VERSIM

VLF/ELF REMOTE SENSING OF THE IONOSPHERE AND MAGNETOSPHERE

2018 WORKSHOP / 19-23 MARCH 2018

POLAR GEOPHYSICAL INSTITUTE / APATITY, RUSSIA

Abstracts

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This collection includes the abstracts which have been accepted by the Science Committee of the 8-th biennial VERSIM Workshop (Polar Geophysical Institute, Apatity, Murmansk region, Russia, 19-23 March 2018, http://pgi.ru/conf/versim2018).

The working group on VLF/ELF Remote Sensing of the Ionosphere and Magnetosphere (VERSIM) is an international group of scientists interested in studying the behaviour of the magnetosphere and ionosphere by means of ELF (300 Hz - 3 kHz) and VLF (3-30 kHz) radio waves, both naturally and artificially generated. The group was set up in 1975 by IAGA (International Association of Geomagnetism and Aeronomy) and URSI (International Union of Radio Science).

Several abstracts have been cancelled due to various reasons after they were accepted. They are included in the end of this collection.

Only minimal formatting was applied to the abstracts sent by the authors.

Sporadic VLF amplitude perturbations in the high latitude D-region ionosphere

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The propagation of very low frequency (VLF) radio waves permit us to study the response of the lower ionosphere (~60-90 km) to sporadic space weather events such as solar proton events (SPEs) and energetic electron precipitation. In this study, we use the 37.5 kHz VLF signal transmitted from NRK (Iceland, L=5.5) recorded at Sodankylä (Finland, L=5.5) since 2010 till 2016. We compare the observed variations in the VLF amplitude measurements with changes in AE index, precipitating electron flux, and nitric oxide (NO) concentration. The analysis was divided in to positive and negative variations of the VLF perturbations with respect to the quiescent level. We found that the positive variations are mainly associated with SPEs and NO concentration enhancements. The observed large negative daytime perturbations are currently unexplained.

External excitation of the Earth-ionosphere cavity resonator by plasmaspheric hiss

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Plasmaspheric hiss waves, which are known to have an important role in radiation belt dynamics, were regularly observed on satellites and on ground stations above 100 Hz. Recently Van Allen Probe satellites detected low frequency plasmaspheric hiss waves extending down to few tens of Hz covering the Schumann-resonance (SR) frequency range, which is the electromagnetic resonance of the Earth-ionosphere cavity with characteristic peaks at ~ 8 Hz, ~ 14 Hz, ~20 Hz, etc. excited by the global lightning activity. We show that the newly discovered extremely low frequency hiss (below 100 Hz) can also penetrate into the Earth-ionosphere cavity and can appear as an external source of SR. We present a case study based on quasi-meridional chains of SR stations using perpendicular induction coils. Highly anisotropic intensification of SR were observed mainly in the north-south propagation direction simultaneously with plasmaspheric hiss detection onboard Van Allen Probes.

Characterization of polar D-region ionospheric variability using wavelet analysis

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The very low frequency (VLF) radio wave technique provides the possibility of investigating the response of the lower ionosphere (~60-90 km) to a diversity of transient and long-term physical phenomena originating from above (e.g. particle precipitation) and from below (e.g. atmospheric waves). In this study, we identify the periodicities that appear in the VLF measurements due to changes in Lyman-α flux, solar wind velocity, AE index, ap index, electrons flux at geostationary orbit, precipitating electron flux, mesospheric temperature, and nitric oxide (NO) concentration. We have applied the wavelet technique to the VLF signal transmitted from the powerful transmitter NAA on the East Coast of the USA, and recorded at Sodankylä, Finland. The analysis was divided in to daytime and nighttime conditions. We found annual and semi-annual periodicities in the VLF measurements linked with mesospheric temperatures and NO concentrations. At the same time, we found periodicities in the VLF measurements related to solar rotation, and planetary wave activity.

