VLF/ELF Remote Sensing of Ionosphere and Magnetospheres
IAGA/URSI joint working group

6th VERSIM Workshop 2014

Abstract and Programme Book

Dunedin, New Zealand 20-23 January 2014

Introduction

Greetings! On behalf of the Local Organising Committee I would like to welcome to you to Dunedin, the University of Otago, and New Zealand. We hope you will have a scientifically stimulating time at the workshop, and also enjoy Dunedin and its surrounds. Following the pattern from previous workshops we have tried to retain a good amount of time for questions, discussion and collaborative networking. Our full programme includes an excursion to see wildlife on Otago Peninsula, and the conference dinner at our Ecosanctuary. We hope will find time enjoy our surrounds while undertaking your scientific discussions!

If you have any questions about the local area, where to eat or what to do then please feel free to ask any of the LOC and we will be more than happy to help. The workshop begins at 8.30 on Monday 20^{th} January in the ground floor of the Department of Physics (Science 3 building). Signposts will direct you to our workshop venue when you arrive at the building.

Finally, I want to thank the sponsors who provided support to our workshop. They are listed at the end of this abstract and programme book.

Prof. Craig J. Rodger
Chair of the Local Organising Committee

Facilities
WiFi will be available throughout the workshop. Log-in information will be provided on the first day of the workshop during the house keeping information talk.

Morning and afternoon tea will be provided in the room adjacent to the space in which we will have the presentations. Lunch is in the University Staff Club, a short walk from the Physics Department. Both of these are included in the registration fee for all scientific participants.

No-smoking Policy
The University of Otago campuses were designated fully smoke-free from 1^{st} January 2014. This means that as well as smoking being prohibited within the Department of Physics, it will also prohibited on any part of the campus grounds, both inside or outside. Anyone wishing to smoke must walk off campus to the roadside. This is less than 50 metres from the Departmental south entrance. Details on the policy can be found at http://www.otago.ac.nz/smokefree/index.html.

About the University of Otago
The University of Otago, founded in 1869 by an ordinance of the Otago Provincial Council, is New Zealands oldest university. Since 1961, when its roll was about 3,000, the University has expanded considerably (in 2010 there were about 21,000 students enrolled). As well as the lure of the spectacular coastal landscape, other attractions include the historic Dunedin Railway Station, and reputedly the worlds steepest street, Baldwin Street, which runs an annual (and literal) gut-buster race. A popular addition to the city is the peaceful Chinese Gardens, created to remember the citys Chinese industrial past. The colourful city centre, just a few minutes walk from the campus, is full of cafes, restaurants, bars, boutiques and shopping centres of an international standard. The Botanic Garden's 28 hectares of trees and park-land is located a few hundred metres from lecture theatres, and is a popular lunchtime venue with students and staff.

The heritage feel of Dunedin is a legacy of the region's 1860s gold rush, which briefly turned the city into the industrial centre of New Zealand. The boom did not last, but Dunedin developed a solid tradition for education, while retaining its sophistication and grandeur.

Scientific Programme Committee

János Lichtenberger (Eötvös University, Budapest, Hungary)
Craig J. Rodger (University of Otago, Dunedin, New Zealand)
Jyrki Manninen (Sodankylä Geophysical Observatory, Sodankylä, Finland)
David Shklyar (Institute of Space Research, Moscow, Russia)
Jacob Bortnik (UCLA, USA)
Ondřej Santolík (Institute of Atmospheric Physics and Charles University, Prague, Czech Republic)
Yoshiharu Omura (Kyoto University, Kyoto, Japan)
Jean-Pierre Raulin (Center for Radio Astronomy and Astrophysics Mackenzie, Mackenzie Presbyterian University, São Paulo, Brazil).

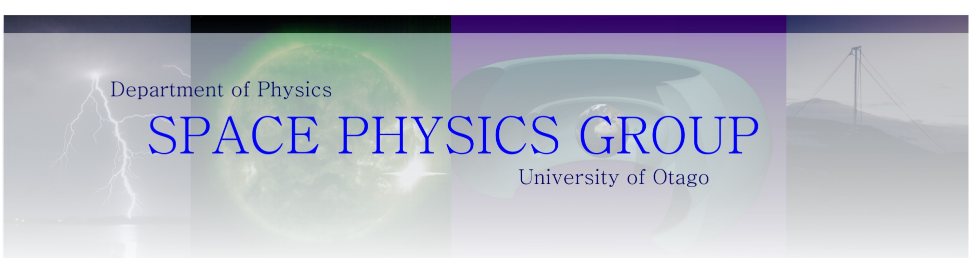
Local Organising Committee

From Physics Dept, University of Otago, New Zealand:
Chaired by Prof. Craig J. Rodger
- Assoc. Prof. Neil R. Thomson
- Dr. Ian Whittaker
- Mr. Aaron Hendry
- Ms. Kathy Cresswell-Moorcock
- Mr. Jason Neal

The LOC also includes:
- Dr. János Lichtenberger (Eötvös University, Budapest, Hungary)

Organisers

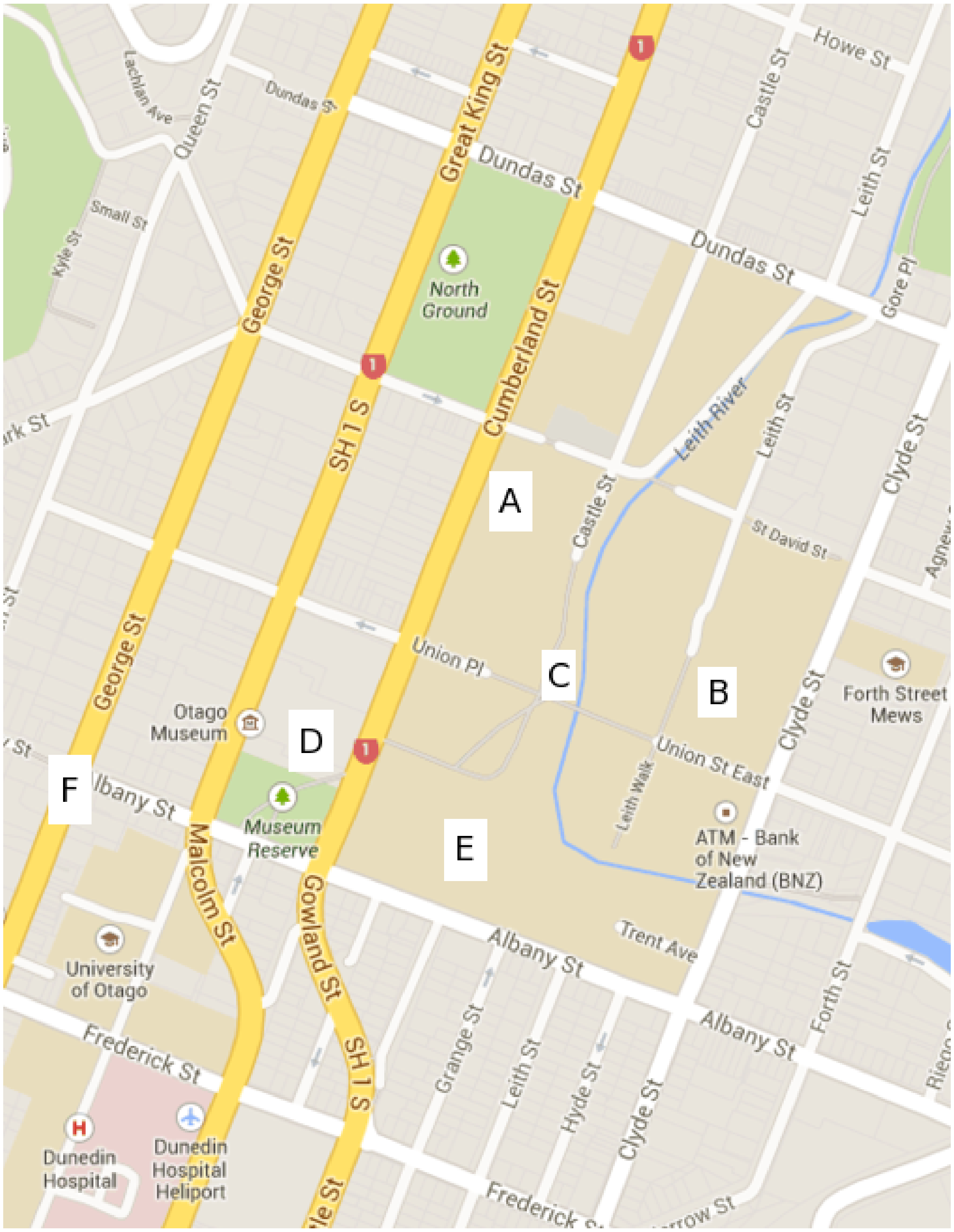
Space Physics Group, Department of Physics, University of Otago, Science 3 Building, 730 Cumberland Street, Dunedin, 9016



Contents

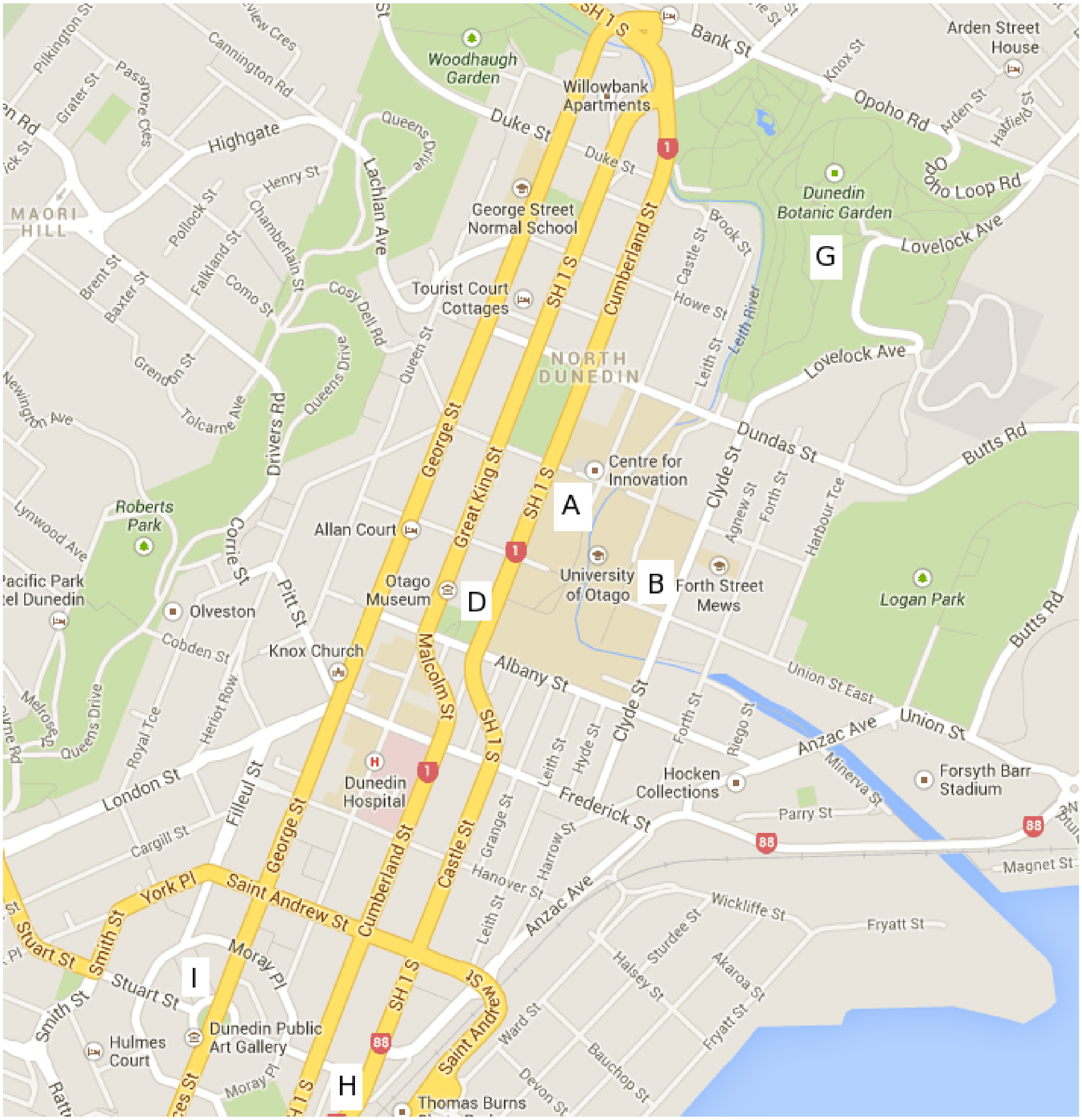
Local maps

Central campus:



Legend:
A: Department of Physics - Science 3 building, 730 Cumberland Street (conference venue)
B: UniCol (conference accommodation and icebreaker BBQ location)
C: University Staff Club (lunch location)
D: Otago Museum
E: University of Otago student union building and main library
F: George Street, main shopping street in Dunedin which leads to the Octagon

Dunedin (Ōtepoti in Māori) map:



Legend:

A: Department of Physics (conference venue)

B: UniCol (conference accommodation and icebreaker BBQ location)

D: Otago Museum

G: Dunedin Botanic Gardens (including aviary)

H: Otago Settlers Museum (next to Dunedin Train Station)

I: Octagon - the centre of town with plenty of bars, cafes and eateries close by.

