IAGA/ URSI Joint Working Group on

VLF/ELF Remote Sensing of Ionospheres and Magnetospheres Newsletter

Editor: Craig J. Rodger No. 21, December 2006

Dear Colleagues,

Normally, we would have expected 2006 to be a quieter year for the VERSIM community, as neither IAGA nor URSI was scheduled to hold assemblies. However, noting this hole in our timetables, we agreed in 2004 to hold the 2nd VERSIM Workshop in 2006. This was hosted by the Sodankylä Geophysical Observatory in Lapland, Finland in September. The workshop was sponsored by the Observatory and supported by IAGA and URSI Commission H. I am grateful to those organisations for making the workshop possible, and indeed, such a success. There were 46 participants attending from 16 countries, ranging from Fiji and Slovenia all the way in scale-size to Brazil and the USA. Together, a total of 52 presentations occurred – 40% more than the first workshop in 2004. The 2nd VERSIM Workshop showed our community in good heart, including 9 young researchers as well as real pioneers in our field. We were proud to welcome Don Carpenter, who is in a real sense the "father of VERSIM", as well as four of the previous six VERSIM co-chairs, and both the current co-chairs (Rodger (New Zealand) and Lichtenberger (Hungary)). There were a particularly strong series of presentations on remote sensing of the upper atmosphere through subionospheric VLF propagation and on the properties and effects whistler mode waves observed on the ground and in space, particularly focused on VLF chorus emissions. A full listing of abstracts can be found at:

http://www.sgo.fi/Events/versim-2006/abstracts.php

Many of you will be aware that the IAGA support for the workshop included a prize for the best presentation by a young scientist. This award provides support to participate in the next IAGA Assembly and was awarded to Ms. Annika Seppälä, a Research Scientist at the Finnish Meteorological Institute. I'd like to congratulate Annika again, but also note that the Workshop Programme Committee had to struggle to decide between so many strong candidates. Thanks to all the young researchers who showed such high quality work at the Workshop.

Next year both IAGA and URSI will have major meetings. The primary will be the 24th General Assembly of the International Union of Geodesy and Geophysics (IUGG), which encompasses IAGA, to be held in Perugia, Italy, over 2-13 July 2007. The IAGA assembly is in the first week from Sunday 1 July (business meetings) to Saturday 7 July 2008. While URSI will not meet in a full general assembly, there is to be a major regional meeting, with the Asia Pacific Radio Science Conference (AP-RASC) heading to Perth, Australian from 17 - 20 September 2007.

There are of course more meetings planned in the future: URSI in 2008 in Chicago (USA), the 3rd VERSIM workshop in Tihany (Hungary) slightly later in 2008, and IAGA in Sopron (Hungary) in 2009. I am also aware of some VERSIM relevant workshops being discussed for the near future, and expect that announcements should go out using the VERSIM email list in the nearish future.

In 2006 we finally changed the way to the VERSIM email list operates, moving to a fully moderated list running using the Mailman system. The moderation is being undertaken by Craig Rodger. Now that the list is again being moderated there is be a delay between sending to the list and the email being send on to the rest of the VERSIM community. This will, however, be kept as short as possible, and this should massively decrease the amount of spam you receive via VERSIM. At the request of some members of the VERSIM community, I have removed the VERSIM Email Directory from our website until we can encode the email addresses listed as images. This should, I hope, decrease the abuse of our email addresses.

I enjoyed the chance to meet so many of the community at various meetings this year, and particularly the Workshop in Sodankylä. Please come along to the VERSIM Business Meeting during the IUGG assembly in Perugia (lunchtime Tuesday 3 July 2007), which should be useful for planning the 3rd Workshop in 2008. I hope the New Year finds you prosperous, productive, and well. Best wishes to you all!

Craig J. Rodger
IAGA co-chair VERSIM working group

Forthcoming meetings

- *IUGG General Assembly, Perugia, Italy, 2-13 July 2007.*
- *AP-RASC Conference, Perth, Australia, 17-20 September 2007*

Reports from VERSIM research groups 2006

This based on information received by the IAGA co-chairman, Craig Rodger, by email from the VERSIM membership. Some reports have been slightly edited so the newsletter has consistent formatting. Hopefully this has not introduced any significant typos.

Belgium - Center for Space Radiations (CSR) and Belgian Institute for Space Aeronomy (IASB-BIRA) report by S. Benck (CSR) and F. Darrouzet (IASB-BIRA).Within the RABEM/SEVEM (Radiation Belts Models/Statistical ELF and VLF Environment Models) project at CSR (Center for Space Radiations, Université Catholique de Louvain, Belgium), the data from the wave experiment ICE (Instrument Champ Electrique) and/or IMSC (Instrument Magnétomètre Search Coil) on board of Demeter as well as from the particle experiment IDP (Instrument Détecteur de Particules) are analyzed. Global maps of the wave intensities distributions in the magnetosphere in the ELF/VLF frequency range have been drawn. It has been observed that the power spectral densities show a rather pronounced dependence with geomagnetic indices, and that during the recovery phase of strong magnetic storms, wave intensity may decrease with a characteristic decay time constant different from the one observed for particles at the same position. The development of a primary statistical ELF and VLF environment model at LEO (Low Earth Orbit) based on Demeter data is now underway. (http://www.spaceradiations.be/)
Concerning CLUSTER data analysis, the electric field spectrograms (2-80 kHz) measured by the resonance sounder and wave analyzer WHISPER are analyzed at IASB-BIRA (Belgian Institute for Space Aeronomy, Belgium) in order to determine the electron plasma frequency, and then the electron density inside the magnetosphere. Several multipoint tool (the spatial gradient of a scalar quantity, applied to electron density and magnetic field strength, and the time delay method applied to electron density) are used, in particular to assess the relation between the electron density distribution and the magnetic field inside the plasmasphere. (http://www.oma.be/cluster/)

