VERSIM NEWSLETTER

YEARLY NEWS FROM THE VLF ELF REMOTE SENSING OF IONOSPHERES AND MAGNETOSPHERES COMMUNITY

DEC. 2023

A warm hello!

Dear friends from the VERSIM community,

As the year 2023 draws to a close, we would like to take the opportunity to update you on the activities of the VERSIM community around the globe. We are delighted to start this newsletter by letting you know that our community is still very much active, joyful, and thriving!

Many of our members participated in the IAGA meeting in Berlin, Germany, and the URSI meeting in Sapporo, Japan. Both of these conferences were highly successful for our community. Particularly noteworthy was the opportunity for our "younger" members to engage in the URSI networking event we organized. The event did so well that it has been decided it would become a fixture in future URSI meetings!
Furthermore, ***Ondřej Santolík***, a core member of VERSIM, was awarded the URSI Appleton Prize for his outstanding contributions to experimental studies of electromagnetic waves in space.

During the VERSIM business meeting in Berlin, we elected ***František Němec*** from Charles University, Czechia, as our new IAGA co-chair. Meanwhile, in Sapporo, ***Claudia Martinez-Calderon*** from Nagoya University, Japan was voted in as the URSI co-chair.

In this inaugural newsletter, Claudia and František would like to recognize the hard work and dedication of the previous co-chairs, Andrei and Mark. They have endeavored to keep the VERSIM spirit thriving for many years. We hope that we will be able to follow in their footsteps, continuing to encourage and support our VERSIM friends, both old and new!

MEET OUR NEW CHAIRS, FRANTIŠEK NĚMEC (CHARLES U.) AND CLAUDIA MARTINEZ-CALDERON (NAGOYA U.)

NEWS BITES

The **11th VERSIM workshop** will take place at Breckenridge, Colorado, USA, tentatively from 30 Sept. to 4 Oct., 2024.
Be sure to keep up with upcoming news on our email newsletter and website.

VERSIM website is back to life!
http://versim.matfyz.cz

IN MEMORIAM: CRAIG KLETZING (1958-2023)

On August 10, 2023, Craig Kletzing died at his home in Iowa City, Iowa.

Craig will be remembered not just for his immense contributions to the field of space plasma physics, but for his mentorship, enthusiasm, generosity, and friendship.

Having earned his Bachelor's degree from the University of California, Berkeley, and his Master's degree and PhD from the University of California, San Diego, Craig held positions at the University of Alabama at Huntsville, the University of New Hampshire, and Max-Planck-Institut für extraterrestrische Physik before moving to the University of Iowa in 1996, where he remained until his passing.

Craig was involved in over 30 space missions, including being Principal Investigator for the EMFISIS instrument suite on NASA's Van Allen Probes mission, being Co-Investigator and leading hardware contributions on NASA's MMS mission, and leading multiple NASA sounding rocket missions. In 2019, Craig led a successful proposal for TRACERS, a NASA Small Explorer Mission. TRACERS will study how the solar wind and Earth's magnetic fields interact in the cusp region, dynamically driven by magnetic reconnection.

Craig thoroughly enjoyed public outreach, exemplified by his many media interviews including on the high-profile Science Friday show on National Public Radio. He was a highly respected teacher and loved his time in the classroom. He cared deeply about sharing his love of physics with all students, and often preferred teaching large undergraduate College Physics courses for non-majors, capturing the students' interest with lively demonstrations and the fascination he had for physics overall.

Music was a passion in Craig's life. Together with his wife, Jeanette Welch, he played in many Iowa City bands, including Hold My Llama, Bipolar, Brace for Blast, House of Escher, Truffle Pig, and Fork in the Road.

A celebration of Craig's career is planned for summer 2024 in Iowa City.

by David Hartley (david-hartley@uiowa.edu) and Allison Jaynes (allison-n-jaynes@uiowa.edu), University of Iowa

IN MEMORIAM:
TAUNO TURUNEN (1946-2023)

Tauno passed away on July 5, 2023.

He was the director of the Sodankylä Geophysical Observatory (SGO) from 1992 to 2011. He started his studies in mathematics at Oulu University in 1966. After 3 years, he was offered work as an assistant in the Department of Physics and decided to switch from mathematics to physics.

During his work, Tauno renewed almost all the laboratory exercises in the physics laboratory. He was also very interested in electronics, so much so that he was invited to move to the Department of Electronics as an associate professor. However, at the same time, SGO was seeking a new head for their ionospheric station. Tauno decided to move to Sodankylä instead of accepting the associate professorship in Oulu.

Since 1971, Tauno had been the head of the aeronomy unit at SGO, working with the ionosonde. In 1975, when planning for the EISCAT radar system began, Tauno was appointed as the representative of Finland to the design group. He played a crucial role in the EISCAT Scientific Association, serving as its technical deputy director from 1984 to 1987, and later as the director from 1998 to 2002. He received the international Beynon Medal in 2003.

Tauno was exceptionally skilled in designing new instruments, such as the world's most sensitive ELF-VLF receiver (still now, 31 years later!). This receiver has been operational since 1992, and has been running at Kannuslehto since 2006. Tauno also developed highly efficient software for signal analysis, creating a sophisticated and very effective sferics and power line harmonic radiation filters for ELF-VLF analysis. In 2005, Tauno built a new ionosonde with the capability of 1-min sounding, a feature that has remained challenging for other ionosondes around the world, even in recent times. He also harbored innovative ideas for developing a new riometer, but retired before he was able to start this project.

Tauno was a very international scientist, with a huge number of friends all over the world. He was appointed a professor in 2003. Tauno had three children.

by Jyrki Manninen (jyrki.manninen@oulu.fi), Sodankylä Geophysical Observatory

IN MEMORIAM: FRANÇOIS LEFEUVRE (1944-2022)

François was involved in the development and data analysis of many wave experiments onboard satellites (GEOS-1 and 2, AUREOL-3, INTERBALL, CLUSTER, DEMETER, TARANIS). He served as the Director of the Laboratory of Physics and Chemistry of the Environment from 1994 to 2003. He spent 21 years in the service of URSI, serving as President during the periods 2005-2008 and 2009-2011. He published more than 100 scientific papers on wave and turbulence analysis techniques, and on natural and artificial ULF to MF emissions in the Earth's magnetosphere.

IN MEMORIAM: YAKOV N. ISTOMIN (1946-2022)

In the early 1970s, Yakov made a significant contribution to the theory of resonant wave-particle interactions and triggering emissions. Since 1978, he has worked in the Department of Theoretical Physics of the Lebedev Physical Institute. He has achieved several fundamental results in the theory of the magnetosphere and the radio emission of pulsars. He did everything with passion: working, traveling, playing chess. Engaging in an emotional argument about science or politics was his forte.

IN MEMORIAM: NICOLE CORNILLEAU-WEHRLIN (1945-2023)

Nicole devoted her entire career to studying plasma waves and wave-particle interactions in Earth's and planetary magnetospheres using spacecraft. She has been deeply involved in the development, construction, and data analysis of many wave experiments in space missions. However, she is best known for her leadership and key role in the Cluster mission as the PI of the STAFF experiment, and later as PI of the same experiment on the Double Star mission. She was also the director of the Nançay RadioAstronomy Observatory.

IN MEMORIAM: SATOKO NAKAMURA (1988-2023)

Satoko was a Designated Assistant Professor at the Institute for Space and Earth Environmental Research of Nagoya University. Her work focused on the study of magnetospheric physics and radiation belt dynamics, and more recently on Geomagnetic Induced Currents and space weather. She was an integral part of the ERG data center and a very promising scientist. Her lively demeanor and friendliness, as well as her love for coffee, will be remembered fondly.

BELGIUM

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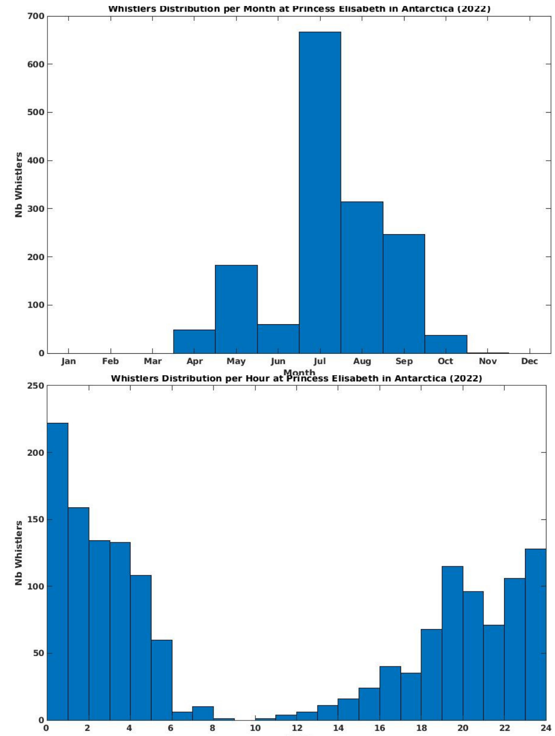
We continue our project to detect whistler waves with two VLF antennas that are part of the Automatic Whistler Detector and Analyzer system's network (AWDAnet). This network covers low, mid, and high magnetic latitudes including conjugate locations. It has been initiated by Dr. J. Lichtenberger (Hungary).