Local places to eat and drink

The Octagon is the centre of town (location I in the above map) and while there are a lot of places to eat and drink there, the main high street (George Street) also contains many good places to either get a coffee or a meal. A *small* number of these places with approximate walking time from the university are listed below. There are many more not listed; on George Street and in the Octagon as well as in the local campus area. For personal recommendations/advice please talk to any of the LOC.

Key:
F = Full meals available   L = Light meals/snacks available   E = Open in the evening
# = Average evening meal price < $15 $ = Average evening meal price > $30

The Good Earth(FL) - Cafe
765 Cumberland Street, (*1 minute*)

Otago Museum(FL) - Cafe
419 Great King Street, (*3 minutes*)

Poppa's Pizza(FE) - Pizzeria
74 Albany Street, (*5 minutes*)

Eureka(FLE $) - Bar and restaurant
116 Albany Street, (*5 minutes*)

Lone Star(FE $) - Bar and grill
484 George Street, (*10 minutes*)

Everyday Gourmet(L) - Coffee shop
434 George Street, (*10 minutes*)

Friendly Khymer Satay House(FE #) - Restaurant
466 George Street, (*10 minutes*)

Capers(F) - Cafe, specialising in pancakes/breakfasts
412 George Street, (*10 minutes*)

The Fix - Coffee shop
15 Frederick Street, (*10 minutes*)

Thai Over(FE) - Thai restaurant
388 George Street, (*12 minutes*)

The Bog(FE) - Irish pub
387 George Street, (*12 minutes*)

Velvet Burger(FE) - Burger bar with take away option
375 George Street, (*12 minutes*)

Tokyo House(FE #) - Sushi restaurant
367 George Street, (*12 minutes*)

The Reef(FE $) - Seafood restaurant
333 George Street, (*15 minutes*)

The Good Oil(FL) - Cafe
314 George Street, (*15 minutes*)

The Huntsman(FE $) - Steakhouse
311 George Street, (*15 minutes*)

Meridian Mall(FL) - Several places to eat on the lower floor and take away stalls on the ground floor
267 George Street, (*20 minutes*)

Starbucks(L) - Coffee shop
207 George Street, (*20 minutes*)

Circadian Rhythm(FLE) - Specialist vegetarian and gluten free cafe/restaurant
72 St. Andrew Street, (*20 minutes*)

Yuki Izakaya(FE) - Japanese restaurant
29 Bath Street, (*25 minutes*)

The Jitsu(FE) - Japanese restaurant
127 Stuart Street, (*25 minutes*)

Scotia(FE $) - Bar and Bistro (large selection of whisky's available upstairs)
199 Stuart Street, (*25 minutes*)

Nova(FE $) - Restaurant
29 The Octagon, (*25 minutes*)

Ratbags and Innocent Bystander(FE) - Pizzeria and nightclub
11 The Octagon, (*25 minutes*)

Alibi(FE $) - Bar and restaurant
1 Princes Street, (*25 minutes*)

Jizo(FE #) - Japanese restaurant
56 Princes Street, (*25 minutes*)

Timetable

Monday 20th January 2014

08.30 Pickup conference bags/name tags

09.00 Welcome and housekeeping

09.20 Craig Kletzing (invited)
Initial results from the electric and magnetic field instrument suite and integrated science (EMFISIS) on the Van Allen probes

09.50 Adam Kellerman
Combining relativistic electron measurements from high-altitude equatorial and low-Earth orbiting spacecraft to study outer radiation belt source and loss processes from wave-particle interactions

10.10 Morning tea

10.40 Jacob Bortnik
The development of a global, time varying distribution of chorus waves and its utility in modeling radiation belt acceleration events

11.00 Ondřej Santolík
Propagation parameters of whistler-mode waves in the outer radiation belt: results from the Van Allen probes and Cluster

11.20 Bruce Tsurutani
Extremely intense ELF magnetosonic waves and a possible new source for plasmaspheric hiss?: Polar observations

11.40 Jacob Bortnik and Craig Rodger
The new SCOSTEP programme, SPeCIMEN (Specification and Prediction of the Coupled Inner-Magnetospheric Environment)

12.00 Lunch (buffet at staff club from noon)

13.30 Yoshiharu Omura (invited)
Generation Mechanism of Whistler-Mode Chorus Emissions

14.00 Anthony Chan
Simulation of radial transport, local acceleration, and loss in the radiation belts

14.20 Bruce Tsurutani
Chorus properties: Importance for wave-particle modeling

14.40 Etienne Koen
Simulations of Ion Acoustic Waves in Saturn's Magnetosphere

15.00 Afternoon tea

15.30 Jacob Bortnik
Detection of resonant electron pitch angle scattering by whistler waves in a laboratory plasma

15.50 Michael Rietveld
Powerful VHF radars, like EISCAT-3D, as a source of ELF/VLF waves

16.10 Poster session

18.00 Ice-breaker BBQ at UniCol

Tuesday 21st January 2014

09.00 Neil Thomson (invited)
Height and sharpness of the ceiling of the Earth-ionosphere waveguide

09.30 Daniela Wenzel
Establishment of a 'Global Ionospheric Flare Detection System' (GIFDS)

09.50 Sandip Chakrabarti
Earth as a Gigantic detector: GEANT4/LWPC Simulation of X-ray Detection and Comparison with Observation

10.10 Morning tea

10.40 Jean-Pierre Raulin
The South America VLF network: Extension and new results

11.00 Israel Silber
Links between Mesopause Temperatures and Ground Based VLF Narrowband Radio Signals

11.20 Kathy Cresswell-Moorcock
Detecting space weather events with subionospheric VLF observations

11.40 Andy Smith
Two solar cycles of VELOX recordings at Halley, Antarctica

12.00 Lunch (buffet at staff club from noon)

12.55 Meet outside the St David Lecture Theatre for our Excursion (drive up Otago Peninsula, board Monarch to sail around Taiaroa Head, return to land and visit the Yellow Eyed Penguin reserve, probable quick look at the Otakou Marae, then reboard the Monarch for afternoon tea and sail back to Dunedin City, dropped off by the Harbour about 7pm). Transfer back to the Physics Department is possible after the excursion.

Wednesday 22nd January 2014

09.00 Steven Cummer (invited)
Measurements and implications of the source altitude of terrestrial gamma-ray flashes

09.30 Mike Kosch
Stratospheric Sprite Streamers

09.50 Sushil Kumar
Early VLF perturbations at low latitude in the South Pacific region: AWESOME and SOFTPAL observations

10.10 Morning tea

10.40 Rajesh Singh
First observations of TLE's and Gigantic Jet in Indian subcontinent

11.00 Hiroyo Ohya
Detection of daytime tweek atmospherics in Japan

11.20 Steven Cummer
Modeling and measurements of very low frequency wave propagation through the ionosphere

11.40 Ivana Kolmasova
Ground-based measurements of lightning induced signals related to the TARANIS mission

12.00 Lunch (buffet at staff club from noon)

13.30 Mark Clilverd (invited)
Energetic electron precipitation from inside and outside of the plasmasphere during space weather events

14.00 Aaron Hendry
Combining ground-based and satellite observations to estimate typical energetic particle fluxes for EMIC-wave driven precipitation events

14.20 Craig Rodger
A statistical approach to determining energetic outer radiation-belt electron precipitation fluxes for ground based data

14.40 Jason Neal
Long term determination of Variations in energetic electron precipitation into the atmosphere using AARDDVARK

15.00 Afternoon tea

15.30 Ian Whittaker
Electron precipitation spectra - a global view using DEMETER and POES

15.50 Craig Rodger
VLF Wave-driven energetic electron precipitation: Wave-particle interactions affecting the polar atmosphere

16.10 Annika Seppälä
Impact of energetic particle precipitation on polar winter atmosphere and climate

16.30 Drop off any belongings at your accommodation (or store in a locked rom in the Physics department).

16.50 Depart from St David Lecture Theatre for Orokonui Ecosanctuary. Spend ∼1 hour walking inside the space (self-guided), then return for drinks and canaps on the deck followed by our meal. Transport provided back to the St David Lecture Theatre.

Thursday 23rd January 2014

09.00 Michael Rycroft (invited)
The physics of lightning-induced electron precipitation (LEP)

09.30 Jyrki Manninen
Some simultaneous observations of VLF events at two receivers separated by 400km in longitude

09.50 James Brundell
UltraMSK: A narrowband subionospheric VLF radio receiver

10.10 Morning tea

10.40 Neil Cobbett
An autonomous low powered phase stable VLF receiver designed for remote field operation

11.00 Sandip Chakrabarti
Propagation Effects of VLF Signals in Earth-Ionosphere Waveguide During the Eclipses of July 2009 and January 2010

11.20 Jyrki Manninen
Latest results from Finnish ELF-VLF campaign held in December 2013

11.40 VERSIM Business Meeting

12.30 Lunch (buffet at staff club from noon)

14.00 János Lichtenberger
Plasmaspheric density models in whistler inversion and whistler-FLR cross calibration

14.20 Daniela Wenzel
Topside ionosphere and plasmasphere electron energy density distribution from space based CHAMP and GRACE data

14.40 Balazs Heilig
PLASMON FLRID: An automated detection of field line resonances

15.00 Rajesh Singh
Geo-location and propagation features of very low latitude whistlers (L=1.08)

15.20 János Lichtenberger
Plasmaspheric electron densities and plasmasphere-ionosphere coupling fluxes

15.40 Closing afternoon tea and departure

Abstracts

Monday 20th January 2014

Initial results from the electric and magnetic field instrument suite and integrated science (EMFISIS) on the Van Allen probes

C. A. Kletzing[1]*, W. S. Kurth, R. MacDowall, R. B. Torbert, G. R. Hospodarsky, S. R. Bounds, C. W. Smith, J. Connerney, O. Santolik, R. Thorne, V. Jordanova, J. Wygant, and J. W. Bonnell*

1: Department of Physics and Astronomy, University of Iowa, Iowa City, IA, USA

The physics of the creation, loss, and transport of radiation belt particles is intimately connected to the electric and magnetic fields which mediate these processes. A large range of field and particle interactions are involved in this physics from large-scale ring current ion and magnetic field dynamics to microscopic kinetic interactions of whistler-mode chorus waves with energetic electrons. To measure these kinds of radiation belt interactions, NASA implemented the two-satellite Van Allen Probes mission. As part of the mission, the Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) investigation is an integrated set of instruments consisting of a tri-axial fluxgate magnetometer (MAG) and a Waves instrument which includes a tri-axial search coil magnetometer (MSC). These wave measurements include AC electric and magnetic fields from 10Hz to 400 kHz. We show examples of plasmapause identification and variation determined by the upper hybrid resonance, low frequency ULF pulsations, and whistler mode waves including upper and lower band chorus. These data are compared with particle measurements to show relationships between wave activity and particle energization.

