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

Annual newsletter of VERSIM: a joint IAGA/URSI working group
Editor: Andrei Demekhov No. 37, December 2022

Dear VERSIM friends and colleagues,

As a small gift to you for the coming year 2023, I am bringing our annual newsletter to your kind attention.

We seem to have overcome in most respects the pandemy consequences but much more troublesome circumstances of a war conflict betweeen European countries have arisen. This is affecting our lives quite much. Nevertheless, scientific cooperations and collaborations within our VERSIM community and wider continue. Most members of our working group can travel much more freely or even quite freely these days, and this helps much in science communication, although online communication mode has become ubiquitous for our work during recent years. Overall our community has continued a highly active work, as you may find out by reading the reports compiled below. I am most grateful to all of you who supports our working group by sharing your relevant research and related news, both in the annual and regular newsletters.

This year we have had the 10th VERSIM biennial meeting that has been held at the same location where the meetings have started in 2004, i.e., at the Sodankyla Geophysical Observatory. The feedback from the meeting has been very positive, and I would like to thank first of all Jyrki Manninen and all members of the organizing committee for making this workshop happened. As a result of competition between young participants, Dr. Miroslav Hanzelka from the Institute of Atmospheric Physics of the Czech Academy of Sciences (Chechia) has been nominated for a IAGA Early Carreer Award. I have to remind you that, unfortunately, Russian (and Belorussian) scientists were unable to participate in this meeting since the regulations by the Finnish government prevented even online participation for the scientists from those countries because of the Russia's attack on Ukraine. This case obviously did not conform to the policy of our parent organization, IUGG, to follow the regulations of the International Science Council on non-discrimination and universality of science. I am very grateful to the VERSIM community members that a cooperation and collaboration with Russian colleagues continues wherever possible, and especially grateful to our URSI co-Chair Mark Clilverd for supporting my point. Hope you will not blame me for placing this notice on the top page of this newsletter.

Importantly, next year we are having both IAGA and URSI meetings, so it should be a very active year, too.

As usual, I trust that you will read this newsletter with interest, for learning something new about the activities and results of our vibrant community, and perhaps for finding ways for new collaborations.

Please take care and have a happy, healthy, and successful 2023!

Andrei Demekhov,
IAGA co-chair

Mark Clilverd,
URSI co-chair

BELGIUM: Report prepared by Dr. Fabien Darrouzet (Fabien.Darrouzet@aeronomie.be), Royal Belgian Institute for Space Aeronomy (BIRA-IASB), Brussels, Belgium, http://awda.aeronomie.be/

We continue our project to detect whistler waves with 2 VLF antennas that are part of AWDAnet, the Automatic Whistler Detector and Analyzer system's network. This network covers low, mid and high magnetic latitudes including conjugate locations. It has been initiated by Dr. J. Lichtenberger (Hungary).

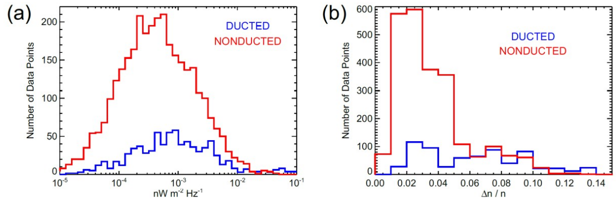
Our 2 VLF antennas are located in Humain, Belgium (Lat. ~ 50.11°N, Long. ~ 5.15°E) and at the Belgian Antarctic station Princess Elisabeth (Lat. ~ 71.57°S, Long. ~ 23.20°E). The antennas detect whistlers that are used to determine electron densities in the equatorial plasmasphere. For the first time since the installation in 2016, the Antarctica antenna has worked during all year around (including the 8 months when the station was not habited) !! But the data will be recovered only in February 2023…

We have also participated to a whistler-mode chorus study in plasmaspheric plumes, lead by Dr. O. Santolik (Czech Republic).

CZECHIA: Report prepared by Ivana Kolmašová (iko@ufa.cas.cz), František Němec (frantisek.nemec@mff.cuni.cz), and Ondřej Santolík (os@ufa.cas.cz), Institute of Atmospheric Physics of the Czech Academy of Sciences and Charles University, Prague.

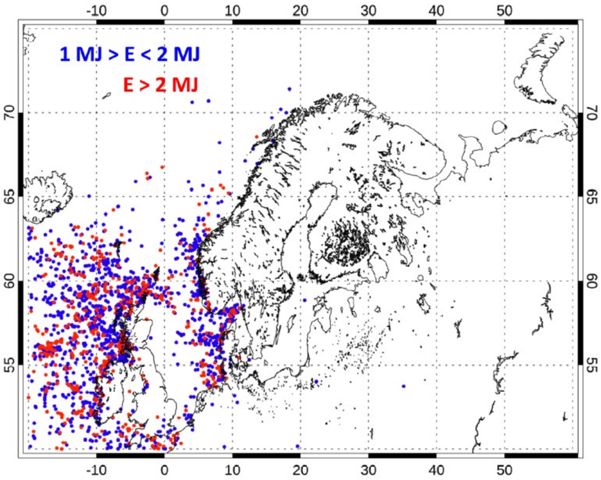
Our group at the Department of Space Physics, Institute of Atmospheric Physics of the Czech Academy of Sciences and at the Faculty of Mathematics and Physics of the Charles University continued to investigate inner magnetospheric electromagnetic waves using ground-based experiments and spacecraft measurements. Examples of our results obtained in 2022 are given below.

We focused on the properties of made-made emissions detected in the magnetosphere. We exploited the 11.9 kHz signals from Alpha transmitters in order to distinguish between their ducted and non-ducted propagation modes and to evaluate their relative importance [1]. We used multicomponent burst mode measurements conducted onboard the Van Allen Probes spacecraft. While being detected less often, the ducted waves tended to have larger Poynting fluxes. The total power propagating in the two modes was thus comparable. We have also found that magnetic local time and in-situ density fluctuations were the main parameters controlling the relative fraction of ducted waves.



Histograms of Poynting fluxes during the time intervals when the signal propagation is classified as ducted/non-ducted are shown by the blue/red lines, respectively. (b) The same as (a), but for histograms of plasma number density fluctuations.