Darrouzet, F., De Keyser, J., Décréau, P. M. E., Lemaire, J. F., and Dunlop, M. W., Spatial gradients in the plasmasphere from Cluster, Geophys. Res. Lett., 33, L08105, doi:10.1029/2006GL025727, 2006.

China - Center for Space Science and Applied Research, Chinese Academy of Sciences, report by Jinbin Cao. Double Star Program (DSP) is the first joint endeavour between the Chinese National Space Administration (CNSA) and the European Space Agency (ESA). The DSP consists of two satellites: one at an eccentric equatorial orbit with an apogee of about 13.32 R_E and the other at a polar orbit with an apogee of about 6.09 R_E. With these two satellites, the DSP can detect the temporal-spatial variations of fields and particles in the near-Earth equatorial and polar active regions
There are eight scientific instruments onboard the polar satellite DSP-2 (TC-2). They are Neutral Atom Imager (NUADU), FluxGate Magnetometer (FGM), Low Energy Ion Detector (LEID), Heavy Ion Detector (HID), High Energy Electron Detector (HEED), High Energy Proton Detector (HEPD), Low Frequency Electromagnetic Wave Detector (LFEW), and Plasma Electron and Current Experiment (PEACE).
On Nov. 08 2004, the HEED of TC-2 observed an loss event of high energetic electrons which lasted about 240 s in the recovery phase of substorm. At same time, the LFEW of TC-2 observed a wave burst. The wave burst began 60s earlier than the loss event of energetic electrons. The frequency of waves range form 300 Hz to over 10 kHz. The analyses of wave characteristics indicate that the wave was whistler-mode. Thus it is very possible that the loss of high energy electron was caused by wave activities through wave particle interaction.
In addition, it is worth noting that the lost electrons in the energy range 0.2-0.4 MeV don't completely precipitate into the atmosphere. Some electrons in the energy range 0.2-0.4 MeV are accelerated into higher energy range and are thus considered as "seed" electrons for the generation of MeV electrons. However these electrons accelerated into higher energy usually occupy a small part of lost electrons in the energy range 0.2-0.4 MeV.

Czech Republic - The VLF phenomena are studied at two institutions in the Czech Republic: at the Institute of Atmospheric Physics and at the Charles University in Prague, Faculty of Mathematics and Physics. Both institutions are in close cooperation. Report by Jaroslav Chum.
Our VLF research has mainly been based on spacecraft data (DEMETER, MAGION5, CLUSTER, Double-Star, Polar, Freja and Cassini projects). We are interested in various types of VLF waves: chorus emissions, equatorial noise, auroral hiss, lion roars, lightning induced whistlers, magnetospheric line radiation, power line harmonic radiation, and in wave phenomena associated with possible seismo-ionospheric coupling.
For example, we have investigated oblique propagation of chorus waves and their accessibility to lower altitudes using both the ray-tracing simulations and analysis of experimental data [1,2]. Using large data sets we are systematically analyzing properties of chorus waves, their occurrence and propagation in different regions of the magnetosphere. We have also investigated penetration of lightning induced whistlers through the ionosphere estimating the size of the area of penetration by assigning the causative lightning to the whistlers observed on satellites [3]. We have continued our previous work on analysis methods for wave measurements [4]. We have also studied occurrence of power line harmonics as observed on a spacecraft [5] and we have continued our effort to statistically analyze VLF waves which could reflect possible seismo-ionospheric effects.

[1] Chum J., Santolík O.: Propagation of whistler-mode chorus to low altitudes: divergent ray trajectories and ground accessibility, Annales Geophysicae, 23, 3727-3738, 2005
[2] Santolik O., Chum J., Parrot M., Gurnett D. A., Pickett J. S., Cornilleau-Wehrlin N.: Propagation of whistler-mode chorus to low altitudes: Spacecraft observations of structured ELF hiss, J. Geophys. Res., Vol 111, A10208, 2006, DOI:10.1029/2005JA011462
[3] Chum, J., F. Jiricek, O. Santolik, M. Parrot, G. Diendorfer, and J. Fiser, Assigning the causative lightning to the whistlers observed on satellites, Ann. Geophys., 24, 2921–2929, 2006.
[4] Santolik, O., F. Nemec, M. Parrot, D. Lagoutte, L. Madrias, J.J. Berthelier, Analysis methods for multi-component wave measurements on board the DEMETER spacecraft, Planetary and Space Science 54, 512-527, 2006.
[5] Nemec, F. O. Santolik, M. Parrot, and J. J. Berthelier, Power line harmonic radiation (PLHR) observed by the DEMETER spacecraft, J. Geophys. Res. 111, A04308, doi:10.1029/2005JA011480, 2006.