Combining relativistic electron measurements from high-altitude equatorial and low-Earth orbiting spacecraft to study outer radiation belt source and loss processes from wave-particle interactions

D. L. Turner[1], A. Kellerman[1], W. Li[2], and V. Angelopoulos[1]

1: Dept. of Earth, Planetary, and Space Sciences, University of California, Los Angeles, USA

2: Dept. of Atmospheric and Oceanic Sciences, University of California, Los Angeles, CA, USA

We present a novel technique that combines observations of relativistic, >1 MeV electron observations from spacecraft in both high-altitude equatorial (HAEO) and low-Earth (LEO) orbits. HAEO spacecraft, such as those from NASA's THEMIS and Van Allen Probes missions, allow the opportunity to examine the near-full pitch-angle distribution of trapped electrons in Earth's outer radiation belt. However, due to the small size of the atmospheric loss cone at outer belt L-shells along the magnetic equator (< 6 deg) and practical limitations on the field-of-view of energetic particle instruments, HAEO spacecraft are physically unable to resolve the atmospheric loss cone. At LEO altitudes, the loss cone opens up to ∼60 deg, making it possible to simultaneously observe both the trapped and precipitating populations there. The NOAA-POES spacecraft do exactly this; with two, identical instruments, one pointed approximately perpendicular and one pointed approximately parallel (or anti-parallel depending on the hemisphere), POES provide simultaneous measurements of electrons and protons stably trapped near their mirror points and precipitating into the loss cone. Furthermore, near global coverage of the trapped and precipitating populations at LEO is available thanks to the current 6 POES spacecraft spread out over nearly the full range in MLT.

Here, we show an example of how the trapped >1 MeV electron measurements from POES can be scaled to fit onto the full equatorial pitch angle distribution of trapped, >1 MeV electrons from the THEMIS-SST instruments. When combined with an equivalently scaled, simultaneous precipitation measurement from POES, this combination of measurements allows one to estimate the precipitation rate into the atmosphere as a percentage of the full trapped population on any particular L-shell. Such estimates provide a characteristic loss timescale for electrons on any given L-shell throughout the belt. We demonstrate how this technique can be used to estimate total atmospheric losses during outer radiation belt dropout events, in which the vast majority (up to and exceeding 90%) of the pre-dropout population of relativistic electrons throughout the belt are lost. We present details from preliminary cases and discuss the implications for the primary loss mechanism during dropouts: rapid precipitation into the atmospheric loss cone due to interactions with electromagnetic ion cyclotron and whistler mode chorus waves vs. sudden loss to the magnetopause resulting in a rapid cascade of outward radial transport that perpetuates losses to lower L-shells.

Finally, since dropouts essentially wipe out the majority of the pre-existing outer belt population, we discuss how the combination of HAEO and LEO observations can be used to examine the subsequent source mechanism responsible for replenishing relativistic electrons within less than a day after dropouts. Our observational results strongly support the theory of local acceleration by resonant interactions with whistler mode chorus. HAEO observations from THEMIS and Van Allen Probes are used to show growing peaks in equatorial electron phase space density collocated with enhanced VLF emissions identified as chorus. Meanwhile, LEO observations of lower energy (>30 keV) electrons from POES can be used to estimate the global distribution of chorus waves. Such a combination of observations again proves invaluable by allowing the system to be accurately modeled, showing how local acceleration of electrons by VLF chorus waves can result in the observed enhancements of the outer radiation belt.

The development of a global, time varying distribution of chorus waves and its utility in modeling radiation belt acceleration events

J. Bortnik[1,2], W. Li[1], R. M. Thorne[1], B. Ni[1], J. C. Green[3], C. A. Kletzing[4], W. S. Kurth[4] and G. B. Hospodarsky[4]

1: Department of Atmospheric and Oceanic Sciences, UCLA, Los Angeles, California, USA

2: Center for Solar-Terrestrial Physics, New Jersey Institute of Technology, Newark, New Jersey, USA

3: National Geophysical Data Center, National Oceanic and Atmospheric Administration, Boulder, Colorado, USA

4: Department of Physics and Astronomy, University of Iowa, Iowa City, IA, USA

Using a set of observations of 30-100 keV precipitating electron fluxes from several Low Earth Orbiting POES satellites, we infer the time-varying global chorus wave field and show that it provides a reasonable estimate to chorus waves measured simultaneously near the equatorial source region. This is accomplished with the aid of a physics-based model that describes the scattering of electrons in the vicinity of the loss-cone, which is then compared to POES observations at LEO made at roughly parallel and perpendicular angles to the field line, corresponding to equatorial pitch angles that straddle the loss cone. Using in situ observations made simultaneously by the twin Van Allen Probes during the October 8-9 2012 geomagnetic storm, we show that our inferred chorus wave fields are in good agreement with measured values. We then use our inferred global chorus wave fields to estimate rates of pitch angle and energy diffusion to be used in a Fokker-Planck diffusion code, and show that the observed electron acceleration event, which stretches to ultra-relativistic energies, can be reproduced very accurately, identifying chorus as the dominant acceleration mechanism in this storm.

Propagation parameters of whistler-mode waves in the outer radiation belt: results from the Van Allen probes and Cluster

O. Santolík[1,2], G. B. Hospodarsky[3], W. S. Kurth[3], T. F. Averkamp[3], C. A. Kletzing[3] and N. Cornilleau-Wehrlin[4,5]

1: Institute of Atmospheric Physics ASCR, Prague, Czech Republic

2: Charles University, Prague, Czech Republic

3: Department of Physics and Astronomy, University of Iowa, Iowa City, IA, USA

4: LPPP/CNRS-Ecole Polytechnique, Palaiseau, France

5: LESIA, Observatoire de Paris, Meudon, France

The role of whistler-mode chorus waves in the dynamics of Earths VanAllen radiation belts has been demonstrated for both losses and local acceleration of relativistic electrons by wave-particle interactions. These waves can cause pitch-angle and/or energy diffusion of electron populations at different energies. Wave propagation directions are a crucial parameter of the underlying wave-particle interactions. We use new measurements of whistler-mode waves by the Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) onboard the Van Allen Probes spacecraft. Multicomponent data recorded and processed by this instrument allow us to systematically estimate the wave propagation parameters. We use the survey data from the first year of operations of the EMFISIS instrument to determine probability density functions of propagation characteristics. We compare these results with a large database of measurements of the STAFF-SA instrument onboard the Cluster spacecraft, covering a time interval of more than one solar cycle. This work receives EU support through the FP7-Space grant agreement no 284520 for the MAARBLE collaborative research project.

Extremely intense ELF magnetosonic waves and a possible new source for plasmaspheric hiss?: Polar observations

B. T. Tsurutani[1], *B. J. Falkowski*[2,3], *O. P. Verkhoglyadova*[2,4], *J. S. Pickett*[5], *O. Santolik*[6,7] *and G. S. Lakhina*[8]

1: Space Physics Institute, S.M., CA

2: Jet Propulsion Laboratory, California Institute of Technology, CA

3: Glendale City College, Glendale, CA

4: CSPAR, University of Alabama, Huntsville, AL

5: Department of Physics and Astronomy, University of Iowa, Iowa City, IA, USA

6: Institute of Atmospheric Physics ASCR, Prague, Czech Republic

7: Charles University, Prague, Czech Republic

8: Indian Institute of Geomagnetism, Navi Mumbai, India

From a survey of Polar plasma waves conducted over the interval 1 April, 1996 to 4 April, 1997 (during solar minimum) at and inside the plasmasphere, magnetosonic waves were detected at all local times with a slight preference of occurrence in the midnight-postmidnight sector at L= 3 to 4. The waves occurred primarily during heightened geomagnetic (AE) activity. Wave occurrence (and intensities) peaked at $\sim \pm 5^\circ$ of the magnetic equator, with half-maxima at $\sim \pm 10^\circ$. An extreme magnetosonic wave intensity event of amplitude Bw = $\sim \pm 1$ nT and Ew = $\sim \pm 25$ mV/m was detected during the survey period. The event occurred near local midnight (0022 MLT), at the magnetic equator (MLAT = -0.5°), at the plasmapause (L = 3.5), and during a substorm/convection event (AE = 624 nT; SYM-H = -33 nT). If more stringent requirements ($|$ MLAT$| \leq 5^\circ$ and AE $>$ 300 nT) are imposed, the wave occurrence rate approaches $\sim$50% for the 23 to 00 MLT bin at L = 3 to 4. A strong local time anisotropy in the location of magnetosonic wave occurrence rate supports the idea of generation by protons injected from the plasmasheet into the midnight sector magnetosphere. The authors speculate that intense magnetosonic waves are always present somewhere in the magnetosphere during strong substorm/convection events. For other wave events, magnetosonic waves were also detected as far from the equator as +20° and -60° MLAT, but at lower intensities. The wave magnetic component oscillations are aligned along B0, the ambient magnetic field direction, and the electric component oscillations are orthogonal to B0, indicating linear polarization. The magnetosonic wave amplitudes decreased at locations further from the magnetic equator, while transverse whistler mode wave amplitudes increased. The authors speculate that either charged particle interactions with the magnetosonic waves or direct mode conversion is leading to the generation of the transverse whistler mode waves. Thus this mechanism, if correct, may be a new source for the low frequency component of plasmaspheric hiss, adding to other sources, previously discussed in the literature. As a final comment, we argue that modelers should use dynamic particle tracing codes and the maximum (rather than average) wave amplitudes to simulate wave-particle interactions.

The new SCOSTEP programme, SPeCIMEN (Specification and Prediction of the Coupled Inner-Magnetospheric Environment)

J. Bortnik[1] *and C. J. Rodger*[2]
1: Department of Atmospheric and Oceanic Sciences, UCLA, CA, USA
2: Department of Physics, University of Otago, Dunedin, New Zealand

The Earths inner magnetosphere is an exceedingly complex, coupled system that is driven by fluctuations in the solar wind, ultimately reflecting conditions in the Suns corona. This inner magnetospheric environment is host to a variety of particle species (including electrons and heavy ions) that cover a broad range of energies from sub-eV to tens of MeV, and plasma waves that cover essentially the entire frequency spectrum. Incoming energy from the solar wind is processed through the system and results in a variety of effects such as the energization of electrons and protons to MeV energies (i.e., the formation of the radiation belts), and the precipitation of particles into the dense upper atmosphere resulting in bright auroral displays, modification of the distribution of ionospheric conductivities, and a slew of chemical reactions that propagate through the Earths atmosphere and may couple to surface climate. These effects also act as feedback processes to inner magnetospheric dynamics, throttling rates of reconnection or convection, modifying the pattern of the global electric field and hence wave excitation (which, in turn, affect the higher energy particles), and loading or unloading the systems mass dynamics via substorms, flows, and related effects.
The Scientific Committee On Solar-TErrestrial Physics (SCOSTEP) has recently started a new 5 year programme (2014-2018) entitled VarSITI, which stands for Variability of the Sun and Its Terrestrial Impact. The VarSITI programme includes 4 projects, one of which is called SPeCIMEN (Specification and Prediction of the Coupled Inner-Magnetospheric Environment). Its primary scientific question is “What is the physics behind radiation belt electron flux dynamics that would enable the development of predictive models?”, and the primary goal is to produce quantitative prediction and specification of the Earths inner magnetospheric environment based on Sun/solar wind driving inputs, through a combination of physical and statistical/predictive models.
In this presentation we will describe SPeCIMEN, which is hopefully going to be part of our communities scientific activities in the next 5 years.

