*).

**Hungary** The Space Research Group of Department of Geophysics, Eotvos University, Budapest, Hungary made the following activities in 2004:

1. The automatic whistler detector system runs now at Tihany non-stop since February 2002 and at Nagycenk since mid-2003. They collect whistler traces in the order of 100.000 per year. The automatic analyzer systems that is planned to analyze the traces caught by the detector system is still in development phase. Continuous Omnipal narrow-band VLF recordings at three different locations (Budapest, Erd, tihany) have been continued. Theoretical works have been done on full-wave solution of Maxwell's equation for Earth-Ionosphere waveguide. It describes the mode propagation of sherics resulting tweeks.
2. The new generation of Signal Analyzer and Sampler equipment developed by the group (SAS-2 and -3) will be launched soon on KOMPASS-2 satellite and set up on ISS inside OBSTANOVKA experiment. KOMPASS-2 is in preflight calibration phase, while OBSTANOVKA should reach this phase in mid-2005.

**India** Birbal Singh (R.B.S.College) has provided a detailed report on his groups activities, primarily based at their Bichpuri, Agra campus (Geomag. Lat. 17.1º N, $L$=1.15). A new PC based whistler recording and analyzing set up has been developed at Agra which has replaced the conventional analogue system consisting of tape recording and digital sonagraph based analysis. This extends the 40-year history of whistler observations in India. The new system is simple, inexpensive, and automatic. It employs an antenna, amplifier, a sound card, and a PC loaded with software. It is expected that the current program of ground based low latitude whistler observations at Agra in coordination with DEMETER satellite observations will yield some new results about the structure and dynamics of the low latitude ionosphere. The group has been designated USER-1 category for utilizing DEMETER satellite data for studies in the field of space science and seismo-electromagnetics. Dr. Birbal Singh and his research students were invited to discuss seismo-electromagnetics with the President of India in October, 2004, an honour for this group!

A collaborative study of phase and amplitude variation of 24 kHz sub-ionospheric VLF transmitter signals monitored simultaneously at Budapest (Lat. $47.5^0$N, Long. $19.17^0$E), Hungary and Agra (Lat. $27.2^0$N, Long. $78^0$E), India has been carried out. This has produced observations of sunrise variations in the *D*-region, and geomagnetic storm effects. Ionosonde observations of ionospheric changes have also been observed prior to 6 major earthquakes.

The group is to undertake a new project entitled "Wave-particle interaction and precipitation in the low latitude ionosphere", over a period of three years.

The full report, which contains additional details, research conclusions and collaborations, and recent publications, is available here (*www.physics.otago.ac.nz/versim/VERSIM_2004_India_Agra.pdf*).

**Japan** Tadanori Ondoh (Space Earth Environment Laboratory) reports that he presented a paper at session D3.5 (Boundary Layers, Waves and Non-linear Dynamical Processes) during the 35th COSPAR Scientific Assembly in Paris. The magnetospheric VLF hiss observed by a low altitude polar orbiter represents integrated spectra of whistler mode VLF hiss waves propagating along geomagnetic field lines from wide-altitude sources in the magnetosphere. We investigate latitudinal changes of the magnetospheric VLF hiss associated with magnetospheric processes in geomagnetic quiet and disturbed periods by using VLF hiss intensity data at 6 frequency narrow-bands processed from VLF electric field (50 Hz -30 kHz) data of ISIS-2 (1400 m altitude) polar orbiter. The magnetospheric VLF hiss observed by the ISIS-2 mainly consists of a broad-band polar hiss and narrow-band plasmapause hiss. The polar hiss is due to whistler mode Cerenkov emissions in the polar magnetosphere generated from inverted-V electrons (100 eV -40 keV) precipitating from the plasma sheet boundary layer. The plasmapause hiss is also whistler-mode waves excited by the cyclotron instability of energetic electrons convected inward from the magnetotail.

In a geomagnetically very quiet period, only a plasmaspheric ELF hiss and diffused whistlers appear at invariant latitudes below 73º. The broad-band polar hiss and narrow-band plasmapause hiss (or LHR hiss) occur respectively at night-side invariant latitudes from the middle of the auroral zone to the polar cap and for nighttime invariant latitudes of 50º- 64º in a quiet or weakly disturbed period. In a substorm period, the polar hiss region shifts to lower latitudes due to an inward movement of the plasma sheet inner edge associated with an intensified substorm westward electric field in the magnetotail. Also, an island of the plasmapause hiss appears between regions of the polar hiss and plasmapause hiss on the night side in a lingering substorm period. This seems to correspond to a plasmaspheric plume outside the night-time plasmapause. As the substorm develops in the expansion phase, the polar hiss region finally joins to the plasmapause region.

