VLF/ELF Remote Sensing of Ionospheres and Magnetospheres (VERSIM)

Annual newsletter of VERSIM: a joint IAGA/URSI working group
Editor: Jacob Bortnik No. 32, December 2017

Dear VERSIM colleagues,

From the detection of solar X-rays to the microscopic structure of plasma waves, from the global characterization and localization of lightning, to ground-induced electrical currents impacting power grids, to space weather, machine learning and fundamental plasma theory, the VERSIM community covers every spatial and temporal scale under the sun (so to speak) and extends from pole to pole and East to West. We are truly a global community of scientists working on universal phenomena that are of scientific as well as societal importance, as you will read in the following pages of the 2017 VERSIM end-of-year newsletter.

This year marked the first total solar eclipse in 99 years that extended across the entire contiguous United States, traveling from coast-to-coast on 21 August 2017 in about 1.5 hours. Many members of the VERSIM community got involved in this spectacular event by performing scientific observations of D-region modifications using the propagation of VLF/LF subionospheric waves, launching a student-designed high altitude balloon, and of course public education and outreach including the youngest member of the VERSIM community, seen being trained by Prof. Morris Cohen on p. 12.

Next year we are excited to gather as a community at the 8th biennial VERSIM workshop, hosted by our friends and colleagues at the Polar Geophysical Institute in the city of Apatity, Murmansk region, Russia, over the week of 19-23 March 2018. Preparation and organization is well under way and the workshop promises to be a resounding success, with science, skiing, and auroras included! To round out the experience, our friends at the Sodankyla Geophysical Observatory have organized a "happy bus" to transport attendees from Finland to Russia and back, to enjoy the spectacular countryside.

In closing, I note again the vibrancy of our VERSIM community. The reports that follow represent just a small fraction of the myriad of current activities, and I would urge you to read them carefully, reach out, and form collaborations! I wish you all the very best for a successful and productive 2018.

Jacob Bortnik, IAGA co-chair of VERSIM

Mark Clilverd, URSI co-chair VERSIM

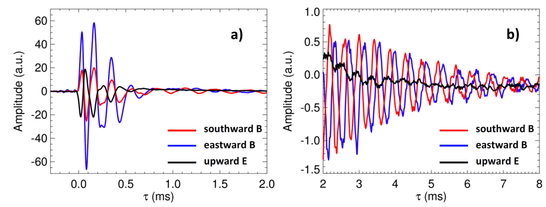
CZECHIA: Report prepared by Frantisek Nemec (frantisek.nemec@gmail.com), Ondrej Santolik (os@ufa.cas.cz) and Ivana Kolmasova (iko@ufa.cas.cz), Institute of Atmospheric Physics of the Czech Academy of Sciences, Prague and Charles University, Prague.

Our group at the Institute of Atmospheric Physics of the Czech Academy of Sciences and at the Charles University continued to investigate electromagnetic waves using spacecraft measurements and ground-based experiments. Examples of our results obtained in 2017 are given below.

We reported the first European observation of unusual daytime atmospherics with dispersion signatures [1]. These daytime tweeks originated from strong thunderstorms which occurred in January 2015 in the North Atlantic region. Using newly developed analysis techniques we determined the source location and attributed these rare atmospherics to both positive and negative lightning strokes in northern Europe. We consistently found a left hand polarization of the waves close to the cutoff frequency of the first waveguide mode and unusually large heights of the reflective ionospheric layer which made the dayside subionospheric propagation possible.

We analyzed quasiperiodic (QP) emissions which exhibit a sudden change in the wave vector and Poynting vector directions [2]. These QP emissions were recorded by the DEMETER spacecraft. The change happened in a short interval of latitudes. We explained this behavior by ionospheric reflection and presented a ray-tracing simulation. We also attempted to locate the source region of these emissions and concluded that they were probably generated at the inner boundary of the plasmapause which also acted as a guide during the propagation of the QP emissions.

We also analyzed intense emissions at discrete, harmonically spaced frequencies occurring in the DEMETER data. We demonstrate that this phenomenon was caused by European VLF transmitters [3]. The occurrence of these events was correlated with the simultaneous detection of signals from VLF transmitters. A bicoherence analysis was employed to demonstrate that wave-wave coupling took place. Finally, it was shown that the occurrence of the events was associated with a significantly increased precipitation of energetic electrons in a wide range of energies.



Caption: Polarization of observed tweeks. (a) Broadband linearly polarized atmospheric.(b) Immediately following quasi-sinusoidal circularly polarized signal of a tweek.

References:
1. Santolik, O. and I. Kolmasova (2017), Unusual Electromagnetic Signatures of European North Atlantic Winter Thunderstorms, Scientific Reports 7, Article number: 13948, doi:10.1038/s41598-017-13849-4.

2. Hanzelka, M., O. Santolik, M. Hajos, F. Nemec, and M. Parrot (2017), Observation of ionospherically Reflected Quasiperiodic Emissions by the DEMETER Spacecraft, *Geophys. Res. Lett.*, 44, 8721-8729.

3. Nemec, F., K. Cizek, M. Parrot, O. Santolik, and J. Zahlava (2017), Line Radiation Events Induced by Very Low Frequency Transmitters Observed by the DEMETER Spacecraft, *J. Geophys. Res. Space Physics*, 122, 7226-7239, doi: 10.1002/2017JA024007.

FIJI: Report prepared by Prof. Sushil Kumar (kumar_su@usp.ac.fj), The University of the South Pacific (USP), Suva, Fiji.