Our two VLF antennas are located in Humain, Belgium (Lat. ~ 50.11°N, Long. ~ 5.15°E) and at the Belgian Antarctic station Princess Elisabeth (Lat. ~ 71.57°S, Long. ~ 23.20°E). The antennas detect whistlers that are used to determine electron densities in the equatorial plasmasphere. For the second time since its installation in 2016, the Antarctica antenna has worked all year around (including the 8 months when the station is uninhabited!). However, the data will be recovered only in February 2024... The statistical analysis of recent data measured at the Princess Elisabeth Antarctica station shows that whistlers are detected mainly during summer and during the night from 6 PM to 6 AM.

We participated in the organization of Open Doors at our Belgian site in Humain in September 2023. This was very successful, and we could show the 12-meter VLF antenna as well as a portable instrument doing some live tests.



Statistical analysis of whistlers detected at the Princess Elisabeth station in Antarctica in 2022. (top) As a function of the month and (bottom) as a function of local time.

Open Doors at the observatory of Humain in Belgium: (top) 12-meter VLF antenna, and (bottom) portable search-coil instrument to directly detect and observe VLF waves.

CZECHIA

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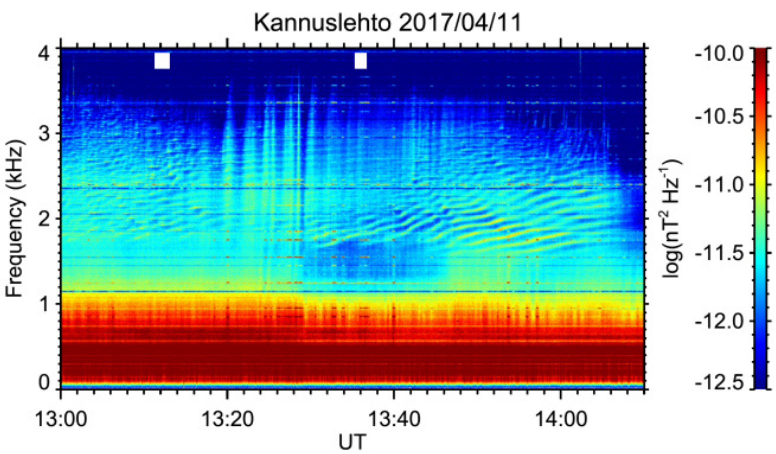
Our group at the Department of Space Physics, Institute of Atmospheric Physics of the Czech Academy of Sciences and at the Faculty of Mathematics and Physics of the Charles University continued to investigate electromagnetic waves at very low frequencies using spacecraft and ground-based measurements. Examples of our results obtained in 2023 are given below.



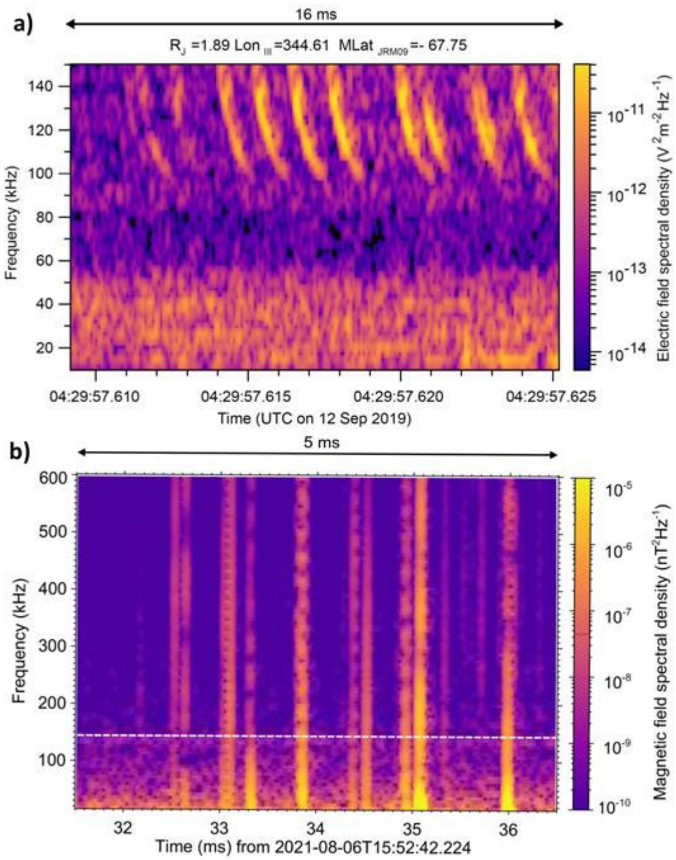
Frequency-time spectrogram of power spectral density of magnetic field fluctuations measured by the ground-based station Kannuslehto on 11 April 2017. MLR event lasting for nearly the entire plotted time interval can be seen. The white bars at the top mark the time intervals when Van Allen Probe A high-resolution burst mode measurements were available.

We systematically investigated the occurrence and properties of Magnetospheric Line Radiation (MLR) events by analyzing continuous intervals of high-resolution multicomponent wave data acquired by the Van Allen Probes spacecraft [1]. These events predominantly manifest on the dayside at frequencies from 1 to 5 kHz and propagate with oblique wave normals away from the geomagnetic equator.

In a specific instance, concurrent ground-based observations are available, establishing constraints on the spatial extent of the event, which is found to be limited to the high-density plasmasphere region. Notably, in three events, an electrostatic wave is observed at a frequency corresponding to the modulation frequency of MLR. This observation is unprecedented and likely associated with the event's formation mechanism. Our findings can contribute to a deeper understanding of the formation mechanisms of MLR phenomena.

We used the high temporal resolution records from the radio receiver Waves onboard the Juno spacecraft, which provided us with regular snapshots every second when Juno was close to the planet. We analyzed the properties of the identified pulse groups and compared them with the characteristics of pulse groups generated by terrestrial lightning phenomena detected by ground-based radio receivers [2]. We identified radio pulses with typical time separations of one millisecond, which suggests step-like extensions of lightning channels and indicates that Jovian lightning initiation processes are similar to the initiation of intracloud lightning at Earth. The average prolongation of Jovian lightning channels might happen in steps of several hundred to a few thousand meters long.

CZECHIA



a) Frequency-time spectrogram of power spectral density of electric field fluctuations of a group of dispersed pulses recorded by the Juno satellite on 12 September 2017 after 04:29:57 UTC at a radial distance of 1.89 RJ (Jovian radii). b) Frequency-time spectrogram of power spectral density of magnetic field fluctuations showing the 5 ms long detail of the initiation of an intracloud flash that occurred on 6 August 2021 at 15:52:42 UTC. The measurement was conducted by a broadband magnetic field antenna (5 kHz to 90 MHz) installed at the Dlouhá Louka observatory in Czechia. For comparison with the dispersed pulses from panel a), the white dashed line indicates the upper frequency limit of the Juno measurements.

We further continued to explore quasiperiodic emissions, focusing on their fine structure [3] and correlation with geomagnetic pulsations [4]. We analyzed simultaneous observations of intense very low frequency whistler mode events by the Kannuslehto station and Van Allen Probes [5]. We also contributed to a significant enhancement of the quality of the Van Allen Probes electric field data by participating in the instrument team work on quantification of the impact of the antenna sheath on the effective length for different plasma densities [6].

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FIJI

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Since our joining in 2003, we have continued to take part in the World-Wide Lightning Location Network (WWLLN). We still record narrowband VLF signals from six transmitters using the USP Suva Physics Building's SoftPAL data acquisition system (18.15ºS, 178.45ºE), which was installed in 2006. Efforts are being made to record narrowband VLF recordings with SoftPAL station in Port Villa, Vanuatu, and Apia, Samoa, where our university has its regional campuses.