Generation Mechanism of Whistler-Mode Chorus Emissions

Y. Omura[1]
1: Kyoto University, Kyoto, Japan

We describe the nonlinear dynamics of resonant electrons interacting with a coherent whistler-mode wave and the formation of electromagnetic electron holes or hills in the velocity phase space. In the presence of the inhomogeneity due to the frequency variation and the gradient of the magnetic field, the electron holes or hills result in resonant currents generating rising-tone emissions or falling-tone emissions, respectively. After formation of a coherent wave at the maximum linear growth rate, triggering of the nonlinear wave growth takes place when the wave amplitude is close to the optimum wave amplitude. The wave amplitude also has to be above the threshold amplitude so that the nonlinear wave growth can occur as an absolute instability at the magnetic equator. The triggering process is repeated at progressively higher frequencies in the case of a rising-tone emission, generating subpackets of a chorus element. We also describe the mechanism of nonlinear wave damping due to quasi-oblique propagation from the equator, which results in the formation of a gap at half the electron cyclotron frequency, separating a long rising-tone chorus emission into the upper-band and lower-band chorus emissions.

Simulation of radial transport, local acceleration, and loss in the radiation belts

A. A. Chan[1]*, S. R. Elkington*[2]*, J. M. Albert*[3]*, and L. Zheng*[1]

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2: LASP, University of Colorado, Boulder, Colorado, USA

3: AFRL, Kirkland AFB, Albuquerque, New Mexico, USA

Although much is known about the dynamics of the radiation belts there are still many unanswered questions on the basic physical processes responsible for the storm-time variations of relativistic electrons. Two physical processes that are thought to be especially important are (i) drift-resonant wave-particle interactions with ULF perturbations, which may lead to radial diffusion, and (ii) cyclotron-resonant wave-particle interactions with VLF/ELF waves, which may lead to local energy and pitch-angle diffusion. While there is theoretical and observational support that both of these processes play important roles in radiation belt dynamics, their relative contributions are still not well understood quantitatively. Also, recent work suggests that magnetopause shadowing may play a larger role than previously expected, and the physical connections between changes in the radiation belts and different solar interplanetary drivers are not well understood. In this presentation I will present recent results (particularly for high-speed-stream storms) that emphasize comparison of theories and observations of the radiation belts.

Chorus properties: Importance for wave-particle modeling

B. T. Tsurutani[1]*, G. S. Lakhina*[1]*, O. P. Verkhoglyadova*[1]*, B. J. Falkowski*[1]*, J. S. Pickett*[1] *and O. Santolík*[1]

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Chorus is a magnetospheric electromagnetic wave which is important for the precipitation and acceleration of energetic (∼5 to 100 keV) and relativistic magnetospheric electrons. The purpose of this talk will be to review chorus properties, both those which are well understood and those which need further investigation. The topic of wave-particle interactions with whistler mode chorus will be discussed in detail, hopefully aiding theoretical modeling during the Van Allen Belt Probes (and other) missions.

Simulations of Ion Acoustic Waves in Saturn's Magnetosphere

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Previously, the high frequency modes (electron plasma, electron acoustic and beam-driven) occurring in the Earth's auroral region were studied using a Particle-in-Cell (PIC) simulation. This work extends the study to the low frequency ion acoustic wave mode. Existence domains and characteristics of ion acoustic waves are studied in a plasma with kappa-distributed electrons of two temperatures, low density adiabatic ions. Such an environment has been found in Saturns magnetosphere. Using a PIC simulation, the evolution of the spatial electric field is tracked during the entire simulation, after which a dispersion diagram is constructed to study the dispersion characteristics of the ion acoustic mode. This presentation will give an introduction to the PIC method and the results obtained by using CASSINI measurements (from Saturn's magnetosphere) as the input parameters to explore the dispersion characteristics of the ion acoustic mode. Since the ion acoustic mode is the one of interest, the main focus of the study is on the ion dynamics and the lower frequency part of the dispersion diagram.

Detection of resonant electron pitch angle scattering by whistler waves in a laboratory plasma

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The resonant interaction between a whistler mode wave and energetic electrons is a fundamental ingredient in controlling the dynamics of the space environment, and in particular the high-energy radiation belts. Although the theory describing resonant wave particle interactions has been developed several decades ago, it has not been hitherto tested in a controlled laboratory environment. In this talk, we report on the first laboratory experiment to directly observe resonant pitch angle scattering of keV electrons due to whistler mode waves. We show that the whistler mode wave deflects energetic electrons at precisely the predicted resonant energy, and that varying both the maximum beam energy, and the wave frequency, alters the energetic electron beam very close to the resonant energy.

Powerful VHF radars, like EISCAT-3D, as a source of ELF/VLF waves

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1: EISCAT Scientific Association, Norway

The European Incoherent Scatter Scientific Association (EISCAT) is planning to build a new generation phased array radar in the near future for atmospheric, ionospheric and space research in the auroral region of northern Scandinavia. The high power of 10 MW, frequency around 230 MHz, and high duty cycle of this EISCAT_3D (E_3D) radar means that D region electrons can be heated by the VHF wave so that the conductivity is modulated. In the presence of horizontal currents in the auroral or possibly equatorial regions, this conductivity modulation should result in radiation of ELF and VLF pulses which could be observed on the ground or in space. This has been observed repeatedly with powerful HF transmitters, and theoretically predicted at a weaker level for current VHF transmitters [Rietveld and Stubbe, Radio Science, 1987] but has never been observed. Since E_3D should run continuously this will potentially provide a continuous source of ELF/VLF pulses although detection may not always be possible when conditions are unsuitable. A relatively simple broadband ELF/VLF receiving system situated nearby is used to detect VLF broadband pulses in synchronism with the radar pulses. Using orthogonal antennas the polarization ellipse of the ELF/VLF signals is obtained from which one can deduce horizontal electric fields and D region parameters. Together with ionospheric parameters obtained from the radar, the ELF/VLF signals can be used to test models of the ELF/VLF generation process. Once the idea has been proven to work, it could become an interesting new geophysical technique.

Tuesday 21st January 2014

Height and sharpness of the ceiling of the Earth-ionosphere waveguide

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Phase and amplitude measurements of VLF radio waves from man-made transmitters provide an important technique for determining the height and sharpness of the lowest edge of the D-region of the Earth's ionosphere. The measurements need to be made both near ($<\sim$100 km) the transmitter and also, at least, at one greater distance typically either at $\sim$300-400 km from the transmitter where, by day, the amplitude of the ground wave is comparable with the ionospherically reflected wave or, for a reasonably homogeneous path, at, say, $\sim$5-10 Mm from the transmitter where the ground wave is negligible and there has been considerable ionospheric averaging with distance. These phase and amplitude observations can then be compared with the corresponding calculations from suitable VLF waveguide propagation codes (LWPC, ModeFinder, WaveHop) using a range of appropriate values of height, H', in km, and sharpness, β, in km^{-1}, from which a unique pair of H' and β values can be found which match the observations.
Results from this technique will be reviewed mainly under quiet daytime conditions but also under other conditions such as night, solar flares and changing solar cycle. Additional results from recent observations, towards solar maximum, at both low and high latitudes will also be presented and discussed.

Establishment of a "Global Ionospheric Flare Detection System" (GIFDS)

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Solar flares affect the Earths surrounding and their technical systems for several minutes up to half an hour. Due to frequent interactions with coronal mass ejections (CMEs), these phenomena are very often precursors of space weather storms. Hence, a continuous and reliable monitoring of flares and their impacts on the ionospheric system is becoming indispendable. In order to establish an operational near real time warning system, DLR Neustrelitz started the project 'Global Ionospheric Flare Detection System GIFDS', by the beginning of the last year. This will be realised by ground based measurements from a couple of VLF receivers. If an X ray flare impacts the Earths space, one can observe an increase of the ionization of the bottomside ionosphere, which causes amongst others an abrupt characteristic change in the signal strength of VLF waves during daytime. Thus, the basic requirement for a permanent record of the dayside sector is a network of VLF receivers around the globe. DLR is installing and operating two stations, at DLR Neustrelitz and in US at Boston College. Operational measurements are obtained by Software Defined Radios, Perseus SDR receivers, providing multiple channels of frequencies from 10 to 60 kHz. Once concurrent signals at different frequencies exhibit the same significant variation of a flare, an X ray event is assumed and a warning will be automatically sent out. With regard to space based measurements of GOES satellite, preliminary studies will discuss the reliability, strength and time resolution of derived warnings.

Earth as a Gigantic detector: GEANT4/LWPC Simulation of X-ray Detection and Comparison with Observation

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We carry out extensive Monte-Carlo Simulation (GEANT4) to compute the effects of the impinging of X-rays and gamma-rays onto the ionosphere. we then compute the resulting electron density at different altitudes and used LWPC code to reconstruct the VLF amplitude variation. We compare results from this ab initio analysis with a few solar flares and discuss the similarities and differences.

The South America VLF network: Extension and new results

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In this work we will present the latest upgrades performed on the South America VLF Network (SAVNET). In particular, reforms were realized at Atibaia (ATI) receiver station, and a new receiver base will be installed early 2014 in the northern part of Brazil. The latest results will be also presented. They refer to the ionospheric disturbances produced by explosive solar Lyman-a radiation, and the effects of the solar eclipse of 2010, July 11. Recent findings on the ionospheric imprints of X-ray bursts from a remote astrophysical object will also be discussed.

Links between mesopause temperatures and ground-based VLF narrowband radio signals

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The Upper Mesosphere-Lower Thermosphere (UMLT) region of the atmosphere is known to vary on many temporal and spatial scales. However, this region of the atmosphere is very difficult to measure and monitor continuously.

In this talk we demonstrate an intriguing connection between mesopause temperatures and the intensity of Very Low Frequencies (VLF) narrowband (NB) signals reflected off the lower ionosphere. The temperature data used are from the SABER instrument on-board the TIMED satellite, while the VLF data are obtained from various ground-based receiving systems. The results of the analysis show a high anti-correlation between temperature and VLF amplitude. It is shown that the variability of the UMLT temperatures and VLF amplitudes can be explained by global seasonal solar irradiance changes (∼72% of the variability), while the remaining variability has its origins from other sources (∼28%). High resolution mesopause temperature estimates might be achieved in the future by combining VLF NB observations and calculated solar irradiance variability (as a function of hour, day, and location, i.e., latitude.

Detecting space weather events with subionospheric VLF observations

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2: British Antarctic Survey, Cambridge, UK

The ionization rate of the upper atmosphere can be significantly increased by space weather events, examples being solar proton events (SPE) and solar flares. An increase in the ionization rate leads to a lowering of the lower edge of the ionospheric D-region. To study the effect of space weather events on our atmosphere it is important 1) to be able to detect the events and also 2) to have some way of determining changes in height of the D-region. Very low frequency (VLF) radio waves propagate in the waveguide between the surface of the Earth and the lower edge of the ionosphere (D region). Changes in the height of the D-region lead to changes in the amplitude and phase of the received signal. To gain an accurate indication of the size of these changes we need to know what the undisturbed signal, known as a Quiet Day Curve (QDC), would have been if no space weather event had taken place.
High power narrow-band communications transmitters operated by multiple nations provide the VLF radio signals used in this technique. Here we use observations from the Antarctic-Arctic Radiation-belt Dynamic Deposition VLF Atmospheric Research Konsortia (AARDDVARK) [Clilverd et al.,Space Weather,7,S04001,2009] network of receivers.
In this study we use radio wave observations from the AARDDVARK receivers located at Edmonton, Canada and Scott Base, Antarctica to determine the typical behaviour of the received amplitude.
We will present work we are undertaking to develop an algorithm to automatically define the QDC for a given transmitter receiver path from many years worth of observations. We demonstrate two methods for determining a QDC by algorithm. These are Principal Component Analysis and 2 dimensional Fourier Transforms. Diurnal variations for each day of the year and yearly variations will be found. Once the QDC is determined we then provide examples of how the differences between the received VLF signal and the QDC can be used to detect space weather events, in particular those caused by solar flares and SPEs.