Our group continues participating in the World-Wide Lightning Location Network (WWLLN) since our joining in 2003. This year the old hardware has been replaced with updated one supplied by WWLLN Director. We record narrowband VLF signals of six transmitters using SoftPAL data acquisition system located at Physics, USP. We analysed amplitude perturbations of local origin on the VLF transmitter signals (NPM, NLK, NAA, and JJI) observed during tropical cyclone (TC), Evan, 9–16 December 2012 when TC was in the proximity of the transmitter-receiver links. The perturbations were observed before the storm was classified as a TC, at a time when it was a tropical depression, suggesting the broader conclusion that severe convective storms, in general, perturb the mesosphere and the stratosphere through which the perturbations propagate.

We have more than 10 years of SoftPAL recorded narrowband VLF data that have been analysed for solar activity dependence of solar flares effect on the D-region. Some of the lower C class solar flares have shown VLF enhancements only during low solar activity and a clear solar activity dependence on the level of the amplitude perturbation and hence on the D-region Wait parameters has been found.

Under the Strategic Research Theme funding of our University a project has been approved to us to study the VLF perturbations associated with natural hazards (TCs, Earthquakes and severe Space Weather events) on the D-region with VLF stations in Fiji, Samoa and Vanuatu under which a new SoftPAL VLF system will be installed at the university Campus in Vanuatu during early 2018. Thus we will have three SoftPAL VLF stations in the South Pacific Region (SPR) that could be called "South Pacific SoftPAL Tri-station Network".

The state of art ionospheric total electron content and scintillation GNSS recording system was installed under a MoU with Institute of Ionosphere and Magnetosphere, School of Electronic Information, Wuhan University, China, at USP, Fiji. Another similar GNSS system was installed later this year at university Campus in Kiribati which along with SoftPAL will help us study the lower and upper ionosphere response to Natural Hazards in the SPR.

For details please visit USP's electronic research repositoryhttp://repository.usp.ac.fj/ and research our research group web http://sep.fste.usp.ac.fj/index.php?id=15705

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1. Kumar, S., S. NaitAmor, O. Chanrion, and T. Neubert (2017), Perturbations to the lower ionosphere by tropical cyclone Evan in the South Pacific Region, *J. Geophys. Res. Space Physics*,122,8720–8732, doi:10.1002/2017JA024023.

2. Ramendra Prasad and Sushil Kumar (2017), Day and nighttime L-Band amplitude scintillations during low solar activity at a low latitude station in the South Pacific region, *J. Atmos. and Sol.-Terr. Phys.*, Vol. 165–166, 54-66.https://authors.elsevier.com/a/1W5Hn4sIlkeh61

FINLAND: Report prepared by Dr. Jyrki Manninen (Jyrki.Manninen@sgo.fi), Sodankylä Geophysical Observatory, University of Oulu, Finland, www.sgo.fi

Winter 2016-2017 ELF-VLF campaign started on 7 October 2016 and ended on 25 April 2017. It was the longest campaign so far. It lasted altogether 200 days and among them we had some problems (i.e., data losses) during 10 days. This year we started our campaign already on 1 September 2017, because we wanted to record ELF-VLF data during Japanese ARASE satellite campaign. Unfortunately, our good generator quit its contract on 18 October 2017. It worked nicely for about 17 000 hours. A new generator started to work on 9 November 2017. So, our current campaign is going on. This campaign will continue at least till mid-January, but maybe even longer.

The quick-look plots (24-h, 1-h, and 1-min) have been slightly re-organised thanks to user comments. Now all plots are organised by year and month to own directories. Only those months, when we have data, are available at http://www.sgo.fi/vlf/. The frequency range of quick-look plots is from 0 to 16 kHz, while the data contain the range from 0 to 39 kHz. Upper band is available if someone is interested in.

It should be reminded that now all quick-look plots, what are in our server, have been analysed with both PLHR and sferics filters. If you are interested in our data, just contact Jyrki.Manninen@sgo.fi. We can make a vast amount of different kind of analysis for our ELF-VLF data.

Some new results will be shown in 8th biennial VERSIM and Radiation Belt Symposia will be held from 19-23 March 2018 in Apatity, Russia.

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5. Macotela Cruz, E., J.-P. Raulin, J. Manninen, E. Correia, T. Turunen, and A. Magalhaes (2017). Lower ionosphere sensitivity to solar X-ray flares over a complete solar cycle evaluated from VLF signal measurements. J. Geophys. Res. Space Physics, doi:10.1002/2017JA024493

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7. Demekhov, A.G., J. Manninen, O. Santolik, and E.E. Titova (2017). Conjugate ground–spacecraft observations of VLF chorus elements. Geophys. Res. Lett., 44, doi:10.1002/2017GL076139

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There were also several oral and poster presentations in 2017.

HUNGARY: Report prepared by Prof. János Lichtenberger (lityi@sas.elte.hu), Space Research Group, Department of Geophysics and Space Sciences, Eötvös University, Budapest, Hungary

Our group continued the theoretical modeling and model-calculations of monochromatic and transient (Ultra Wide Band) electromagnetic signals and are seeking a solution of the electromagnetic wave propagation in general relativistic situations (coupled solution of the Maxwell and Einstein equations).

The whistler inversion algorithm applied to the Russian Alpha navigation signal recorded on board satellites (RBSPs) proved to be a good tool to measure the electron density at low altitudes, where the upper hybrid resonance is greater than the upper frequency limit of EMFISIS.

We have made a statistical survey on ground based VLF transmitter signals recorded by RBSP EMFISIS.