Estimation of the high-latitude lower ionosphere electron density profile using ground-based VLF observations in ionosphere heating experiments

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The experiments of ionosphere heating by a powerful modulated radio signal on high latitudes are conducted to investigate the physical processes in the ionospheric plasma and the mechanisms of excitation of low-frequency waves in the Earth-ionosphere waveguide. In this work, we present the results of estimation of the ionosphere electron density profiles at altitudes within 50-100 km range during the heating experiment that was conducted by AARI at the EISCAT/Heating facility in October 2016. Estimation of profiles is an inverse problem solved with Monte-Carlo method. As input, we used ground-based measurements of electromagnetic ELF/VLF fields at the observatories PGI “Lovozero” and “Verkhnetulomsky” at the frequencies 1017 and 3017 Hz to obtain phase velocities of TEM and TE01 waveguide modes initiated by the ionospheric ELF/VLF source. We modeled the electromagnetic field components and phase velocities employing the full-wave method for multiple modifications of the basic electron density profile. To evaluate the basic profile for the experiment time that was a subject for modifications we used IRI-2016 model. Estimation of optimal electron density is made by comparing the results of modeling with the measurements of phase velocities. The results are discussed.

Spatial structure and statistical properties of VLF emissions by ground-based measurements in high latitudes

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Satellite measurements of natural VLF emissions indicate that these emissions can be represented as a superposition of random plane waves characterized by spatial structure, probability density functions of their amplitudes and phases and distribution of wave normal angles. As a result, the values of the azimuthal angle of Poynting vector, polarization and wave impedance of the ELF/VLF emissions measured at the ground are random values described by probability density functions. We present a new method for estimation of spatial structure and statistical properties of natural VLF emissions obtained by ground-based measurements. The estimation is based on a comparison of the probability density functions of the azimuthal angle of Poynting vector, the circular polarization index and the wave impedance measured near the ground with those obtained by modeling of propagation of spatially confined wave pack consisting of whistler mode plane waves through the ionosphere to the ground. The modeling of propagation is conducted by the full-wave method. Also, we present a case study of the spatial structure and statistical properties of several natural VLF events obtained by ground-based measurements in high latitudes.

Nonlinear simulations of ionospheric heating

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High-power radio waves can substantially modify the electrical properties of the D-region ionosphere, producing significant changes in electron temperature and electron density. This type of heating changes the way that the radio waves propagate through the ionosphere and it leads to non-linear effects such as self-absorption and cross modulation. Three types of radio sources are considered in this paper: HF transmitters, VLF transmitters, and lightning.

An ionospheric heating FDTD model is presented and validated using observations performed during experiments at the High-frequency Active Auroral Research Program (HAARP) Observatory in Gakona, Alaska. Cross-modulation experiments were performed at HAARP on 15 November 2012 [*Langston and Moore*, *Geophys. Res. Lett.*, doi:10.1002/grl.50391]. Excellent agreement between experimental observations and numerical simulations is demonstrated.

Additional simulations of lightning and its effect on the D-region ionosphere are presented. In particular, we present an analysis of transionospheric radio wave propagation.

Modelling and prediction of D region characteristics using nonlinear autoregression and neural network

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The terrestrial ionosphere from D-region (60 km) to F-region (500 km) plays an important role in radio wave propagation between the Earth and ionosphere. Properties of the D layer (the lower end of the ionosphere) is effectively obtained by receiving VLF/LF transmitter signals. Although, the ionospheric condition varies both in time and space due to various external forcings from the atmosphere and space weather parameters, quantitative information of contributions influencing the ionosphere from every external forcing parameter have not understood well. In this paper nonlinear autoregressive with exogenous input and neural network is applied first time to identify the ionospheric characteristics based on the VLF radio wave propagation. One step ahead prediction of the daily nighttime means of VLF electric amplitude in three different latitude paths and two receiving stations by using NARXNN has been carried out. The relative contribution to the ionospheric conditions (VLF electric amplitude variability) from every external forcing has been revealed. Moreover, the proposed model extends for multi-step ahead prediction to evaluate the performance of prediction accuracy for five and ten days ahead. Physical interpretation of relative contribution to the ionospheric conditions from major external forcing parameters have been made.

