VERSIM NEWSLETTER

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

DEC. 2024

Hello solar maximum!

Dear VERSIM colleagues and friends,

As we approach the end of 2024 and the solar activity maximum, it is time for the annual VERSIM newsletter. This is a wonderful opportunity to keep our community informed on our progress and developments worldwide. Spoiler alert: we are thrilled to report that our community lives long and prospers!

In 2024, the 11th VERSIM Workshop took place. Organized in Breckenridge, Colorado, it was the first-ever VERSIM meeting held in the USA. We take this opportunity to extend our heartfelt thanks to ***Robert Marshall***, ***Allison Jaynes***, ***Mark Golkowski***, and ***Poorya Hosseini*** for their outstanding organization and efforts in creating an amazing experience. We had fun! A more detailed meeting report, along with some pictures, is included in the newsletter. During this meeting, ***Paraksh Vankawala***, a graduate student at the University of Colorado Boulder was selected as the VERSIM nomination for the IAGA Early Career Presentation Award. Congratulations Paraksh!

For the upcoming 12th VERSIM Workshop in 2026, two candidate venues were proposed: Sopron, Hungary (by János Lichtenberger) and Lonavala, India (by Sneha Gokani). To ensure a democratic decision, we organized an online poll open to all the members of the community. An impressive 47 members cast their votes.
Based on the results, we are happy to announce that the VERSIM 2026 Workshop will be held in ***Sopron, Hungary***. The exact dates of the workshop are yet to be decided – stay tuned!

OUR CHAIRS, FRANTIŠEK AND CLAUDIA, POSING FOR THE CAMERA DURING A 'BREATHTAKING' HIKE.

NEWS BITES

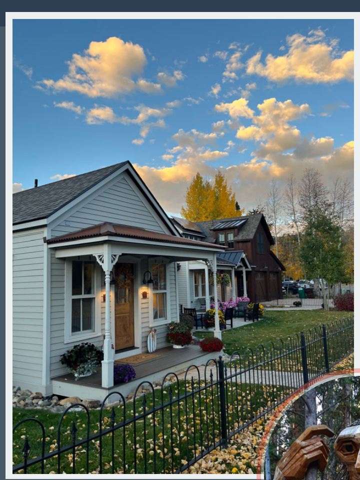
Check out our **special spread** on the 11th VERSIM workshop held at Breckenridge, Colorado.

The VERSIM community has decided our next workshop will be in **Sopron, Hungary**.
See you there in 2026!

http://versim.matfyz.cz/

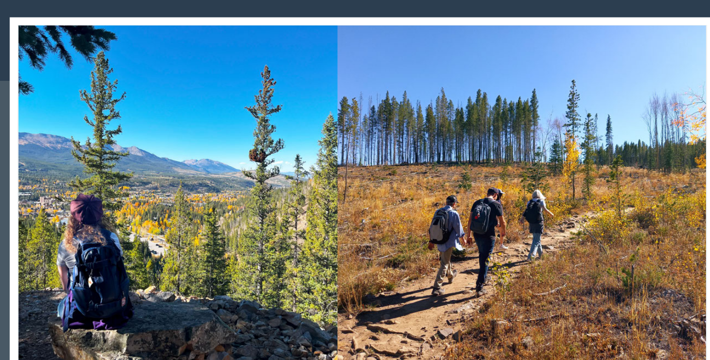
VERSIM 2024

The 11th VERSIM workshop took place in Breckenridge, Colorado, a charming mountain town in the heart of the Rockies, celebrated for its stunning alpine scenery and rich history. Once a bustling 19th-century mining town, its heritage shines through in the beautifully preserved Victorian buildings that now host shops, restaurants, and galleries.



Breckenridge is a heaven for outdoor enthusiasts, and many VERSIM participants made the most of their free time by mountain biking, hiking, exploring the town, or soaking up a late-season tan. These activities were powered by hearty breakfasts and various multicultural lunches provided by the organizers. Lunch was also when most of us took the opportunity to eat outdoors, a refreshing change from the indoor rooms, letting us soak up the blue skies and the absence of clouds. Some of us came prepared with hats, sunglasses and sunscreen, while others leaned more toward the lobster category. Between sessions, tea and coffee breaks gave participants a chance to recharge and stay hydrated—a crucial strategy for keeping mountain sickness at bay.

In the evenings, the clear skies provided the perfect backdrop for stargazing while sharing beers, mocktails or ice cream with colleagues. For the early risers, the local foxes made excellent running companions at dawn. At midday, squirrels and chipmunks were busy



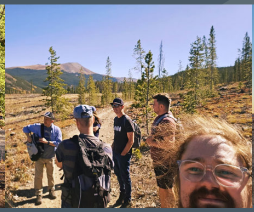


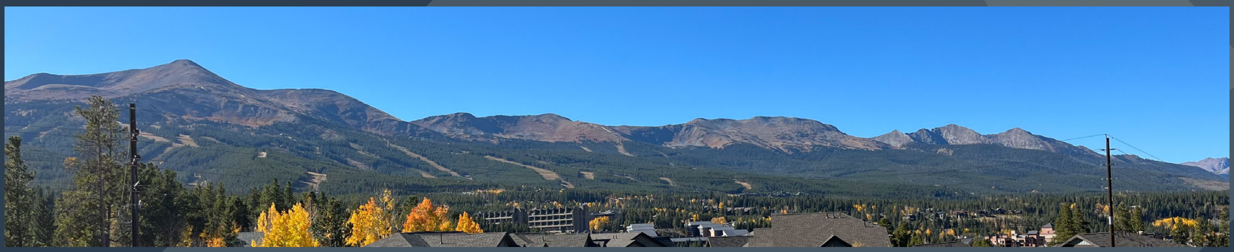
scurrying about trying to avoid becoming the next social media stars. The real prize, though, was the elusive moose. While plenty of us tried our hand at "moose hunting," only a lucky few managed to spot one.

As usual, our workshop had a truly international flavor, with attendees from 12 countries across 4 continents: 43 participants from North America, 13 from Europe, 6 from Asia, and 1 from New Zealand. This provided a vibrant platform for cross-cultural dialogue and collaboration. With 56 presentations on topics ranging from simulations and wave-particle interactions to active experiments, space mission results, wave propagation, and wave-induced particle precipitation, the program showcased the depth and breadth of research in the field.

We once again thank and congratulate the LOC for a wonderful workshop, and are looking forward to our next meeting in Hungary!

From left to right: *Allison Jaynes, Assoc. Prof. at the University of Iowa; Robert 'Bob' Marshall, Assoc. Prof. at the University of Colorado; Mark Golkowski, Prof. at the University of Colorado. MIA: Poorya Hosseini*


Photography contributors :
Claudia Martinez-Calderon, "The" Rachel Black, Mirek Hanzelka, Milla Kalliokoski, Aaron Hendry, Ivana Kolmasova, and the LOC

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).

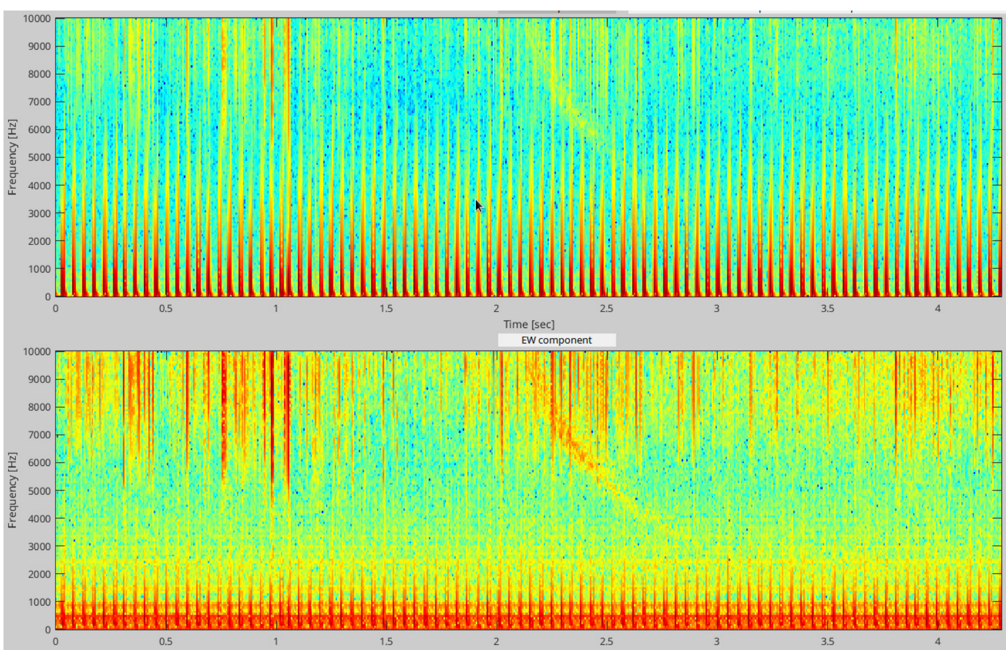
Our two VLF antennas are located in Humain, Belgium (Lat. ~ 50.11°N, Long. ~ 5.15°E) and at the Belgian Antarctic station Princess Elisabeth (Lat. ~ 71.57°S, Long. ~ 23.20°E). The antennas detect whistlers that are used to determine electron densities in the equatorial plasmasphere.