Two solar cycles of VELOX recordings at Halley, Antarctica

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The VELOX (VLF ELF LOgger eXperiment) instrument records VLF and ELF wave activity on the ground in eight quasi-logarithmically spaced wideband channels from 500 Hz to 10 kHz. Data are logged continuously with a time resolution of 1 second. At Halley, Antarctica (75.5S, 26.7W, L=4.3) recordings were begun just 22 years ago, on 14th January 1992 and have continued to the present day with few missed recordings (98% coverage). There is thus a unique archive of ground based ELF/VLF wave data spanning approximately two solar cycles to date. The instrument is operated by British Antarctic Survey and the data are available on the Internet.

At a previous VERSIM meeting, the characteristics of the waves received during one and a half cycles (from 1992 to 2007) were summarised and subsequently published. This talk updates these results to take account of the most recent half solar cycle (2008-1013). The original receiver was replaced in 2007 by a newer one with a nominally identical (but actually slightly different) response. The later data have been harmonised with the earlier data using a 247-day overlap interval (6 February - 30 September 2007) when both receivers were operated simultaneously.

The main types of waves received are chorus, mid-latitude hiss, auroral hiss and summer lightning (spherics). The occurrence of these maximise in different frequency, MLT and month of the year ranges and this can be used these to investigate their variation (if any) with solar cycle phase, and also any long term (decadal scale) rate of change. In particular, chorus appears to be correlated with solar activity but with a maximum delayed with respect to the solar maximum. There is a decreasing trend averaging about -0.25 dB per year over the two solar cycles.

Wednesday 22nd January 2014

Measurements and implications of the source altitude of terrestrial gamma-ray flashes

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Radio emissions continue to provide a unique view into the electrodynamics of terrestrial gamma ray flash (TGF) production. It is generally agreed that most and perhaps all TGFs are produced during the early, upward leader stage of normal polarity IC lightning flashes. Observations have shown that at least some TGFs are effectively simultaneous with a distinct low frequency pulse, indicating likely production of that pulse by the TGF-generating electron acceleration process itself [Cummer et al., GRL, 2011]. Additional observations of an anti-correlation between the TGF-radio association rate and TGF duration [Connaughton et al., JGR, 2013], and detailed comparisons of simulation and measurement [Dwyer and Cummer, JGR, 2013] strongly support this picture.

A subset of TGF events detected over the past several years by the GBM instrument on the Fermi satellite, and also measured by our network of low frequency radio sensors, produced radio emissions that are sufficiently distinct to estimate the TGF source altitude from multiple ground-ionosphere reflections. By combining the gamma ray measurements, radio measurements, and Monte Carlo modeling, the self consistency of the source altitude, gamma ray flux, and radio emission duration and magnitude can be rigorously and quantitatively tested in the context of TGF generation theories. We will present several of these observations and associated analysis, and attempt to draw some firm conclusions about the physics behind TGFs.

Stratospheric Sprite Streamers

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Sprites are composed of individual streamer discharges (e.g., Pasko, 2010) which split into streamer tips (McHarg et al., 2010) with diameters ∼50-100 m at ∼60-80 km height (Kanmae et al., 2012). The sprite luminosity coincides in time and space with extremely low frequency electromagnetic radiation <3 kHz in excellent agreement with theory (Cummer and Fullekrug,2001). This theory is based on current flowing in the body of sprites at 70-80 km height associated with large streamer densities (Pasko et al., 1998). A more detailed study shows specifically that the exponential growth and splitting of streamers at 70-80 km height results in an electron multiplication associated with the acceleration of electrons to a few eV. The accelerated electrons radiate a small amount of electromagnetic energy and the incoherent superposition of many streamers causes the observed electromagnetic radiation (Qin et al., 2012).

It has been predicted that this newly recognized physical mechanism might also result in low frequency (∼30-300 kHz) electromagnetic radiation emanating from sprite streamers near ∼40 km height in the stratosphere, albeit with very small magnetic fields 10^{-17}-10^{-12} T from a single streamer (Qin et al., 2012). The presence of this predicted radiation was promptly confirmed by low frequency radio noise measurements during dancing sprites with a very sensitive radio receiver (Fullekrug et al., 2013). Specifically, it was found that the sprite luminosity coincides with sudden enhancements of the radio noise. These initial observations are extended here with a more detailed analysis to study the spatial coherence of the radio noise and its relationship to sprite luminosities.The sprite luminosities are inferred from video recordings by use of sophisticated image processing techniques which are applied for the first time to video footage of sprites. The rise times of sprite luminosities are measured by recordings of the second positive group from molecular nitrogen at a wavelength of ∼334-346 nm with a photomultiplier tube at 1 μs resolution. The rise times are compared to the rise times of the lightning electromagnetic pulses to determine the response time of atmospheric luminosities to forcing by lightning electgromagnetic fields.

Early VLF perturbations at low latitude in the South Pacific region: AWESOME and SOFTPAL observations

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The SoftPAL and AWESOME VLF data recording systems were installed at Suva (18.1° S, 178.5° E, L=1.16) in the year 2006 and 2009, respectively, to study short-time scale ($\sim$ 1-100 s) early VLF events on Very Low Frequency (VLF) transmitter signals. Typical records showing simultaneous occurrence of VLF events recorded by both the systems show SoftPAL as an equally reliable data recorder. Daytime early/fast events on NWC transmission are associated with only negative amplitude perturbations and have comparatively lower recovery times as compared to most nighttime events. The observations of early/slow events in the daylight propagation will be presented. The unusually long recoveries ($\geq$ 5 min) with strong perturbations ($\geq$ 1 dB) are mainly observed on the transmissions from NPM and NLK in the nighttime only. Such unusually long recovery early/fast events may be associated with large ionic conductivity perturbations associated with gigantic jets or with the combination of sprite and gigantic jets. World-Wide Lightning Location Network detected lightnings show that 73% of early VLF events were due to narrow-angle scattering and 27% lightnings due to wide-angle scattering under the current literature criteria of size of D-region perturbations of about 100-150 km associated with TLE producing discharges. Strong perturbation events will be analyzed to examine signatures of infrasound waves associated with lightnings producing VLF perturbations.

First observations of TLE's and Gigantic Jet in Indian subcontinent

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In this paper we present first observations of TLE's and Gigantic Jet in Indian Sub-continent observed during 2012-2013. Transient Luminous Events (TLEs) are the newly and widely studied phenomenon in atmospheric sciences. These short lived optical emissions include sprites, halos, blue starters, blue jets, gigantic jets and elves, which are observed above large thunderstorms in the stratosphere and mesosphere regions of Earths atmosphere. In India we are continually operating a TLE detection camera system since April 2012 at a site located in north central India Allahabad (Geographic lat.29.360° N, long.79.460° E). We observed first sprite event on 11^{th} April 2012 and since then we have total 15 event days till September 2013. The observed TLE events are mostly sprite with two events of gigantic jets and two possible events of elves. Event days mostly correspond to pre to post monsoon season (April to September months) in north India. The event detection range varies from 210 to 540 km surrounding Allahabad. Along with optical observations, we have also used ULF, VLF (broadband and narrowband) and GLD360, WWLLN lightning data in order to qualify and quantify parameters of the parent lightning discharge associated with the TLEs and their effects on lower ionosphere/atmosphere. Observations of TLEs are important as, these events raise new science questions about the characteristics of TLE producing thunderstorm, as previously it was thought that, TLEs cant be observed over Indian thunder clouds as they do not form Mesoscale Convective Systems (MCSs) during monsoon seasons which are proposed to produce sprite events.

Detection of daytime tweek atmospherics in Japan

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It is well known that tweek atmospherics can be observed only at night except for solar eclipse days, because daytime attenuation rate of the tweeks is much larger ($\sim$70dB/Mm) than that in nighttime ($\sim$3 dB/Mm). In this presentation, we firstly report detection of daytime tweeks at Moshiri (Geographic coordinate: 44.37°N, 142.27°E) and Kagoshima (31.48°N, 130.72°E), Japan, on non-solar eclipse days in December, 1980. The daytime tweeks were observed both on magnetically quiet and storm days during 16-20 December, 1980. The minimum Dst value was -240 nT at 04:00 UT on 20 December. The average occurrence numbers of the daytime tweeks at Moshiri and Kagoshima were 2.7 and 0.3 tweeks per minute, respectively. The local times (LT) when the daytime tweeks occurred were through 07:00 17:00 LT at Moshiri, while they were 07:00 09:00 LT and 15:00 17:00 LT at Kagoshima. All the daytime tweeks show clear frequency dispersion. The average duration was 18.94 ms, while that of nighttime tweeks is $\sim$50 ms. The average reflection heights of daytime tweeks at Moshiri and Kagoshima were 86.2 km and 94.7 km, respectively. The variation of the daytime tweek reflection height was larger than that of nighttime tweeks. The horizontal propagation distance could not be estimated from the dispersion, because the duration was too short to estimate the distance. However, the daytime propagation distance could be considered to be more than 1 Mm, because clear dispersion was observed. The occurrence of the daytime tweeks is inconsistent with the daytime attenuation of $\sim$70dB/Mm. In this talk, we will show these characteristics of the daytime tweeks and discuss their occurrence mechanism.

Modeling and measurements of very low frequency wave propagation through the ionosphere

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High altitude radiation belt particles from either natural or man-made origin have a significant impact on the satellite environment. An important loss mechanism for these particles is their interaction with very low frequency (VLF) electromagnetic waves. Wave energy at these frequencies is naturally resonant with high-energy radiation belt particles and, through nonlinear wave-particle interactions causing pitch angle scattering, can cause their precipitation and loss into the atmosphere. Predicting the upward propagation of very low frequency radio waves through the ionosphere to radiation belt altitudes is thus an important element of understanding radiation belt dynamics. Recent analysis of high altitude satellite measurements of VLF transmitter signals has shown that measured field amplitudes are consistently 20 dB lower than predictions from a simplified model. There thus appears to be a significant discrepancy between satellite measurements and model predictions, and this discrepancy has a major impact on previous calculations of radiation belt lifetimes.

Using a unique existing dataset of simultaneous high altitude and ground-level VLF field measurements of broadband lightning signals we probed many different facets of the missing VLF power. This dataset comes from two sources. On one hand we have data coming from the Lightning Bolt rocket experiment, which flew in 2000. On the other hand we have ground-based broadband VLF measurements performed at Duke University during the flight. We present an empirical model based on this analysis which shows how VLF attenuation varies with frequency and altitude. To validate the model, we extensively simulated the VLF power and field distribution in the vicinity of ground-based VLF transmitters and compared the predictions to the two sets of measurements. The simulations were performed with our custom made finite-difference-time-domain code capable to model in detail the propagation of electromagnetic waves produced by ground-based sources through ionosphere hundreds of kilometers away from the transmitter.

Ground-based measurements of lightning induced signals related to the TARANIS mission

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We present results of ground-based broadband measurements of lightning-induced signals, which we have recorded during the observational campaigns in Prague, Czech Republic (2011-2012) and in Rustrel, France (2012-2013). Waveforms of the vertical electric field and two horizontal components of the magnetic field have been measured by a ground-based version of the VLF/ELF analyzer ELMAVAN with a sampling interval of 20 μs, which we are preparing for the Russian RESONANCE satellites. We also analyze waveforms of the horizontal magnetic field measured by a ground-based version of the IME-HF analyzer with a sampling interval of 12.5 ns, which we are preparing for the French TARANIS mission.