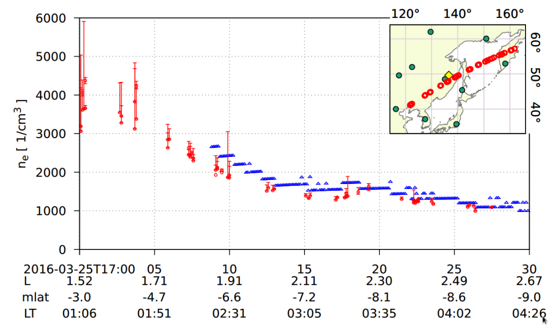
The whistler inversion algorithm used to process AWDANet data has been changed from Virtual Trace Transformation to Reduction to Sferic algorithm. The main reason was to overcome the problem of so called ‘outlier’ points on spectrograms. The Reduction to Sferic (or dechirping) algorithm were originally used in time domain, however, the difficulties in full removal of sferics from the raw signal prevented us from the successful implementation of the algorithm. Therefore we have swapped back to frequency domain and the algorithm works now on spectrograms. The inversion algorithm has also been enhanced with using IRI 2016 model to calculate foF2 frequency needed for correction of ionospheric propagation. It will be further enhanced with real-time IRTAM data soon. We have started to reprocess all archive whistler data collected by AWDANet stations since 2002.

We have continued to analyze anomalistic or less understood VLF phenomena, using fine structure and spectral analysis in satellite data (DEMETER, RBSP/VAP).

We are working on the estimation of energetic electron density in the Radiation Belts from frequency sweep rates of choruses recorded on the ground

We are working on the development of three nano- and microsatellite wave experiments (Chibis-AI, ISS/Obstanovka Phase-2 and Trabant) with Russian partners.

Wideband ELF recodings collected on the ground and in satellite wave experiments (e.g. C/NOSF, Themis, Chibis, Relek/Vernon, VAP) have been analyzed to resolve occurrence and possible generation mechanisms of low frequency (< 100 Hz) hiss-like waves.



Electron densities derived from upper hybrid resonance (blue triangles, from NURD) and from fractional inversion of the Russian Alpha signals measured RBSP-B. The inlet shows the satellite footprints when the Alpha signal was recorded (red circles). The yellow diamond is the location of the Khabarovsk transmitter, the green circles are the locations of the nearby ionosondes.

INDIA: Report prepared by Dr. Devbrat Pundhir (devbratpundhir@gmail.com), RBS Engineering Technical Campus, Bichpuri, Agra.

Agra VLF research station is now 42 years old and research activities at this center have been communicated to annual VERSIM bulletins regularly in the past. As communicated before, in recent years, we have worked on three different equipments, namely, phase and amplitude monitoring of VLF transmitter signals using Abs PAL/Soft PAL receivers, ULF magnetic field studies using a set of 3-component search coil magnetometers, and ionospheric TEC measurements using a dual frequency GPS receiver. These experiments have been operated for studies in Atmospheric sciences as well as in Seismo-Electromagnetics. Our research works in these areas have been fully supported by the Department of Science and Technology (DST) and Ministry of Earth Sciences (MoES), Government of India, New Delhi in project modes.

Our recent projects sanctioned by the above mentioned two funding agencies for research work in the fields of Schumann resonance and Earthquake precursor studies have been completed last year. The monitoring of phase and amplitude of NWC signals at 19.8 kHz for studies of solar flare induced D-region perturbation and early/slow events has also yielded some good results published in Astrophysics and Space Science and Acta Geophysica.

Our ground based observations of low latitude whistlers were revived to examine if the whistlers recorded at DEMETER satellite over Indian longitudes propagated to ground or not. Unfortunately no such whistlers were recorded at our Agra station suggesting nonducted/non-PL mode whistlers cannot be recorded at low latitude ground stations.

We have been sanctioned with a new MoES research project in April, 2016 to work on long-term recording and analysis of ELF/VLF/TEC data to examine if real earthquake precursors exist or not. This project is being looked after by Dr. Dushyant Singh as Principal Investigator and Prof. Birbal Singh (Emeritus Scientist) as Co-Principal Investigator. One of our students Mrs. Uma Pandey has completed her Ph.D. and joined Physics Department of Banaras Hindu University, Varanasi on Kothari Post Doctoral Fellowship, and another student Mr. Devbrat Pundhir has been awarded his Ph. D degree from Banasthali University, Jaipur. We have one M. Tech student Miss Dhananjali Singh who has currently worked on "Nighttime fluctuations" analysis technique using NWC VLF transmitter signal data to ascertain earthquake precursors. Some of our recent publications are as under;

1. Singh, D., Singh, B., and Pundhir, D., Ionospheric perturbations due to earthquakes as determined from VLF and GPS-TEC data analysis at Agra, India, Advances in Space Research, 2017, DOI: https://doi.org/10.1016/j.asr.2017.11.017.

2. Pundhir, D., Singh, B., Singh, O. P., and Gupta, S. K., Study of ionospheric precursors using GPS and GIM-TEC data related to earthquakes occurred on 16 April and 24 September, 2013 in Pakistan region, Advances in Space Research, 60, 1978–1987 2017.

3. Pundhir, D., Singh, B., Singh, O. P., and Gupta, S. K., A morphological study of low latitude ionosphere and its implication in identifying earthquake precursors, Journal of Indian Geophysical Union, 21(3), 214-222, 2017.

JAPAN: Report prepared by Dr. Hiroyo Ohya (ohya@faculty.chiba-u.jp), Chiba University, Chiba, JAPAN

We introduce the SATREPS (Science and Technology Research Partnership for Sustainable Development) project started from 2017 (the total 5 years), which is supported by Japan Science and Technology Agent. The project title is "Development of Extreme Weather Monitoring and Information Sharing System in the Philippines". The PIs are Prof. Yukihiro Takahashi, Hokkaido University, Japan, and Dr. Joel Joseph S. Marciano Jr., Department of Science and Technology- Advanced Science and Technology Institute (DOST-ASTI), Philippines. 35 Japanese researchers and 51 Philippine researchers attend in the SATREPS project. The purpose of the project is to monitor torrential rainfall from thunderstorms and typhoons using micro-satellites "DIWATA-1, -2, and -3" and high-density VLF/ELF ground-observation network with 60 observation sites in Philippines. The VLF/ELF ground-observation network and "DIWATA" satellites will be useful for investigating three-dimensional structure of thunderstorm over Manila with high accuracies for time and space. For VLF observations in the South-east Asia, we will also develop the AVON (Asia VLF Observation Network) system.