**Russia** David Shklyar (IZMIRAN) reported on joint work undertaken with the Institute of Atmospheric Physics in the Czech Republic. His report:

Numerical modelling of VLF spectrograms related to lightning-induced emissions is becoming a new line in studies of whistlers in the magnetosphere. However, most of work in this direction was based on intuitive ideas, rather than on well grounded concepts. This limited the numerically simulated spectrograms to an interesting and useful illustration of real ones. To make numerical simulation a powerful and reliable tool in the ionospheric and magnetospheric studies, the approach to numerical modelling has been substantiated, and the frame of validity of the method has been clarified. The points explicated include: the way of construction the frequency-time plots on spectrograms, i.e. finite-width curves on which the spectral intensity differs from zero; and determining the time-dependent spectral amplitude as a function of frequency and time from the wave packet amplitude, with the account of the evolution of the latter in space and time. Special attention has been given to the wave packet spreading in the course of propagation. The developed method has been applied to the analysis of Nu whistlers basing on the observations by the MAGION 5 satellite. With the information from this numerical modelling, it becomes possible to distinguish the characteristics of the spectrograms that depend on the site of the lightning strokes from those determined mainly by the position of the satellite. This leads to identification of the region in the magnetosphere where Nu whistlers should be observed most often, and the geomagnetic conditions favouring their appearance. The results of this study is published in:

D.R. Shklyar, J. Chum, and F. Jiricek. Characteristic properties of Nu-whistlers as inferred from observations and numerical modeling. *Annales Geophysicae*, V. 22, N10, pp. 3589-3606, 2004.

**Serbia & Montenegro** D. Šulić & D. Grubor (Inst. of Phys.)
**Slovenia** Vida Žigman (Nova Gorica Polytechnic)
Together, this team provided a joint report on AbsPAL narrow-band recording VLF observations undertaken from the Institute of Physics Belgrade, continuously since installation in September 2003. Over 2004 the working group using this AbsPAL receiver has compiled data bases of amplitude and phase disturbances of stable VLF signals from transmitters: NAA Cutler, Maine, 24 kHz; NWC Australia, 19.8 kHz, Authorn, 22,1 KHz. Observations have revealed both longer- and shorter-time scale disturbances, identified as solar-flare- and lightning- induced, respectively.

On the grounds of monitored data, we have been able to link VLF amplitude and phase disturbances to GOES satellite X-ray flux magnitudes. These lead to long time-scale VLF amplitude and phase disturbances with delay times around ~20-45 min, manifest enhancements of D region electron densities caused by solar flares. The team has gone on to contrast their observations with the computer LWPC- Long Wave Propagation Capability (LWPC) programme of NOSC, modified to the particular receiver conditions.

The full report, which contains additional details, research conclusions, figures, future projects, and recent publications, is available here (*www.physics.otago.ac.nz/versim/Versim04_Report_Vida.pdf*).

**Sprite Summer School** The NATO Advanced Study Institute on "Sprites, Elves and Intense Lightning Discharges" was held in Corte, Corsica from 24-31 July 2004. The Summer School was primarily funded by NATO and the European Science Foundation, with the intention that it is to be a true teaching environment providing opportunity for people to come along to get an understanding of the interlinked but disparate scientific areas relevant to this field of study. The framework of the NATO ASI provided a unique chance for leaders in the field and young researches to work in close cooperation. It was concluded that more extensive experimental and theoretical work is needed for a complete understanding of TLE phenomena and their long-lasting effects in the atmosphere and in the ionosphere. Extensive discussions revealed new perspectives and directions for future investigations in this field of research.

VERSIM members participated widely in the Summer School. Some of the community were present as "experts" (particularly in the ULF/ELF/VLF remote sensing sessions), providing lectures and practical sessions while others attended as students. Nonetheless, a great deal was learnt by all! The NATO ASI is to lead to a published book, summarizing the state of the field from the various speakers, which will probably be useful for many of the VERSIM community. Full report: at (*www.physics.otago.ac.nz/versim/arwasi-general-short.pdf*)

**New Zealand** Craig Rodger and Neil Thomson (University of Otago) report an active year. The group has focused on electron and proton precipitation and solar flare studies. Both the effects on the ionosphere and the implications of the precipitation as a loss mechanism from the radiation belts have been investigated by experimental and theoretical studies. Strong collaborative research has been undertaken, particularly with the British Antarctic Survey, Southampton University, and LF*EM Ltd.