Our data from PEA are still polluted by lots of noise, and the number of whistlers detected is very low, less than 500 in 2 years !! And even if a whistler is detected, the background noise makes it difficult to derive the electron density (see Figure).

Some tests are currently done at Princess Elisabeth station to have cleaner signal. If successful, the antenna might be moved to this new location (possibly in a container close to the airstrip of the station).

In 2024, we also rewrote our web site with a more modern template:

http://awda.aeronomie.be



Whistler detected at Princess Elisabeth station in Antarctica on 16 July 2024 with lots of background noise making it difficult to analyze.

CZECHIA

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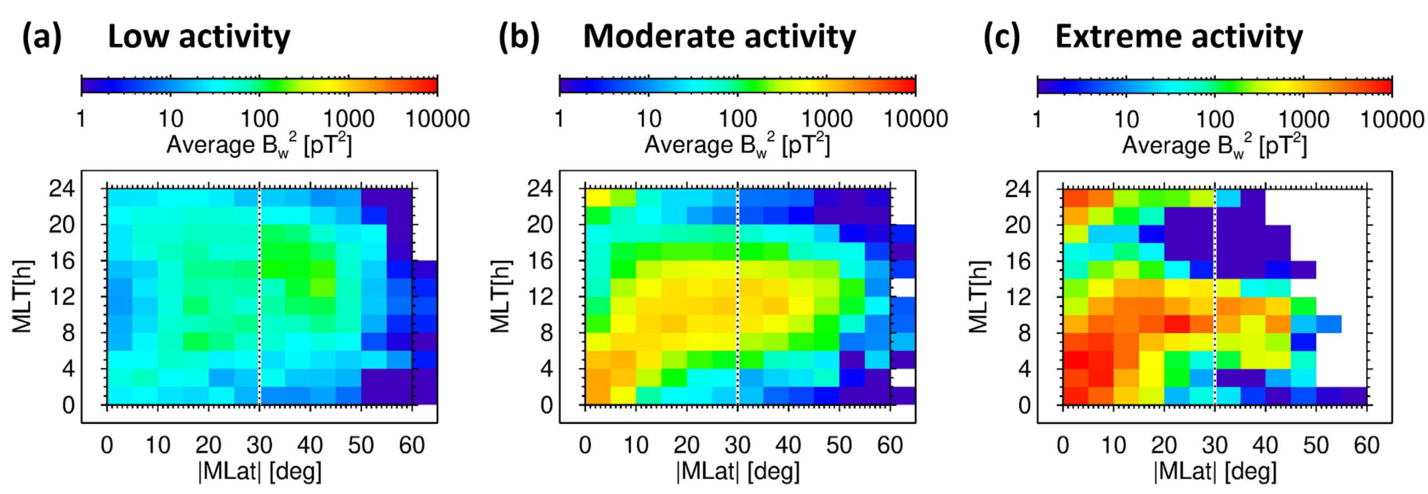
Our group at the Department of Space Physics, Institute of Atmospheric Physics of the Czech Academy of Sciences and at the Faculty of Mathematics and Physics of the Charles University continued to investigate electromagnetic waves at very low frequencies using spacecraft and ground-based measurements.
Examples of our results obtained in 2024 are given below.

We employ extensive databases of spacecraft observations to determine how lower-band whistler mode chorus waves behave under extreme geomagnetic conditions **[1]**. Chorus occurring close to the geomagnetic equator is known for causing rapid increases of ultra-relativistic electron fluxes under disturbed geomagnetic conditions. However, chorus can also propagate to high latitudes and here its presence may lead to losses of these electrons. We showed that under extreme geomagnetic conditions, amplitudes of chorus waves at high latitudes grow much slower than chorus amplitudes close to the equator. They therefore have a net effect of accelerating ultra-relativistic electrons, which results in an increase of fluxes at multi-MeV energies by several orders of magnitude.

We reported observations of a large number of whistler echo trains at a high-latitude station in Kannuslehto, Finland **[2]**. Our findings demonstrated that:

i) causative lightning sferics arrived at the duct entry point from three distinct winter thunderstorms

ii) the duct persisted for nearly 8 hours



External driving of chorus. Color scale shows the long-term average squared amplitudes of chorus magnetic field fluctuations in pT2. A joint data set of two Van Allen Probes and four Cluster spacecraft is analyzed in 12 13 discrete bins in magnetic local time and absolute value of magnetic latitude, where cumulative results for latitudes above 60o are shown on the outer edge of the plot. (A) Data from periods of low geomagnetic activity: see Supplementary Method 4; (B) the same for moderate geomagnetic activity; (C) the same for extreme cases of the highest geomagnetic activity. A vertical dotted line shows an approximate boundary between the equatorial region, where chorus strongly responds to geomagnetic activity, and the high-latitude region, where the response is weak.

iii) sferics were capable of triggering echo trains even after propagating 4000 km in the Earth-ionosphere waveguide.

We systematically investigated the effects of bouncing on the properties of quasiperiodic emissions [3] and magnetospheric line radiation [4].

Through the analysis of simultaneous electromagnetic wave observations by the low-altitude DEMETER spacecraft and ground-based receivers, we showed that, in contrast to spacecraft measurements, ground wave intensities are only sporadically enhanced during geomagnetically active periods [5, 6].

Using data from the same spacecraft, we explored temporal variations in lightning-induced electron precipitation [7].

A theoretical study described sub-MeV electron precipitation driven by EMIC waves [8].

References:

[1] Santolík, O., Shprits, Y., Kolmašová, I., Wang, D., Taubenschuss, U., Turčičová, M., & Hanzelka, M. (2024). Strong effects of chorus waves on radiation belts expected for future magnetic superstorms. AGU Advances, 5, e2024AV001234. https://doi.org/10.1029/2024AV001234.

[2] Kolmašová, I., Santolík, O. & Manninen, J. (2024). Whistler echo trains triggered by energetic winter lightning. Nat Commun 15, 7166. https://doi.org/10.1038/s41467-024-51684-0.

[3] Němec, F., Santolík, O., Hospodarsky, G. B., & Kurth, W. S. (2024). Quasiperiodic emissions: Fine structure corresponding to a bouncing wave. Geophysical Research Letters, 51, e2023GL106459. https://doi.org/10.1029/2023GL106459.

[4] Němec, F., Santolík, O., Hospodarsky, G. B., & Kurth, W. S. (2024). Magnetospheric line radiation: Temporal modulation corresponding to a bouncing wave. Geophysical Research Letters, 51, e2024GL111477. https://doi.org/10.1029/2024GL111477.

[5] Němec, F., Drastichová, K., Manninen, J., Martinez -Calderon, C., Shiokawa, K., & Connors, M. (2024). Comparison of very low frequency wave intensities measured by a low-altitude spacecraft and on the ground. Journal of Geophysical Research: Space Physics, 129, e2024JA032655. https://doi.org/10.1029/2024JA032655.