The sub-ionospheric early VLF perturbations observed on the NWC (19.8 kHz) navigational transmitter signal monitored at a low-latitude station, Suva (18.1ºS, 178.5ºE), Fiji, during campaign periods of November 2011, 2012, and 2014 and December 2014, were analyzed. Using the WWLLN data, we studied the relationship between the energy of lightning strokes and the level of VLF perturbations. Generally, the greater the energy of lightning, the stronger VLF perturbation. However, a low-energy lightning stroke can also produce a comparable level of perturbation to that of strong lightning.

A comprehensive analysis of subionospheric Very Low Frequency (VLF) signals from transmitters with call signs NWC, NPM, and NLK monitored at a low-latitude station, Suva, Fiji, was carried out to determine the D-region effects of intense geomagnetic storms for a period of 7 years (2011–2016 and 2018).

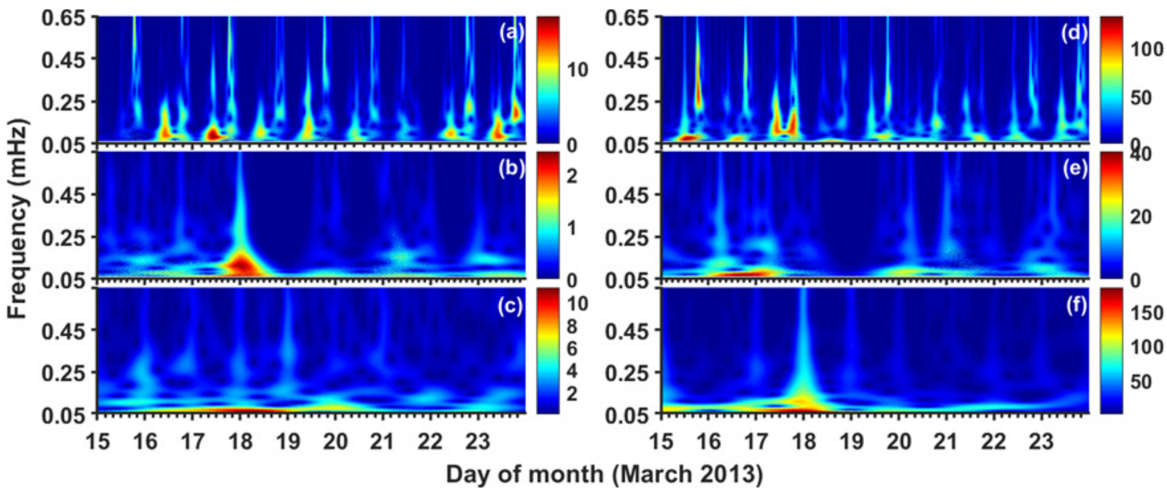
Seven out of 12 geomagnetic storms revealed VLF anomalies during the storm main phase day and storm recovery phase days under the criteria of signal changes exceeding three standard deviations (±3σ) over two continuous hours above the average value of five geomagnetically quiet days. Wavelet analysis of signal anomalies showed clear wave-like spectra (0.05–0.18 mHz) of atmospheric gravity waves indicating traveling ionospheric disturbances propagating toward low latitudes due to storm-associated Joule heating at high latitudes.

In order to investigate the variations in the atmospheric electric field brought on by changes in meteorological conditions, such as strong thunderstorms, we recorded the atmospheric electric field using an Electric Field Mill (EFM 100) placed close to the Physics building at USP, Suva. Continuous observations started in August 2022 at the sampling frequency of 1 Hz.

We continue our ionospheric observations using the new Global Navigation Satellite Systems (GNSS) station for Ionospheric Monitoring (TEC and scintillations) and Precise Point Positioning (PPP) Research.

The GNSS was installed under an MoU between the School of Information Technology, Engineering, Mathematics and Physics (SEP), USP, and the School of Electronics and Information Engineering (SEIE), Beihang University, China.

For details please visit USP's electronic research repository at http://repository.usp.ac.fj/



(a, d) Sample analysis wavelet spectra of the NWC signal amplitude and phase for 24 hours. (b, e) Daytime. (c, f) Nighttime.

References:

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FINLAND

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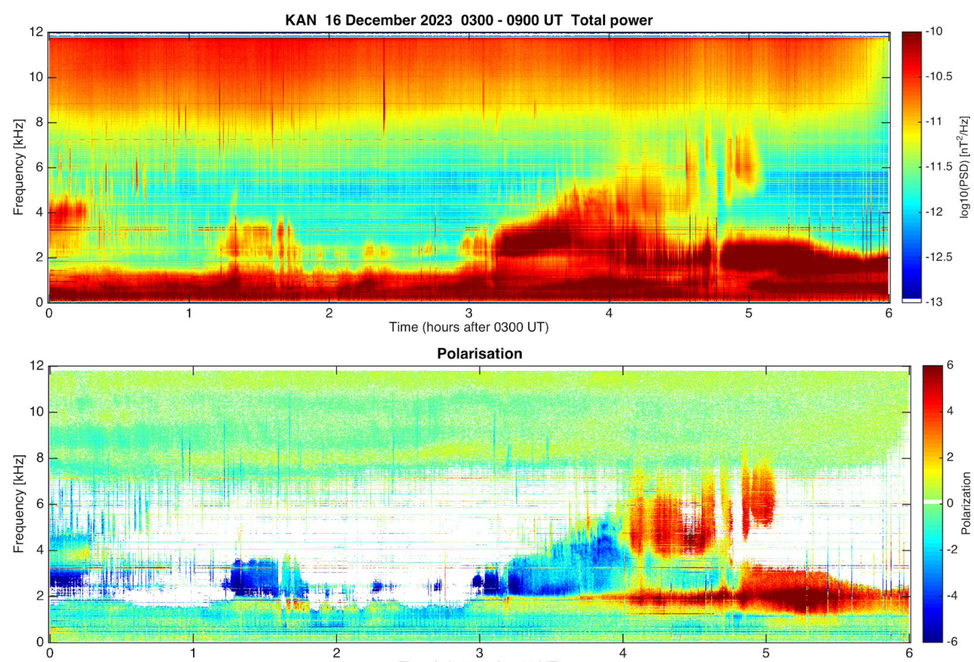
The Finnish ELF-VLF campaign started already on 7 September 2021, and will continue uninterrupted as long as our instrumentation works. Although there is usually strong lightning and saturation during summer time, it is reasonable to have continuous measurements, because many significant magnetic storms have also occurred in the summer.

The campaign quick-look plots (24-hours, 1-hour, and 1-minute) are available at http://www.sgo.fi/vlf/. During the campaign, new plots are updated within a few days after recording. The frequency range of quick-look plots is from 0 to 16 kHz, while the data itself ranges from 0 to 39 kHz. The upper band is available if someone is interested. We would like to remind you that all quick-look plots currently on our servers, have been analyzed with both PLHR and sferics filters on.

In October, Dr. Jyrki Manninen spent one month visiting ISEE at Nagoya University. The trip was funded by the ISEE Joint Research Program, received alongside Prof. František Němec (Charles University, Czechia). During this visit, the main topic was to search for simultaneous events in the KAN and PWING VLF data. Some nice events have been found.

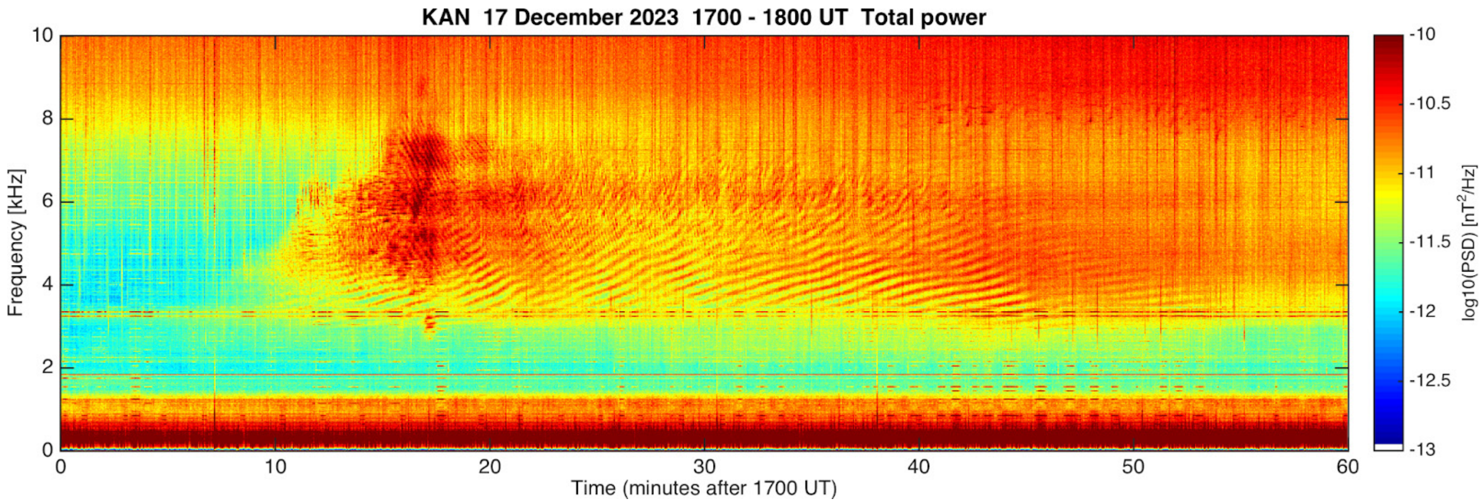
This year, five peer-reviewed papers were published. Also, a lot of different activities have been planned for the after-pandemic era.