In the other study [2], we presented a systematic analysis of Power Line Harmonic Radiation (PLHR) electromagnetic wave events observed by the Van Allen Probes spacecraft over the entire duration of the mission (2012–2019). PLHR events are radiated by electric power systems on the ground at harmonics of the base power system frequency (50 or 60 Hz, depending on the region). We analyzed wave intensities at frequencies corresponding to the first few harmonics and demonstrated that they were significantly enhanced at the times when the field-aligned magnetic footprint of the spacecraft was above industrialized areas. Considering the spacecraft locations close to the equatorial plane, this represents experimental evidence that PLHR emissions may propagate up to radial distances as large as about 4 Earth radii. Multicomponent wave measurements allowed us to figure out that the waves were typically right-handed elliptically or nearly circularly polarized, and propagated with oblique wave normal angles from low-latitude sources and more field-aligned wave vectors from high-latitude sources.



Spatial distribution of superbolts (strokes with energies of 1–2 MJ and above 2 MJ are represented by the blue and red points, respectively).

We used the World Wide Lightning Location Network data and investigated the properties of more than 90 000 lightning strokes, which hit northern Europe during an unusually stormy winter in 2014/15 [3]. We found that the number of individual winter lightning strokes was about 4 times larger than the long-term median calculated over the last decade. In the colder months of December, January, and February, the mean energy of detected strokes was two orders of magnitude larger than the global mean stroke energy of 1 kJ. We showed for the first time that winter superbolts with radiated electromagnetic energies above 1 MJ appeared at night and in the morning hours, while the diurnal distribution of all detected lightning was nearly uniform. The lightning strokes were concentrated above the ocean close to the western coastal areas. All these lightning characteristics presume anomalously efficient winter thundercloud charging in the eastern North Atlantic, especially at the sea-land boundary. We hypothesize that the enormous amount of lightning in winter 2014/15 might originate in the co-occurrence of two large-scale climatic events: a positive phase of the North Atlantic Oscillation and a starting super El Niño. Both events are known to warm the sea surface and the cold-to-warm transition phase of El Niño is believed to be accompanied by increased updraft strengths. A combination of these two effects probably led to the production of unusually highly charged winter clouds producing numerous lightning.

We also focused on the rare events of equatorial noise occurring at ionospheric altitudes during periods of strongly increased geomagnetic activity [4]. We used multicomponent electromagnetic measurements from the entire DEMETER spacecraft mission (2004–2010) to analyze propagation properties of measured waves. We found that, close to the Earth, these emissions experienced a larger spread in latitudes than at larger radial distances. Additionally, their wave normal angles could significantly deviate from the direction perpendicular to the local magnetic field. We compared these results to ray tracing simulations, in which whistler mode rays with initially nearly perpendicular wave vectors propagated down to low altitudes. We performed nonlinear fitting of the simulated latitudinal distribution of incident rays to the observed occurrence and we estimated the distribution of wave normal angles in the source. The assumed Gaussian distribution provided the best fit with a standard deviation of 2° from the perpendicular direction. Ray tracing analysis further showed that small initial deviations from the meridional plane could rapidly increase during the propagation and resulted in deflection of the emissions before they could reach the altitudes of DEMETER.

Using the principal component analysis (PCA), we investigated intensity variations of very low frequency (0–12 kHz) waves measured by the Kannuslehto station, Finland between 2016 and 2020 [5]. We have chosen either daily frequency-time spectrograms or individual frequency spectra as the PCA basis vectors. Analysis of the first three principal components showed substantial variations of the wave intensity due to seasonal and local time effects. Intensity variations related to the geomagnetic activity characterized by Kp and AE indices and standard deviation of the magnetic field magnitude were less significant.

References:

1. Němec, F., Santolík, O., Hospodarsky, G. B., & Kurth, W. S. (2022). Alpha transmitter signals observed by the Van Allen Probes: Ducted versus nonducted propagation. Geophysical Research Letters, 49, e2022GL098328. https://doi.org/10.1029/2022GL098328

2. Němec, F., Santolík, O., Hospodarsky, G. B., Kurth, W. S., & Kletzing, C. (2022). Power Line Harmonic Radiation observed by the Van Allen Probes spacecraft. Journal of Geophysical Research: Space Physics, 127, e2022JA030320. https://doi.org/10.1029/2022JA030320

3. Kolmašová, I., Santolík, O., and Rosická, K.: Lightning activity in northern Europe during a stormy winter: disruptions of weather patterns originating in global climate phenomena (2022), Atmos. Chem. Phys., 22, 3379-3389. https://doi.org/10.5194/acp-22-3379-2022. https://doi.org/10.1029/2020JA029017

4. Hanzelka, M., Němec, F., Santolík, O., & Parrot, M. (2022). Statistical analysis of wave propagation properties of equatorial noise observed at low altitudes. Journal of Geophysical Research: Space Physics, 127, e2022JA030416. https://doi.org/10.1029/2022JA030416

5. Bezděková, B., Němec, F., Manninen, J. (2022), Ground-based VLF wave intensity variations investigated by the principal component analysis, Earth, Planets and Space. https://doi.org/10.1186/s40623-022-01588-4

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

We continue participating in the World-Wide Lightning Location Network (WWLLN) since our joining in 2003. We continue recording narrowband very low frequency (VLF) signals of six transmitters using the SoftPAL data acquisition system located at Physics building, USP, Suva (18.15°S, long. 178.45°E) which was started in the year 2006. The narrowband VLF recording with one more SoftPAL station in Port Villa, Vanuatu, where our university has its regional campus, was also made.

The JJI VLF (22.2 kHz) transmitter signal recorded at two low-latitude stations, one in Port Vila (geog. 17.73°S, 168.33°E), Vanuatu and the other in Suva (18.14°S, 178.44°E), Fiji, was analyzed for any VLF changes due to 16 Earthquakes (EQs) with magnitudes from 5.5 to 7.7, during 2018 (JJI-Vanuatu path, 6.8 Mm) and 2007 to 2018 (JJI-Suva path, 7.5 Mm). The VLF signal amplitude analysis included terminator time (TT), average daytime and nighttime amplitude variation, nighttime fluctuation, and mother Morlet wavelet methods. Out of 16 EQs only eleven EQs have shown sub-ionospheric VLF changes including a decrease in the amplitude for about 2-8 hours on the EQ day, unusual shifts in the TT up to 5-9 min, and a decrease in the average daytime and nighttime signal amplitude of about 1-1.5 dB and 1-5 dB, respectively, on the mainshock day of the EQs.