[6] Drastichová, K., Němec, F., & Manninen, J. (2024). Whistler-mode waves observed by the DEMETER spacecraft and the Kannuslehto station: Spatial extent and propagation to the ground. Journal of Geophysical Research: Space Physics, 129, e2024JA032802. https://doi.org/10.1029/2024JA032802.

[7] Linzmayer, V., Němec, F., Santolík, O., & Kolmašová, I. (2024). Lightning-induced energetic electron precipitation observed in long-term DEMETER spacecraft measurements. Journal of Geophysical Research: Space Physics, 129, e2024JA032713. https://doi.org/10.1029/2024JA032713.

[8] Hanzelka, M., Li, W., Qin, M., Capannolo, L., Shen, X., Ma, Q., et al. (2024). Sub-MeV electron precipitation driven by EMIC waves through nonlinear fractional resonances. Geophysical Research Letters, 51, e2023GL107355. https://doi.org/10.1029/2023GL107355.

FINLAND

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The Finnish ELF-VLF campaign started already on 7 September 2021, and it was successfully continued until 28 May 2024 at 1516:16 UT. That was the moment when a lightning discharge hit one of the antenna poles at KAN. Unfortunately, it destroyed all the electronics and computers.

Since the summer, our technicians have been evaluating damages and simultaneously preparing copies of electronics layouts to rebuild necessary preamplifiers and some other electronics cards. It was not a straight forward task, because after the 'latest' drawings, Prof. Tauno Turunen made some small additions and changes to them. Those changes must be 'read' directly from broken electronics cards.

The current idea is that KAN receiver could be restarted some time in summer 2025. Fortunately, many parts can nowadays be bought from shop. It was not the situation 32 years ago, when the main parts of KAN receiver were made.

One positive thing is that in August 2024 we were able to install a second Japanese PWING VLF receiver at Angeli (ANG) in Inari municipality. ANG is located about 145 km north of KAN, and its L value is 6.2 (KAN's L value is 5.6 and OUJ's L value is 4.4). Due to some IT problems at ISEE ANG data does not exist in cdf format, yet. OUJ cdfs are ready up to 12 Dec 2024.

Since the agreement about Istok data has ended already in 2021, no VLF data above L=6.0 was available. That's why a new ANG VLF receiver is very important to study and understand VLF bursty-patches.

The quick-look plots (24-h, 1-h, and 1-min) are available at **https://www.sgo.fi/pub_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 data is available on request if someone needs it.

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

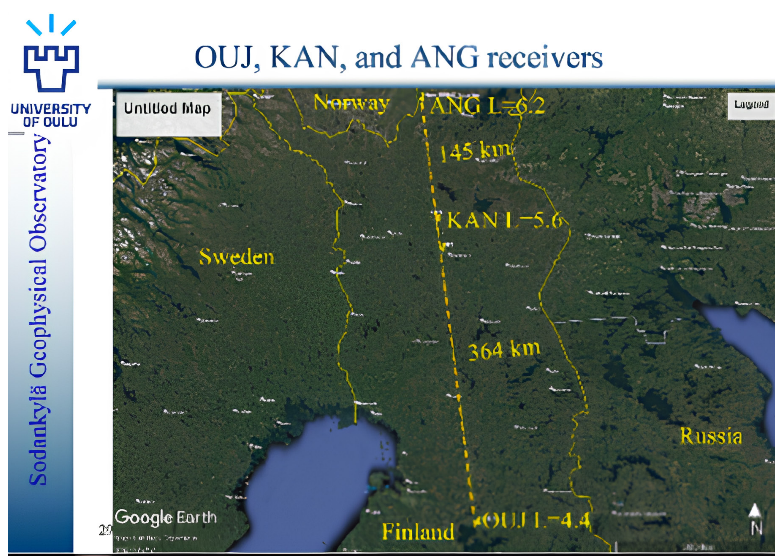

Figure 1. A map showing locations of OUJ, KAN, and ANG receivers. They are surprisingly well along a straight line.

FINLAND

Figure 1 shows a map presenting the locations of OUJ, KAN, and ANG stations in Finland. The effect on event finding when using sferics filter for OUJ data is shown in Figure 2. This is the first time when the sferics filter has been used for PWING data. Thanks to Dr. David Pisa form IAP, Prague, Czechia the sferics filter works now with PWING data.

In October-November Dr. J. Manninen visited one month at ISEE in Nagoya University. The trip was paid by the grant he got from ISEE. During this visit, the main topic was to search simultaneous events from KAN and PWING VLF data, and continue the research started during earlier visit in autumn 2023. More nice events have been found.

The number of peer-reviewed papers during this year was three.

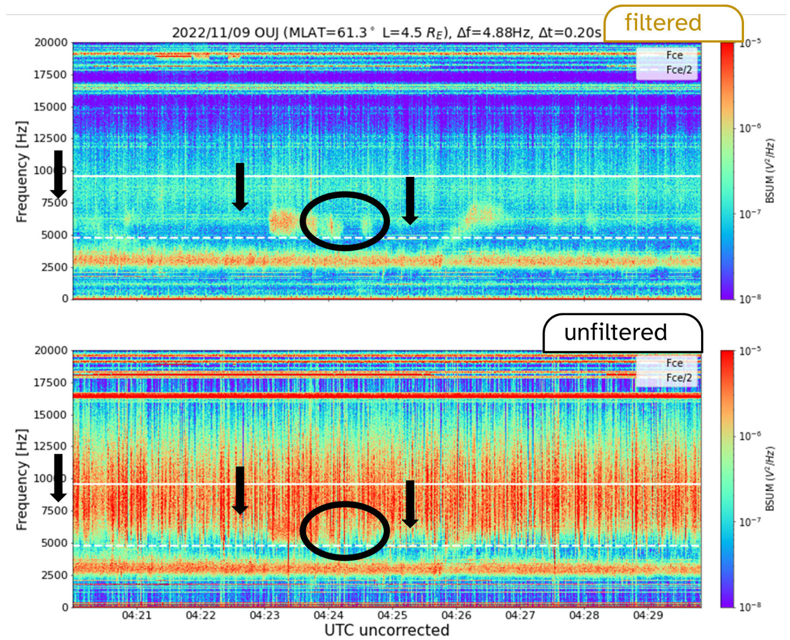

Figure 2. First example showing the effect of the sferics filter applied to OUJ data. It is obvious that marked events could not be detected easily without filtering.

References:

[1] Kolmasova, I., O. Santolik, J. Manninen (2024). Whistler echo trains triggered by energetic winter lightning. Nature Communications, 15:7166, https://doi.org/10.1038/s41467-024-51684-0

[2] Nemec, F., K. Drastichova, J. Manninen, C. Martinez-Calderon, K. Shiokawa, and M. Connors (2024). Comparison of very low frequency wave intensities measured by a low-altitude spacecraft and on the ground. Journal of Geophysical Research: Space Physics, 129, 7, e2024JA032655, https://doi.org/10.1029/2024JA032655

[3] Drastichová, K., Němec, F., & Manninen, J. (2024). Whistler-mode waves observed by the DEMETER spacecraft and the Kannuslehto station: Spatial extent and propagation to the ground. Journal of Geophysical Research: Space Physics, 129, e2024JA032802, https://doi.org/10.1029/2024JA032802

HUNGARY

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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 plasmaspheric products developed in PLASMA European Space Agency project have been published in the ESA Space Weather Portal:

https://swe.ssa.esa.int/elte-plasma-federated

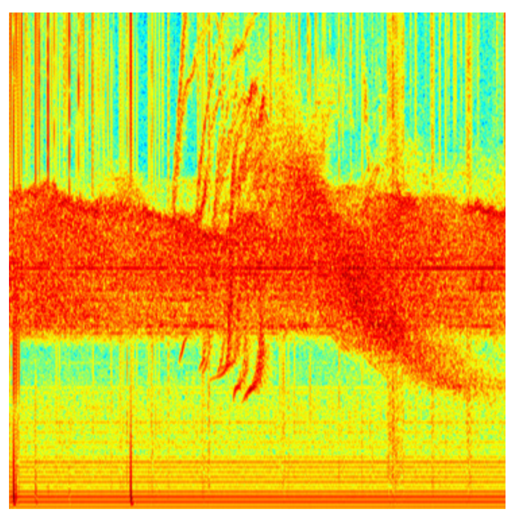
The products are updated in every 15 minutes.