If you are interested in our data, please feel free to contact the PI, at his email Jyrki.Manninen@oulu.fi. We can make a vast amount of different kinds of analysis for our ELF-VLF data.



6-hour example from 16 December 2023. Upper panel shows total power and lower panel shows polarization. There are many VLF bursty-patches and strong chorus. Polarization is mostly left-handed (blue), but the last 2 hours are right-handed (red).

FINLAND



Beautiful Magnetospheric Line Radiation event on 17 December 2023.

References:

[1] Martinez-Calderon, C., J. K. Manninen, J. T. Manninen, T. Turunen (2023), Statistics of unusual naturally occurring VLF radio emissions termed bursty-patches observed at Kannuslehto, Finland. J. Geophys. Res. Space Phys., 128, e2022JA030792.
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HUNGARY

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

PLASMA is a European Space Agency (ESA) project to develop plasmaspheric products for ESA's Space Situational Awareness Programme. It uses densities derived from AWDANet VLF and EMMA magnetometer network data, as well as in-situ density data. After some unexpected delays, the project has now reached the internal test phase within ESA.

We have started another two ESA projects:

1. RB-FAN2: Specification of radiation environment of the Earth. This project is led by ONERA, France and it will utilize the products developed in PLASMA

2. UJPOPRAD: Measuring the efficacy of a satellite VLF transmitter with magnetic loop/solenoid antenna in a plasma chamber. In this project, the efficacy will be measured in a plasma chamber at West Virginia University, WV, USA

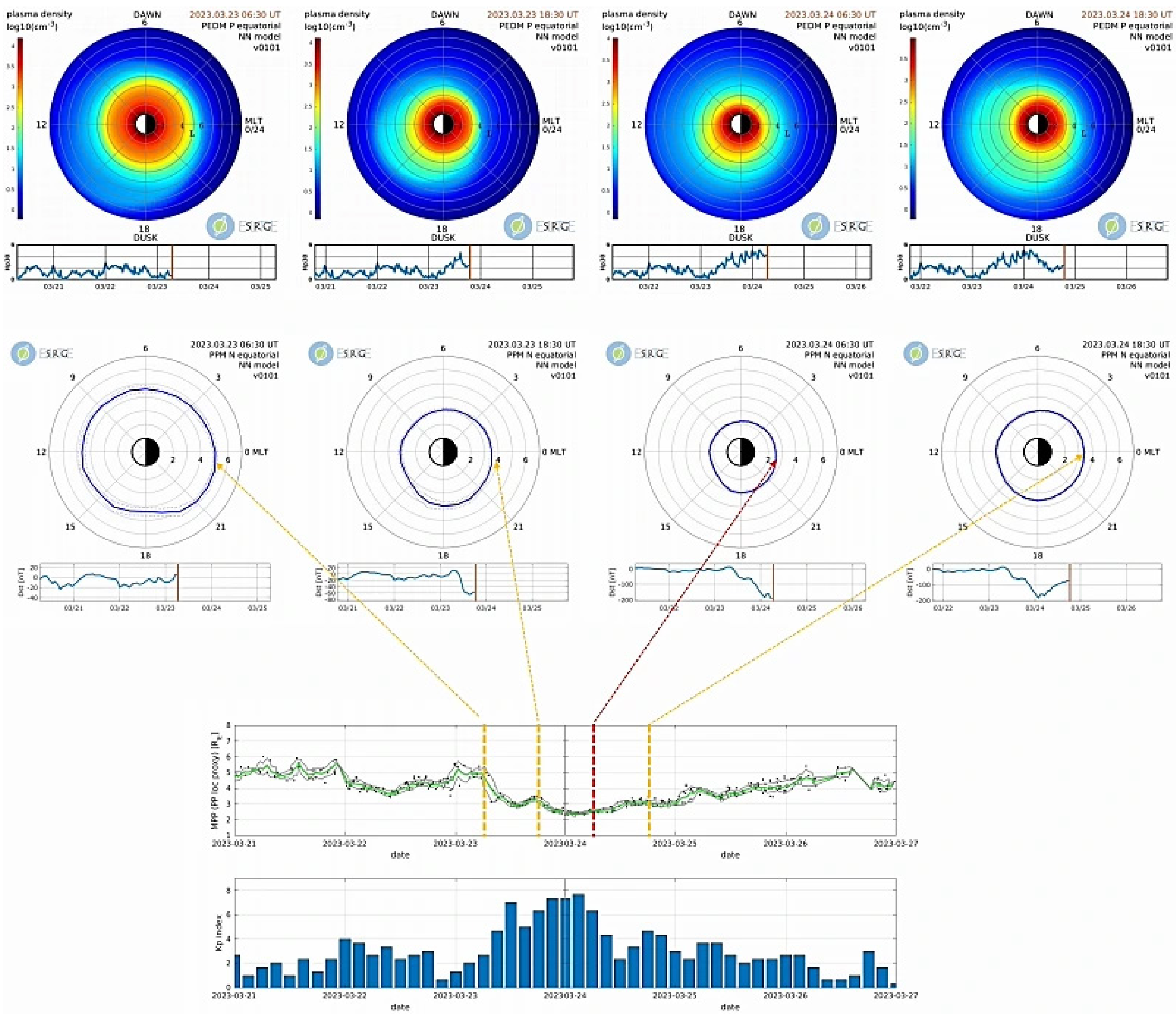
We have also started a Horizon Europe project: Forecast of Actionable Radiation Belt Scenarios (FARBES), where we are developing simple scenarios for spacecraft operators using proxies based on ground VLF and ULF data to forecast a few key event characteristics:

- Time to the most severe environment
- Most severe flux reached
- Time to the end of the event.

The FARBES Team consists of six partners:

- Eötvös University, Hungary (coordinator)
- ONERA, France
- Institute of Atmospheric Physics, Czechia
- National and Kapodistrian University of Athens, Greece
- British Antarctic Survey, United Kingdom
- New Mexico Consortium, NM, USA.

HUNGARY



PLASMA magnetosphere model (top row), plasmapause model (middle row), and the Swarm-based plasmapause proxy for the 23-25 March 2023 storm.

ISRAEL

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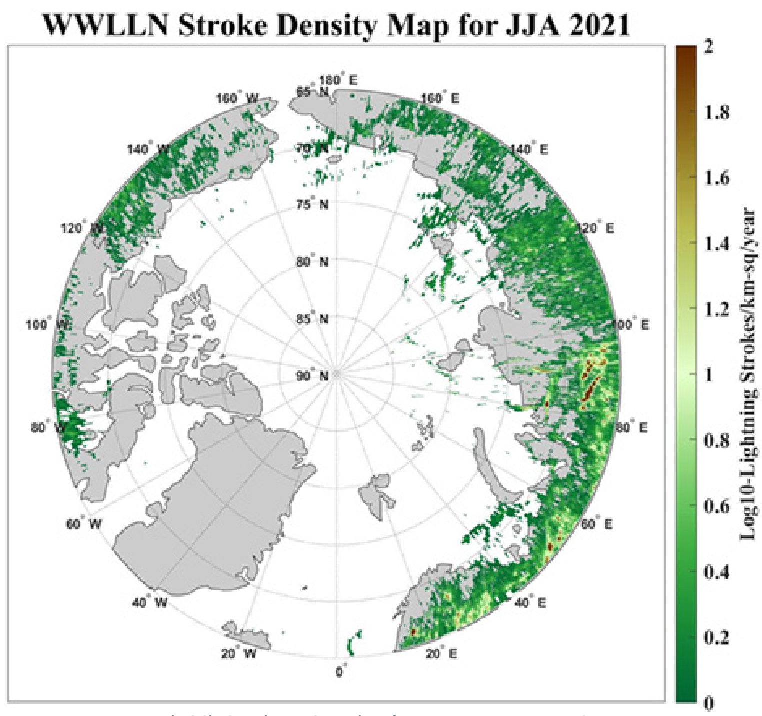
Our Atmospheric Electricity group continues to work on the connection between thunderstorms, lightning, and the Earth's changing climate. We use primarily the global WWLLN (http://wwlln.net) that collects lightning data in the VLF range.