We analysed the D-region ionospheric response during the lifespan (10–19 December 2020) of a severe category 5 tropical cyclone (TC) Yasa in the South Pacific by using the very low frequency (VLF, 3-30 kHz) signals from NPM, NLK, and JJI transmitters recorded at Suva, Fiji. Results indicate enhanced lightning and convective activity in all three regions (eyewall, inner rainbands, and outer rainbands) during the TC Yasa that are also linked to the wave-sensitive zones of these transmitter-receiver great circle paths. Of the three regions, the outer rainbands showed the maximum lightning occurrence; hence convective activity. Prominent eyewall lightning was observed just before the TC started to weaken following its peak intensity. Analysis of VLF signals amplitude showed both negative and positive perturbations (amplitudes exceeding ±3σ mark) lasting for more than 2 hours with maximum change in the daytime and nighttime signal amplitudes of -4.9 dB (NPM) and -19.8 dB (NLK), respectively. The signal perturbations were wave-like, exhibiting periods of oscillations between ~2.2-5.5 hours as revealed by the Morlet wavelet analysis.

Atmospheric Electric Field Mill (EFM 100) was installed near the Physics building, USP, Suva, to study the variations in the atmospheric electric field due to changes in meteorological conditions such as strong thunderstorms. The EFM 100 was installed on the ground, as shown in the figure, with the sensor being at 1.0 m height from the ground surface to measure the atmospheric electric field in Volts per meter (1 meter = 3.28 feet.) The electric fields which accompany thunderstorms normally measure in the thousands of Volts per meter, usually abbreviated to kV/m. Continuous observations started in August 2022 at the sampling frequency of 1 Hz.

We continue ionospheric observations with the new Global Navigation Satellite Systems station for Ionospheric Monitoring (TEC and scintillations) and Precise Point Positioning (PPP) Research under normal and space weather conditions, 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. Please visit for details:
http://www.usp.ac.fj/news/story.php?id=3219

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

References:

Paolo Redoblado, Sarwan Kumar, Abhikesh Kumar and Sushil Kumar (2022), Lightning evolution and VLF perturbations associated with Category 5 TC Yasa in the South Pacific Region, Earth Planets Space, 74, 65. https://doi.org/10.1186/s40623-022-01632-3

Sarwan Kumar, Sushil Kumar and Abhikesh Kumar (2022), Earthquakes Associated Subionospheric VLF Anomalies Recorded at two Low Latitude Stations in the South Pacific Region, Journal of Atmospheric and Solar-Terrestrial Physics, 229, 105834. https://doi.org/10.1016/j.jastp.2022.105834

Ajeet K Maurya, Navin Parihar, Adarsh Dube, Rajesh Singh, Sushil Kumar, Olivier Chanrion, Maja Tomicic, Torsten Neubert (2022), Rare simultaneous imaging observations of Transient Luminous Events (TLEs) and Gravity waves and the associated D-, E- and F-region coupling, Scientific Reports-Nature, 12:581.
https://doi.org/10.1038/s41598-021-03808-5

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

Winter 2021-2022 ELF-VLF campaign started on 7 September 2021 and it is still continuing. The campaign has had no long breaks at all. This campaign was also running over the summer 2022. It was the first time since 1998 when we tried to make recordings during one week around mid-summer. 24 years ago we failed due to a lightning discharge that destroyed our electronics, although the lightning hit the ground about 3 km from our receiver.

The quick-look plots (24-h, 1-h, and 1-min) 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 contain the range from 0 to 39 kHz. Upper band is available if someone is interested in.

It should be reminded that now all quick-look plots, what are in our server, have been analysed with both PLHR and sferics filters 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.

In April-June Dr. J. Manninen was 3 months as a visiting professor at ISEE in Nagoya University. During his visit main topic was to search VLF bursty-patches from PWING VLF data. Some nice events have been found from ground-based data. Next step will be to search them from ERG/Arase data.

The number of peer-reviewed papers during this year was six. Also a lot of different activities have been planned for after-pandemic era.

10th VERSIM Workshop was organised by Sodankylä Geophysical Observatory in Sodankylä area on 7-11 November 2022. We also had 2 days the 1st VERSIM School just before the Workshop (5-6 Nov 2022). Both school and workshop were held in hybrid mode.

References:

1. Bezdekova, B., F. Nemec, and J. Manninen (2022). Ground-based VLF wave intensity variations investigated by the Principal Component Analysis. Earth, Planets and Space, 74:30. https://doi.org/10.1186/s40623-022-01588-4

2. Elliott, S.S., A.W. Breneman, C. Colpitts, J.M. Pettit, C.A. Cattell, A.J. Halford, M. Shumko, J. Sample, A.T. Johnson, Y. Miyoshi, Y. Kasahara, C.M. Cully, S. Nakamura, T. Mitani, T. Hori, I. Shinohara, K. Shiokawa, S. Matsuda, M. Connors, M. Ozaki, and J. Manninen, (2022). Quantifying the size and duration of a microburst-producing chorus region on 5 December 2017. Geophys. Res. Lett., 49, e2022GL099655. https://doi.org/10.1029/2022GL099655