We concentrate our attention on signals radiated by in-cloud processes which are difficult to detect in situ or optically. We analyze sequences of pulses occurring prior to the first stroke of negative lightning flashes (in the frequency range from 200 Hz to 36 MHz). We study also the trains of unipolar pulses occurring between strokes, and a few cases of a bouncing wave type discharge (in the frequency range from 5 kHz to 36 MHz). After the launch of the TARANIS satellite the ground-based measurements will complement the observations from space.

Energetic electron precipitation fluxes from inside and outside of the plasmasphere during space weather events

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We discuss the development of a model of energetic electron precipitation (EEP) fluxes inside and outside of the plasmasphere during space weather events. The aim of the PLASMON EEP model is to identify 3 or 4 MLT zones which are populated by ULF/VLF waves that can generate energetic electron precipitation. The MLT zones are influenced by the MLT-dependent plasmaspheric density structures such as the plasmapause. During geomagnetic disturbances the intensities of the ULF/VLF waves are enhanced, plasmaspheric structures are modified, and differing levels of precipitation flux occur. The model will characterise the storm-time variations in electron precipitation relative to the plasmapause, building on the outputs of the data assimilative model of the plasmasphere undertaken by the PLASMON project, and observations of EEP characteristics made by the AARDDVARK ground-based VLF receiver network.

Combining ground-based and satellite observations to estimate typical energetic particle fluxes for EMIC-wave driven precipitation events

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For some time, theoretical modelling has shown that electromagnetic ion cyclotron (EMIC) waves should play an important role in the loss of relativistic electrons from the radiation belts through precipitation of the electrons into the atmosphere. The same wave will also resonant with comparatively low-energy protons, precipitating them into the atmosphere. Proton resonance with counter-streaming EMIC waves is much like the electron-cyclotron resonance common with whistler mode waves, though with different interaction energies. Relativistic electron resonance takes place through "anomalous resonance" where the electron overtakes the wave. Until recently, it was thought that EMIC wave scattering interactions were limited to electrons with energies >1-2 MeV. Recent calculations [Omura et al., JGR, 2012] have suggested that this lower limit may be as small as 100 keV when considering EMIC waves which are more like those experimentally observed (i.e. non constant frequency which ramps with time).

We report on a continuing study that aims to to determine the typical flux seen by the ionospheric D-region during an EMIC driven precipitation event, in order to link this to plasmaspheric conditions. In this presentation we will investigate a very large set of EMIC-driven relativistic electron precipitation events detected using data from the POES satellite constellation and the AARDDVARK worldwide VLF receiver network [Carson et al., JGR, 2013]. As part of this study, we investigate the response of the MEPED instruments on-board the POES satellites to better characterise the EMIC-driven precipitation. Using the results of a previously reported Monte-Carlo simulation of the MEPED electron and proton telescopes [Yando et al., JGR, 2011], we produce an estimate of the typical precipitating electron and proton fluxes in the bounce loss cone for these events. We go on to show that such events will produce very significant D-region changes detectable using the ground-based AARDDVARK network.

A statistical approach to determining energetic outer radiation-belt electron precipitation fluxes for ground based data

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Energetic electron precipitation into the atmosphere over $3<L<7$ acts as a loss mechanism for the outer radiation belt electron population, and as an indicator of the physical mechanisms taking place in the radiation belts. Through a complex interplay between the acceleration, transport, and loss of electrons, individual geomagnetic storms can drive large changes in the flux of relativistic electrons within the outer radiation belts, potentially damaging satellites, and endangering astronauts. In addition, the energetic electrons lost into the polar atmosphere can cause significant changes in atmospheric chemistry and ozone concentrations, such that these events may couple to climate.

Subionospherically propagating very low frequency (VLF) radio waves can be used to monitor electron precipitation through changes in the ionization rate at altitudes of 50-90 km. As the VLF waves propagate beneath the ionosphere in the Earth-ionosphere waveguide the EEP-induced ionization produces changes in the received amplitude and phase. Due to the low attenuation of VLF subionospheric propagation, the EEP modified ionospheric region may be far from the transmitter or the receiver. This technique is often focused on high-power narrow-band communications transmitters operated by multiple nations. Here we use observations from the Antarctic-Arctic Radiation-belt Dynamic Deposition VLF Atmospheric Research Konsortia (AARDDVARK) [Clilverd et al., 2009] network of receivers (*http://www.physics.otago.ac.nz/space/AARDDVARK_homepage.htm*).

In this study we analyse data from an AARDDVARK receiver located in Churchill, Canada, and concentrate on signals from two US transmitters (call signs NAA, and NDK). We focus on the period July-August 2010 which induced changes in the radiation belt environment through enhancing relativistic electron fluxes. The signals are used to determine the effects of electron precipitation into the atmosphere over the range $3<L<8$, i.e., where outer radiation belt processes occur. We aim to address the limitations of the previous analysis by Clilverd et al. [2010] through additional modeling efforts and by combining the AARDDVARK data from the two paths. We combine the data from the two transmitters in order to confirm estimated fluxes, calculate the error bars, and inter-compare the results.

Long term determination of Variations in energetic electron precipitation into the atmosphere using AARDDVARK

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Earth is surrounded by regions of magnetospherically trapped high energy particles, known as the inner and outer radiation belts. Complex physical mechanisms of acceleration, transport and loss of electrons, influenced by geomagnetic storms, result in large changes to the flux of relativistic elections within the radiation belts. The loss mechanism for the outer radiation belt electron population results in energetic electron precipitation (EEP) into the atmosphere over $3<L<7$. These electrons can cause significant changes to ionization levels in the upper atmosphere, atmospheric chemistry and ozone concentrations, and potentially couple to climate variability.
Energetic electron precipitation can be monitored by their affect on the propagation of very low frequency (VLF) radio waves. EEP induced ionization produces changes in received amplitude and phase of the VLF waves as they propagate through the Earth-ionosphere waveguide. The Antarctic-Arctic Radiation-belt Dynamic Deposition VLF Atmospheric Research Konsortia (AARDDVARK) [Clilverd et al., 2009] network of receivers observes VLF radio signals from high-power narrow-band communication transmitters from multiple nations with the goal of understanding and detecting EEP along many different paths.
In this study we analyze data from an AARDDVARK receiver in Sodankylä, Finland, and concentrate on the signal from the US transmitter with call sign NAA located in Culter, Maine. We use data from 2004 till the end of 2012 to determine long time period EEP into the atmosphere along this path which spans $3<L<7$, i.e., under where outer radiation belt processes occur. We aim to recheck the quite day curves (QDC) produced in Clilverd et al. [2010] with the longer dataset and produce QDC for more MLT sectors. We will use these to estimate the electron fluxes into the atmosphere and attempt to validate these with other measurements of EEP and geomagnetic indices.

Electron precipitation spectra - a global view using DEMETER and POES

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The Detection of Electromagnetic Emissions Transmitted from Earthquake Regions (DEMETER) microsatellite electron flux instrument is comparatively unusual in that it has very high energy resolution (128 channels with 17.9 keV widths in normal survey mode), which lends itself to spectral analysis of electron precipitation from the Earth's radiation belts. Here electron spectra from DEMETER have been analyzed from all 6 years of its operation. Global electron flux maps are produced and average spectral fit values are taken during geomagnetic storm and quiet times. The flux behaviour and spectral variation during geomagnetic storm time and the recovery period are also examined, showing differences between the two radiation belts and the slot region.

The high energy resolution of the DEMETER satellite also allows insightful comparisons with electron flux measurements from MEPED (Medium Energy Proton and Electron Detector) instrument onboard the POES constellation of satellites. Unlike the high-resolution observations, POES/MEPED provide only 3 integral electron telescopes. Our comparison allows a test of the MEPED geometric factor equations given by Yando *et al.*, [JGR (116, A10231), 2011] which characterized proton contamination of the electron telescopes as well as a variation in detector efficiency with energy. Electron fluxes are compared when the MetOp-02 POES satellite is in similar locations to DEMETER (ΔL $<$ 0.5, Δlongitude $< 4^\circ$) using the MEPED 90° telescope as both instruments observe essentially the same particle populations (drift loss cone or trapped particles depending on the L shell). Simplified equations are calculated to reverse the geomagnetic factor (for SEM-2 electron instruments only) and then tested, these equations allow the MEPED electron fluxes to be corrected quickly and easily based on the values from Yando *et al.* 2010.

VLF Wave-driven energetic electron precipitation: Wave-particle interactions affecting the polar atmosphere

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Wave particle interactions are a fundamental physical mechanism driving change in the radiation belts. Growing evidence indicates that cyclotron resonance between VLF whistler-mode waves and energetic electrons play crucial roles for the acceleration of electrons to relativistic energies. It has long been recognised that the same resonances also pitch-angle scatter electrons, moving them towards the loss cone and loss into the atmosphere through precipitation.
In this talk I will combine observations from multiple sources to show how VLF wave activity controls the loss of radiation belt particles, determining both the loss rate and the atmospheric location for which this loss occurs. In particular we will use VLF wave observations made in LEO by the DEMETER spacecraft to contextualise electron precipitation observations provided by the POES spacecraft in LEO as well as the AARDDVARK network of ground-based sensors. These results provide evidence that strong diffusion due to high wave intensities dominates during storm-times, producing rapid pitch angle scattering and hence immediate precipitation. Our suggestion is confirmed by the completely independent observations of atmospheric HOx distributions, produced in the polar atmosphere by electron precipitation.
This work demonstrates how the changing intensity of VLF whistler mode waves can decrease polar ozone concentrations in the mesosphere.

Impact of energetic particle precipitation on polar winter atmosphere and climate

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This presentation we will give an overview of the latest results of energetic particle precipitation (EPP) impact on the polar atmosphere and discuss the potential effects of EPP on regional winter climate. In addition to solar storms the nearly continuous precipitation of energetic particles from the magnetosphere affects ionisation levels in the polar atmosphere. In the atmosphere this ionisation peaks in the middle atmosphere (20-100 km), where it leads to enhanced production of NOx and HOx gases. These are gases, which participate in catalytic ozone destruction. Dynamical (e.g. temperature, winds) coupling mechanisms in the atmosphere can further provide coupling between space weather in the form of particle precipitation and the lower atmosphere and thus have indirect implications to polar climate: the analysis of meteorological data and atmospheric chemistry-climate model results has shown that during the winter season temperatures and winds from about 80km altitude down to the surface show variability depending on the level of EPP. However, the characteristics of the energy spectrum and the precipitating fluxes of precipitating electrons are not known well enough for straightforward inclusion of this important particle precipitation process in atmospheric models.

Thursday 23rd January 2014

The physics of lightning-induced electron precipitation (LEP)

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This overview paper considers the seminal paper of Dungey (1963) on the cyclotron interaction between a lightning-produced whistler and energetic electrons trapped in the magnetosphere, having energies from $\sim$ 40 keV to $\sim$ 1 MeV, and the first experimental demonstration of this effect reported by Rycroft (1973). It discusses the various important physical stages of the process, from the type, orientation and peak return current of the lightning discharge to the propagation of VLF radio waves in the Earth-ionosphere waveguide, their penetration into the D-region ionosphere and the attenuation suffered, and their geomagnetic field-aligned ducting through the F-region and plasmasphere at $\sim 1.5 < L < 4$; the duct width is < 0.03 in L-shell. It considers the energetics of the Doppler-shifted gyroresonant interaction close to the equatorial plane (Rycroft, 1974, 1976) and its detailed non-linear plasma physics (Trakhtengerts and Rycroft, 2008). It is found that the lower frequency components of a whistler (whose amplitude in the equatorial plane is $\sim$ 1-20 pT) push electrons into the loss cone, via pitch angle scattering of a fraction of one degree, whereas the higher frequency components above the nose frequency accelerate the electrons (Trakhtengerts et al., 2003). The fluxes and pitch angle distributions of energetic electrons (LEP) precipitating in the geomagnetically conjugate region to the lightning discharge, as observed aboard satellites in Low Earth Orbit, confirm these ideas. (Chorus also causes the acceleration and depletion of the Van Allen radiation belts, but outside the plasmapause, $L > 4$.) The least certain areas involved in the various physical processes of LEP are pointed out these should form the focus of future studies in this fascinating field. The author is most grateful to the Royal Astronomical Society for a substantial grant towards the travel funds needed in order to attend this VERSIM meeting.