The group is still undertaking long term recordings with Neil Thomson's Doppler experiment which runs every night plus continuous OmniPal/AbsPal narrowband recordings looking at transmitters in our region. In addition the group has made campaign based wideband VLF recordings with the IMAGE satellite, and is attempting an active experiment with the DEMETER satellite.

Of particular note are the results of VLF studies into solar flares and there effects on the ionosphere particularly the *D* region. The largest solar flare every observed to date occurred on 4 November 2003, saturating the X-ray detectors on the GOES satellites. On the basis of the overloaded observations this flare was estimated to be a X28-class. However, studying the effects that the flare had on VLF signals propagating under the flare-modified ionosphere, a new measurement has indicated this event was in fact X45 ± 5. This study was published in GRL, and was accompanied by world wide publicity:

Thomson, N R, C J Rodger, and R L Dowden, Ionosphere gives size of greatest solar flare, *Geophys. Res. Lett.*, 31(6), L06803, 10.1029/2003GL019345, 2004.

Craig Rodger would like to draw the communities attention to recent papers using "Trimpi" VLF perturbation observations to describe the significance of energetic electron losses from the inner radiation belts. The group's publication listing for 2004 (and before) can be found at its website: *www.physics.otago.ac.nz/research/space/spacehome.html*

Richard Dowden's (LF*EM Ltd.) VLF lightning detection consortia, the World Wide Lightning Location network is still growing. There are currently 20 partner institutions in this network, with future stations planned in Peru, Puerto Rico and Agentina. The network is growing quite quickly and quite successfully, and provides real-time practical data. In the last year there have been much attention to the location accuracy of the network, and several papers have appeared. The Israeli sprite hunting experiment during the STS107 mission made use of the web based lightning maps from this network to orient the shuttle towards probable thunderstorm locations, as described in recent publications from that group. Currently historic data access is available to the hosts, and other institutions should discuss data access with the Prof. Bob Holzworth of the University of Seattle. Current real-time lightning maps are available on the web (*http://flash.ess.washington.edu/*). A joint study into the detection efficiency of the network is planned.

**UK** British Antarctic Survey report from A.J. Smith and M.A. Clilverd

Synoptic broadband VLF recordings at Halley station, Antarctica ($L$=4.3), using Digital Audio Tape, have continued on a 1-minute-in-15 synoptic schedule, with occasional recordings at 1-minute-in-15 or continuous.

Continuous (since 1992) recordings of VLF activity in 10 ELF/VLF bands, at 1-s resolution (VELOX), including spheric counters, have continued at Halley. More than a whole solar cycle of data (1992-2003) is now available.

1-s resolution data are available on the Web using the BAS Data Access & Browsing System (DABS) *http://dabs.nerc-bas.ac.uk/*

Daily summary plots 1992--2003 are on the Web at: *http://www.nerc-bas.ac.uk/uasd/data/dataserv.html*

A narrow-band tunable receiver at Halley is tuned to 19.4 kHz to receive the transmissions from the South Pole beacon. The narrow band receiver "OmniPAL" is operating at Sodankyla, Finland (Oct 2002 – June 2003, Oct 2004 - present), and Ny Alesund, Spitzbergen (since June 2003). Northern hemisphere transmitters in Europe and USA are being received at 0.1-1.25 sec resolution.

A VLF Doppler receiver has continued to operate at Rothera station, Antarctica ($L$=2.8), receiving whistler mode and subionspheric signals from NAA. In 2004 it has also been used to monitor the South Pole Beacon transmissions at 19.4 kHz with 1 second resolution.

AGOs (Automatic Geophysical Observatories) programme: VELOX receivers on A80 ($L$=6.3) and A84 ($L$=8.1) have continued to operate through 2004. A80 is planned to close at the end of the year. A84 will continue long-term.