Next, we introduce variations in LF amplitude and phase during magnetic storm of 7-8 September, 2017 (minimum Dst index: -142 nT) in Figure 1, using a LF ground-observation network installed by Dr. Fuminori Tsuchiya, Tohoku University, Japan. The transmitter and receiver are NRK (37.5 kHz, Iceland) and NYA (Ny-Alesund, Norway), respectively. The blue line indicates the onset of substorm. The red rectangular indicates the precipitations of energetic electrons from the inner magnetosphere. The change amount of the amplitude, phase, and reflection height are -7 dB, +70 degrees, and -8 km, respectively. In rough estimation based on the IRI-2012 model, these changes correspond to increase in the D-region electron density by about 80 % compared to usual level.

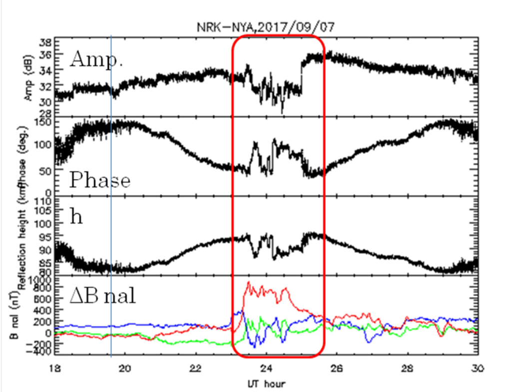


Figure 1 Amplitude, phase, reflection height on NRK-NYA path, and change amount of magnetic data at Ny-Alesund (nal) from 18:00 UT on 7 September to 06:00 UT on 8 September, 2017. The blue line indicates onset of substorm.

NEW ZEALAND: Report prepared by Dr. Craig J. Rodger (craig.rodger@otago.ac.nz), University of Otago, Dunedin, NZ; http://www.physics.otago.ac.nz/nx/space/space-physics-home.html

This has been a very active year for the Otago Space Physics group. We have gained a new member, Annika Seppälä, who came to Otago from the Finnish Meteorological Institute. Many VERSIM members will remember Annika, as she won the best presentation by an early career researcher at the second VERSIM meeting (Sodankylä)!

Speaking of best presentations, Emma Douma won this last year at the 7th VERSIM workshop (Hermanus), and had it awarded at the 2017 IAGA Assembly (Cape Town). Emma had her first paper published [1], looking at the occurrence of relativistic electron microbursts, and showing the occurrence patterns are consistent with whistler-mode chorus. Emma was also awarded an URSI Young Scientist Award, and attended the Montreal URSI GASS.

Many of you will have met Otago PhD student Aaron Hendry. This year he had another paper accepted on electron precipitation from EMIC events [2], showing that the peak energies precipitated are considerably lower than classic resonant scattering. Most importantly, this year Aaron submitted his PhD! We are just working through the examination process now. Aaron plans to travel to Prague to take up a PostDoc, and so will remain inside the VERSIM community.

A lot of Craig's time has gone into our new-ish project into Geomagnetically Induced Currents (GIC) in the New Zealand power grid. It turns out we are very fortunate in our country as the power network engineers have been measuring and archiving GIC for ~15 years! From our analysis of this data we have been able to show that there is huge spatial variability in GIC - by measuring in just one location you might get the impression there will be no problem, while a transformer ~100 km away may have vastly higher GIC magnitudes. So far this year we have published 4 GIC papers in AGU's Space Weather journal [e.g., 3].

Otago Space Physics group annual team photo from 22 September 2017. In the photo from right to left: Nathan Williams, Neil Thomson, Emma Douma, Daniel Mac Manus, Craig Rodger, James Brundell, Tim Divett, Aaron Hendry, and Annika Seppälä.

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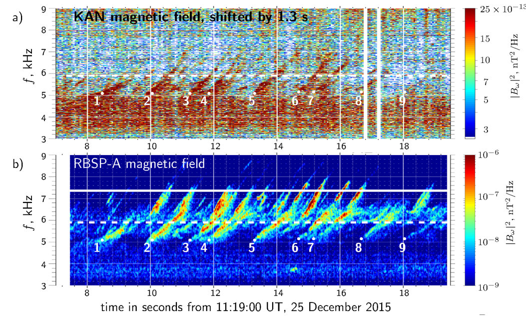
2. Hendry, A. T., C. J. Rodger, and M. A. Clilverd (2017), Evidence of sub-MeV EMIC-driven electron precipitation, Geophys. Res. Lett., 44, 1210–1218, doi:10.1002/2016GL071807.

3. Rodger, C. J., Mac Manus, D. H., Dalzell, M., Thomson, A. W. P., Clarke, E., Petersen, T., … Divett, T. (2017). Long-term geomagnetically induced current observations from New Zealand: Peak current estimates for extreme geomagnetic storms. Space Weather, 15. https://doi.org/10.1002/2017SW001691

RUSSIA: Report prepared by Dr. Andrei Demekhov (andrei@ipfran.ru), Polar Geophysical Institute, Apatity, and Institute of Applied Physics RAS, Nizhny Novgorod, Russia

Our joint group from the two institutes (PGI and IAP RAS) has completed a 2.5 year project funded by the Russian Science Foundation and devoted to studies of wave-particle interactions in the magnetosphere. Among other results, we have found several very interesting events of conjugate observations of VLF emissions on the ground and in the magnetosphere [1,2]. One of them contains the same chorus elements observed with a 1.3 s delay, which is consistent with quasi-parallel propagation upward from the ground to the Van Allen Probe A [1]. Our work on ground-based data from Kannuslehto, Finland, was possible due to friendly collaboration with Jyrki Manninen and was supported by the Academy of Finland. Jointly with Ulrich Taubenschuss and Ondrej Santolík from the IAP CAS in Prague, we have studied a chorus event observed by THEMIS within the framework of the backward wave oscillator model. With known parameters of the geomagnetic field, plasma density, and the initial wave frequency, we successfully reproduced individual chorus elements in the simulation [3]. In particular, the measured growth rate, wave amplitude, and frequency drift rate are in agreement with observed values.