Some simultaneous observations of VLF events at two receivers separated by 400 km in longitude

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Since November 2012 a 3-component digital VLF receiver has been in operation at Lovozero in Kola Peninsula. Altogether 3 measurement campaigns were held at Kannuslehto in Northern Finland between December 2012 and April 2013. These two stations (KAN and LOZ) are located roughly at same magnetic latitude, ϕ=64.2 and ϕ=64.1, respectively. In this presentation we will show how similar or totally different are some VLF events at these two stations.

UltraMSK: A narrowband subionospheric VLF radio receiver

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UltraMSK is a software defined VLF radio receiver. The receiver records the amplitude and phase of minimum shift keying (MSK) modulated or continuous wave (CW) VLF communication transmissions. By utilizing a precision 1 pulse per second (PPS) signal from a GPS unit, the UltraMSK receiver has excellent phase stability on both long and short term time scales. This makes the receiver suitable for use in a wide range of applications involving the long range remote sensing of the lower ionosphere. Such applications include the monitoring of solar flares, whistler and relativistic electron precipitation, and many other atmospheric and space weather events that result in ionospheric modifications at D-region altitudes. UltraMSK receivers are in use by individual researchers around the world and in global scale collaborative networks such as AARDDVARK.
The receiver software can run on a wide variety of computer hardware from standard desktop computers through to low power embedded processor boards. Readily available multichannel audio sound cards are capable of digitizing the broadband VLF signal at sampling rates of up to 96 or 192 kHz, enabling the receiver's operation to extend into the lower LF range if required. Recent improvements to the receiver software include the ability to measure the absolute phase of received signals relative to the UT second. Also phase coherent on-off keying CW transmissions can be demodulated and recorded. Many LF time code stations use this transmission format.

An autonomous low powered phase stable VLF receiver designed for remote field operation

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We discuss the development and design challenges of an autonomous remote VLF MSK receiver system. The instruments are wind, solar and battery powered, running in temperatures below -60 degrees centigrade with over 100 days of continuous darkness. We record accurate amplitude and phase of the Hawaiian MSK transmitter on the L=4 magnetic field line at three remote Antarctic locations. Scientific and instrument performance data is transferred via satellite every day to BAS in the UK. Utilising many recent advancements in low power technologies driven principally by the mobile phone and tablet markets has allowed new possibilities in terms of recording and processing VLF radio signals in extremely remote locations anywhere on earth.

Propagation Effects of VLF Signals in Earth-Ionosphere Waveguide During the Eclipses of July 2009 and January 2010

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We carried out a VLF campaign during July 2009 solar eclipse in which we detected VLF signal variation from several stations on a daily basis before, during and after the eclipse. We find that in some places the signal is attenuated and in some other places the signal is enhanced. Using LWPC code we model these variations successfully and show that the result depends on the propagation path. We also present the result of our campaign in January 2010 eclipse during which we detected effects of the eclipse as well as the effects of the partial blocking of a solar flare by the moon. We separate the effects and identify the locations of the solar flare which were blocked by the moon.

Latest results from Finnish ELF-VLF campaign held in December 2013

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We are going to present our newest results observed in December at Kannuslehto in Finland, and hopefully simultaneous observations made at Lovozero, Russia.

Plasmaspheric density models in whistler inversion and whistler-FLR cross calibration

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One of the major objective in PLASMON project (*http://plasmon.elte.hu*) is to provide plasma densities for data assimilative modeling of plasmasphere from two ground based measurements: whistlers and field line resonances (FLRs). The whistler inversion method used in this procedure includes various model, such as wave propagation, magnetic field, field aligned density distribution and equatorial electron density models. The latter one is a special one used for multiple-path whistler groups. In this paper we will present the effect of various models used in the inversion procedure. As one can obtain electron densities from whistler inversion and plasma mass densities from FLRs, the ion constitution would be required to connect the to data set (that are intended to use in the plasmasphere model), which is rarely known or available. Therefore we have developed a method for cross calibration of the data from the two sources. It includes physics based and experimental field aligned plasma density distribution models as well as comparison with in situ wave and density (IMAGE, Cluster and Van Allen Probes) measurements.

Topside ionosphere and plasmasphere electron energy density distribution from space based CHAMP and GRACE data

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The capability of sounding the ionosphere by using signals from Global Navigation Satellite Systems (GNSS) onboard Low Earth Orbiting (LEO) satellites has been demonstrated by several satellite missions such as CHAMP and COSMIC. Besides GNSS radio occultation measurements as well as navigation data can be used to get information about the ionospheric ionization. Whereas radio occultation data enable retrieving electron density profiles from satellite orbit height downward, dual frequency navigation data enable reconstructing the electron density distribution from LEO satellite orbit height upward to GNSS orbit height at about 20.000 km. Both techniques have been used in DLR Neustrelitz, utilizing data received from CHAMP and GRACE satellite missions since 2001 (see also *http://swaciweb.dlr.de*).
To reconstruct the electron density distribution in the vicinity of the LEO satellite plane, up to about 3000 dual frequency measurements are obtained during one revolution. Differential code and carrier phases at both frequencies are analyzed to retrieve calibrated total electron content (TEC) values along the radio links between LEO and GNSS satellites. Subsequently, the calibrated TEC data are assimilated into the Parameterized Ionospheric Model (PIM) to obtain a more realistic description of the electron density distribution in the topside ionosphere/plasmasphere. Thus, about 15- 16 electron density reconstructions are obtained in the vicinity of the LEO satellite orbit plane every day.
These data sets, covering more than one solar cycle, are well suited for coordinated analysis with whistler data, providing L-shell related electron density data.

PLASMON FLRID: An automated detection of field line resonances

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EMMA is the acronym for the European quasi-Meridional Magnetometer Array set up in the frame of the EU funded PLASMON project to detect geomagnetic field line resonances (FLRs). FLRs are used to estimate the plasma mass density in the magnetosphere. In the last years a fully automated FLR detection algorithm (FLRID) has been developed. FLRID identifies FLRs in highly varying conditions, e.g. both at low and high latitudes, during quiet and stormy space weather. We present some problems emerged during the development, and offer some possible solutions. We also present some of the possible applications of the obtained results.

Geo-location and propagation features of very low latitude whistlers (L=1.08)

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The purpose of this study is to establish the source location and study the propagation characteristics of whistlers observed at Allahabad, Indian low latitude station (L=1.08). Whistler data set used is for the period of one year (Dec, 2010 to Nov, 2011). Total of 15 whistler activity days were found with ~2000 whistlers, out of which GLD360 and WWLLN was able to detect ~65% of causative lightning discharges in the vicinity of conjugate region. The dispersion of observed whistlers is found to be ~12 $sec^{1/2}$. To emphasize the correlation with lightning data, arrival azimuths of the observed whistlers are determined. We observed ~73% of whistlers whose arrival azimuths were found to match closely with that of causative sferics detected by GLD360 and WWLLN, with difference of ~2°. The L-shell parameter is also calculated and found to be in the range of ~1.14. GLD360 and WWLLN detected lightning strikes are also inspected for their energy values and it is observed that 30 kA/100-2000 J energy threshold is needed to trigger the whistler activity at low latitudes. The seasonal variation of observed whistlers leads to the highest activity in winter months followed by equinox months. No whistler activity is detected in summer, which in turn increases the importance of dependence on lightning activity in conjugate region. With a close look to the results, the source region of the observed low latitude whistlers is found near conjugate region and possibility of ducted mode of propagation through the low latitude ionosphere.

Plasmaspheric electron densities and plasmasphere-ionosphere coupling fluxes

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The Automatic Whistler Detector and Analyzer Network (AWDANet) is able to detect and analyze whistlers in quasi-realtime and can provide equatorial electron density data. The plasmaspheric electron densities and ionosphere-plasmasphere coupling fluxes are key parameters for plasmasphere models in Space Weather related investigations, particularly in modeling charged particle accelerations and losses in Radiation Belts. The global AWDANet detects millions of whistlers in a year. The system has been recently completed with automatic analyzer capability in PLASMON (*http://plasmon.elte.hu*) project.It is based on a recently developed whistler inversion model,that opened the way for an automated process of whistler analysis, not only for single whistler events but for complex analysis of multiple-path propagation whistler groups. In this paper we present the first results of quasi-real-time runs processing whistlers from quiet and disturb periods. Refilling rates, that are not yet known in details are also presented for the various periods.

Poster abstracts

Effective recombination coefficient and solar zenith angle effects on Low-latitude D-region ionosphere evaluated from VLF signal amplitude and its time delay during X-ray solar flares

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VLF signal amplitude perturbation (ΔA) and amplitude time delay (Δt) (vis-á-vis corresponding X-ray light curve as measured by GOES-15) of NWC/19.8 kHz signal have been computed for solar flares which is detected by us during Jan-Sep 2011. The signal is recorded by SoftPAL facility of IERC/ICSP, Sitapur (22d27'N, 87d45'E), India. Using the well known LWPC technique, we simulate the flare induced excess lower ionospheric electron density by amplitude perturbation method. Unperturbed D-region electron density is also obtained from simulation and compared with IRI-model results. Using these simulation results and time delay as key parameters, we calculate the effective electron recombination coefficient (α_{eff}) at solar flare peak region. Our results match with the same obtained by other established models. In the second part, we dealt with the solar zenith angle effect on D-region during flares. We relate this VLF data with the solar X-ray data. We find that the peak of the VLF amplitude occurs later than the time of the X-ray peak for each flare. We investigate this so-called time delay (Δt). For the C-class flares we find that there is a direct correspondence between Δt of a solar flare and the average solar zenith angle Z over the signal propagation path at flare occurrence time. Now for deeper analysis, we compute the Δt for different local diurnal time slots DT. We find that while the time delay is anti-correlated with the flare peak energy lux Φ max independent of these time slots, the goodness of fit, as measured by reduced-χ2, actually worsens as the day progresses. The variation of the Z dependence of reduced-χ2 seems to follow the variation of standard deviation of Z along the T x -R x propagation path. In other words, for the flares having almost constant Z over the path a tighter anti-correlation between Δt and ϕ max was observed.

Study of Precursors of Earthquakes from Indian Centre for Space Physics

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We classify three types of signal anomalies observed 1-5 days before major earthquakes and suggest that these could be taken as earthquake pre-cursors. These are the anomalies of the (a) terminator shifts (b) night time fluctuation shifts and (c) D-layer preparation and D-layer disappearance time respectively. We compute the correlations among these anomalies and also among the earthquake magnitudes and show that the correlation is possibly real. We also show on a cases by cases basis that anomaly persists.