Electron precipitation from the outer radiation belt during the St Patrick's Day storm

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Electron precipitation fluxes from the outer radiation belt are determined during the St Patrick's Day storm, which occurred in March 2015. Narrow-band very low frequency (VLF) radio waves from the 22.1 kHz UK transmitter (call sign GVT) are received at Reykjavik, Iceland, with the signal propagation path spanning the magnetic footprint of the outer radiation belt. The received signals are analysed for changes in phase and amplitude caused by precipitating energetic electrons associated with radiation belt acceleration and loss processes enhanced by the St Patrick's Day geomagnetic storm. Phase perturbations of ~95 degrees and amplitude perturbations of ~7.5 dB are observed at the storm peak. Electron precipitation is seen to last for up to 8 days following the onset of the storm. Combining phase and amplitude modelling using the Long Wave Propagation Code (LWPC) we show that the peak fluxes can be modelled by energetic electron precipitation fluxes of 10^5 el. cm^{-2} s^{-1} sr^{-1} for >30 keV with a power law gradient of -5. We compare this finding with observed POES satellite MEPED >30 keV precipitating electron integral fluxes and estimated spectral gradient. Finally we will compare the flux characteristics driven by the St Patrick's Day storm with the equivalent fluxes and D-region ionisation provided in the CMIP6 (Coupled model intercomparison project phase 6) solar forcing dataset [Matthes et al., Geosci. Model Dev. Discuss., doi:10.5194/gmd-2016-91, 2017].

Influence of solar flares on ionospheric absorption observed in ionosonde and satellite VLF measurements

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We present a case study in the ionospheric effects of solar flares. The studied solar flare events in December 2006 and selected from the GOES database, were selected from the measurement period of the DEMETER satellite. We identified effects of these events on the transionospheric VLF absorption by measuring ground based VLF transmitter signals on the satellite in low Earth orbit. To our knowledge, such case studies have not been done before. We complement these measurements with ionograms from the same geographical region as the observed transmitters, focusing on changes in ionospheric parameters, including fmin and foE (focusing on the lower ionosphere, which have been less studied in this regard). In both kind of measurements, we try to identify any dependence on latitude (or solar zenith angle). In addition, we attempt an ionospheric modeling of the observed absorption to estimate changes in physical parameters, such as electron density.

Gamma-ray flashes from polar atmosphere as observed in Vernov and Lomonosov missions

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The Vernov satellite was launched in 2014 into a polar solar-synchronous orbit with small eccentricity 640x830 km and period about 98 min. Such orbit provides favorable conditions for the Atmosphere study at different latitudes including Equatorial and Polar Regions. The wide band observations of the Atmosphere from radio to gamma rays as well as detection of relativistic electrons and electromagnetic waves in the near-Earth space were realized by RELEC payload in this experiment.

The main instrument for TGF observation is DRGE gamma-ray spectrometer with four detectors directed to atmosphere providing measurements in 10-3000 keV energy range with time resolution ~15 mcs. Total area of DRGE detectors is ~500 cm^2. The data were recorded both in monitoring and gamma by gamma modes.

Terrestrial Gamma Flashes (TGF) were observed during the Vernov mission from July, 8 to December, 14, 2014. Events with 10-40 gammas in a burst with duration <1ms were detected. The TGF candidate database includes dozens of events among which a few ones were detected in Polar Regions far away from Thunderstorms. The duration of polar events is about few milliseconds being some longer than the duration of equatorial ones. There is no direct indication that those flashes were accompanied by radio pulses in low frequency ($\sim 0.1 - 4 \cdot 10^4$ Hz) and radio frequency (0.05-15 MHz) bands as well as by lightning from WWLN. The possible connection of these events with electron precipitation is under discussion.

Similar 10-3000 keV gamma-ray detectors are used in BDRG instrument on-board Lomonosov satellite launched to the polar ~500 km high orbit on 28.04.2016. The instrument was designed for cosmic GRB study but its characteristics allow one to provide the TGF search using fast on-board trigger (t=10ms) as well as the analysis of non-triggered data recorded in gamma-by-gamma mode. The first results of TGF search by BDRG/Lomonosov will be reported.

UV atmospheric transient events measured by the TUS detector on board Lomonosov satellite with high temporal resolution

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TUS (Tracking Ultraviolet Set-up) is an orbital imaging telescope of UV atmospheric radiation. It was launched into orbit on April 28, 2016, as a part of the scientific payload of the Lomonosov satellite to the solar-synchronous orbit 500 km of height. The field of view of the detector in the atmosphere is 80×80=6400 km2 with spatial resolution in the atmosphere of 5 km. Photo receiver of the detector is composed of 256 Hamamatsu PMTs sensitive in near UV wavelength band (240-400 nm). The TUS detector has several modes of operation with different temporal resolution (0.8 μs, 25.6 μs, 0.4 ms and 6.6 ms).