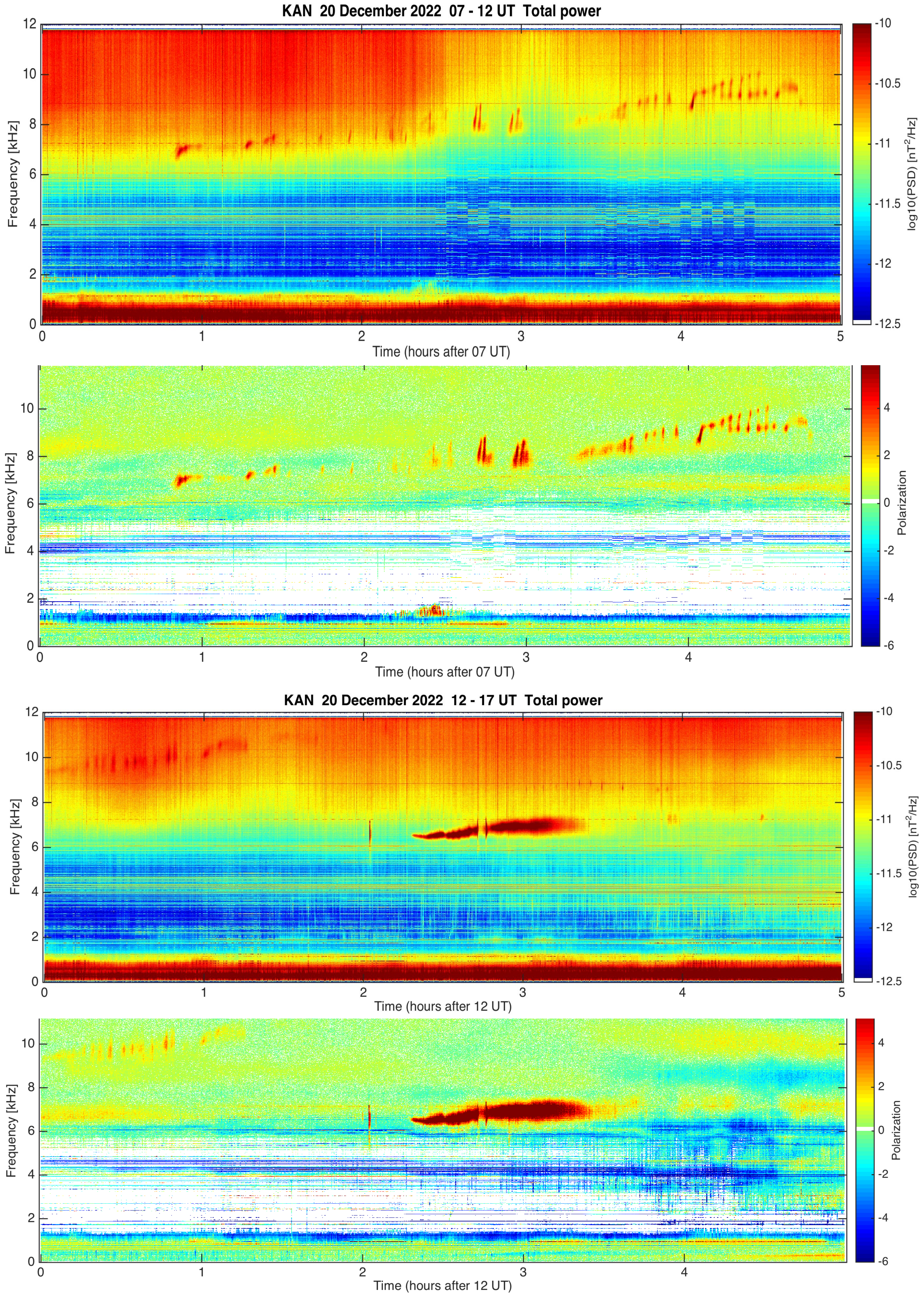
3. Manninen, J., N.G. Kleimenova, C. Martinez-Calderon, L.I. Gromova, and T. Turunen (2022). Unexpected VLF bursty-patches above 5 kHz: A review of long-duration VLF series observed at Kannuslehto, Northern Finland,
Surveys in Geophysics.
https://doi.org/10.1007/s10712-022-09741-0

4. Martinez-Calderon, C., J.K. Manninen, J.T. Manninen, and T. Turunen (2022). Statistics of unusual VLF bursty-patches observed at Kannuslehto, Finland. Accepted in J. Geophys. Res.

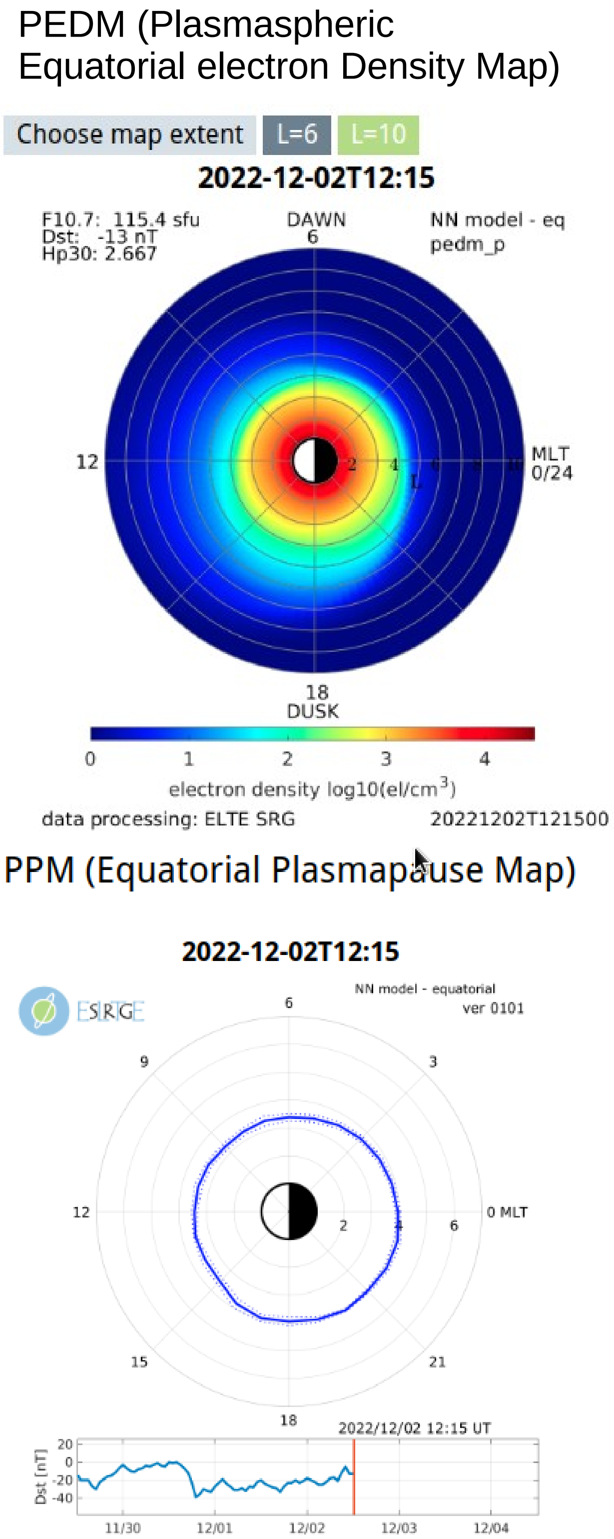
5. Nikitenko, A.S., J. Manninen, Yu.V. Fedorenko, N.G. Kleimenova, M.V. Kuznetsova, A.V. Larchenko, E.B. Beketova, and S.V. Pilgaev (2022). Spatial structure of the VLF illumination region of the auroral hiss based on ground-based observations at auroral latitudes. Geomagnetism and Aeronomy, 62, 3, 209–216.
https://doi.org/10.1134/S0016793222030124