In the last year, we have published a few papers using the WWLLN data as an indicator of deep convection on Earth. Two highlights are, finding that deforestation over the Amazon in the past few decades has actually caused a decrease in thunderstorm activity over the deforested areas, due to the reduction of latent heat release, less evapotranspiration, and increased atmospheric stability [1].

Another interesting finding is that we have found a link between the interannual variability in Arctic summer sea ice melt and thunderstorm activity in the Arctic [2]. Thunderstorms increase the amount of upper tropospheric water vapor [3] and high-altitude cirrus clouds [4], both of which act as strong absorbers for infrared radiation emitted from the Earth, and hence warm the surface of our planet.

With recent observations of increases in lightning activity in the Arctic over the past decade (likely due to global warming), further increases in upper tropospheric water vapor and cirrus clouds due to increased thunderstorm activity will increase further the surface temperatures over the Arctic, and hence enhance the sea ice melt in the summer months.



Spatial lightning density from WWLLN VLF data over the Arctic for JJA 2021.

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JAPAN

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To continue monitoring ELF and VLF waves from the ground, a new PWING station was installed in Oulujärvi, Finland (OUJ, L=4.5, MLAT=61.3ºN). This new station is located 370 km south of the existing receiver of Kannuslehto (KAN, L=5.5, MLAT=64.4ºN) and approximately at the same longitude.

OUJ has allowed us to investigate the latitudinal propagation of VLF emissions and their magneto-ionospheric propagation.
Preliminary results of overall wave occurrence, conjugated events, localization of ionospheric exit points, and characteristics of VLF bursty-patches have already been presented (e.g., URSI GASS 2023, AGU 2023). The first publications should be coming up shortly.

We also studied the longitudinal extent of quasi-periodic (QP) emissions and investigated their simultaneous and conjugated observations at seven PWING stations. We found that the longitudinal extent of 90% of QP waves showing one-to-one correspondence (same spectral and frequency features) at multiple locations was around 4 hours in MLT [1].

Using statistics of so-called VLF bursty-patches (i.e., waves detected on the ground at f > local f_{ce}), we found that these patches seem to be related to usual VLF waves.

It is likely that both bursty-patches and usual VLF waves are generated by the same processes (temperature anisotropy), but the patches have a particular propagation mechanism. Bursty-patches show the highest occurrence during the local morning (5-12 MLT) and their detection on the ground appears associated with low variations of the local geomagnetic field [2].

Claudia Martinez-Calderon visited Finland during the summer to check on the OUJ receiver status, and found the site in great condition. Along with Jyrki Manninen, she took also checked possible future VLF receiver locations northwards of KAN as we consider expanding the existing VLF network.

While the PWING project has ended, its successor, PBASE, will allow us to carry on the study of waves, particles, and related phenomena through a combination of ground instruments and satellites, complemented by numerical simulations. The PBASE program aims to significantly contribute to understanding and predicting geospace variabilities covering a wide area in altitude, latitude, and longitude.

Oulujärvi VLF receiver in the summertime, when the weather is high ♫♪

- More information on PBASE
https://www.isee.nagoya-u.ac.jp/dimr/PBASE/en/

- Acces to PWING VLF data
https://stdb2.isee.nagoya-u.ac.jp/vlf/
  ➞ Quicklook plots

https://ergsc.isee.nagoya-u.ac.jp/data/ergsc/ground/vlf/
  ➞ CDF files

References:

[1] Martinez-Calderon, C., T. Oonishi, K. Shiokawa, J. K. Manninen, A. Oinats, M. Ozaki (2023), Characteristics and longitudinal extent of VLF quasi-periodic emissions using multi-point ground-based observations, Earth, Planets and Space, 75, 148.
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https://doi.org/10.1029/2022JA030792

NEW ZEALAND

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As 2023 draws to a close I find myself wondering where a years worth of time went. It was a tumultuous year, with international shocks through war and inflation, an election as well as financial crisis's across the New Zealand university sector, and personal shocks. All and all 2023 was a year which spun by faster than I had realised.

We had some successes during the year. Dr. Daniel Mac Manus submitted his PhD, which was awarded mid-year. Malcolm Crack also submitted his MSc thesis, and his examination process ended successfully mid-year as well. We sent Dr. James Brundell to Antarctica twice, once with Malcolm (Expedition 14 in February), and once with Daniel (Expedition 15 in November). James and Craig also travelled to Edmonton in March to visit our ARDDVARK site near that city – a maintenance trip which was clearly needed, as we have not been there in 9 years!

In other “VLF news”, we helped support an active injection campaign, where the NZ HVDC link joining the North and South Islands of New Zealand was used to inject hundred's of amps of current into a substation near Wellington – a controlled Geomagnetically Induced Current (GIC) simulation! Part of this work involved monitoring harmonics produced by half-cycle saturation coming from the transformers in the substation using broadband VLF. I expect Mark Clilverd's report will have more information on this.

Craig and Annika travelled to the IUGG meeting in Berlin (July), and the CHAMOS workshop in Finland (November). Craig also went to the URSI GASS in Sapporo and ESWW in Toulouse – and visited UK collaborators in Newcastle and Edinburgh. Daniel attended ESWW, Mikhail visited ETH Zurich, and Hannah travelled to the Fall Meeting. It is clear the Otago group is out on the road again! Note also that Aaron Hendry has left us (again), taking up a role at the British Antarctic Survey.

A lot of our research outputs have been dominated by space weather/ GIC, which is typically less interesting to the VERSIM community – so I will only mention 2 outputs, one of which is focused on GIC.

[1] Submitted after Daniel's PhD, but based on work in his thesis, we have recently had a paper accepted on GIC mitigation. This research involved us travelling to Wellington to work alongside Transpower NZ control room staff to develop the new operational plan to respond to a very large geomagnetic disturbance – removing redundant power lines from the NZ electrical network to decrease the GIC entering transformers. As mitigation is not often discussed in the literature, Daniel's paper was made a

The Otago Space Physics Group updated our team picture on 11 August 2023. Shown in the photo from left to right: Neil Thomson, Tasmin Leonard-Paterson, James Brundell, Hannah Kessenich, Zade Johnston, Annika Seppälä, Romain Meyrand, Craig Rodger, Jono Squire, Daniel Mac Manus, and Mikhail Kruglyakov. Unfortunately Aaron Hendry was missing.

Space Weather Spotlight, and described in EOS: https://eos.org/research-spotlights/protecting-power-grids-from-space-weather

[2] We expect substorms should trigger strong whistler mode chorus, which will lead to precipitation of electrons over a wide energy range – in last year's VERSIM newsletter we reported on a paper looking at the precipitation measurements. This year we report on a study looking at polar atmospheric ozone data from the mesosphere, showing decreases following strong substorm events. Such atmospheric changes had been predicted from modelling, but we think this is the first time such changes have been seen (note, these events are not during geomagnetic storms).

References:

[1] Mac Manus, D. H., C. J. Rodger, A. Renton, J. Ronald, D. Harper, C. Taylor, M. Dalzell, T. Divett, M. A. Clilverd (2023), Geomagnetically Induced Current mitigation in New Zealand: Operational mitigation method development with industry input, Space Weather, 21, e2023SW003533. https://doi.org/10.1029/2023SW003533

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RUSSIA

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We have been continuing studies of wave phenomena and wave-particle interactions in the magnetosphere, as a joint group from the two institutes (PGI and IAP RAS). Several papers have been published or accepted and some more are under review.

Quantitative analysis of the relationship between the wave activity parameters and precipitating charged particle fluxes requires a rigorous consideration of the wave field structure. It is especially important for the discrete quasi-monochromatic wave packets.