In the RB-FAN2 (Specification of radiation environment of the Earth) ESA project, the 3D version of PLASMA products are used.

In the UJPOPRAD (Measuring the efficacy of a satellite VLF transmitter with magnetic loop/solenoid antenna in a plasma chamber) ESA project, the original plan to use the modified plasma chamber at West Virginia University, failed due to lack of local support in the USA.
Together with ESTEC, ESA, we have decided to build a new plasma chamber for the planned tests in ESTEC. It is in the design phase at the moment.

In FARBES (Forecast of Actionable Radiation Belt Scenarios, https://farbes.eu), we have developed and validated a VLF wave propagation model from the equatorial region to a ground receiver. Using this model, we can estimate the VLF wave power at the equator from ground based (AWDANet) chorus measurements.

We have found experimental evidences in ground based VLF data (AWDANet) for a hiss generation mechanism, originally suggested by R. Dowden in 1971. The mechanism suggests that the plasmaspheric hisses can be generated by multiple hop whistlers (whistler echoes). Our evidences complement this theory with triggered emissions, i.e. hisses can be generated by a combination of whistler echos and triggered emissions. A snapshot of the process is show in the figure below.



A snapshot of the hiss generation procedure by whistler echoes and triggered emissions. The spectrogram is generated from a 4 sec long VLF signal recorded at Dunedin, New Zealand at 03:22:50UT on 13 May 2015. The frequency axis spans from 0 to 10kHz. The event lasted for ~30 minutes from 03:00 to 03:30UT.

JAPAN

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In 2024, we have continued to expand the PWING network with an additional receiver at Angeli, Inari, Finland (ANG, L=6.2, MLAT=69.6ºN). This station is located about 150 km north of the existing Kannuslehto site (KAN, L=5.5, MLAT=64.4ºN), which itself is around 370 km north of Oulujärvi (OUJ, L=4.5, MLAT=61.3ºN). The idea was to create the first latitudinal chain of continuously recording VLF receivers. Unfortunately, that plan was cut short when KAN was destroyed by a lightning strike on May 28th 2024 (see Finland report).

Although KAN is gone, it's definitely not forgotten! We are continuing to study latitudinal wave propagation using data collecte from OUJ & KAN while they were operating at the same time and new data from OUJ & ANG since its installation this summer.

Analyzing 2022–2023 data from OUJ and KAN has already given us some early insights into latitudinal wave propagation and the properties of ionospheric exit points for simultaneously observed VLF waves. So far, occurrence rates show that 20–30% of VLF waves detected at KAN and OUJ share the same source region. In most cases, the ionospheric exit point of simultaneously detected waves is aligned in the East-West direction. Interestingly, we also found that 'unusual' high-frequency VLF bursty-patches are detected at OUJ about ten times less often than at KAN, despite OUJ being at lower L-shells, where the source for these waves would typically be expected. Meanwhile, early results from ANG indicate that bursty patches do not seem to be detected at higher latitudes. We are currently working on a long-term statistical analysis, ray tracing, and the effect of energetic electron precipitation at high latitudes to dig deeper into these findings.

In the meantime, we are doing our best to find the time to publish these preliminary results—stay tuned!

This year Claudia Martinez-Calderon visited the Institute of Atmospheric Physics and Charles University in Prague, Czechia twice! Of particular interest both times, was the preparation, testing, and finalization of a PLHR + sferics filter that will be implemented in all PWING stations (Thanks to D. Pisa). This was followed by an invited colloquium at the Institute of The Leibniz Institute of Atmospheric Physics, in Kühlungsborn, Germany (Thanks to J. Chau). Finally, Claudia's European tour ended in Finland, with a visit of the Sodankylä Geophysical Observatory and the installation of the ANG receiver (Thanks to Jyrki and special thanks to Andreas, Timo, Toppi, and Kristyna).

Claudia also participated in the 11th VERSIM workshop in Breckenridge, Colorado, USA, presenting our latest results.

We also had visitors at ISEE, as Jyrki Manninen spent a month with us this past Fall. The main topic of this research visit was the use of more PWING stations to investigate the properties of bursty-patches.
We also discussed our possibilities for replacing the VLF receiver at KAN.

We would like to remind the ELF/VLF community that while the PWING project has 'officially' ended, its successor, PBASE allows us to carry on the study of waves, particles, and related phenomena.

- **PBASE Website**
https://www.isee.nagoya-u.ac.jp/dimr/PBASE/en/

- **PWING VLF data**
  - ➜ Quicklook plots
https://stdb2.isee.nagoya-u.ac.jp/vlf/
  - ➜ CDF files
https://ergsc.isee.nagoya-u.ac.jp/data/ergsc/ground/vlf/

Jyrki Mannninen, Claudia Martinez-Calderon, and Kristýna Drastichová at the Bear's Nest stones in Inari after the VLF receiver installation .

Angeli VLF receiver installled in August 2024 in Inari, Northern Finland.

NEW ZEALAND

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I assume it is something about the passage of age, but 2024 has disappeared into a blur with too much activity in it, and the feeling that I can't remember the details of a lot of what happened! Otago has had another fairly successful year, with strong research activity from all members (including the mostly retired!).

This year we hosted Mark Clilverd (BAS) for his normal annual visit, but we also had Allison Jaynes (U. Iowa) in Dunedin for almost 5 months at the start of the year! Dan Welling and Pauline Dredger (both U. Michigan) spent time with us, as did Shannon Killey (U. Northumbria). It feels like we have been rather lucky in terms of people coming to see us.

We also headed out to the world. Daniel Mac Manus spent a few months working in Edinburgh at the British Geological Survey (BGS), and will be heading to the AGU Fall Meeting in mid-late December. Mikhail went to BGS in Scotland and GFZ in Germany, and attended the 26th EM Induction Workshop in Japan.

The group also welcomed Johnny Malone-Leigh from Ireland to take up a PostDoc role looking after our MANA variometer network. Johnny went with Craig to the Workshop on Geomagnetically Induced Currents in Maryland (USA), and will head to Antarctica with James Brundell early next year (Expedition 16)!

Craig visited U. Michigan, BAS, U. Northumbria (and some NZ Universities). He also attended many domestic and international meetings, gave public talks, and was on the TV and radio rather a lot too.

One of the major things this year was the 'Gannon' G5 geomagnetic disturbance from 10-12 May 2024. Last year I reported on an operational plan we developed with Transpower NZ control room staff to help them respond to a very large geomagnetic disturbance. The plan involved removing redundant power lines from the NZ electrical network to decrease GIC entering transformers. Once the May 2024 storm disturbance levels reached the G5 threshold, the GIC mitigation strategy was enacted by the Transpower control room staff following the plan protocols.

Throughout the storm, regular communication continued between our space weather research team and the electricity industry, particularly the Transpower control room leadership. There was no disruption to New Zealand's electrical supply from the Gannon storm. But, because the magnetic field changes during the Gannon storm were so significant, it has provided a wealth of new observations and chances to improve our understanding of the potential impact of extreme space weather on an electrical network - and provided the first test of our GIC mitigation plan. As a reminder, that plan was the final output of Daniel Mac Manus' PhD, completed early last year!

NEW ZEALAND

For the last few years 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] Further confirmation on the energy range of electrons precipitated by EMIC waves peaking at a few hundred keV, and not starting in the MeV range as used to be expected. Mark Clilverd recently published a study we have had cooking for quite a while, looking very carefully at electron precipitation caused by IPDP, observed by the very high energy resolution loss cone measurements by DEMETER IDP, and taking into account proton contamination impacts (which are very important for EMIC precipitation). The Otago group has been reporting this for many years using POES and DEMETER observations, and it has since been confirmed by US researchers using FIREBIRD II and ELFIN.

[2] Drilling more deeply into the use of even order harmonic distortion to investigate space weather/GIC impacts on main grid transformers. MSc graduate Malcolm Crack found that the story Craig has been telling for the last few years is too simplistic, and we need to take into account that the harmonics propagate from stressed transformers down the electrical transmission lines. However, viewed with care the even order harmonic distortion measurements in the grid can be used to confirm the location of GIC hotspots where transformers may be at risk!