6. Titova, E.E., D.R. Shklyar, and J. Manninen (2022). Broadband whistler waves and differential electron fluxes in the equatorial region of the magnetosphere behind the plasmapause during substorm injections. Geomagnetism and Aeronomy, 62, 4, 399-412.
https://doi.org/10.1134/S0016793222040168

There were also several oral and poster presentations held in URSI AT-AP-RASC 2022 and in 10th VERSIM Workshop in 2022.



Two 4-hour examples of high-frequency events detected at Kannuslehto, Finland. Upper panel presents afternoon One 10-hour example of this December events. The first two panels present morning time VLF bursty-patches and last two panels show afternoon VLF bursty-patches on 20 Dec 2022 in frequency range of 0-12 kHz. 1st and 3rd panels show total power while 2nd and 4th panels show polarization of the events (red means right hand polarization).



Real time plasmasphere and plasmapause maps. The products are under final test and will be published on ESA SWE portal mid-next year.

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

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

Unfortunately, due the Ukrainian war, the development of Trabant and Chibis-AI mission with Russian partners has been suspended.

We have continued the PLASMA project with the European Space Agency to develop plasmaspheric products for ESA Space Situational Awareness Programme using densities derived from AWDANet VLF and EMMA magnetometer network data as well as in-situ density data. We have developed several plasmaspheric products, including empirical plasmasphere model using neural networks, the training set includes a more than two decades long in-situ database (Akebono, Arase, IMAGE, Polar, THEMIS and Van Allen Probes); a data assimilative plasmasphere model that uses the empirical model and real time ground based data as inputs and an empirical plasmapause model, also based on machine learning.

Reference:

Pataki, B. Á., Lichtenberger, J., Clilverd, M., Máthé, G., Steinbach, P., Pásztor, S., et al. (2022). Monitoring space weather: Using automated, accurate neural network based whistler segmentation for whistler inversion. Space Weather, 20, e2021SW002981. https://doi.org/10.1029/2021SW002981

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

For the last few years I have complained that the New Zealand border has been essentially closed, meaning we could not get overseas (except Antarctica), and colleagues could not visit us. This changed from mid-2023, allowing the group to re-connect with the world. I certainly took advantage of this, visiting our collaborators in Edinburgh and Newcastle upon Tyne (UK), participating in a International School of Space Science at the University of L'Aquila (Italy), and attending the 18th European Space Week (ESWW) in Zagreb plus the 10th VERSIM workshop (and 1st VERSIM School) in Sodankylä. It has been extremely pleasing to get out to the wider world and see our community! At the same time Mark Clilverd (BAS, UK) was able to come to New Zealand for the first time in ~2.5 years. Space Physics PhD student Daniel Mac Manus went to ESWW in Croatia, and is currently finishing off the writing of his PhD - and PostDoc Aaron Hendry went to the Chatham Islands (a very distant part of New Zealand) to install a magnetic variometer.

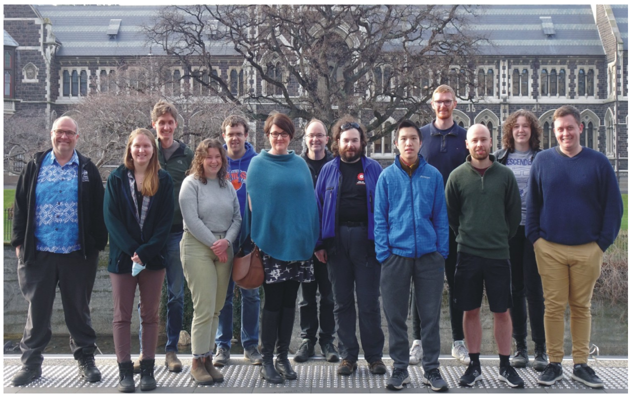
Craig's activities have been dominated by space weather research, particularly interacting with our energy industry partners (power grid & gas pipeline owners) and also talking to parts of the New Zealand government about the risks posed by extreme space weather events. The group is still active in radiation belt, D-region, and lightning research, collecting and analysing ground and space-based datasets.

Research outputs this year have been lower than "normal", and dominated by space weather rather than traditional VERSIM topics.

[1] The final piece of the PhD work of Daniel Mac Manus, modelling the magnitudes of Geomagnetically Induced Currents (GIC) across all the primary transformers in the NZ power grid. This paper is particularly important in that includes (for the first time we think) industry provided estimates of GIC hazard levels, i.e., GIC threshold levels over given time periods. Nine different extreme storm scenarios were considering, with differing time and latitude variations. The main finding is that typical the same transformers show up as "hot spots" where mitigation could be considered;

[2] A Craig Rodger-led paper looking at how precipitating electron fluxes in the radiation belts change before and after clusters of substorms, showing strong MLT and AE dependence. The MLT patterns remain similar, but the precipitation magnitude is strongly AE dependent. This likely reflects the behaviour of whistler mode chorus. One important aspect is that the energy spectra does not seem to change with AE, while the magnitude does;

[3] Neil Thomson's latest work on D-region electron density levels determined from subionospheric VLF, making comparisons with the new(ish) D-region model produced using rocket observations - the agreement is often is very good!