Fiji - The University of the South Pacific, Suva, Fiji, report from Dr. Sushil Kumar and Dr. V. Ramachandran of the Electrical Communication Research Group. The ELF/VLF data

are recorded using the *World Wide Lightning Location Network (WWLLN)* VLF setup at our university. The system was extended to record lightning generated sferics and whistlers in the year 2004. The data were recorded for 5 min. duration at every hour during 2006 and are analysed for tweeks and whistlers. The tweeks are utilised to estimate the nighttime reflection heights (h) and the electron density (N_e) at the reflection heights. The recording of the waveforms of lightning generated sferics using high sampling rate data logger has been started since September 2006. The results were presented in AOGS-2006 and 2nd VERSIM workshop 2006. The lighting data obtained with *WWLLN* system and *LIS* onboard *TRMM* satellite were analysed for the lighting occurrence in the South Pacific Region. The theoretical study on the effects of energetic electron beams flowing upwards/downwards on whistler mode waves observed by ground and satellite-based facilities undertaken previously has been accepted for publication.
A narrow band receiver "SofPAL" has been installed in September 2006 in collaborative with research group at University of Otago, New Zealand. The recording of amplitude and phase of the signals from seven MSK VLF transmitters is being carried out simultaneously. We thank Prof. Richard Dowden, Dr. N. R. Thomson and Dr. C. J. Rodger for their valuable help and suggestions in support of our research activities in the area of ELF/VLF at The University of the South Pacific, Suva, Fiji. The efforts are made to install the Stanford University VLF system in collaboration with Prof. Umran Inan, Stanford University, USA, under UN/NASA support program for third world countries. We thank Prof. Inan for his timely support in this regard.

Finland - Sodankylä Geophysical Observatory, report by Jyrki Manninen. Some information about VERSIM activity in Finland:
The first PhD thesis on ELF-VLF research in Finland was examined in December 2005. Dr. Jyrki Manninen's thesis (pdf format) can be found in the Internet (http://www.sgo.fi/Publications/thesis.php/). The opponent was Dr. Craig Rodger from University of Otago, Dunedin, New Zealand. Also some photos of the 'big day' can be found in the Internet (http://www.sgo.fi/~jyrki/Jyrki_17122005/Jyrki_17122005.html).
2nd VERSIM Workshop 2006 was held in Sodankylä Geophysical Observatory in Finland on 26-30 September 2006. We had 46 participants from 17 countries. There were given 46 oral presentations and 6 poster presentations. More information can be found on the Internet (http://www.sgo.fi/Events/versim-2006/versim-2006.php) and the VERSIM Workshop report http://www.physics.otago.ac.nz/versim/SGO_Workshop_2006_report.pdf
An international measurement campaign was organised on 20-29 November 2006. Simultaneous measurements were made by all EISCAT radars (VHF, UHF, ESR, Heater), DEMETER satellite, auroral photometers, OmniPAL receiver, and some other instruments. Continuous wide-band ELF-VLF recordings were made with a new (again!) receiver in the frequency band of 0.2-39.0 kHz. The sensitivity of the receiver is such that it can observe the signal strength of 1 aT ($=10^{-18}$ T). This receiver uses 24-bit resolution, which means the data flow of about 2.1 GB/hour. It was easily receiving all natural signals and more than 10 VLF transmitter signals below 39 kHz. In most cases the arrival directions of Tx signals were observed with accuracy of a couple of degrees. The preliminary analysis of some time intervals showed that the arrival direction can vary even 10 degrees during precipitation events. Some interesting type of emissions were also observed. The quick-look plots will be made in January 2007 and they will be available in the Internet.
Next campaign is probably in the coming spring in 2007.

France - LPCE/CNRS report by Michel Parrot: VLF research in LPCE is mainly related to the data processing of the satellites CLUSTER, Double Star, and DEMETER. With CLUSTER and Double Star the chorus emissions have been studied. The main scientific objective of DEMETER is related with the seismic activity but DEMETER can also study the electromagnetic environment of the Earth. A dedicated workshop was held in Toulouse in June (few CD-Roms with presentations are still available). Various active experiments are performed in relation with DEMETER (heating and wave generation with HAARP, Sura, and Tromsoe, acoustic emission). The DEMETER data is also used to prepare the future mission TARANIS in which the LPCE is deeply involved. TARANIS will study the luminous events and the electrostatic discharges which appear between the top of the thunderstorm clouds and the lower ionosphere. The launch will be in 2011. We use the results of the neural network onboard DEMETER which counts the whistlers and determines their dispersion. A ground-based VLF antenna has been also installed at Nançay in collaboration with the Stanford group in order to compare satellite and ground-based data.