This year Craig failed to organise a group photo, and hence we don't have one. Instead I am including a picture taken during the 11th VERSIM Workshop in Breckenridge (Colorado, USA). I attended this, and grabbed this photo with two former members of the Otago University Space Physics Group: Aaron Hendry (now at the British Antarctic Survey), and Harriet George (now at CU Boulder). Image taken on 2 October 2024.

References:

[1] Clilverd, M. A., C. J. Rodger, A. T. Hendry, A. R. Lozinski, J-A. Sauvaud, M. R. Lessard, and T. Raita, Improved Energy Resolution Measurements of Electron Precipitation Observed during an IPDP-type EMIC event, J. Geophys. Res., 129, doi:10.1029/2024JA032785, 2024.

[2] Crack, M., C. J. Rodger, M. A. Clilverd, D. H. Mac Manus, I. Martin, M. Dalzel, S. P. Subritzky, N. R. Watson, and T. Petersen, Even-Order Harmonic Distortion Observations during Multiple Geomagnetic Disturbances: Investigation from New Zealand, Space Weather, 22, e2024SW003879, doi:10.1029/2024SW003879, 2024.

RUSSIA

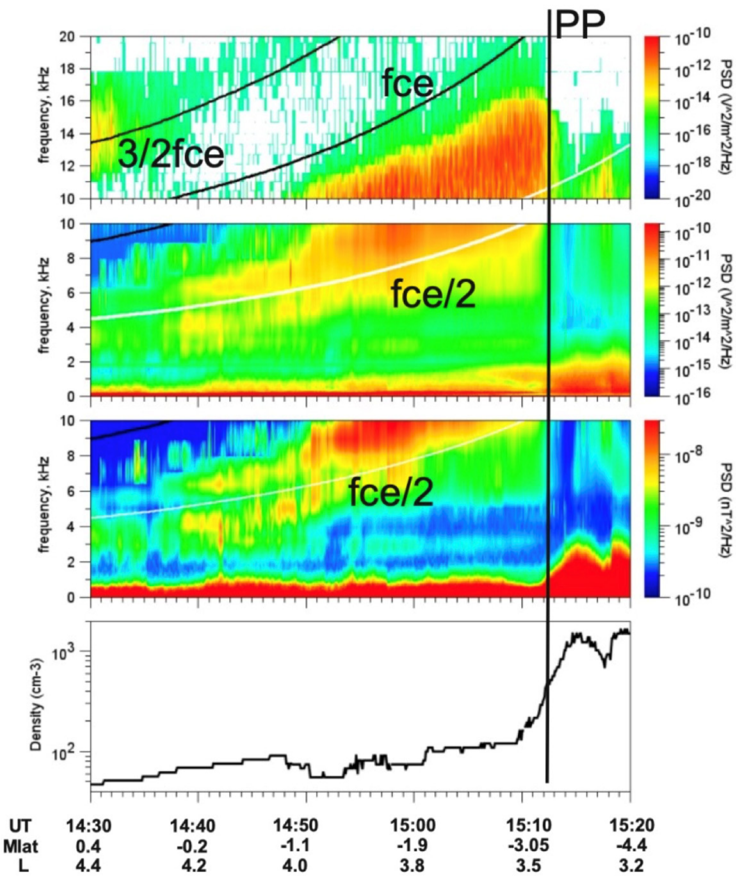
David Shklyar (david@iki.rssi.ru), Elena E. Titova, and Andris A. Lubchich, Space Research Institute of RAS, Moscow, Russia

Our research activity in 2024 was directed, among other topics, to the investigation of two-band whistler-mode waves in the equatorial region of the Earth's magnetosphere.

This is a continuation of our investigations of similar emissions observed outside the plasmapause performed in 2022-2023. In all these studies we used the wave and particle data from Van Allen Probes. An example of wave and cold plasma density used in the study is shown in the Figure.

The peculiarity of the observed spectrum is the presence of two spectral maxima below and above half the electron gyrofrequency. Such a peculiarity, typical of the spectra of chorus emissions, was observed for noise emissions in the case under discussion. Simultaneously with the observation of VLF emissions, the satellite also measured differential fluxes of energetic electrons, the magnitude of the magnetic field, and the density of cold plasma.

An explanation of the observed spectrum of noise emissions is proposed based on the evaluation of the linear growth rate of whistler waves calculated from the energetic electron distribution function inferred from their differential fluxes. A comparison of the observed spectra and the calculated wave growth rate shows their good agreement.



Spectrograms of two-band VLF emissions (the first three panels) and the cold plasma density along Van Allen Probe B path on 30 November 2015.

References:

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RUSSIA

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We obtained new results of a study on two traditional problems connected with the propagation and excitation of ELF and VLF waves in the magnetosphere. The work we have done is characterized by the following abstracts.

[1] We considered the problem of the effect of small plasma density variations on the propagation and reflection of ELF electromagnetic wave incident from above on the morning ionosphere. Modifications of the electromagnetic wave field near the Earth's surface and the coefficient of wave energy reflection from the ionosphere caused by infrasonic wave are studied. The greatest modifications of the field on the Earth's surface and reflection coefficient are related to the density perturbations at altitudes of strong electromagnetic wave attenuation (80–110 km). Reflection of electromagnetic waves is especially sensitive to the plasma density perturbations if the value of the horizontal refractive index is close to a unit. In this case, the modulation percentage of reflection coefficient can exceed the modulation percentage of density in the infrasonic wave by an order of magnitude.

[2] We focused on studying the quantitative characteristics of the excitation mechanism of chorus emissions. The study is based on the processing of information accumulated by the Van Allen Probe spacecraft through the analysis of high-resolution data. We have chosen two typical examples of chorus emissions with spectral forms predominantly in the upper-frequency band. We have developed and implemented a calculation algorithm that enables us to represent the results of wave field measurements in a high-resolution data channel in the form of a rectangular event matrix, (each row of corresponding to a cycle of the wave process). In the event matrix, we select the rows corresponding to fragments of chorus that best characterize the natural source of emissions. The results obtained in this way from observational data are in a good agreement with relevant theory of chorus emissions excitation by amplifying noise electromagnetic pulses in a duct with a depleted density of cold plasma.

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RUSSIA

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The focus of our studies as a joint group from two institutes (PGI and IAP RAS) has been on wave-particle interactions in the magnetosphere, as previously. Several papers have been published on this topic. I will present only two of them below.

Jointly with colleagues from UCLA, we have studied, for the first time, two types of latitude (L-shell) dependence of the energy of relativistic electrons precipitating due to their interaction with electromagnetic ion-cyclotron (EMIC) waves **[1]**. EMIC-driven precipitation bursts can be detected by low-altitude spacecraft, and analysis of the fine structure of such bursts may reveal unique information about the near-equatorial EMIC source region. Using ELFIN cubesat data, we have identified 84 EMIC-driven precipitation events exhibiting clear dependence of energy E on the L-shell. In 65% of cases, we observe $dE/dL < 0$. We interpreted this dependence as being related to the typical inward radial gradient of cold plasma density and equatorial magnetic field. Precipitation with $dE/dL > 0$ is interpreted (consistent with observations) as being related to an outward radial gradient of the equatorial magnetic field, likely produced by energetic ions freshly injected into the ring current (~35% of the statistics). We reproduced the observed energy dispersion of EMIC-driven electron precipitation in simulations.

I would like also to draw your attention to a laboratory modeling paper **[2]**. In this study, discrete signals with positive frequency drift have been detected in a laboratory setup including a wide-aperture electron beam injected in a magnetized plasma at the large-scale Krot device. Such experiments are used for better understanding, by means of limited modeling, the interaction between waves and particles in the near-Earth plasma. The spectrum of detected electromagnetic radiation includes whistler noise, which is presumably due to the current instability, and discrete (narrowband) signals near harmonics of the electron cyclotron and plasma frequencies. We show that narrowband signals with a positive frequency drift that have been observed upon the injection of the electron beam are caused by nonstationary variations of the plasma density due to an additional ionization of a neutral gas by accelerated electrons. This study demonstrates the importance of taking into account some effects specific to laboratory plasma conditions when interpreting various forms of the wave dynamic spectrum in laboratory experiments aimed at simulating processes in the Earth's ionosphere and magnetosphere.