We analyzed the interaction of relativistic electrons with electromagnetic ion-cyclotron (EMIC) wave packets of finite duration and small amplitude in the Earth's radiation belts, and obtained a rigorous mathematical description of such an interaction. The analytical estimates of the electron pitch-angle diffusion rate obtained on this basis agree well with test-particle simulations. A decrease in the wave packet duration extends the energy range of interacting particles to lower energies, and this formally non-resonant interaction can now be correctly described.

We developed a new numerical model for VLF chorus emissions generation based on the EPOCH PIC code.

The initial distribution function of energetic elections is assumed to have a finite-width step-like to the deformation in the velocities parallel geomagnetic field. This allowed us to verify and generalize the analytical and numerical results obtained earlier within the framework of a backward wave oscillator (BWO) model in which a sharp step feature is assumed.

In the presence of either a sharp or smooth step, chorus emissions can be generated for a realistic flux of energetic electrons even if the initial velocity distribution (without the step) is isotropic. Simulated chorus emissions behave very similarly both for sharp and finite-width steps. In particular, the generation of repetitive chirping chorus elements occurs if the coupling parameter exceeds the linear generation threshold several times. For smaller threshold excess, quasi-stationary or relaxation oscillation regimes take place.

For the first time, we systematically studied the dependence of the chorus emissions properties on the energetic electron distribution parameters, in particular, on the step width and the effective wave-particle coupling parameter proportional to the energetic electron flux and step height.

RUSSIA

We showed that the functional dependences of the linear growth rate on the coupling parameter obtained earlier for the sharp step within the framework of the BWO model remain the same for a smooth step gradient. The threshold flux of energetic electrons above which whistler mode waves are generated increases very fast with increasing step width. With a fixed relative step height, the threshold flux is about an order of magnitude higher for a step width of 8% than for a sharp step.

References:

[1] Grach, V. S., A. G. Demekhov (2023), Interaction of relativistic electrons with packets of the electromagnetic ion cyclotron waves of finite length and low amplitude, Plasma Physics Reports, 49, 901–911. https://doi.org/10.1134/S1063780X23600561

[2] Pasmanik, D. L., A. G. Demekhov (2023), VLF chorus emissions modeling using EPOCH PIC code: Generation regimes and comparison with a backward wave oscillator theory. Phys. Plasmas, 30, 112106. https://doi.org/10.1063/5.0169410

SERBIA

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The activities of our group were focused on scientific research, organization of conferences, participation in international meetings, realization of special issues in journals, and continuation of cooperation within the European network of VLF/LF receivers INFREP.

Research based on the analysis of the data recorded by the VLF/LF receivers located at the Institute of Physics Belgrade was aimed at the continuation of i) examination of changes that are considered potential precursors of earthquakes, and ii) examination of the influence of solar radiation on the ionospheric D-region. The mentioned potential earthquake precursors were first observed in the analysis of the ICV signal recorded in Belgrade before the earthquake that occurred near Kraljevo, Serbia on 3 November 2010, and manifested in the reduction of the amplitude and phase noise, wave excitations with periods below 1.5 s, as well as their attenuations at small wave periods.

This year, we submitted a manuscript which completed a pilot study of the indicated three earthquake precursors for four cases, and which formulated parameters of VLF signals that should be analysed in future statistical analyses that should examine their connections with seismic activity [1].

We also continue these investigations for the period of intense seismic activity where the amplitude noise reductions before earthquakes are also recorded, but it is possible that during one instance of amplitude noise reduction more powerful earthquakes with the epicentres in a localized area can occur without additional reductions in the amplitude noise.

We also participated in a multidisciplinary investigation of the impact of solar X-ray flares and CME on the terrestrial atmosphere based on multi-instrumental data [2].

In addition, we continue activities in the European VLF/LF network INFREP and EUROPLANET, and we submit several proposals for international projects.

We organized the first International Conference on Recent Trends in Geoscience Research and Applications 2023 (GeosciRA23) [3] and the fifth Meeting on Astrophysical Spectroscopy – A&M DATA – Astronomy & Earth Observations.

Also, the members of our group participated in several international conferences and worked as guest editors in three special issues in international journals.

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[1] Nina, A., Analysis of VLF signal noise changes in the time domain and excitations/attenuations of short-period waves in the frequency domain as potential earthquake precursors, Remote Sens., submitted.

[2] Kolarski, A., N. Veselinović, V. A. Srećković, Z Mijić, M. Savić, A. Dragić (2023), Impacts of extreme space weather events on September 6th, 2017 on ionosphere and primary cosmic rays, Remote Sens., 15(5), 1403. https://doi.org/10.3390/rs15051403

[3] Book of abstracts and contributed papers of the International Conference on Recent Trends in Geoscience Research and Applications 2023, October 23–27, 2023, Belgrade, Serbia & virtual, Eds. Aleksandra Nina, Snežana Dragović, and Dejan Doljak. https://geoscira.wixsite.com/2023

SLOVENIA

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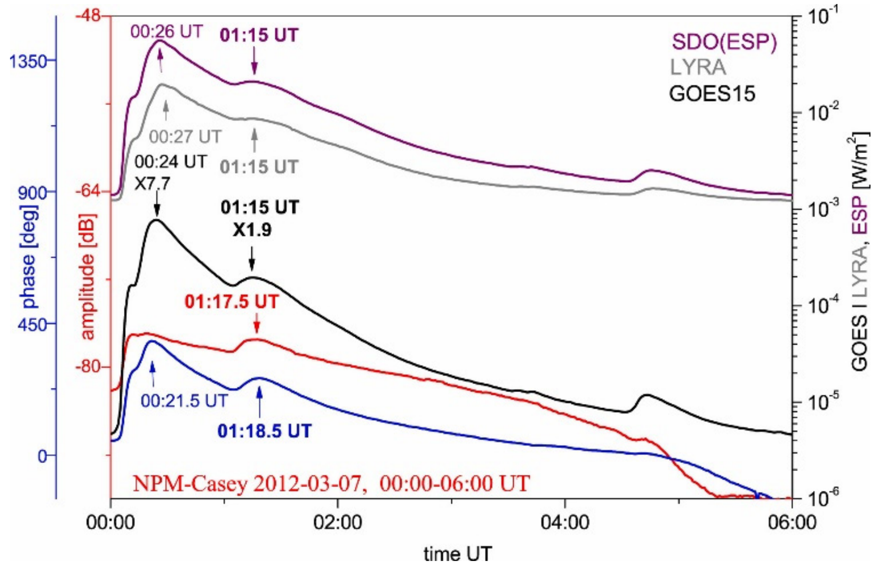
https://www.ung.si

This year has witnessed the result of a fine collaboration of VERSIM colleagues, among others, on the development of the N(t,h) model.

Based on the coupling of the continuity equation and the Appleton relation, the model predicts the D-region electron density time-height profile during solar flares. Solar flares measured in parallel within different bandpass domains: the standard long X-ray GOES (0.1-0.8 nm), the SDO (0.1 - 7 nm), and the LYRA (1-2 + 6-20 nm) have been used in coincidence with ground recorded active transmissions of VLF signals. The ionization efficiency has been calculated using the solar spectral irradiance according to two data sources: the XUV Photometer System (XPS)-Level 4 model (Woods et al., 2008, 2012) and the Flare Irradiance Spectral Model FISM2 (Chamberlin et al., 2020). Thus, the ionization efficiency is associated with each particular flare and to each particular bandpass in which this is recorded. Relating flare irradiance with ground-based VLF amplitude and phase measurements results in the concept and quantity of time delay – the time lag of the extreme VLF amplitude and phase behind the flare irradiance maximum.

By analysing several M- and X- class flares, we have shown that the amplitude and phase time delays



Solar Irradiance on 2012–03-07 as measured by GOES15, LYRA and SDO(ESP), simultaneous VLF amplitude and phase for the NPM/21.4 kHz signal, recorded at Casey, Antarctica. For the X7.7 flare at 00:24 UT, negative amplitude and phase time delays are apparent.

apply to the N(t,h) model at equal footing. It was ascertained that the physically inadmissible "negative" time delay actually indicates that some other ionization/ radiation driver closely preceding the one yielding $\Delta t<0$ is dominating the ionization process. This opened a new ongoing study of flares in harder X-ray domains (e.g. short GOES, RHESSI). Such is the case of the extraordinary 2012-03-07 X7.7 flare, also detected by the Fermi Large Area Telescope in gamma-ray wavelengths.

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UNITED KINGDOM

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Our group has continued monitoring the ionosphere and magnetosphere using ELF and VLF waves this year. We had some successes, e.g., our unmanned Antarctic station Halley ran all year without power failure, but we also had some challenges, e.g., the failure of the Ascension Island aerial system which has affected WWLLN sferic detection operations for the latter half of the year, and the failure of the Ny Alesund (Svalbard) logging computer mid-year, affecting Ultra narrowband data since July.