Greece - University of Crete report by Christos Haldoupis. A comprehensive and lengthy report was provided. Craig has the taken the liberty of including only a fraction below. The full report can be found at http://www.physics.otago.ac.nz/versim/UoCrete-VERSIMreport2006.pdf
During 2006, we have continued our research efforts and studies on the physics of subionospheric VLF (Very Low Frequency) and ULF (Ultra Low Frequency) signatures observed in association with active thunderstorms in the troposphere and transient luminous events (TLEs) in the upper atmosphere. This was done in the frame of our involvement in the EU-RTN (European Union – Research Training Network) CAL (Coupling of Atmospheric Layers) project which terminated on November 1, 2006. In the last year we have also participated in the *EuroSprite2006* campaigns by operating in Crete support experiments which included two automated VLF receiver systems and a sensitive magnetometer station measuring background electromagnetic noise at ULF.
Our research has focused on the analysis and physical interpretation of narrow- and broad-band VLF recordings, as well as ULF measurements in relation with sprite occurrences, detected during *EuroSprite*-2003 and 2005 campaigns in Southwest Europe, and with elves observed either with ground-based cameras or from satellites using imagers for TLEs and atmospheric lightning detection. Our main results obtained during the 4th CAL year were presented in three papers, which have been already published.
During the 4rd CAL year, our University of Crete CAL team continued and strengthen further scientific collaborations with CAL and non-CAL members, and developed new scientific contacts. At present, we have collaborations with Dr. Torsten Neubert of the Danish Space Center, Prof. Umran Inan of Stanford University, Dr. Tilmann Bössinger of University of Oulu, Finland, Dr. Sergei Shalimov, the Institute of Physics of the Earth, Russia, Prof. Serge Soula of the University Paul Sabatier in Toulouse, Dr. Janos Lichtenberger of Eötvos University in Budapest, Dr. A. Collier, University of KwaZulu

at Durban, South Africa, and Profs. R. R. Hsu and H. T. Su, of the National Cheng Kung University in Taiwan, Prof. Dave Nunn, University of Southampton, UK, Dr. Craig Rodger, University of Otago, New Zealand. Several of these collaborations have led to joint scientific work and research papers which are either published/submitted or are presently under preparation.

Hungary - Space Research Group, Eötvös University report by Janos Lichtenberger. The Compass-2 satellite was launched from Barents sea on 26th May 2006 with the first advanced ULF-VLF electromagnetic signal analyzer, the SAS2 instrument with EM mapping and event detection capabilities. After the successful launch serious problems arose in the power system of the satellite. Majority of these problems was solved from May to November and in the second half of November the switch-on and control/calibration processes of the scientific payload has been started. The first switch-on of the SAS2-K2 was successful on 29th November 2006 and recorded high quality broad band ULF-VLF (10 Hz-20 kHz) data. The analysis of the recorded data including whistlers has been started.

The theoretical model development of the electromagnetic wave propagation phenomena around the Earth and in the interplanetary space environment has been going on. We have developed the accurate models for UWB (Ultra Wide Band) short impulse signals guided in vacuum-filled waveguides and for waveguides filled by anisotropic, homogeneous plasma. The results of the theoretical investigations have been compared continuously with the measured data (DEMETER database). We have successfully interpreted some new measured electromagnetic phenomena, with unknown origin. We have recognized, modeled and interpreted the effect of spiky whistlers, and gave some possible theoretical background in the case of X -type whistlers with bifurcated spectra.

Within the frame of the DEMETER Guest Investigator Programme, ELTE SRG has performed systematic wave investigation on electric and magnetic field VLF burst data of the satellite's ICE and IMSC data. First application of their real full-wave, oblique propagation code gave a new picture about the whistler propagation in the ionosphere, accurately explaining the waveforms of the short-path fractional-hop whistlers acquired on board. Running the Hungarian narrow-band, Omnipal-based VLF network continued, the system is part of the AARDVAARK global network. Extension of this network in the Carpathian basin, in Europe and is in progress. First operational test of their newly developed trimpi detecting algorithm is successfully completed.

The development of the Automatic Whistler Detector and Analyzer (AWDA) system was continued and now it is capable to analyze mid-latitude whistler traces. Almost 100,000 whistlers collected by AWDA at Tihany between 2002 and mid -2005 were processed and the resulted L-value distribution exhibits '*L*-discrepancy' (an unexpected gap between Tihany's *L*-value and the peak *L*-value of the distribution). An AWDA system was setup at SANAE (Antarctica) and conjugate measurements were made at Grahamstown, South Africa in collaboration with University of KwaZulu-Natal, Durban. Statistics of diurnal and seasonal distribution of whistlers recorded at Dunedin in collaboration with University of Otago, Dunedin, New-Zealand from May 2005-February 2006 were made and the diurnal one exhibits peek at local daytime unexpectedly. Extension of AWDA network and he Hungarian narrow-band, Omnipal-based VLF network in the Carpathian basin, in Europe and in the rest of the world is in progress.

India - Faculty of Engineering, R.B.S. College, Agra, report by Birbal Singh. An International workshop on Electromagnetic studies related to Earthquakes and Volcanoes (IWEMSEV-2006) will be organized by the Faculty of Engineering, R.B.S. College, Agra during 20- 22 November, 2006 at Agra (Convener: Dr. Birbal Singh) under the purview of IAGA-EMSEV. Although, the theme of the workshop is to discuss basically electromagnetic methods in Seismology and Volcanology including ground and satellite based studies of ULF-VLF and ionospheric precursors, one session has been created to deal mostly non-seismic problems such as whistler propagation, ionospheric structure and dynamics, space weather, global electric circuit etc. About 70 Indian and 20 foreign scientists will be participating.