High temporal resolution and sensitivity of the detector allow measurements of various transient and dim atmospheric UV events. A number of ELVES (arc-shaped fast moving events) related to thunderstorm activity were measured. Some of them has complicated structure with several peaks of radiation intensity (fig.1). Their fine time spatial structure is discussed in the presentation. The joint analyses with ground based lightning location networks was made. A number of unusual transient UV flashes were measured far from thunderstorm regions (known from the data of lightning location networks). Most of them occur above oceans and some at rather high latitudes. Their temporal and spatial structure are discussed as well as the hypothesis of their origin.

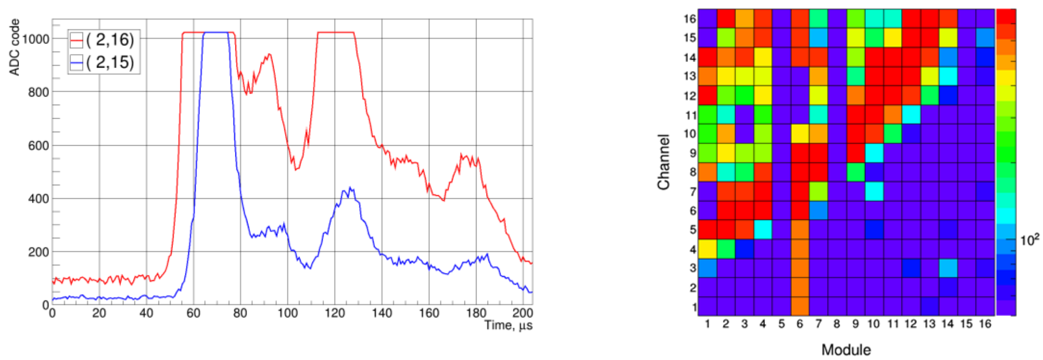

Fig. 1 Example of ELVE with complicated time-spatial structure measured by the TUS detector on August 04, 2017. Left panel: waveforms of two pixels. Right panel: pixel map.

Radio signatures of sprites and gigantic jets

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ELF/VLF measurements at Palmer Station, McMurdo Station, and South Pole Station, Antarctica are used to detect lightning-generated ELF/VLF radio atmospherics from around the globe. The Antarctic ELF/VLF receivers complement a Northern hemisphere ELF/VLF monitoring array. In this paper, we present our latest observational results, including a statistical analysis of radio atmospherics associated specifically with the transient luminous events known as gigantic jets and sprites.

Lightning electrical property deduced from high speed photometric observations from space station

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Optical observations from the orbiting satellite is generally used to derive the spatio-temporal distributions of the global lighting activity. However electrical properties of the lightning such as peak current and lightning charge are difficult to obtain from the space. In particular, CGs with considerably large lightning charge moment changes (CMC) and peak currents are crucial parameters to generate red sprites and elves, respectively, and so it must be useful to obtain these parameters from space. In this paper, we report the lightning optical signatures by using high speed photometric observations from the International Space Station GLIMS (Global Lightning and Sprite MeasurementS JEM-EF) mission. These optical waveforms (lightning optical irradiance) were compared quantitatively with those from ELF electromagnetic wave observations (current moment) on the ground. As a result, remarkable similarity in both waveforms were found with a high cross-correlation ($R > 0.9$). Rather high correlation ($R > 0.7$) was also obtained between the integrated irradiance and the lightning CMC. Our results indicate the possibility to derive lightning electrical properties (current moment and CMC) from optical measurement from space. Moreover, we hope that these results will also contribute to forthcoming space missions such as microsatellite TARANIS and ISS ASIM.