A highlight for the year was to be able to work with a long-time supporter of VERSIM, Prof. Vida Źigman (University of Nova Gorica, Slovenia), in using ground-based measurements to develop a new model of the D-region electron density variations during solar flares. The associated paper (*see SLOVENIA report*) is an indication of the recent interest in utilizing space-borne solar irradiance measurements made over a wider range of wavelengths to fully describe the impact of solar flares on the lower ionosphere.

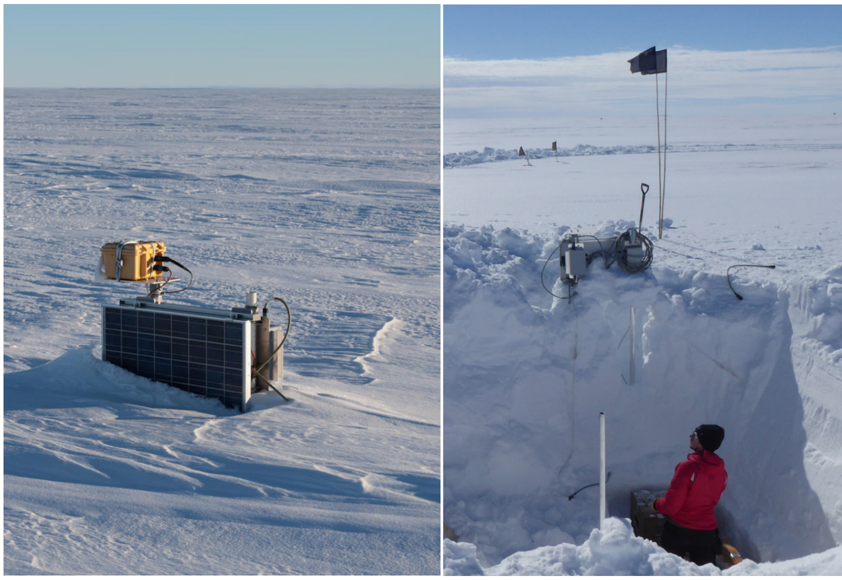
The open-access BAS database of VLF data continues to be a source of observations for a number of interesting research topics.

https://psddb.nerc-bas.ac.uk/data/access/main.php?menu=1,7

→ BAS VLF database

Using BAS data the effects of ozone shadowing of the D-region ionosphere during sunrise has been a continuing area of study by Dr. Lilliana Macotela (University of Bath, UK), while studies of seasonal variations in VLF transmitter subionospheric propagation conditions have been undertaken by researchers at the German Aerospace Center (DLR), overseen by Dr. Daniela Banys.

BAS data are also being used to contribute to an EU project on forecasting radiation belt behaviour during geomagnetic storms, led by VERSIM's Prof. Janos Lichtenberger (Eötvös Loránd University, Hungary). Please contact Mark at BAS if you would like to investigate the use of the data, or to access it by the bucket-load.



The continuous battle against accumulating snow levels at Halley. Instruments need to be raised each year or lost. (left) A solar-powered VLF system after the winter. (right) Digging it out to raise it to the surface again.

UKRAINE

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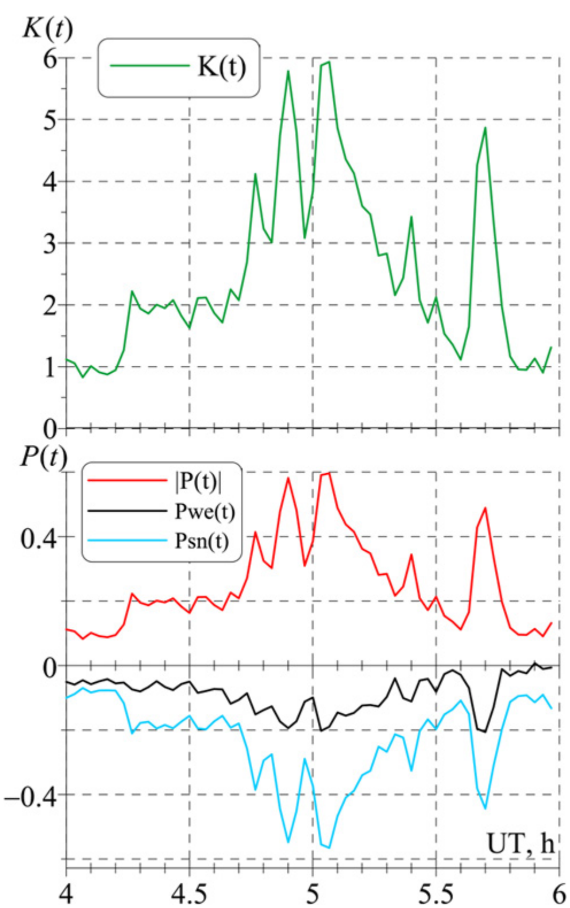
In 2023, our group continued working in the ELF radio propagation at the Schumann resonance frequencies by participating in a great international team. We have completed a series of three studies comparing global observational and model data on disturbances in the Schumann resonance power, driven by the eruption of the Tonga volcano on January 15, 2022 [1, 2, 3].

Our additional work implies a realistic model of the Earth-ionosphere cavity and of the global thunderstorm activity. It evaluates the accuracy of measurements of the level of global thunderstorms by using the integral intensity of the Schumann resonance at the Earth's poles or in the high latitudes of the northern and southern hemispheres [4].

Unfortunately, our joy of seeing the papers in print could not be shared by Dr. Alexander Yuryevich Shchekotov, who suddenly left this world as a result of an aortic aneurysm in April 2022.



The excess in the ELF power flux K conditioned by the Tonga eruption.

References:

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[3] Nickolaenko, A. P., A. V. Shvets, Yu. P. Galuk, A. Yu. Schekotov, M. Hayakawa, A. Mezentsev, R. Romero, R. De Rosa, I. G. Kudintseva (2023), Power flux in the Schumann resonance band linked to the eruption of Tonga volcano on Jan. 15, 2022. (Two point measurements of Umov-Poynting vector), J. Atmos. Solar-Terr. Phys., 247, 106078. https://doi.org/10.1016/j.jastp.2023.106078

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UNITED STATES

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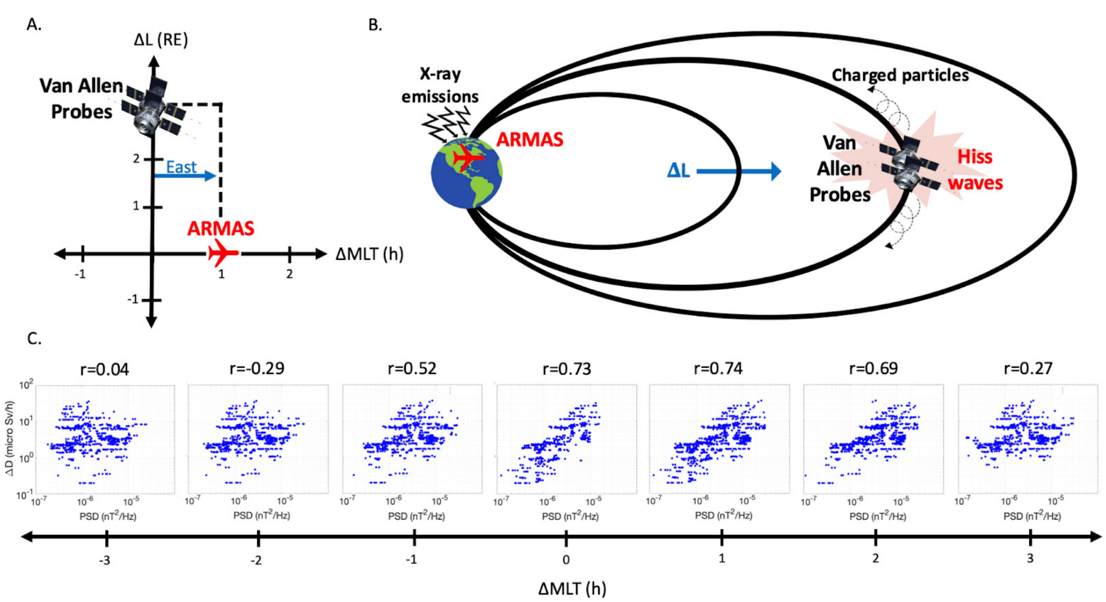
The UCLA Bortnik group had a productive year investigating a range of topics centered on magnetospheric plasma waves and energetic particle dynamics. A big focus this year has been on the precipitation (e.g., [1]) and loss of energetic electrons from the radiation belts.