Remote Sensing Space Weather Events Through Ionospheric Radio: The AARDDVARK Network

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The joint NZ-UK Antarctic-Arctic Radiation-belt (Dynamic) Deposition - VLF Atmospheric Research Konsortia (AARDDVARK) is a new extension of a well-establish experimental technique, allowing long-range probing of ionisation changes at comparatively low altitudes. 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 Earth-ionosphere waveguide, with variability largely coming from changes in the electron density profiles at and below the lower ionosphere. Most other instruments which can probe the same altitudes are limited to essentially overhead measurements. We have recently developed the AARDDVARK global-scale network of sensors that monitor fixed-frequency communications transmitters, and hence provide continuous long-range observations between the transmitter and receiver locations. Our receivers log small changes in the phase and amplitude of powerful VLF communications transmitters (~13-30 kHz). By monitoring distant VLF stations we undertake long-range remote sensing of changes to the waveguide, and particularly the ionosphere. This Science area impacts our knowledge of space weather processes, global atmospheric change, communications, and navigation.
AARDDVARK measurements are well suited for comparison with spacecraft measurements, to provide continuous measurements of radiation belt precipitation while satellites observe dynamic changes, particularly near the geomagnetic equator. Future additions to the network will increase the science potential and provide global coverage of space weather event signatures. In 2010 a new AARDDVARK station was deployed near Edmonton, Canada. This was followed by two new "deep field" sites in the Antarctic in 2012 as well as two more Canadian receivers, all to support the planned fleet of radiation belt science platforms (RBSP, DSX, RESONANCE, ERG, etc).
This poster will provide updates on the AARDDVARK network of receivers, as well as some recent AARDDVARK-science.
More information can be found at the homepage of the AARDDVARK network:
http://www.physics.otago.ac.nz/space/AARDDVARK_homepage.htm

A reexamination of latitudinal limits of substorm-produced energetic electron precipitation

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The primary sources of energetic electron precipitation (EEP) which affect altitudes <100 km (>30 keV) are expected to be from the radiation belts, and during substorms. EEP from the radiation belts should be restricted to locations between L=1.5-8, while substorm produced EEP is expected to range from L=4-9.5 during quiet geomagnetic conditions. Therefore, one would not expect any significant D-region impact due to electron precipitation at geomagnetic latitudes beyond about L=10. In this study we report on large unexpectedly high latitude D-region ionization enhancements, detected by an incoherent scatter radar at L16, which appear to be caused by electron precipitation from substorms. We go on to reexamine the latitudinal limits of substorm produced EEP using data from multiple low-Earth orbiting spacecraft, and demonstrate that the precipitation stretches many hundreds of kilometers polewards of the previously suggested limits. We find that a typical substorm will produce significant EEP over the IGRF L- shell range L=4.6±0.2-14.5±1.2, peaking at L=6-7. However, there is significant variability from event to event; in contrast to the median case, the strongest 25% of substorms have significant EEP in the range spaning L=4.1±0.1-20.7±2.2, while the weakest 25% of substorms have significant EEP in the range spaning L=5.5±0.1-10.1±0.7.

Sensitive measurement of lightning current and charge motion using coherent averaging of low frequency magnetic field observations

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Measuring lightning charge transfer, especially on time scales longer than several milliseconds, is a challenge. Instrumented towers can measure this quantity precisely but only for a tiny fraction of cloud-to-ground lightning. Electrostatic field measurements of lightning signals can provide robust estimates of this quantity, but the fast decay with distance of the electric field limits the measurement range to roughly 100 km at best. In contrast, low frequency and nearly-static magnetic fields from slowly varying lightning current decay much more slowly with distance and can therefore be measured at very long ranges. By measuring these low frequency magnetic fields, it is possible to broaden the geographic reach of lightning charge measurements. Sensitivity and noise, however, often limit these measurements to very large charge transfer lightning. Using data collected via search coil magnetic field sensors, we show how time-aligned coherent summation of many signals from lightning in a small geographic window can dramatically reduce the noise and thus enable the measurement of average (not individual) lightning currents and charge motion with very high precision and sensitivity. These average values (especially for long continuing currents) are often below the noise floor of remote measurement systems, especially for systems operating at long ranges (thousands of km) from the individual lightning events. Furthermore, by calculating averages over many thousands of lightning events, it is possible to achieve robust averages of different types of lightning under different storm conditions. Increasing the number of events analyzed further decreases the average noise received by the system, thus yielding improved results.

Detection of whistlers by the Belgian VLF antenna: Statistical analysis and comparison with CLUSTER data and a plasmaspheric model

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Whistlers are VLF (3-30 kHz) emissions initiated by lightning, propagating along magnetic field lines, observed on ground and in space. Whistler wave analysis is an effective tool for studying the plasmasphere. Whistlers acquire particular frequency-time characteristics while they propagate through the magnetospheric plasma, and in particular through the plasmasphere. Their propagation time depends on the plasma density along their propagation paths. It is possible to derive the plasmaspheric electron density distribution from these propagation times. We therefore have started a project to detect whistlers with VLF measurements.A VLF antenna has been installed in early 2011 in Humain, Belgium (50.11°N, 5.15°E). The VLF antenna is made of two perpendicular magnetic loops, oriented North-South and East-West, and with an area of approximately 50 m^2 each. This antenna is part of AWDAnet, the Automatic Whistler Detector and Analyzer system's network. This network covers low, mid and high magnetic latitudes, including conjugate locations.We use the AWDA system to automatically retrieve electron density profiles from whistler measurements made in Belgium. In this contribution, results of whistler occurrence are shown, as well as a comparison with density data obtained from the WHISPER instrument onboard Cluster and from a plasmaspheric model.

Simulations of oblique electrostatic wave propagation

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Previously, the high frequency modes, namely the electron plasma, electron acoustic and beam-driven mode occurring in the Earth's auroral region was studied using a Particle-in-Cell (PIC) simulation. This work is extended by including a weak intrinsic magnetic field. Waves are allowed to propagate with an angle with respect to the magnetic field. The inertia of the ions are neglected in this model, allowing only the motion of electrons.

The electron acoustic instability in a magnetised plasma having three electron components, one of which is a field-aligned beam of intermediate temperature, is investigated using the extended PIC simulation. When the magnetic field strength is such that the plasma frequency of the cool electrons is less than the electron gyrofrequency, the only instability in the electron acoustic frequency range is the strongly magnetized electron acoustic instability. Its growth rate and real frequency exhibit a decrease with propagation angle and it grows at small to intermediate wave numbers.

Temporal change of VLF polarization: A case study

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A VLF hiss burst lasting for two hours was observed on 12 April 2011 at 04-06 UT at Kannuslehto in Northern Finland. The event occurred in the end of the initial phase of a small magnetic storm. At the beginning, the polarization of the event was left-handed, which can be interpreted as the long-distance travelling of the waves in the Earth-ionosphere waveguide. The arrival direction was mostly from south. After one hour, the polarization gradually turned to right-handed, which can indicate that the ionosphere wave exit point was nearly overhead of the receiver. In this poster we will show geophysical conditions, which may be related to this polarization change.

VLF-CHAIN campaign at sub-auroral latitudes

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One of the most natural and intense electromagnetic wave emissions are known as chorus waves, they propagate in whistler-mode from the geomagnetic equator through the geomagnetic field lines to the ionosphere. Chorus waves are believed to be one of the major contributions to the acceleration and scattering of radiation belt particles (e.g., Inan et al., 1982; Omura et al., 2007). Consequently we are interested in the spatial and temporal motion of the acceleration region of the radiation belt electrons which might be directly linked to the motion of the ionospheric footprints of VLF/ELF waves. This research will focus on studying VLF/ELF chorus characteristics at frequencies of 0.003-30kHz with the objective of locating their ionospheric exit point from two-point ground-based observations.
For a period of 9 days, from February 17 to 25, 2012, the VLF-CHAIN campaign observed VLF/ELF emissions at sub-auroral latitudes using two loop antennas at Athabasca (MLAT=61.31, L=4.3) and Fort Vermillion (MLAT=64.51, L=5.4), Canada. Since the end of this campaign, continuous measurements of VLF/ELF waves with a sampling rate of 100 kHz, have been made at Athabasca.
Several interesting features of chorus emissions have been observed such as quasi-periodic emissions, falling-tone and rising-tone chorus, as well as “bursty-patch” emissions. We have applied a polarization and spectral analysis to make the first comprehensive study of the physical properties of VLF/ELF chorus waves at sub-auroral latitudes. Combining these analysis with a triangulation method we have identified location and motion of the ionospheric exit points of various types of chorus waves discussed above.

Empirical determination of solar proton access to the polar atmosphere

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Violent expulsions on the Suns surface release high energy solar protons that ultimately affect ionization levels and the local chemical composition in the upper atmosphere as well as High Frequency (HF) communication used by aircraft. The geomagnetic field screens the low altitude equatorial region, but these protons can access the atmosphere over the poles. The latitudes over which the solar protons can reach vary with geomagnetic indices such as Kp and Dst. In this study we use observations from Low Earth Orbit to determine the atmospheric access of solar protons and hence the flights paths most likely to be affected. Observations taken by up to six polar orbiting satellites during 15 solar proton events are analyzed. From this we determine 16,850 proton rigidity cutoff estimates across 3 energy channels. Empirical fits are undertaken to estimate the most likely behavior of the cutoff dependence with geomagnetic activity.

We provide simple equations by which the geomagnetic latitude (spatial extent) at which the protons impact the atmosphere can be determined from a given Kp or Dst value. The variation found in the cutoff with Kp is similar to that used in existing operational models, although the changing Kp value is found to lead the variation in the cutoffs by ∼3 hours .We also suggest a ∼1-2° equatorward shift in latitude would provide greater accuracy. This solar proton access can be used as an input into coupled chemistry climate models and give the likely polar regions to be effected by Polar Cap Absorption (PCA) which causes HF radio blackout zones. We find that a Kp predictive model can provide additional warning to the variation in proton cutoffs. Hence a prediction of the cutoff latitudes can be made ∼3 hours to as much as 7 hours into the future, meeting suggested minimum planning times required by the aviation industry.

Empirical determination of solar proton access to the polar atmosphere

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Electromagnetic waves at frequencies from about 0.5 to 4 kHz sometimes exhibit a periodic time modulation of wave intensity, with typical modulation periods on the order of minutes. These VLF emissions are usually called quasi-periodic (QP), and they have been observed both by ground-based instruments and by satellites in the inner magnetosphere. Their generation mechanism is still not entirely understood, but it is likely related to ULF magnetic field pulsations which are sometimes observed at the same time.

Wave-like signatures in the low-mid latitude D-region ionosphere associated with 22 July 2009 total solar eclipse

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In the present work, we have focused on the 22 July 2009 total solar eclipse caused periodic Wave-Like Signatures (WLS) in the D-region ionosphere using JJI, Japan, VLF navigational transmitter signal (22.2 kHz) observations at Allahabad, Varanasi and Nainital in Indian Sector, Busan in Korea and Suva in Fiji. The great circle paths of JJI signal to these stations encountered from almost full eclipsed condition to varying partial conditions. The Allahabad-JJI path was intercepted by the totality shadow and was slowly covered by partiality varying from 95 % at JJI to 54 % at Suva. The signal amplitude increased on 22 July by ∼6 and 7 dB at Allahabad and Varanasi and decreased by ∼ 2.7, 3.5, and 0.5 dB at Nainital, Busan and Suva, respectively, compared with 24 July (normal day). The increase/decrease in the amplitude can be understood in terms of modal interference due to mode conversion at the discontinuity created by the eclipse intercepting/facing the different transmitter-receiver great circle paths. The wavelet analysis shows the strong WLS of period 30-150 min in the D-region ionosphere at all the stations. The intensity of WLS was minimum in the fully eclipsed region and maximum in the partially eclipsed regions. The features of WLS on eclipse day seem almost similar to WLS observed in the nighttime of normal days (e.g. 24 July). The WLS could be generated by sudden cutoff of the photo-ionization creating nighttime like conditions and electron density gradients in the D-region ionosphere and solar eclipse induced gravity waves coming to ionosphere from below. The significance of the present study lies in providing the observational evidence for WLS in the eclipsed D-region using subionospheric VLF signal and in discussing the possible source mechanisms for the observed oscillation.

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