A latitudinal chain of VELOX receivers (VELOXnet), aimed at substorm research using SCEs (substorm chorus events), has been deployed in both hemispheres; in addition to Halley, receivers are operating at Sodankyla (Finland), Casey station (Antarctica) and Churchill (Canada). For details, see: *www.antarctica.ac.uk/BAS_Science/Programmes/MRS/Substorms/veloxnet/index.html*

**USA** Augsburg College report from Mark Engebretson:

Mark Engebretson (Augsburg College) reported that has been collaborating with Andy Smith (British Antarctic Survey) and the Stanford VLF group, making comparisons between ULF and VLF emissions. Their statistical and case study of QP and PE emissions observed at multiple Antarctic ground stations has been published as:

Engebretson, M. J., J. L. Posch, A. J. Halford, G. A. Shelburne, A. J. Smith, M. Spasojevic`, U. S. Inan, and R. L. Arnoldy, Latitudinal and seasonal variations of quasiperiodic and periodic VLF emissions in the outer magnetosphere, *J. Geophys. Res*., 109, A05216, doi:10.1029/2003JA010335, 2004.

Stanford University report from Bob Helliwell:

My activities have been mainly directed to finishing a book on the VLF wave injection experiments performed at Siple Station over the period 1973-1988, shortly after which the station was closed by NSF as a result of safety concerns connected with excessive ice loading on the station arch (which had become completely buried by ice). Many of these results had already been published (mostly in JGR and GRL). This new book, to be published by Cambridge University Press, brings all of the Siple WIF (wave injection facility) data together in one place where they can be compared and interpreted. The results of this inter-comparison provide some clear answers to the basic questions of what generates emissions and why there is disagreement among workers in the field as to the explanation of the observations.

UCLA report from Richard M. Thorne:

Over the past year we have been working on the scattering of electrons by VLF waves causing either precipitation loss or local acceleration. This has been a collaborative effort by a number of people and has lead to the following publications:

1) D. Summers, C. Ma, N. P. Meredith, R. B. Horne, R. M. Thorne, and R. R. Anderson, Modeling outer-zone relativistic electron response to whistler-mode activity during substorms, *J. Atmos. Sol. Terr. Phys*., 66, 133, 2004.

Paper uses CRRES wave data to evaluate energy diffusion rates and model electron acceleration during extended substorm activity.

2) Y. Shprits and R. M. Thorne, Time dependent radial diffusion modeling of relativistic electrons with realistic loss rates, *Geophys. Res., Lett., 31, doi:10.1029/2004GL019591, 2004.*

*Paper s*hows that when realistic rates of loss are included, radial diffusion cannot account for observed electron enhancements: a local acceleration source is also required.

3) M. P. Meredith, R. B. Horne, R. M. Thorne, D. Summers, and R. R. Anderson, Substorm dependence of plasmaspheric hiss, *J. Geophys. Res*., 109, A06209, doi:10.1029/2004JA010387, 2004.

Paper demonstrates the dependence of hiss amplitudes on geomagnetic activity and suggest implications for wave excitation and electron scattering.

4) R. B. Horne, R. M. Thorne, S. A. Glauert, J. M. Albert, N. P. Meridith, and R. R. Anderson., Timescales for radiation belt electron acceleration by whistler mode chorus waves, *J. Geophys. Res.,* submitted, 2004.

Paper evaluates the timescale for local acceleration based on statistical properties of chorus emissions seen on CRRES.

5) R. M. Thorne, R. B. Horne, S. A. Glauert, N. P. Meredith, Y. Y. Shprits, D, Summers, and R. R. Anderson, The influence of wave-particle interactions on relativistic electron dynamics during storms, AGU monograph, *Global Physics of the Coupled Inner Magnetosphere*, in press, 2004.

A review of the role of VLF waves on relativistic electrons based on an invited paper at the Yosemite meeting.

6) R. M. Thorne, T. P. O'Brien, Y. Y. Shprits, D. Summers, and R. B. Horne, Timescale for MeV electron microburst loss during geomagnetic storms, *J. Geophys. Res*., submitted, 2004.

Paper evaluating the loss rate of MeV electrons during resonant interactions with chorus microbursts. Loss time fall to a day during the main phase of a storm but are longer in the storm recovery when local acceleration can dominate.

I've also recently started to look at the role of VLF wave scattering during Co-rotating Interaction Regions triggered by fast solar wind storms. Plan to give a talk on this at the meeting next year in Brazil.

**Participants of the VLF Workshop 2004 the Sodankylä Geophysical Observatory (27 September – 1 October 2004).**