Israel - Department of Geophysics and Planetary Sciences, Tel Aviv University, report by Colin Price. The Tel Aviv University group, led by Colin Price, hosts three different VLF antennas. One large IGY (9 meter high) VLF antenna constructed with the help of the Stanford University VLF group has been working in campaign mode for nearly ten years. Due to the remote location at Sde Boker in the Negev Desert, we have encountered numerous technical problems, including our cables being cut without our knowledge. We collected a few months of "noise" before discovering the problem.

A more recent VLF antenna is related to the WWLLN lightning network constructed and run by Dick Dowden and Bob Holzworth of the University of Otago and the University of Washington. We are one of the global sites that helps in the global lightning locations, and these data have been used by our research group to simulate Schumann resonances, and to investigate the connection between lightning in Africa and hurricane generation.

In the last month we have acquired our latest VLF receiver from the AWESOME project of Stanford University. This smaller antenna will be located on the roof of our university building, and used primarily to track narrow band transmitter signals.

Japan - University of Electro-Communications, Tokyo, report by Masashi Hayakawa.

1. Monitoring of lower ionosphere by means of subionospheric VLF/LF network in Japan and seismo-ionospheric perturbations.

   Our Japanese VLF/LF network is composed of seven receiving stations (from the north, Moshiri(Hokkaido), Chofu(Tokyo), Tateyama(Chiba), Shimizu, Kasugai(Nagoya), Maizuru(Kyoto) and Kochi). This network has been established in order to detect the precursory ionospheric signature of earthquakes, and we have been receiving, simultaneously, several VLF/LF transmitter signals (at the moment, JJY(Fukushima, f=40 kHz), NWC(f=19.8 kHz), NPM(f=22.4 kHz), JJI(Kyushu, f=22.2 kHz) and NLK) at each station. For the study of seismo-ionospheric perturbation, we adopt the sampling frequency of 120 seconds. Here we describe some of our latest results. First, we have performed the statistical test on

the correlation between the VLF anomaly (ionospheric perturbations) and earthquakes, by using the 6 years observation for a wave-path from JJY to Kochi. We have found that the correlation between the ionospheric perturbations and earthquakes is significant only for large earthquakes (with magnitude greater than 6.0) close to the great-circle path. The anomaly appears in the form of average amplitude decrease and enhancement in fluctuation, a few days to 5 days before the earthquake (Maekawa et al., Ann. Geophys., 24, 2219,2006). Case studies are also carried out and we show only the result for the Sumatra earthquake in December, 2004. By using the paths from NWC to Japanese stations, we have found that the ionosphere above the epicentre with radius, at least, 2 Mm, is disturbed a few days before the Sumatra earthquake (Horie, et al. Int'l J. Remote Sensing, in press, 2006).

2. Observation of Schumann resonances and ELF transients. The observation of ELF waves has been continued at Moshiri(Hokkaido) since 1996 and at Nakatsugawa(near Nagoya) (belonging to Chubu Univ. (Prof. Ohta)) since 1999. At Moshiri we measure two horizontal magnetic fields and one vertical electric field, and the frequency range is up to 50 Hz. While, three orthogonal magnetic fields have been measured at Nakatsugawa with the sampling frequency of 100 Hz. Continuous waveform measurements have been performed at both stations. One important finding is that anomalous Schumann resonance effect (enhancement around 4th harmonic) is observed at Nakatsugawa, in possible association with the earthquakes in Taiwan (Hayakawa et al., Ann. Geophysicae, 23, 1335, 2005). Then, the application of inverse problem to the Schumann resonance data, has enabled us to deduce the snapshot of global lightning activity, to be compared with the satellite observation (Ando et al., Radio Sci., 40, 205). ELF transients are also utilized to deduce the global distribution of huge lightning discharges.
3. Campaign of Japanese winter sprites and related phenomena. Just like the winter of 2004/2005, we have just started a special campaign of Japanese winter sprites in the Hokuruku area (Japan Sea side). The campaign is a coordinated one, consisting of (1) optical measurements at two stations (Chofu and Shimizu), (2) electromagnetic observations: (a) VHF lightning measurement in the Hokuriku area (by SAFIR), one conventional radar (at Komatsu) and one Doppler radar (at Toyama). (b) ELF observation at Moshiri (mentioned before). (3) Observation of ionospheric perturbations (Trimpis) by using the subionospheric VLF/LF data (mentioned above, with higher temporal evolution). By using these coordinated measurements, we would like to study the lightning-atmosphere-ionosphere electromagnetic coupling mechanism.

New Zealand - University of Otago, Dunedin, report by C.J. Rodger. The Space Physics group's activities have focused on better understanding the impact of energetic particle precipitation on the ionosphere and neutral atmospheric composition. Working with collaborators in the United Kingdom, Finland, and Hungary, we undertook both experimental and theoretical studies into solar proton events and energetic electron precipitation. Our paper on the atmospheric implications of manmade control of the radiation belts received a lot of attention, including coverage in New Scientist magazine.

The subionospheric VLF remote sensing network that the group operates in collaboration with the British Antarctic Survey has provided us with new insights into spatially large processes. The Antarctic-Arctic Radiation-belt (Dynamic) Deposition - VLF Atmospheric Research Konsortium (AARDDVARK) network now has its own webpage (http://www.physics.otago.ac.nz/space/AARDDVARK_homepage.htm), including background information on subionospheric VLF propagation and some of the science areas we are working in. There are currently 9 receivers inside the Konsortium, and we anticipate expanding into new longitude sectors in 2007.