The Otago Space Physics Group updated our team picture on 12 August 2022. Shown in the photo from left to right: From left to right: Craig Rodger, Hannah Kessenich, Jono Squire, Anna Tarr, Daniel Mac Manus, Annika Seppälä, James Brudell, Mikhail Kruglyakov, Jayvan Liu, Harrison Devane, Malcolm Crack, Sophie Cook, and Zade Johnston. Unfortunately, Aaron Hendry, Neil Thomson, and Jackson Fowler were missing could not be part of the photo this year.

References:

1. Mac Manus, D. H., C. J. Rodger, M. Dalzell, A. Renton, G. S. Richardson, T. Petersen, and M. A. Clilverd (2022), Geomagnetically Induced Current Modeling in New Zealand: Extreme Storm analysis using multiple disturbance scenarios and industry provided hazard magnitudes, Space Weather, 20, e2022SW003320 (in press). https://doi.org/10.1029/2022SW003320
2. Rodger, C. J., M. A. Clilverd, A. T. Hendry, and C. Forsyth (2022), Examination of Radiation

Belt Dynamics during Substorm Clusters: Magnetic Local Time Variation and Intensity of Precipitating Fluxes, J. Geophys. Res., 127, e2022JA030750 (in press). https://doi.org/10.1029/2022JA030750

3. Thomson, N. R., M. A. Clilverd, and C. J. Rodger (2022), Ionospheric D region: VLF-measured Electron Densities compared with Rocket-Based FIRI-2018 Model, J. Geophys. Res., 127, e2022JA030977. https://doi.org/10.1029/2022JA030977

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

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). Unfortunately, our collaboration with Finnish colleagues has been suspended by the Finnish Ministry of Education because of the Russian attack on Ukraine, but we are still able to publish join papers based on the data selected earlier. Our collaborations with other VERSIM Colleagues have mostly continued. This year our group has published only one result on the VERSIM topics but several others are awaiting publication and hopefully will be reported next year.

Relativistic electron losses in Earth's radiation belts are usually attributed to electron resonant scattering by electromagnetic waves. One of the most important wave modes for such scattering is the electromagnetic ion cyclotron (EMIC) mode. Within the quasi-linear diffusion framework, the cyclotron resonance of relativistic electrons with EMIC waves results in very fast electron precipitation to the atmosphere. However, wave intensities often exceed the threshold for nonlinear resonant interaction, and such intense EMIC waves have been shown to transport electrons away from the loss cone due to the force bunching effect. We investigated if this transport can block electron precipitation. We combined test particle simulations, low-altitude ELFIN observations of EMIC-driven electron precipitation, and ground-based EMIC observations. Comparing simulations and observations, we were able to show that, despite the low pitch-angle electrons being transported away from the loss cone, the scattering at higher pitch angles results in the loss cone filling and electron precipitation.

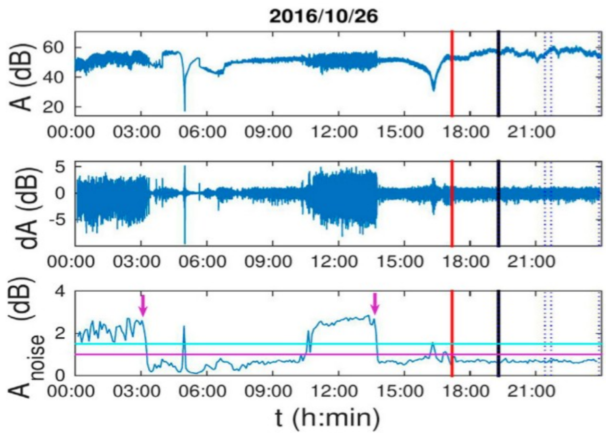
Reference:

1. Grach, V. S., Artemyev, A. V., Demekhov, A. G., Zhang, X.-J., Bortnik, J., Angelopoulos, V., et al. (2022). Relativistic electron precipitation by EMIC waves: Importance of nonlinear resonant effects. Geophysical Research Letters, 49, e2022GL099994. https://doi.org/10.1029/2022GL099994

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

We continued investigation of properties of the ICV very low frequency (VLF) signal emitted in Italy and recorded at the Institute of Physics Belgrade in the time period around earthquakes, and further developed our Quiet Ionospheric D-region (QIonDR) model.

We extend previous research of ICV signal characteristics noise reduction before a particular earthquake to studying the noise amplitude during periods of intense seismic activity in a localized area near the signal propagation path. In [1], we analyse variations in noise of the amplitude of ICV signal over a period of 10 days (25 October–3 November 2016) when 981 earthquakes occurred in Central Italy. The obtained results show the existence of the noise amplitude reduction preceding individual strong or relatively strong earthquakes, and earthquakes followed by others that occurred in a shorter time interval. However, the additional noise amplitude reductions are either not pronounced or they do not exist before the considered events in periods of the reduced noise amplitude remain from previous earthquakes. The 2D Hybrid technique is demonstrated on a ICV signal in time vicinity of the occurrence of an earthquake on 3 November 2010, near Kraljevo, Serbia [2].



The time evolutions of the recorded ICV signal amplitude, A, its deviation, dA, from the base curve, and the noise amplitude, Anoise. Vertical lines indicate the times of earthquakes of magnitudes 4.1 and 4.7 (blue lines), 5.5 (red line) and 6.1 (black line). The beginnings of the amplitude noise reductions are indicated by the magenta arrows.

We examine the influence of the estimation of the quiet ionosphere parameters on the determination of the electron density and total electron content in the D-region during the influence of a solar X-ray flare [3]. We present a new procedure based on our QIonDR model in which parameters describing the quiet ionosphere are calculated based on observations of the analysed area by a VLF/LF signal at the observed time.

During this year we continue activities in the European VLF/LF network INFREP, and EUROPLANET, participated in several conferences and worked as Guest editors in the Special Issues of Frontiers in Environmental Sciences and Remote Sensing.