We used a new database of radiation enhancement events (called ARMAS) observed by dosimeters flown on commercial flights at standard aviation altitudes (~9-11 km), to show that there was a strong (~73%) correlation between radiation enhancement events and plasmaspheric hiss (a major surprise in itself), and that this correlation was robust and behaved in a physically consistent manner.

The figure shows that when the ARMAS observation location was moved relative to the Van Allen Probes spacecraft, the correlation continued to be significant for ~2 hours to the East, but not to the West, and also broke down when ARMAS was moved in L-shell [2]. An even bigger surprise was that Monte Carlo modeling indicated that we should not be seeing any such precipitation signature, and this will form a topic of intense investigation in 2024.

Machine Learning (ML) continued to be a theme of great interest in our group, and this year we continued to move towards the topic of ML interpretability.



(After [2], Figure 3) Panel A illustrates the conjunction window geometry which includes MLT and L shifts for ARMAS, respectively, relative to the Van Allen Probes location. Panel B shows a schematic of the Van Allen Probes simultaneously observing plasmaspheric hiss in the equatorial magnetosphere while in magnetic conjunction with ARMAS instrument at aviation altitudes. Panel C shows the variation of the correlation coefficient for different MLT shifts (-3≤ΔMLT≤3) in the conjunction windows of ARMAS relative to the Van Allen Probes.

We used SHAP-assisted re-interpretation of the standard superposed epoch analysis to reveal that the resultant radiation belt fluxes following geomagnetic storms were dependent on the total, integrated AL from the pressure maximum, and the only difference between enhancement and loss events was indeed the integrated AL value [3].

Outside of our core research topics, we looked at lightning associated with pyro-cumulous clouds, non-resonant scattering, ionospheric gravity waves, equatorial plasma bubbles, and of course results from our previous VIPER rocket. The science continues to surprise and fascinate and we love to follow wherever it leads.

References:

[1] Kang, N, J. Bortnik, Q. Ma, S. Claudepierre (2023), Modeling the global distribution of chorus wave induced relativistic microburst spatial scale size, J. Geophys. Res. Space Phys., submitted.

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UNITED STATES

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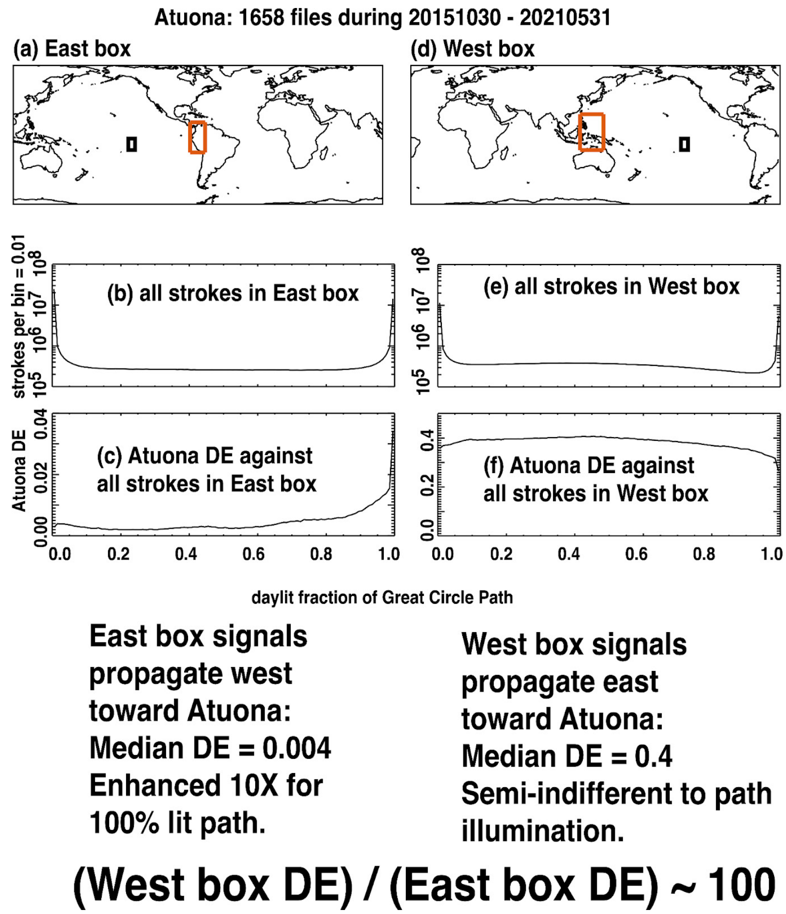
Our team has been using the World Wide Lightning Location Network (WWLLN) to test observed versus modeled VLF propagation in the Earth-ionosphere waveguide. WWLLN records and uploads the pulse rms amplitude within a 1.3 ms window for each station. During a special campaign, WWLLN also uploaded the recorded waveforms themselves. We have documented and quantified the low-magnetic-latitude asymmetry in the WWLLN detection performance for East-propagating versus West-propagating pulses.



Comparison of observed Atuona detection efficiency against strokes in two roughly equidistant, rectangular geographic boxes. (a) Showing the East box, over northwestern South America. (b) For all strokes in the East box, showing the distribution of the fraction of instantaneous path (to Atuona) that is daylit. This includes all strokes in the East box, not just those detected by Atuona. The horizontal resolution is 0.01. (c) Detection efficiency (DE) of Atuona against strokes in the East box, as a function of the instantaneous daylit fraction of the path. (d) Showing the West box. (e) For all strokes in the West box, showing the distribution of the fraction of instantaneous path (to Atuona) that is daylit. (f) Detection efficiency (DE) of Atuona against strokes in the West box, as a function of the instantaneous daylit fraction of the path. Note the order-of-magnitude difference in DE scales between the (c) East and (f) West boxes.

References:

[1] Jacobson, A. R., R. H. Holzworth, J. B. Brundell (2021), Using the World Wide Lightning Location Network (WWLLN) to study very low frequency transmission in the Earth-ionosphere waveguide: 1. Comparison with a full-wave model, Radio Science, 56, e2021RS007293. https://doi.org/10.1029/2021RS007293

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[3] WWLLN Team, AGU 2023 Fall meeting, SA43B-3072 poster: Using WWLLN recorded waveforms to test VLF propagation in the Earth-ionosphere waveguide.

VERSIM JOURNAL CLUB (INTERNATIONAL)

Rachel Black (rablack75@bas.ac.uk), British Antarctic Survey/University of Exeter, UK; and Miroslav Hanzelka (mirekhanzelka@gmail.com), GFZ-Potsdam, Germany

The VERSIM Journal Club (JC) brings together a collection of international students, early-career, and senior researchers in scientific conversations about various VERSIM-related topics.

Established in 2018, the purpose of the club is to encourage early career scientists to discuss recent findings within the field, or practice presenting their own work in front of a friendly, approachable audience. It also provides an opportunity for students and researchers from across the world to connect in between attending conferences, or if unable to attend conferences at all.

The Journal Club went through an 8-month break following January this year, with the regular monthly sessions beginning again in September. Although there were only four sessions that ran this year, particularly novel and engaging research was discussed, heavily focused upon the radiation belts.

Mirek Hanzelka (GFZ-Potsdam) hosted two discussions on recent papers; during the first, original work on non-resonant scattering of EMIC waves by An et al. was compared to older theories/methods, and the second involved reviewing a new explanation for the banded structure of chorus waves from results by Xin Tao.

Rachel Black (University of Exeter/BAS) presented a review of work explaining a machine learning-based radiation belt model by Ma et al. And finally, Tom Daggitt (University of Cambridge/BAS) presented work by Guo et al. on a simulation modelling the acceleration of ultra-relativistic electrons during a geomagnetic storm.

In our September meeting, we also discussed the format of Journal Club, and how best to promote the group to a wider audience. We hope to invite more senior scientists to speak in the new year, as this has been incredibly successful in the past.

Our main message is that anyone can join Journal Club! Volunteers to speak, be that about their own work, or any research they find interesting, are particularly encouraged. As well as a mailing list, we also have a Slack channel, where informal discussions can be held, and speakers for the next meetings are advertised.

Please contact us at versim.jc@gmail.com if you would like to join in any capacity – to come along, to speak, or simply to be added to the mailing list!

More info can be found at:
http://versim.matfyz.cz/index_jc.html

VERSIM NEWSLETTER
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December 2023