Caption: The same chorus elements detected by Kannuslehto and Van Allen Probe A.

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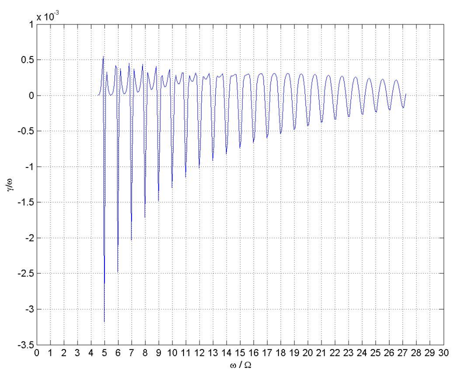
1. Demekhov, A. G., J. Manninen, O. Santolík, and E. E. Titova (2017), Conjugate ground–spacecraft observations of VLF chorus elements, Geophys. Res. Lett., 44, doi:10.1002/2017GL076139.

2. Titova, E. E., A. G. Demekhov, J. Manninen, D. L. Pasmanik, and A. V. Larchenko (2017), Localization of the Sources of Narrow-Band Noise VLF Emissions in the Range 4–10 kHz from Simultaneous Ground-Based and Van Allen Probes Satellite Observations, Geomagnetism & Aeron., 57, No. 6, 706–718.

3. Demekhov, A. G., U. Taubenschuss, and O. Santolík (2017), Simulation of VLF chorus emissions in the magnetosphere and comparison with THEMIS spacecraft data, J. Geophys. Res. Space Physics, 122, 166–184, doi:10.1002/2016JA023057.

RUSSIA: Report prepared by Dr. David Shklyar (david@iki.rssi.ru), Space Research Institute of RAS, Moscow, Russia

This report is from D.R. Shklyar and E.E. Titova. This year, 2017, we investigated the wave phenomenon known as the Equatorial noise, which attracted new interest after Cluster measurements of magnetic field fluctuations below the LHR frequency in the equatorial region on $L \sim 4$. These measurements contain emissions of which a typical (f - t)- spectrogram shows a pattern of stripes related to high-order proton cyclotron harmonics. These emissions have previously been attributed to the instability of ring-type distribution of energetic protons, based on the analysis of frequency dependence of the growth rate. We underline that the growth rate γ varies both in sign and in magnitude along the wave packet path, thus, the wave amplification, but not the growth rate, is the crucial quantity determining the observed spectrum. We have developed a consistent model of the observed wave phenomenon using a smooth distribution function of energetic protons, which depends on particle energy W and equatorial pitch angle α, tends to zero as $\alpha \rightarrow 0$ and has maximum at $\alpha = \pi/2$. The calculated growth rate γ differs essentially from that previously reported; in particular, γ has negative minimums, instead of positive maximums, at exact cyclotron resonances. This property is a key to understanding the peculiarity of the observed spectrum which consists in that often, although not always, the spectral intensity below the exact cyclotron harmonic is much higher than above. We have calculated the net amplification for a *3D* set of wave packets. Assuming that the process of wave excitation is stationary and applying appropriate boundary conditions we show that our model reproduces the wave phenomenon in outline.



Normalized growth rate as a function of normalized frequency for fixed $\theta = 89^{o}$.

References:

1. Shklyar, D. R., M.A. Balikhin, and E.E. Titova (2017), A contribution to the theory of equatorial noise generated in the Earth's magnetosphere, Geomagnetism and Aeronomy, 57, 691-697.

2. Shklyar, D. R., M.A. Balikhin (2017), Whistler mode waves below lower hybrid resonance frequency: Generation and spectral features, J. Geophys. Res. Space Physics, 122, 10,072–10,083. https://doi.org/10.1002/2017JA024416

SERBIA: Report prepared by Dr. Aleksandra Nina (sandrast@ipb.ac.rs), Institute of Physics, University of Belgrade, Belgrade, Serbia

Activities of researchers from several institutions in Serbia continued analyzing the data recorded by two VLF/LF receivers located in the Institute of Physics in Belgrade and Tektronix RSA 306 spectrum analyzer at the University of Defence in Belgrade. We have been continued investigations of the D-region perturbations induced by different events [1] including the solar X-ray flares, gamma-ray bursts, earthquakes solar eclipse [2] and tropical depressions [3] influences.

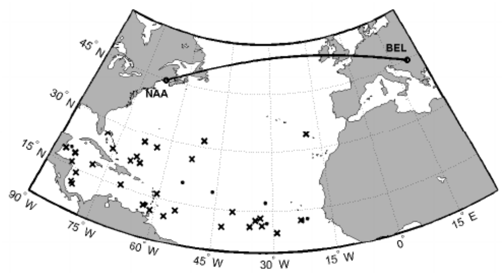
In [1] we give a review of how to detect different low ionospheric reactions (sudden ionospheric disturbances) to various terrestrial and extra-terrestrial events, show their classification according to intensity and time duration, and present some methods for their detections in time and frequency domains.

Eclipse-related perturbations in the ionospheric D-region were presented in common study of four independent observations in Belgrade on 20 March 2015 (see paper [2]).

In [3] we study the reactions of the low ionosphere during tropical depressions (TDs) which have been detected before the hurricane appearances in the Atlantic Ocean. We explore 41 TD events using very low frequency (VLF) radio signals emitted by NAA transmitter located in the USA and recorded by VLF receiver located in Belgrade (Serbia). We found VLF signal deviations (caused ionospheric turbulence) in the case of 36 out of 41 TD events (88%) and we found analyzed SID types in the case of 33 out of 41 TD events (80%).