A statistical analysis of conjugate LEP events

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Following the St. Patrick's Day 2015 geomagnetic storm, a large number of lightninginduced electron precipitation (LEP) events were observed simultaneously in the northern and southern hemispheres using very low frequency receivers. Fifty clear and welldefined conjugate LEP events are selected and used to statistically analyze LEP characteristics, such as onset time, onset duration, maximum perturbation, and recovery time. We investigate the role that the Earth's asymmetric geomagnetic field plays in these observations. Scattered field analysis is adopted for both isolated and overlapping events. Different types of overlapping events are observed and defined. Several new LEP event characteristics are identified for use with scattered field analysis. For instance, the event onset time and duration are different when calculated using scattered field magnitude than using only signal amplitude. LEP events were detected in the northern hemisphere using the VLF remote sensing method by tracking the NAA transmitter signal (24.0 kHz, Cutler, Maine) at Tuscaloosa, Alabama. In the southern hemisphere, the NPM transmitter signal (21.4 kHz, Laulaulei, Hawii) is tracked at Palmer station, Antarctica. In each case, the GLD-360 dataset from Vaisala is used to determine the location and timing of the causative lightning flash. In this paper, we compare and contrast LEP event properties calculated using multiple different methods, and we provide a statistical analysis of the properties using 50 conjugate LEP events.

Spectral features of natural VLF emissions in the equatorial region of upper ionosphere as observed by the DEMETER satellite

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VLF wave measurements performed on board the DEMETER satellite contain many known and then unknown wave phenomena observed in the upper ionosphere in the frequency band from hundreds Hz to 20 kHz. Apart from well-known sferics and electron and proton whistlers, generated by lightnings, the observations include magnetospheric line radiation, wedge-like spectra, ionospherically reflected proton whistlers first registered by DEMETER, and many other emissions. One of unusual wave phenomena registered in some cases over equatorial part of DEMETER orbit, which has not yet received an explanation, is U-shape spectrum shown in Fig. 1. According to the measurements, this type of overview spectrum is observed simultaneously with unusually high plasma concentration. The explanation of this spectrum suggested in the present report is based on the assumption that the corresponding emission is formed by waves generated by lightning strokes, while the shape of the spectrum is determined by the features of VLF wave propagation and attenuation in the near-equatorial region of the upper ionosphere. Due to refraction properties of the ionosphere, lightning-induced waves in the near-equatorial region have large wave normal angles which, however, are inside the resonance cone practically for all latitudes except the region of about one degree wide in latitude around the equator. Nevertheless, collisional damping of these waves is essential, and it increases with increasing frequency, which leads to appearance of the upper cut-off frequency in the spectrum. The enhancement of this effect with the increase of plasma density can be understood as follows. With the increase of electron plasma frequency the wave group velocity decreases and the wave spatial attenuation increases accordingly. That is why, passing the same distance from the generation region to the observation point on the satellite, the waves experience larger attenuation. These considerations are confirmed by numerical modeling of spectrograms.

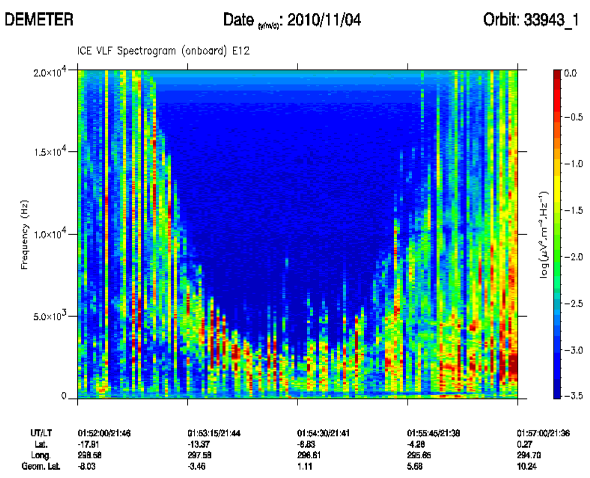

Fig. 1

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DEMETER observations of ELF whistler events with a reduced intensity

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Very low frequency (VLF) frequency-time spectrograms measured by the DEMETER spacecraft (2004-2010, altitude about 700 km) sometimes contain fractional hop whistlers whose intensity is significantly reduced at specific frequencies. The frequencies of the reduced intensity vary smoothly over the event duration, and they are generally larger than 1.7 or 3.4 kHz (the first and the second cutoff frequencies of the Earth-ionosphere waveguide, respectively). These events were explained by the lightning generated spherics propagating in the Earth-ionosphere waveguide, and a resulting interference of the first few waveguide modes. Here we present an analysis of apparently similar events observed at frequencies lower than about 1 kHz. Altogether, we analyze 263 events identified at the times when DEMETER operated in the Burst mode. The vast majority of the events (95%) took place during the nighttime, and they occurred more frequently during spring/autumn than during winter/summer. All six electromagnetic field components measured by DEMETER allow us to perform a detailed wave analysis. We present an overview of the event properties, and we suggest that they might be caused by the wave propagation in the ionospheric waveguide formed due to the refractive index maximum at altitudes of about 90-120 km.