The group has also been working with the PIs of the World Wide Lightning Location Network (WWLLN), which currently has 26 operational receiver sites. In 2005/2006 we undertook calibration studies to estimate and model the detection efficiency of WWLLN. We are now working with the PIs of the network, Professors Dowden (LF*EM Research) and Holzworth (University of Washington), in the automation of the calibration process. The current goal is to extent the capabilities of the WWLLN observations to include measurements of lightning currents. More information on WWLLN, including regularly updated lightning movies can be found at the WWLLN website: http://webflash.ess.washington.edu/

An up to date listing of our publications is available from the Groups website: www.physics.otago.ac.nz/research/space/spacehome.html

Serbia/Slovenia joint report - Institute of Physics; Belgrade and University of Nova Gorica, report by D. Šulić, D. Grubor and Vida Žigman. The AbsPal VLF station at the Institute of Physics, Belgrade has been continuously in operation since August 2003. Signals from three transmitters: NAA/24.0 kHz, NWC/19.8 kHz and GQD/22.1 kHz, are recorded regularly. A survey of recorded data is carried out every two weeks.

In 2006 we have carried on with our activities within the Cost-724 project, and within the bilateral (Slovenian-Serbian) project "Radio diagnostics and modelling of the plasma of the lower ionosphere" that has been approved by our respective countries for the period 2005-2006. Apart of participating in a number of national meetings, in 2006, the members of our VLF team, Dr. Desanka Sulic and Dr. Davorka Grubor (Belgrade, Serbia) and Dr. Vida Zigman (Nova Gorica, Slovenia) took part at two conferences VERSIM 06 and the Third European Space Weather Week (ESWW3, COST 724), contributing papers with results on VLF diagnostics of the X-ray Solar flare and LEP effects on the lower ionosphere.

South Africa - Space Physics Research Institute, University of KwaZulu-Natal, Durban, report by A. B. Collier. During the annual relief voyage at the beginning of the year a Hungarian automatic whistler detector was installed at the SANAE-IV research base in antarctica. This system has since running in parallel with the existing DVRAS VLF system. It is the first time that the system has been operated at such high L and some optimisation was required to adapt to higher-L whistlers. The operation of the system was monitored remotely via ssh, however, it would be convenient if the system automatically generated a daily report which could be emailed to the investigators involved.

An observing campaign was conducted again in Grahamstown this year. However, the increased noise at the site and frequent power interruptions may have seriously compromised the quality of this data.

As part of the IPY we plan on installing a VLF receiver, whistler detector and Doppler instrument on Marion Island. Two visits to the island were made during the year to assess

suitable locations for the antenna and instruments. The necessary environmental impact assessment is currently being drafted. Marion Island is an excellent location for conjugate studies since it conjugate is located in the Baltic Sea, where observations can be made nearby. A location on the German island of Hiddensee is presently under consideration for a VLF receiver.
In May 2007 the second South African satellite, Sumbandilasat, will be launched. We have a VLF receiver on board the satellite. The hardware for the receiver was fabricated by the University of Stellenbosch and preliminary software for the on board analysis and reduction of the data was done in our group. We plan on appointing a Masters student to continue with this work.
Various issues with the WWLLN node in Durban have been resolved. A second node was installed in Hermanus but is not yet on line since we are still experiencing various difficulties.

Ukraine - Dept. of Remote Sensing, Usikov Institute for Radio-Physics and Electronics, Nat. Acad. of Sci. of the Ukraine, Kharkov, Ukraine, report by A. Nickolaenko. The 3-year STCU project (*Project title:* Global Lightning Monitoring System) ended in June. The main goal of the project was processing of Schumann resonance signals accumulated at the Lehta observatory (Karelia, Russia, ~64ºN and 34ºE) since 1999. Data processing was completed of Schumann resonance spectra and cumulative intensities of E_z, H_x and H_y field components. The observation period ends in July 2005 owing to a disaster at the field site: a direct lightning strike into the local power supply line has 'killed' the whole equipment. The repair is still due.
The routine processing of the resonance data was performed by E. Yatsevich. It was aimed on obtaining estimates for the diurnal/monthly variations of the global thunderstorm activity. The 'podium' signal was addressed always present in daily patterns: the signal consists of a variable in time part and of a 'constant' podium. The peak-to peak variation of the variable part is approximately equal to the height of podium. Both of them change with the season, and they change similarly. Most probably, the variable component is connected with the 'regular' activity circling the globe during the day. The podium signal should be attributed to the 'odd' lightning strokes that occur at 'wrong' time, in particular to the nocturnal activity. Schumann resonance intensity indicates that contributions are comparable from these two types of storms.
Some modeling was made that included compact and distributes random sources of ELF radiation, and a model based on the OTD data. The models allowed us to obtain the diurnal intensity patterns similar to those observed. However, the detailed coincidence was not achieved in any model, including the OTD data. Model daily frequency variations are similar to the observational data during boreal winter months only.
Data accumulated were analyzed in detail by A. Shvets during the periods adjacent to large SPE. Relevant model computations were made by L. Rabinowicz. The greatest SPE result in modifications of polar ionosphere that cause a reduction in SR peak frequencies. If we assume that the so-called ionosphere factor $L=(Z/kh)$ [Z is the effective surface impedance of the ionosphere boundary and h is its effective height] varies with co-latitude θ as $L = (1 + \rho^2 \cos^2\theta)$, the parameter ρ found from experimental data lies between 0.5 and 1. It means in particular that the effective surface impedance of the lower ionosphere increases at the pole by the factor of two during the SPE disturbance.
Papers were prepared by Nickolaenko for special section of Radio Science (V. Pasko is the invited editor) devoted to Schumann resonance. One of them was made together with D. Sentman, it surveys the Schumann resonance data indicating on the line splitting under the influence of geomagnetic field. Thus experiments initiated long ago received at last the theoretical support allowing for unambiguous demonstration of a successful detection of line splitting. The other paper made with M. Hayakawa and M. Sekiguchi compares seasonal alterations in the SR intensity and in the global ground surface temperature (GST). Substantial regular variations are observed of annual and semi-annual periods when SR intensity correlates with GST in the middle latitude interval rather than with GST in the tropical belt. Simultaneously, the principal component analysis extracted small inter-annual changes. SR variations of this kind resemble temperature inter-annual trend in the tropics.
At present, A. Nickolaenko is busy with processing of experimental data accumulated in Antarctica in 1989, the measurements of the long distance man-made ELF radio signal.