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SERBIA

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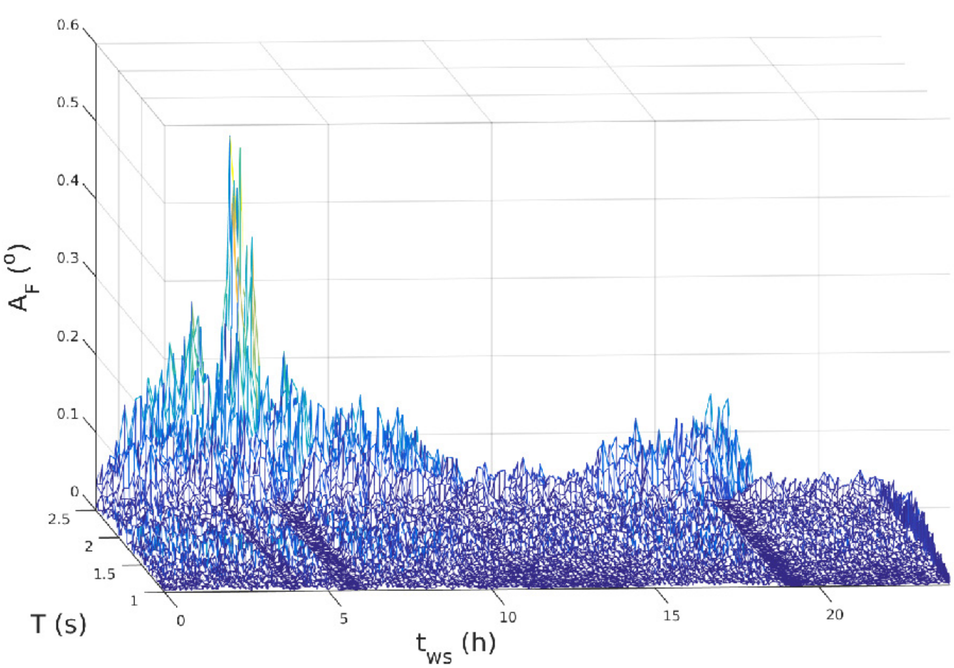
The activities of our group were focused on scientific research, organization of conferences, the participation in international meetings, and continuation of cooperation within the European network of VLF/LF receivers INFREP.

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 examination of changes that are considered potential precursors of earthquakes.
A pilot research of three earthquake precursors manifested in reduction of the amplitude and phase noise, wave excitations with periods below 1.5 s, and their attenuations at small wave periods for four cases is completed in a study presented in [1]. This study provides parameters of VLF signals that should be analysed in future statistical analyses that should examine their connections with characteristics of seismic activity.

Analysis of the excitations and attenuations in the ICV signal amplitude at small wave periods during intense seismic activity indicated the existence of relevant changes compared to calm conditions, but also differences compared to changes starting before the earthquake when intense seismic activity was not present [2].

In addition, the previously implemented machine learning classification methods on VLF data for automatic, data-driven anomaly detection were expanded through the utilization of a low-code machine learning library [3].



Dependencies of the Fourier amplitude AF on the wave period T and the start time tws of the window time intervals during during intense seismic activity (29 October 2016).

SERBIA

Our two bilateral projects with colleagues from Austria and Slovakia began in 2024.

This year, the project aimed at developing the system of the VLF/LF Receiver and Software for detection of VLF/LF SIGnal NoisE Reductions as EarthQuake Precursors (RS-SIGNER -EQP system) was implemented. This system consists of a new VLF/LF receiver (Receiver for STudy of Electromagnetic signal Perturbations - STEP receiver) and Software for detection of VLF/LF SIGnal NoisE Reductions as EarthQuake Precursors (SIGNER-EQP software).

References:

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SLOVENIA

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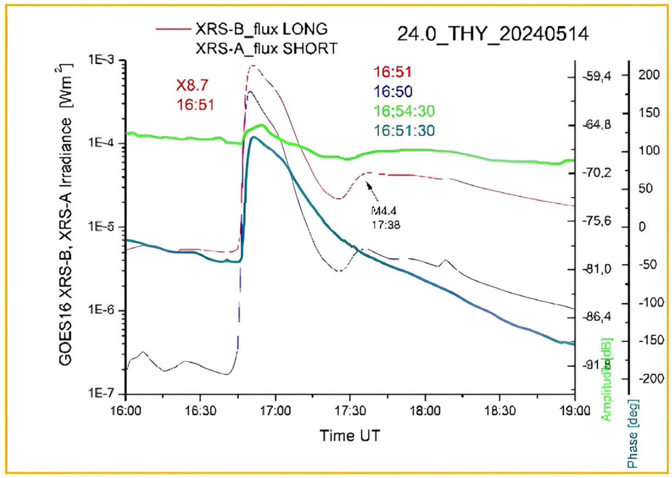
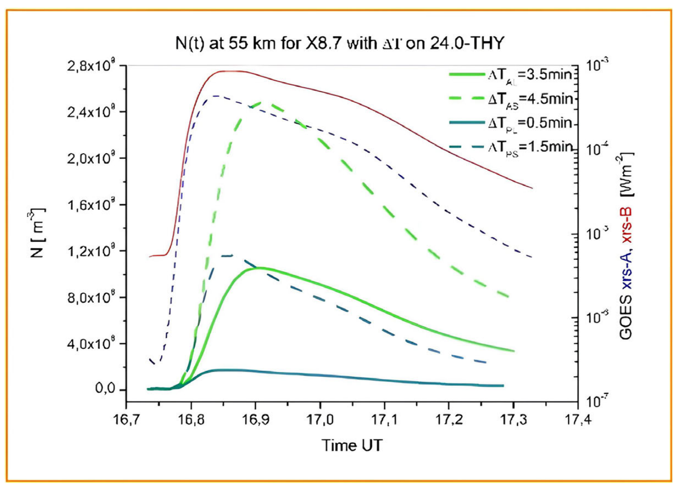
The continuous work on VLF detection of solar flares turned to be well suited for the year 2024, exceptionally rich in super strong solar storms and major X-class flares, the latter reaching 49 in number, up to December 15th 2024. Especially intense and spectacular was the sequence of X-class May 2024 flares (20 in number).

In collaboration with the Space Research Group of the Eötvös University, Budapest, we analysed the major flares of May 14th 2024, the X1.2 and X8.7 in particular, and their impact on the ionospheric D-region.

The GOES-16 XRS-A and XRS-B flare irradiance has been related to the disturbed amplitude and phase of VLF signal on several midlatitude VLF paths. To accomplish accurate ionospheric modelling, we have widened the research so as to analyse the time lag of maximal VLF disturbance behind the flare irradiance maximum, considering both the amplitude (ΔT_A) and phase (ΔT_P) time delays on equal terms. By applying the N(t,h) model we have shown that both ΔT_A and ΔT_P can be used in estimating the flare induced electron density enhancements in the D-region. We have also established that negative time delay with respect to irradiance in the soft X rays (0.1-0.8 nm), standard in flare classification, is an indication of the presence of some harder radiation other than the soft X-rays driving the ionization in the initial stage of the flare, and most efficiently at the lowest heights. Thus, negative time delay can give insight into the particular flare irradiance spectral composition.