References:

1. Nina A., P.F. Biagi, S. Pulinets, G. Nico, S.T. Mitrović, V.M. Čadež, M. Radovanović, M. Urošev and L.Č. Popović (2022), Variation in the VLF signal noise amplitude during the period of intense seismic activity in Central Italy from 25 October to 3 November 2016, Front. Environ. Sci., 10:1005575. https://doi.org/10.3389/fenvs.2022.1005575

2. Kovačević, A. B., A. Nina, L. Č. Popović and M. Radovanović (2022), Two-Dimensional Correlation Analysis of Periodicity in Noisy Series: Case of VLF Signal Amplitude Variations in the Time Vicinity of an Earthquake. Math., 10(22), 4278. https://doi.org/10.3390/math10224278

3. Nina, A. (2022), Modelling of the Electron Density and Total Electron Content in the Quiet and Solar X-ray Flare Perturbed Ionospheric D-Region Based on Remote Sensing by VLF/LF Signals Remote Sens. 2022, 14, 54. https://doi.org/10.3390/rs14010054

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

This year has seen a slow return to more normal operations. Some sites operated by BAS have undergone upgrades as we seek to replace aging hardware where possible, and that work will continue over the coming years as we address the covid-backlog of technical issues.

BROADBAND RECORDINGS in Antarctica:

Whistler-detection and data collection has continued at Rothera (L=2.8) throughout 2022 using an upgraded version of the Hungarian Automatic Whistler Detection (AWD) system that was installed in February. Unfortunately a base-wide power failure at Halley (L=4.6) resulted in data loss from July 5 onwards at that site. Data collection resumed at Halley on December 5. BAS also continues to operate another AWD site, at Eskdalemuir in Southern Scotland (L=2.7) although there has been a significant data gap in the second half of the year due to harddrive failures. Upgrades to the system are ongoing.

UltraVELOX RECORDINGS:

UltraVELOX data logging has continued at Halley (first half of the year), Rothera, and Ottawa. This dataset is partially equivalent to VELOXnet recordings, with 46-93Hz bin resolution up to a maximum frequency of 48 kHz, 0.2-10 sec time resolution depending on site, amplitude only.

NARROW-BAND RECORDINGS:

'Ultra' narrow-band recordings have continued at Halley (first half of the year) and

Rothera (Antarctica), Seattle (USA), Canadian sites Ottawa, St Johns, and Churchill (first half of the year), Eskdalemuir (Scotland), Sodankyla (Finland), Reykjavik (Iceland), and Ny Alesund (Svalbard) throughout 2022. BAS is also hosting Ultra data from Fairbanks, Alaska, collected as part of a collaboration with WWLLN. Data logging at Churchill, Canada stopped at the beginning of August and is unlikely to resume – equivalent propagation paths are currently logged at Fairbanks.

The software VLF Doppler system has continued at Rothera station, Antarctica (L=2.8) in 2022 receiving whistler mode signals primarily from NAA (24.0 kHz).

WWLLN sites:

British Antarctic Survey has continued to operate several World Wide Lightning Location Network systems in 2022. St Johns, Ascension, and Rothera have successfully provided lighting location information all year, while Halley has again experienced a 5 month data gap during to the loss of power to the whole site in the second half of the year. In recent months the BAS site at Reykjavik has started to provide WWLLN data, partially replacing the loss of the data from the Churchill site.

Please contact Mark Clilverd (macl at bas.ac.uk) for details regarding on-line access to the datasets mentioned above.

Regards, Mark Clilverd

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

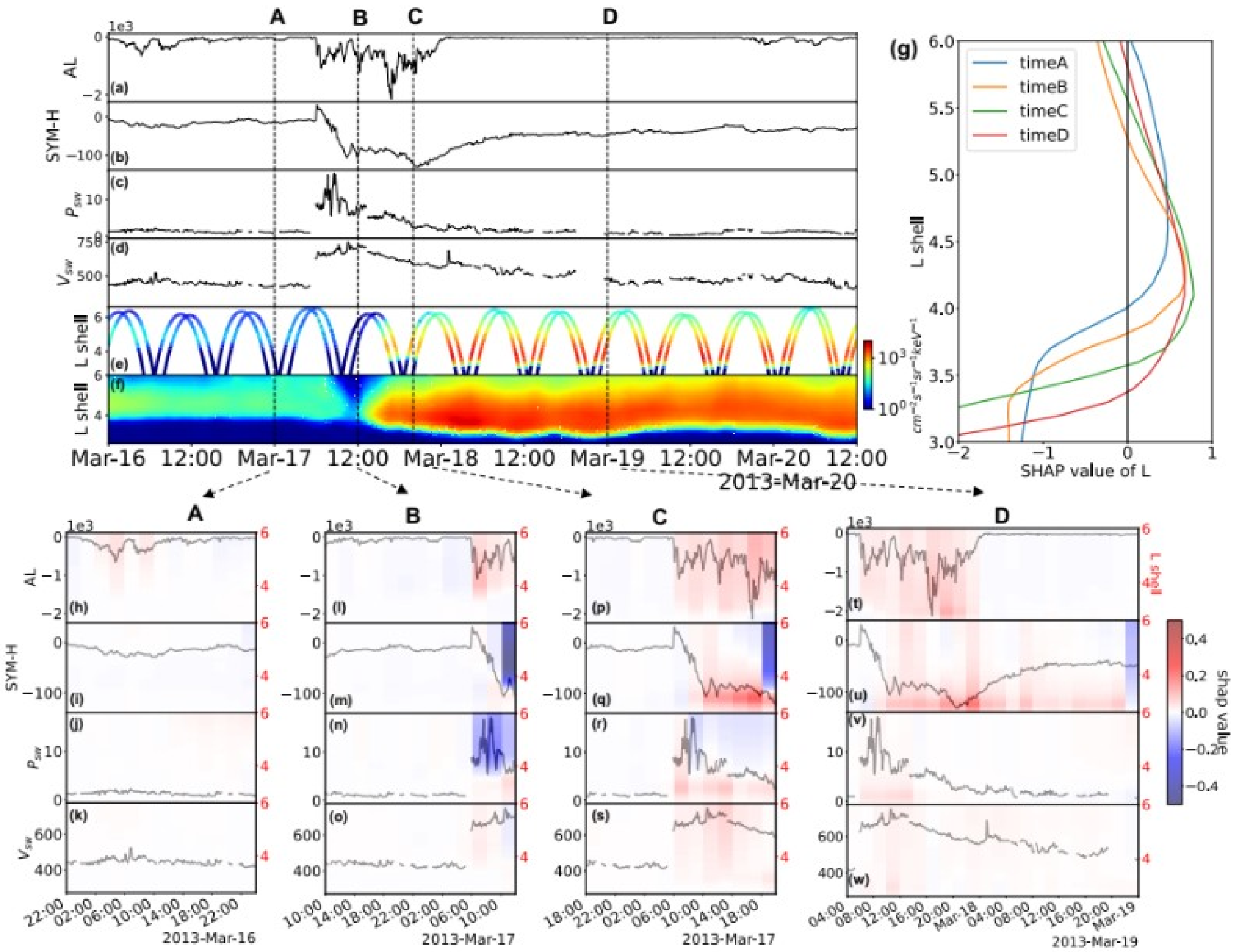
The UCLA Bortnik group had a productive year investigating a range of topics centered on magnetospheric plasma waves and energetic particle dynamics. A big focus this year has been on the precipitation and loss of energetic electrons from the radiation belts: here, we tried to observe the precipitation of electrons using the PFISR incoherent scatter radar, through conjunctions with the Van Allen Probes [Sanchez et a., 2022; Q. Ma et al., 2022a], we modeled the precipitation of relativistic electrons due to Electro-Magnetic Ion Cyclotron (EMIC) waves, showing a nonlinear rapid advection of near-loss-cone particles to higher pitch angles [Grach et al., 2022; Bortnik et al., 2022], assessed the electron loss due to VLF transmitters [Q. Ma et al., 2022b], as well as all potential loss mechanisms below L~4 [Claudepierre et al., 2022], and derived an analytical expression for quantifying nonresonant scattering by EMIC waves [An et al, 2022], which could account for the precipitation of electrons far below the minimum resonant energy, a few 100 keV.