Our activities were made within national projects, COST action Big Data Era in Sky and Earth Observation (BIG-SKY-EARTH), the COST action Time dependent seismology

(TIDES) and VarSITI . During this year, Jovan Bajčetić finished her PhD at the Faculty of Technical Sciences, University of Novi Sad.



Caption: Locations of TDs with (x) and without (•) detected relevant signal variations [3].

References:

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UNITED KINGDOM: Report prepared by Mark Clilverd (macl@bas.ac.uk), British Antarctic Survey, webpage (https://www.bas.ac.uk/)

BAS report to VERSIM – December 2017

This year it seemed easier to start with a summary, and finish with the details. The main issue at BAS has been the closure of the Halley Station, Antarctica since February 2017. This is due to the ice-shelf, on which the base sits, cracking in several directions. This means that all VLF recordings at Halley (L=4.5) have stopped. A possible restart is underway, but data recordings should be considered at risk in 2018 and beyond. This has affected VLF broadband recordings (VELOX), lightning (WWLLN), whistler detection (AWD), and 'Ultra' narrow band. Mitigation for 2018 has begun in terms of installing stand-alone low-powered systems to cover the broad and narrow band recordings at Halley. Fortunately, in our broader instrument collection it has generally a good year of data collection, with a high percentage of up time on most instruments.

BROADBAND RECORDINGS in Antarctica:
Whistler-detection and data collection has continued Rothera (L=2.9) throughout 2017 using the Hungarian Automatic Whistler Detection (AWD) system. BAS also continues to operate another AWD site, at Eskdalemuir in Southern Scotland (L=2.7). However, Eskdalemuir AWD has continued to be off-air since mid-November 2016 due to network issues. These sites continue to operate beyond the lifetime of the PLASMON FP7 project which finished in August 2014.

VELOX RECORDINGS at Halley, Antarctica:
Unfortunately the quasi-continuous (since 1992) recordings of VLF activity in 10 ELF/VLF bands, at 1-s resolution (VELOX and VELOXNET) were stopped at Halley in February 2017.

NARROW-BAND RECORDINGS:
'Ultra' narrow-band recordings have continued at Rothera (Antarctica), the Australian Casey station (Antarctica), Forks, Seattle (USA), Ottawa, St Johns, and Churchill (all Canada), Eskdalemuir (Scotland), Sodankyla (Finland), Reykjavik (Iceland), and Ny Alesund (Svalbard) throughout 2017. After the suggestion that Reykjavik was at risk last year, the system has restarted and run through 2017 without a hitch – many thanks to Dr Richard Yeo for his continued support of the instrument there.

The software VLF Doppler system has continued at Rothera station, Antarctica (L=2.8) in2017 receiving whistler mode and sub-ionospheric signals primarily from NAA (24.0 kHz). A similar Doppler system has been in operation at Marion Island, South Africa (L=2.9) during 2017, hosted by SANSA, Hermanus.

WWLLN sites:
British Antarctic Survey has continued to operate two/three World Wide Lightning Location Network systems in 2017. Apart from the loss of Halley in Feb 2017, Ascension, and Rothera have successfully provided lighting location information all year.

Regards, Mark Clilverd

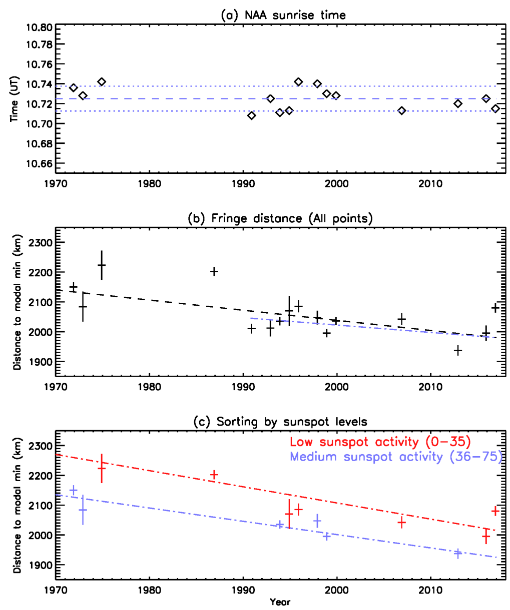

Figure ((a) The times of sunrise fades overhead of the NAA transmitter during the 45 year study period. The 10:43:30 UT average, and 45 s either side are indicated by the blue dashed and dotted lines respectively. (b) The calculated distance of the penultimate sunrise amplitude fade from the NAA transmitter. Standard errors bars are shown as vertical lines, and a linear best fit line indicates an interference fringe pattern contraction of 3.6 km/yr over the whole dataset. A fit is also shown for just the 1990-2016 data points (blue, dashed-dot line) indicating a contraction of 2.6 km/yr.(c) The calculated distance of the penultimate sunrise amplitude fade from the NAA transmitter separated into periods of low (red) and medium (blue) sunspot activity levels. Interference fringe pattern contractions of 4-5 km/yr can be seen.)

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UNITED STATES: Report prepared by Prof. Jacob Bortnik (jbortnik@gmail.com), University of California at Los Angeles (UCLA), Los Angeles, California, United States.

The “radiation belts and waves” research group at UCLA has had another productive year, studying the physical processes occurring in the Earth’s inner magnetospheric environment through a combination of multi-spacecraft data analysis, laboratory simulations of whistler wave excitation supplemented by numerical simulation, and techniques in machine learning.