Influence of interplanetary shocks on ELF/VLF waves observed in the Earth's magnetosphere

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We investigate the influence of interplanetary (IP) shocks on the intensity of extremely and very low frequency (ELF/VLF) waves measured by the French DEMETER spacecraft between 2004 and 2010. DEMETER is particularly useful for this kind of analysis, because it had a Sun-synchronous orbit (local time 10:30 and 22:30), operated at a low altitude (700 km) with 14 orbits per day, which allows a fast sampling of a given portion of the magnetosphere. Altogether, 225 IP shocks were detected in the Wind spacecraft data (close to L1 point) during the duration of the DEMETER mission (more than 6 years). Among these, there were 87 fast forward (FF), 31 fast reverse (FR), 59 slow forward (SF), and 48 slow reverse (SR) shocks. The analysis was performed using one component of power spectral density of electric field fluctuations measured in the frequency range up to 20 kHz. The overall geomagnetic activity around the times of the shocks increases after the time of the shock arrival. However, the variation of the measured wave intensity (along with the observed time delay) depends on the type of the shock. The most significant effect was observed for FF shocks. These results were also verified by the principal component analysis, which allows us to conveniently characterize the measured wave intensity and its variations.

Reconstruction of inner magnetospheric density, waves, and particle fluxes based on neural network technique

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The volume of space physics data continues to rise exponentially, and promises to accelerate its growth in the near future to the point that individual projects return on the order of a petabyte of data. At the same time, our analysis techniques have not kept pace with the rapid growth of data, and often do not exploit the capabilities of the data to their fullest potential. In this talk, we present a novel method based on machine learning technology, that aims to convert a sequence of point measurements of some given quantity Q made over a long period of time (for example observations made on a satellite), into a 3-dimensional dynamic spatiotemporal model of that quantity. As an example, we show a three-dimensional dynamic electron density (DEN3D) model in the inner magnetosphere, that can provide full coverage of the inner magnetosphere and in fact is sufficiently accurate that it points the way to new physical discoveries. For instance, we report, an unexpected plasmaspheric density increase at low L shell regions on the nightside during the main phase of a moderate storm during 12-16 October 2004, as opposed to the expected density decrease due to storm-time plasmaspheric erosion. We also show reconstructions of whistler-mode chorus and plasmaspheric hiss waves, and show how these models can be used the understand physical processes on their own, or as inputs to downstream models, that can subsequently predict the dynamics of 'data starved' quantities, such as ultra-relativistic electron fluxes.

Conjugate ground-spacecraft observations of VLF chorus elements

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We present results of simultaneous observations of VLF chorus elements at the ground-based station Kannuslehto in Northern Finland and on board Van Allen Probe A. Visual inspection and correlation analysis of the data reveal one-to-one correspondence of several (at least 12) chorus elements following each other in a sequence. Poynting flux calculated from electromagnetic fields measured by the Electric and Magnetic Field Instrument Suite and Integrated Science instrument on board Van Allen Probe A shows that the waves propagate at small angles to the geomagnetic field and oppositely to its direction, that is, from northern to southern geographic hemisphere. The spacecraft was located at $L\simeq4.1$ at a geomagnetic latitude of -12.4 degrees close to the plasmapause and inside a localized density inhomogeneity with about 30% density increase and a transverse size of about 600 km. The time delay between the waves detected on the ground and on the spacecraft is about 1.3 s, with ground-based detection leading spacecraft detection. The measured time delay is consistent with the wave travel time of quasi-parallel whistler-mode waves for a realistic profile of the plasma density distribution along the field line. The results suggest that chorus discrete elements can preserve their spectral shape during a hop from the generation region to the ground followed by reflection from the ionosphere and return to the near-equatorial region.