XRS-A and XRS-B irradiance; Amplitude and Phase for the 20240514 X8.7 flare on the NAA/24.0 kHz –Tihany (46.9N, 17.9E) path



XRS-A and XRS-B irradiance and N(t) for the X8.7 flare according to the respective ΔT_A and ΔT_P

References:

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UKRAINE

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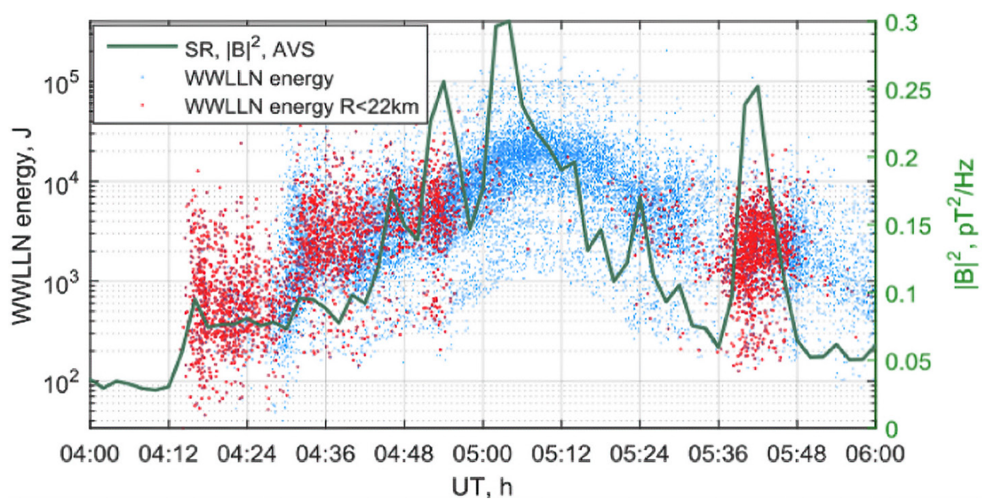
Our group continued modeling the Schumann resonance with an account for the day-night non-uniformity, the seismic effects in the LF radio propagation, and the Schumann resonance reaction to the powerful eruption of the Tonga volcano on January 15, 2022.

The model computations confirm that the day-night non-uniformity of the ionosphere may cause the seasonal and diurnal variations in the Schumann resonance amplitude. However, these changes do not exceed ~1 dB level, which is a few times smaller than the amplitude variations observed experimentally. Thus, the changes driven by the day-night non-uniformity play a minute role in comparison with those caused by the intensity of global thunderstorms.

The idea was numerically checked to assess the impact of anomalous seismogenic DC electric fields in the lower atmosphere on the statistical parameters of electric discharges and the natural radio noise. The resulting effect might cause completely different reactions of the local lightning detection networks: the changes in the recorded pulse rate depend on the pulse detection threshold used in the LF radio receivers.

We compared the ELF/VLF records from the Ukrainian Antarctic Akademik Vernadsky station (AVS) with the WWLLN data during the eruption of the Tonga volcano. This data confirmed our earlier conclusion that the natural ELF radio signals are a sensitive tool for the global detection of electrical activity relevant to volcanic eruptions. The validity of this statement is especially clear at the early stage of an eruption when the lightning strokes occur around the volcano's vent and have relatively weak peak currents. These pulses are not detected in the VLF/LF bands at far distances owing to higher attenuation rate.



Comparison of the Schumann resonance intensity with the WWLLN lightning strokes' energy in the ash plume in the vicinity of the Tonga volcano vent.

References:

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[2] Hayakawa, M., Y. Hobara, K. Michimoto, A.P. Nickolaenko (2024), The Generation of Seismogenic Anomalous Electric Fields in the Lower Atmosphere, and its Application to Very High Frequency and Very Low Frequency/Low Frequency Emissions: A Review, Atmosphere, 15, 1173. https://doi.org/10.3390/atmos15101173

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UNITED KINGDOM

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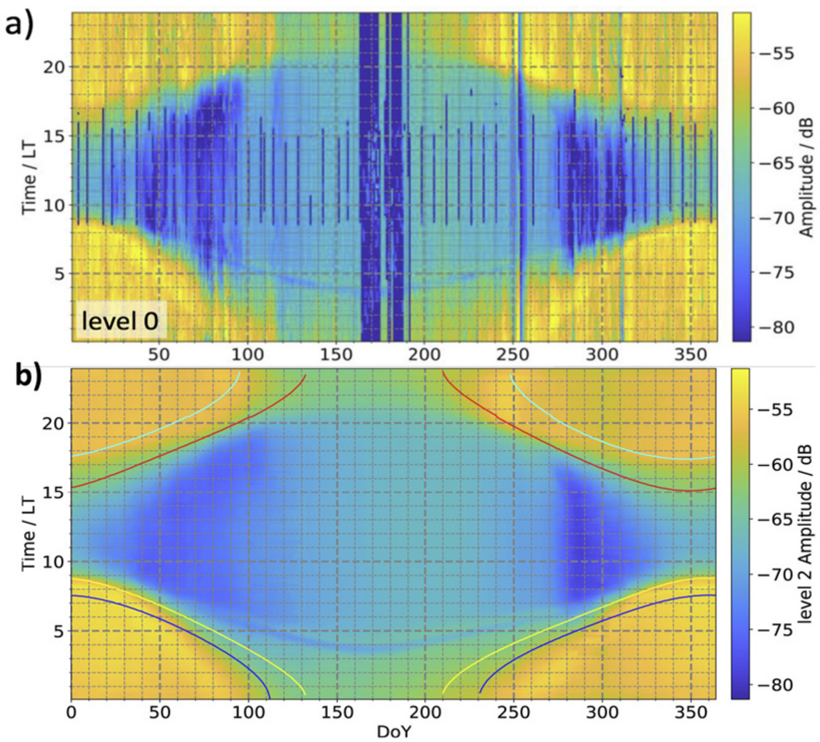
The British Antarctic Survey, Space Weather and Atmosphere Team have maintained their operations in ELF and VLF remote sensing, both in the Antarctic and more globally. We had some challenges, e.g., our unmanned Antarctic station Halley failed 2 weeks before the May 2024 Gannon storm, but we also had some gains in upgrading our Ny Alesund, Svalbard and St Johns, Newfoundland VLF sites. Halley station is now back on air after the summer crew arrived mid-November.

The open access **BAS database of VLF data** continues to be a source of observations for a number of interesting research topics. Using BAS data researchers at the German Aerospace Center (DLR), overseen by Dr Daniela Banys, have developed a new approach for processing long VLF data time series over multiple years. Time series with artificial jumps are leveled, and outliers are removed by a robust and systematic two-step outlier filtering technique [1].

The average seasonal and diurnal variation transmitter-receiver amplitude can be computed from the processed data, and a subsequent application of polynomial fitting can be used to obtain quiet time variations for daytime and nighttime undisturbed conditions of the VLF signal amplitude (see Figure 1 below).

Differences in VLF propagation conditions during spring (March/April) and autumn (September/October) have continued to be analysed using BAS data sets, and this year a detailed analysis of nighttime propagation conditions during the autumn months has been published [2] – part of a series studying the 'Fall effect'.



A composite figure based on the plots in Schneider et al. (2024).
(a) One year of 2017 amplitude data from the NAA transmitter received at Ny Alesund, Svalbard (4.9 Mm), including transmitter off periods, and geomagnetic storm effects.
(b) The derived quiet-time amplitude for the same path, including coloured lines representing Solar Zenith Angle = 108˚, 102˚ and 96˚, i.e., various dawn and dusk conditions.

References:

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UNITED STATES

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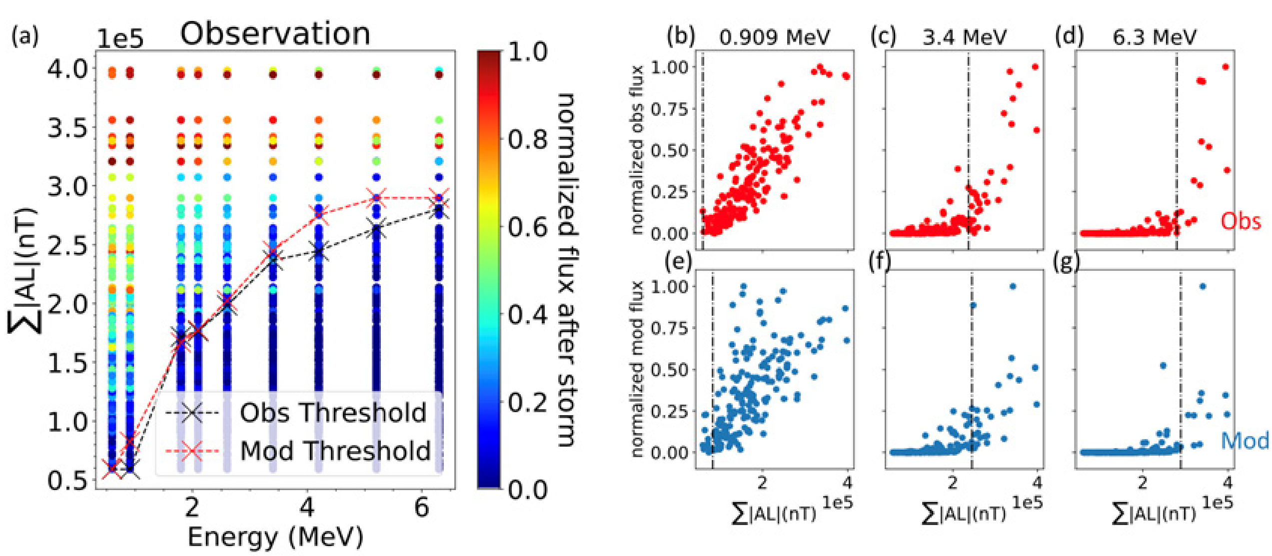
The UCLA Bortnik group had a productive year investigating a range of topics centered on magnetospheric plasma waves and energetic particle dynamics. One of the main themes that emerged in our research this year was the close connection between substorm activity and radiation belt fluxes.