Using a neural network approach, Chu et al. [2017] were able to create a 3-dimensional time-dependent (i.e., dynamic) reconstruction of the plasmasphere based on data from a variety of satellites, and moreover to show that during the main phase of a storm, a somewhat unexpected density enhancement occurs at low L-shells, while the regular depletion of plasma density occurs at higher L-shells as expected from plasmaspheric erosion. In studying the large-scale structure of incoherent Very Low Frequency (VLF) emissions, Li et al. [2017] demonstrated that multiple spacecraft observed the same emissions undergoing spatially coherent modulation over large regions of the dayside magnetosphere, which challenges our existing paradigms of the wave excitation process. In studying the excitation of VLF waves in the Large Plasma Device at UCLA and through numerical simulations, An et al. [2017] investigated the curious relationship between electrostatic and whistler instabilities that are often seen to occur together in both laboratory experiments and simulations and shown how the rapid energy dissipation and exchange controls the relative intensity and timing of the two waves, modulated by the plasma density.

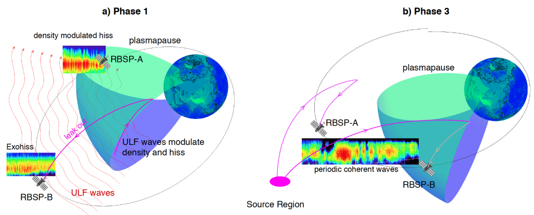

Figure taken from Li et al. [2017, Fig. 4]: Illustration of spatial propagation of coherent waves. (a) plasmaspheric hiss modulated by density fluctuation leaks out to probe B earlier than probe A observed density modulated hiss. (b) periodic rising tone whistler waves originating from a source outside the plasmasphere, and the inner probe observed the waves later then the outer probe because of longer wave path and slower propagating velocity in the plasmasphere.

References:

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UNITED STATES: Report prepared by Prof. Morris Cohen (mcohen@gatech.edu), Georgia Institute of Technology, LF.gatech.edu

It's been a whirlwind of a year. Here's a few highlights:

1. We continue our treasonous exploration of the "LF/MF" band for D-region ionospheric remote sensing, including beacons at 300 kHz which are quite numerous in the US. For a description, take a look at last year's bulletin. We've now published a paper in GRL on the to pic.
2. In the US, all eyes were trained on the sky as we experienced our first coast-to-coast total solar eclipse in 99 years, on 21 August. Following the footsteps of earlier workers, we were ready with a slew of VLF and LF recordings across the US including Alaska and Puerto Rico. And just for fun, we had some students launch a high altitude balloon which caught some incredible overhead view of the entire eclipse shadow. In terms of VLF science, we saw some highly variable ionospheric response and you can look for this hopefully in an upcoming publication.
3. We're shifting the way we look at VLF remote sensing data by employing polarization to replace amplitude and phase. Look for a paper in JGR sometime in Jan 2018.

Figure: Here's me teaching my three-year-old son how to look at the eclipse

References:

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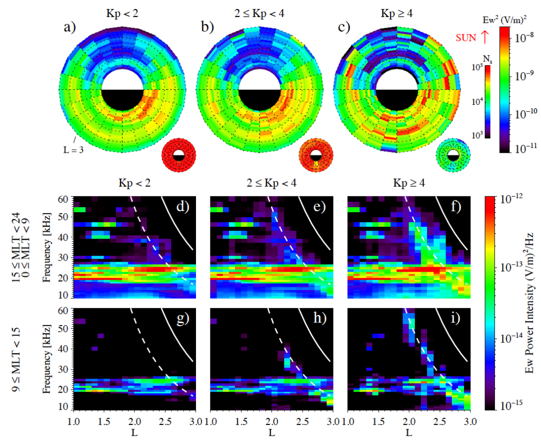
UNITED STATES: Report prepared by Prof. Wen Li (wenli77@bu.edu), Boston University, Boston, Massachusetts, United States

In 2017 our new "wave-particle interaction" group at Boston University investigated the distribution of various VLF waves and evaluated their effects on radiation belt electron dynamics. Below are the highlights of the three interesting studies.

Ma et al. [2017a] developed new statistical models of VLF waves from ground-based transmitters using the Van Allen Probes data and assessed their effects on the dynamics of the inner radiation belt and slot region. Full numerical calculations of quasi-linear pitch angle diffusion rates show that VLF waves from ground-based transmitters decrease electron lifetimes by 1 to 2 orders of magnitude depending on the energy and L-shell, demonstrating the prominent role played by VLF transmitters in controlling energetic electron flux inside the plasmasphere.

Shi et al. [2017] systematically evaluated the distribution of low-frequency hiss (<100 Hz) and its relation to energetic electron injections using Van Allen Probes data. We found that the occurrence rate of low-frequency hiss in association with electron injections is up to 80% in the outer plasmasphere on the dayside, while it is rarely associated with electron injections at lower L shells (<3.5). Our study clearly indicates the important role of electron injections and their drift trajectories toward the dayside plasmasphere in locally amplifying the low-frequency hiss.

Ma et al. [2017b] investigated the gradual diffusion of energetic electrons from the inner edge of the outer radiation belt into the slot region. By quantitatively comparing the simulations and observations from Van Allen Probes, we found that in addition to the major loss caused by plasmaspheric hiss, magnetosonic waves and VLF transmitters can cause the loss of high pitch angle electrons. Our result indicates the importance of balance between radial diffusion and loss through pitch angle scattering in forming the diffusive intrusion of energetic electrons across the slot region.