United Kingdom - Radio and Space Plasma Physics Group - University Of Leicester, report by Anna Odzimek. As part of the CAL (Coupling of Atmospheric Layers) project, Anna Odzimek and Neil Arnold (University of Leicester, U.K.) have been working with Michael Rycroft, of CAESAR Consultancy, Cambridge, U.K. They have been investigating, theoretically: a) the global atmospheric electric circuit, including maps of topography and thunderstorm activity (following Makino and Ogawa, J. of Atmos. Terr. Phys., 46, 431-445, 1984), modelled atmospheric electrical conductivity profiles, and a non-equipotential ionosphere at 80 km altitude, in order to generate "synthetic Carnegie curves", b) how sprites may vary the potential of the ionosphere above an active thunderstorm producing +CG discharges, c) answers to some of the sixteen questions mentioned at the end of the paper by Michael Rycroft "Electrical processes coupling the atmosphere and ionosphere: An overview" (J. Atmos. Solar-Terr. Phys., 68, 445-456, 2006).

United Kingdom - British Antarctic Survey, Cambridge, report by Mark Clilverd.
Broadband Recordings: 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.
VELOX Recordings: 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. The VELOX at Halley will continue indefinitely.
AGOs (Automatic Geophysical Observatories) programme: the VELOX receiver on A84 (L=8.1) was shut down at the end of 2005, and removed. No AGO systems are operating now.
1-s resolution data are available on the Web using the BAS Data Access & Browsing System (DABS) http://dabs.nerc-bas.ac.uk/
Narrow-Band Recordings: The narrow band receiver `OmniPAL' has operated through 2006 at Halley, and Rothera bases, Antarctica, Sodankylä, Finland, and Ny Ålesund, Spitzbergen. Northern hemisphere transmitters in Europe and USA are being received at 0.1-1.25 sec resolution. The

Australian Casey station (Antarctica) has operated as an amplitude-only narrow-band receiver throughout 2006. Southern hemisphere transmitters are being received with ~2 sec resolution.
A VLF Doppler receiver has continued to operate at Rothera station, Antarctica (L=2.8), receiving whistler mode and subionospheric signals primarily from NAA (24.0 kHz).
WWLLN Sites: British Antarctic Survey has operated two World Wide Lightning Location Network systems in 2006. Rothera has provided real-time lightning information since January 2006, and Ascension Island came on-line in April 2006.

United Kingdom - British Antarctic Survey, Cambridge, report by Richard Horne. Richard provided a series of images from the VERSIM Workshop 2006, which are available from http://www.physics.otago.ac.nz/versim/RH_SGO_Workshop_2006_images.pdf

USA - University of California, Los Angeles, report by Jacob Bortnik. I am currently working on modeling the propagation characteristics of whistler-mode chorus, and comparisons to satellite observations. These models are being used to calculate the expected precipitation of energetic radiation-belt electrons, and will be used in the near future in nonlinear modeling of both precipitation and acceleration of electrons. I am also involved in multi-satellite observational studies of radiation-belt dynamics, which involve an interplay of chorus and EMIC scattering.
Other projects which I am involved in are: studies of Pc1 pulsations at low latitudes using a newly developed wave identification algorithm, and the relation of such waves (and other geomagnetic pulsations observed on the ground) to seismic activity. We are also performing studies using the Demeter satellite, searching for any detectable magnetic signals which precede large Earthquakes.

USA - University of California, Los Angeles, report by Richard Thorne. Below is a list of publications dealing with wave processes that my group at UCLA have been involved with. The list is long so I will only give a very brief summary of each.