In a statistical study examining ~6 years of satellite data, **[1]** showed that the best predictor of the upper-limit of radiation belt fluxes across a range of energies spanning ~300 keV to ~10 MeV was the accumulated substorm activity in the previous several hours, as reflected in the integral of the AL index. In a different sequence of studies, **[2]** used the Shapley Additive exPlanations (SHAP) machine learning (ML) interpretability technique, to perform a SHAP-enhanced superposed epoch analysis of radiation belt acceleration and depletion events. They showed that both types of events start off with a rapid dropout of the energetic electron fluxes, but it is the level of substorm activity (i.e., integral of AL) following the dropout which determines whether radiation belt fluxes will ultimately be accelerated to (or above) prestorm values, or remain low and thus be considered a depletion event.

In a follow-up study, **[3]** tested this hypothesis by performing a set of 2D Fokker-Planck simulations for 186 storms, based on Van Allen Probes observations, parameterized purely by the integral of AL.



(After Ma et al., 2024b, Fig 4) A comparison of the modeled electron flux threshold with observation. (a) The observed flux, normalized and color-coded by the maximum and minimum flux levels of each channel. The dashed line and cross show the observed threshold (black) and modeled threshold (red). (b)–(d) The observation results and the threshold at different energies. (e)–(g) The simulation results and the threshold at different energies.

Results show that electron fluxes could not only be reproduced by the integral of AL, but indeed that accumulated substorm activity progressively 'switched on' higher energies, indicating the existence of critical thresholds, as shown in the Figure above.

Various other research projects in our group included the simulation of electron precipitation by ducted chorus waves, inspired by ELFIN cube-sat observations, studying the fine structure of magnetosonic waves, assessing field line curvature scattering for protons, and even venturing to the Jovian environment to assess whistler wave activity at a gas giant.

References:

[1] Hua, M., & Bortnik, J. (2024). Upper limit of outer belt electron acceleration and their controlling geomagnetic conditions: A comparison of storm and non-storm events. Geophysical Research Letters, 51, e2024GL109612. https://doi.org/10.1029/ 2024GL109612

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UNITED STATES

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It has been a fruitful year for ELF/VLF research at the University of Colorado Denver. Thanks to new funding, we were able to return to ELF/VLF experiments at the HAARP facility using HF ionospheric heating to generate ELF/VLF waves for probing the ionosphere and magnetosphere.
The goals of these experiments were to trigger magnetospheric wave-particle interactions and diagnose the local D-region ionosphere. HAARP remains a rare facility that provides researchers a controlled source of ELF/VLF radiation. HAARP is accessible to students at US institutions via the Polar Aeronomy Radio Science (PARS) program and is open to international collaborations.

Our work on modeling whistler mode wave propagation in the magnetosphere using ray tracing and FDTD modeling yielded interesting results that highlight the complexity of wave propagation in the presence of field aligned cold plasma density structures. These effects include shadow regions and waves that are reflected from field aligned structures. Our numerical modeling work was motivated by observations from the Van Allen Probes spacecraft **[1, 2]**.
Our work on nonlinear aspects of whistler mode wave particle interactions turned to the phenomena of particle scattering where we investigated the formation of distinct phase space structures in high resolution and direct comparison to the linear regime **[3]** .
In collaboration with Oleksiy Agapitov at University of California Berkeley, we received National Science Foundation funding to make VLF observations during the 2024 solar eclipse in the United States. We made unique observations where the propagation of VLF waves from the NAA transmitter was along the eclipse path. This novel transmitter-receiver geometry has allowed us to investigate the size of the eclipse induced perturbation region.

Finally, we have had an active year of collaboration with the Krakow ELF group in Poland. Specifically, we have obtained interesting results on the effects of solar flares and day/night changes in ELF observations. This work has further developed and improved our technique of using the ELF propagation velocity as a diagnostic tool and also yielded new results in the deflection of ELF waves by the day/night terminator **[4-6]**.

References:

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[3] Hosseini, P., Harid, V., Gołkowski, M., & Tu, W. (2024). Backward test particle simulation of nonlinear cyclotron wave-particle interactions in the radiation belts. Frontiers in Astronomy and Space Sciences, 11, 1484399.

[4] Kubisz, J., Gołkowski, M., Mlynarczyk, J., Ostrowski, M., & Michalec, A. (2024). New method for determining azimuths of ELF signals associated with the global thunderstorm activity and the Hunga Tonga volcano eruption. Journal of Geophysical Research: Atmospheres, 129(4), e2023JD040318.

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VERSIM JOURNAL CLUB (INTERNATIONAL)

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https://versim.matfyz.cz/index_jc.html

Founded in 2018, the VERSIM Journal Club (JC) is now entering its eighth year as the social hub for early-career researchers in the VERSIM community. The fully online club provides a space where early career researchers from across the global VERSIM community can share ideas, discuss new research, and meet more senior researchers in a friendly, informal environment. It is also a fantastic opportunity to connect outside of conferences, hopefully giving anyone who joins a few more friendly faces within the field.

This year, the JC has welcomed a diverse group of researchers from around the world, representing a wide range of expertise and experience levels. Additionally, the hosts presented exclusively original research, spanning the full breadth of VERSIM science.

The year began with ***Pauline Teysseyre*** (Université Paris Cité, France) sharing her work on VLF propagation in the Earth-ionosphere waveguide.

Aaron Hendry (British Antarctic Survey, UK) followed with an exploration of the "impossible" effect, revealing findings on sub-MeV EMIC-driven electron losses in the radiation belts.

In March, we hosted a special seminar featuring invited guest ***Allison Jaynes*** (University of Iowa, US), who presented results on diffuse-like aurora and precipitation.

Heading into the summer, ***Kristyna Drastichova*** (Charles University, Czechia) presented her study on conjugate ground- and space-based observations of whistler-mode waves, with results on wave spatial scales and propagation.

The impact of electron precipitation became a central theme in the latter part of the year, highlighted by presentations from ***Alina Grishina*** (GFZ-Potsdam, Germany) on ring current precipitation and ***Václav Linzmayer*** (Charles University, Czechia) on lightning-generated whistler induced precipitation.

The year concluded with ***Jodie McLennan*** (University of Iowa, US), who tackled several unresolved questions related to pulsating aurora.

RACHEL

MIREK

VERSIM JOURNAL CLUB (INTERNATIONAL)

From discussions at the VERSIM workshop this year in Colorado, there will be a few changes to the JC moving forward. Larger considerations will be made to include appropriate times for our friends in the US, given that both organizers are based in Europe. There will also be more invited talks from senior researchers, giving early career researchers a chance to interact with more experienced, international colleagues. As well as this, we are hoping to have 'discussion sessions' that will involve debates on various open questions in the field.

Please do get in touch with us at **versim.jc@gmail.com** if you are keen to get involved; to present work or a paper, to give us feedback, or just to join the mailing list. ***Absolutely everyone is welcome!***

More info at our webpage [**link**]

VERSIM NEWSLETTER
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December 2024