(a-c) Global distribution of VLF wave intensity as a function of Kp with the corresponding number of samples displayed in small plots. (d-i) Average VLF wave intensity as a function of Kp and frequency in two different MLT sectors. [From Ma et al., 2017a]

References:

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UNITED STATES: Report prepared by Prof. Robert Marshall (robert.marshall@colorado.edu), University of Colorado Boulder, Boulder, CO, USA

The Lightning, Atmosphere, Ionosphere, and Radiation belts research group (the LAIR) continues to make VLF/LF observations, conduct modeling studies, and build instrumentation. This year we expanded our VLF/LF receiver network from a single site at the National Center for Atmospheric Research (NCAR) Marshall field site (no relation) in South Boulder, to include VLF receivers at Table Mountain, north of Boulder; Bear Lake, Utah; and Elginfield, Ontario, Canada. In addition to ongoing VLF observations, these sites were used to observe the D-region ionosphere response to the 2017 Total Solar Eclipse. The VLF signal paths from the NML transmitter in North Dakota to Boulder and Bear Lake cross directly over the eclipse track; it was no surprise then that both sites observed amplitude perturbations of 10-15 dB, and phase perturbations of 100-150 degrees during the eclipse. These data are still under analysis and in preparation for publication.

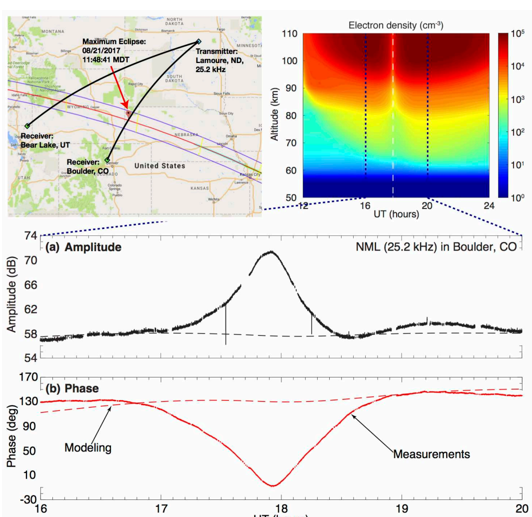

Figure 1: Measurements and modeling of the 2017 Total Solar Eclipse on the D-region ionosphere. Modeling work does not show the eclipse effect because mesospheric cluster ions have not been included.

Our group has recently published a study making direct comparisons between the LWPC model and Finite Difference models, both FDTD and FDFD, used to model propagation in the Earth-ionosphere waveguide [Marshall et al, 2017]. In addition, we are conducting work aimed at using the VLF transmitter signals with an array of receivers, similar to the AARDDVARK network, to estimate the 2D state of the D-region ionosphere. This work involves machine learning and Kalman filter techniques to estimate the state of the ionosphere, and will be useful for studying the spatial scales and region sizes of radiation belt precipitation, lightning-induced ionospheric perturbations, and other D-region phenomena.

In radiation belt precipitation work, we have recently completed a modeling study investigating the effects of precipitation in the stratosphere [Xu et al, 2017]. Radiation belt precipitation creates ionization in the mesosphere, but also produces X-ray and gamma-ray photons by bremsstrahlung; those photons can then propagate to as low as 15 km altitude, where they in turn create new ionization. We quantify the production of ionization and the associated chemical effects (NOx, HOx, and Ox) at these low altitudes.

References:

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UNITED STATES: Report prepared by Dr. Ivan Vasko (ivan.vasko@ssl.berkeley.edu), Dr. Oleksiy Agapitov (oleksiy.agapitov@gmail.com), and Dr. Forrest Mozer (forrest.mozer@gmail.com), Space Science Laboratory, University of California at Berkeley

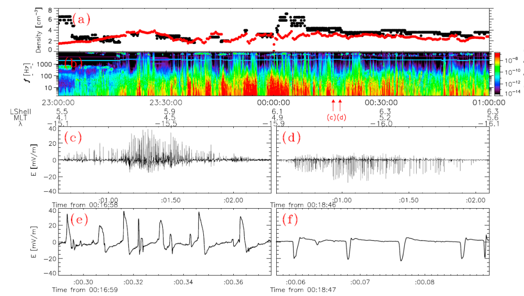
Our group continues to study properties of waves and structures observed in the Earth's inner magnetosphere. The improved version of wave model based on Van Allen Probes and Cluster VLF data sets has been developed [Agapitov et al., 2017JGR].

Using measurements of the twin Van Allen Probe spacecraft, separated by 100-5000 km, we have evaluated the coherency and source scale of chorus waves (in the plane perpendicular to the background magnetic field) that is a fundamental parameter affecting efficiency of the wave-particle interactions. The chorus source scale was found to be about 600–800 km with the distribution of the wave amplitude within the generation region well described by a Gaussian with 300 km half width [Agapitov et al., 2017GRL].

The nature of the asymmetric electric field spikes (one of types of the broadband electrostatic turbulence) has been addressed: we showed that they are electron-acoustic solitons and double layers existing due to presence of cold and hot electrons with the latter population having larger density [Vasko et al., 2017GRL].

We have performed the one-dimensional Vlasov code simulation of evolution of electron phase space holes in inhomogeneous magnetic fields emulating the magnetic field in the outer radiation belt. We have shown that electron holes generated near the equator and propagating to higher latitudes should slow down due to the mirror force acting on electrons trapped within electron hole [Vasko et al., JGR2017, PoP2017; Kuzichev et al., 2017GRL].

The new features of field aligned cold populations have been determined after the one year THEMIS complain of cold plasma measurements [Mozer et al., 2017GRLa]. The direct connection of diffusive scattering and microburts precipitations with chorus wave activity has been reported from the Van Allen Probes and AC-6 spacecraft data [Mozer et al., 2017GRLb].



Caption: An example of asymmetric electric field spikes by Van Allen Probes and interpreted as electron-acoustic solitons and double layers [*Vasko et al.*, 2017]: (a) total electrons density (black) and density of hot (>200 eV) electrons; (b) spectrum of the electric field turbulence in the inner magnetosphere; (c-f) waveforms of asymmetric electric field spikes.

References:

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Best VERSIM wishes for a healthy, fun, and productive 2018!

The VERSIM workshop attendees photographed on the entrance steps of the South African National Space Agency (SANSA), before the conference banquet on Wednesday September 21st, 2016.