Machine Learning (ML) continued to be a theme of great interest in our group, and in this area we started to move towards the topic of interpretation. We used Physics Informed Neural Networks (PINNs) to identify and characterize the radial drift term in the Fokker-Planck equation [Camporeale et al., 2022], we build a high-accuracy ML model of medium-energy (50-900 keV) electrons [D. Ma et al., 2022a] and used this model to "discover" the dominant drives of the model at various snapshots of a geomagnetic storm [D. Ma et al., 2022b] (see Figure).

Finally, we were excited to collaborate on a "radiation belt remediation" project that demonstrated the use of rocket exhaust to amplify VLF transmitter signals by ~20-30 dB and could potentially be used to precipitate energetic electrons from the radiation belts.

References:

1. Ma, D., J. Bortnik, X. Chu, S. G. Claudepierre, A. Kellerman, Q. Ma (2022), Opening the Black Box of the Radiation Belt Machine Learning Model, Space Weather [in review].
2. Claudepierre, S. G., Ma, Q., & Bortnik, J. (2022). Quantifying radiation belt electron loss processes at L < 4. J. Geophys. Res.: Space Physics, 127, e2022JA030756. https://doi.org/10.1029/2022JA030756
3. Ma, Q., Xu, W., Sanchez, E. R., Marshall, R. A., Bortnik, J., Reyes, P. M., et al. (2022). Analysis



(After Ma et al., 2022b, Fig 2.) Feature attribution for the storm time event of 17 March 2013. Input time series: (a) AL index, (b) SYM-H index, (c) Solar wind dynamic pressure, Psw (d) Solar wind speed, Vsw (e) Observed 909 keV electron fluxes as a function of time and L-shell, (f) ORIENT model reconstruction of 909 keV electron fluxes on the equatorial plane, (g) Feature importance based on L-shell, (h)-(k): Color-coded SHAP feature contributions for the model output at time A (2013-Mar-17-0:00) and the corresponding input in a one-day look-back window, (i)-(o): at time B (2013-Mar-17-12:00), (p)-(s): at time C (2013-Mar-17-20:00), (t)-(w): at time D (2013-Mar-19-0:00) but in a two-day look-back window.

of electron precipitation and ionospheric density enhancements due to hiss using incoherent scatter radar and Arase observations. J. Geophys. Res.: Space Physics, 127, e2022JA030545. https://doi.org/10.1029/2022JA030545

VERSIM JOURNAL CLUB (INTERNATIONAL): Report prepared by Miroslav Hanzelka (mha@ufa.cas.cz), Boston University, USA and IAP CAS, Czechia; and Claudia Martinez-Calderon (claudia@isee.nagoya-u.ac.jp), ISEE, Nagoya University, Japan.

The VERSIM Journal Club (JC) is a group founded during the 8th VERSIM Workshop 2018 with the objective of encouraging scientific discussion between students, early career researchers, and senior scientists. As the name of the group suggests, the main activity is dissections of recent VERSIM-related papers, which take place online with attendees from all around the world. Students can also present their original research in front of peers and get feedback in a casual, friendly environment.

In the past year, we held six sessions in total, mostly focused on original research into VERSIM-related and other space science topics: Mirek Hanzelka (IAP CAS, Czechia) presented new results on the propagation of equatorial noise to low altitudes; Claudia Martinez (Nagoya University) discussed a recent paper by Green et al. about the effects of lightning generated whistlers on radiation belt electron loss; Sasha Rubtsov (ISTP, Irkutsk) presented his research on the correlation between ULF waves and substorm occurrence; Aaron Hendry (University of Otago) presented the new Solar Tsunami project dealing , which deals with solar effects on the electric grid; Inchun Park (Nagoya University) talked about recent observations of seed electron populations by the Arase satellite; and Jose Tacza (EPSS, Hungary) discussed his research dealing with solar effects on the global electric circuit.

During the 10th VERSIM School in Sodankylä, Finland, we held a networking session for young scientists and discussed the future of the Journal Club. We talked about the importance of changing the times at which JC sessions are held to accommodate people from different time zones, and the importance of reaching out to students from underrepresented countries was emphasized. We also considered the options for informal communication between sessions; currently, this is facilitated through a Slack channel (chatting and file-sharing service). The results of the discussion in Sodankylä will be helpful deciding the future course of JC.

Finally, we would like to thank all the speakers and attendees for joining our sessions and contributing to our discussions, and we hope to see you again in the year 2023.

To join the Journal Club mailing list and get invitations to online meetings, please contact us at versim.jc@gmail.com.