1) Shprits, Y. Y., R. M. Thorne, R. B. Horne, M. Cartwright, C. T. Russell, D. Baker, and S. G. Kanekal (2006), Acceleration mechanism responsible for the formation of the new radiation belt during the 2003 Halloween solar storm, Geophys. Res. Lett., 33, L05104, doi:10.1029/2005GL024256.
2) Horne, R. B., R. N. P. Meredith, S. A. Glauert, A. Varotsou, R. M. Thorne, Y. Y. Shprits, and R. R. Anderson (2006), Mechanisms for the acceleration of radiation belt electrons, in Recurrent Magnetic Storms: Corotating Solar Wind Streams, Geophys. Monogr. Ser., vol. 167., edited by B. T. Tsurutani, R. L. McPherron, W. D. Gonzalez, G.Lu, J. H. Sobral, and N. Gopalswarmy pp, AGU, Washington, D. C.
These two papers demonstrates how local acceleration by chorus can cause the formation of a new radiation belt in a region normally associated with the slot.

3) Loto'aniu, T. M., R. M. Thorne, B. J. Fraser, and D. Summers (2006), Estimating relativistic electron pitch-angle scattering rates using properties of the electromagnetic ion cyclotron wave spectrum, J. Geophys. Res., 111, A04220, doi:10.1029/2005JA011452.
This paper evaluates scattering rates of electrons by measured EMIC waves

4) Thorne, R. M., R. B. Horne, and N. P. Meredith (2006), Comment on "On the origin of whistler mode radiation in the plasmasphere" by Green et al., J. Geophys. Res., 111, A09210, doi:10.1029/2005JA011477.
In this comment we point out that Green et al. have misinterpreted VLF signals at >3 kHz as plasmaspheric hiss and consequently been led to erroneous conclusions on the process that leads to the formation of the slot between the inner and outer radiation belt. In fact we contend that they are simply observing weak lightning activity.

5) Meredith, N. P., R. B. Horne, S. A. Glauert, R. M. Thorne, D. Summers, and R. R. Anderson (2006), Energetic outer-zone electron lifetimes during low geomagnetic activity, J. Geophys. Res., 111,A05212, doi:10.10292005A011516.
CRRES observations are used to show that plasmaspheric hiss controls the slow decay of the outer radiation belt following storms.

6) Thorne, R. M., R. B. Horne, V. K. Jordanova, J. Bortnik, S. A. Glauert (2006), Interaction of EMIC waves with thermal plasma and radiation belt particles, in Magnetospheric ULF Waves, Geophys. Monogr. Ser., vol. XXX, edited by K. Takahashi, B. Lysak, and P. Chi, pp , AGU, Washington, D. C.
A review is given of energetic particle scattering and heating of plasma by EMIC waves.

7) Meredith, N. P.; Horne, R. B.; Clilverd, M. A.; Horsfall, D.; Thorne, R. M.; Anderson, R. R. (2006), Origins of plasmaspheric hiss, J. Geophys. Res., 111, A09217, doi:10.1029/2006JA011707.
A detailed analysis is presented of the geographic and MLT dependence of VLF hiss and it's possible connection to lightning activity. We conclude that the most intense emission below 1-2 kHz have no correlation to lightning activity but show geomagnetic control consistent with natural instability in the magnetosphere. the much weaker waves at higher frequency show geographic control indicative of an origin in lightning.

8) Bortnik, J, and R. M. Thorne (2006), The dual role of ELF/VLF chorus waves in acceleration and precipitation of radiation belt electrons, J. Atmos. Sol. Terr. Phys., in press.
We show that chorus emissions lead to both scattering loss to the atmosphere and local acceleration during active times.

9) Millan, R. M. and R. M. Thorne (2006), Review of radiation belt relativistic electron loss, J. Atmos. Sol. Terr. Phys., in press.
A review of energetic electron loss processes.

10) Shprits, Y. Y., R. M. Thorne, R. B. Horne, and D. Summers (2006), Bounce-averaged diffusion coefficients for field-aligned chorus waves, J. Geophys. Res., 111, A10225, doi:10.1029/2006JA011725.
We show that a computationally efficient simple field-aligned model for chorus emissions gives scattering rates comparable to results from the PADIE code, which requires considerably more computation time.

11) Bortnik, J., R. M. Thorne, Y. Y. T. P. O'Brien, J. C. Green, R. J. Strangeway, Y. Y. Shprits , and D. N. Baker (2006), Observation of two distinct loss mechanisms during the November 20, 2003 radiation belt dropout event, J. Geophys. Res., in press.
Evidence is given for EMIC scattering at low L during a major magnetic storm.

12) Shprits, Y. Y., W. Li, and R. M. Thorne (2006), The controlling effect of pitch-angle diffusion rates near the edge of the loss cone on electron lifetimes, J. Geophys. Res., in press.
We show that scattering rates near the edge of the loss cone can be used as a accurate estimate particle lifetimes,

13) Thorne, R. M. , Y.Y. Shprits, N. P. Meredith, R. B. Horne, S. A. Glauert. S. Lui, L. R. Lyons, and R. R. Anderson, Refilling of the slot region between the inner and outer electron radiation belts during geomagnetic storms, J. Geophys. Res., submitted, 2006.
We demonstrate that refilling of the electron slot during modest magnetic storms is primarily caused by local acceleration.

Merry Christmas and Happy New Year!

János Lichtenberger and Craig Rodger relax during the 2nd VERSIM Workshop (alas, not János' own fine wine product).