Feasibility studies of "ACHDANet" - How ground-observed chorus and hiss emissions can be used for space weather forecast?

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Chorus and hiss emissions are regularly detected at higher latitude VLF stations of AWDANet1,2. Our goal is to use these emissions for space weather forecast - in a similar way as it have been done in AWDANet. The "ACHDANet" (Automatic Chorus and Hiss Detector and Analyzer Network) project is at an early stage, at which we investigate the project's feasibility. "ACHDANet" is potentially capable of deriving the density and energy range of the source population** from strong chorus emissions, employing the non-linear generation mechanism theory of Omura et al. [2008, 2009, 2011].

First the automatic chorus analyzing method and its accuracy are presented, which we tested on in-situ measurements of Van Allen Probes' EMFISIS and HOPE instruments in the generation region of chorus emissions. Then we reveal the typical occurrence rate of strong chorus emissions in processed synoptic VLF data from Halley Station (UK) 2012-2016. Finally, we discuss the possibility to directly compare intensities of chorus waves recorded in-situ and on the ground.

**few keV – 100 keV electron population injected to the equatorial region from the plasma sheet during magnetic storms

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Auroral hiss during magnetic storms

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Auroral hiss is a well-known type of the whistler mode emission occurring mostly in the evening-night sector of the auroral zone. Here we considered the plausible effects of the magnetic storms in the generation of the auroral hiss recorded in Northern Finland at Kannuslehto (KAN, L ~ 5.5) during the winter campaigns 2013-2017. It was revealed that during magnetic storm, the strong auroral hiss was observed at KAN only in the recovery phase of the storm. That was common for all 14 magnetic storms documented in the studied period. We suppose it could be caused by the shift of the disturbed magnetosphere area towards lower latitudes during the main phase of magnetic storm. The behavior of auroral hiss events has been studied in detail during two strongest magnetic storms of the studied period. The considered auroral hiss emissions were right-hand polarized and occurred simultaneously at KAN and LOZ (Lovozero). LOZ is located at the same geomagnetic latitude but 400 km to the East from KAN. Simultaneous observations could indicate that there was a long latitudinal ionospheric exit area of the VLF waves. The spatial distribution of field-aligned currents (FAC), associated with auroral hiss bursts, have been adopted from the AMPERE data, which is based on the magnetic measurements of 66 globally distributed Iridium communication satellites. We showed that the nighttime auroral hiss bursts are usually accompanied by enhanced field aligned currents, even if these bursts were observed under relatively quiet geomagnetic activity before the local substorm onset. Moreover, a substorm onset usually “switchs off” the auroral hiss recorded on the ground. This is most probably due to increasing absorption of the wave caused by the energetic electron precipitation. However, we have to note that the strongest and the most long lasting auroral hiss events were often observed under rather quiet geomagnetic conditions between magnetic storms.

Bursts of auroral hiss observed on the ground at L~5.5 and optical auroras: A case study

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Traditionally, the auroral hiss emissions are attributed to a visible aurora. However, many details of this relationship have not been established, yet. Here we consider the simultaneous observations of auroral hiss at Kannuslehto (KAN, L~ 5.5) and all-sky camera data at Sodankylä (SOD) located ~40 km from KAN and Abisko (ABK) located ~ 300 km to the west from KAN.

Several individual events have been examined. All considered auroral hiss bursts were the right-hand polarized VLF waves demonstrating that the ionosphere wave exit area was located mainly over-head of KAN with the preferred North-South wave arriving direction. The AMPERE data, based on the magnetic measurements on 66 globally distributed Iridium communication satellites, showed that the studied auroral hiss bursts were accompanied by enhanced field-aligned currents above the Scandinavian meridian. The optical auroras and auroral hiss bursts usually occur simultaneously, however, there were no real correlation between the auroral hiss intensity and integrated optical auroral brightening. Moreover, we found that the auroral hiss intensity was stronger when a bright arc was located much northward of KAN than in the case when a moderate brightened auroral arc was recorded near the zenith. It was shown that the auroral break-up and substorm onset lead to the cessation of the ground-based hiss emissions. Apparently, this was due to the sharp increase of absorption caused by energetic particle precipitation. Majority of the studied auroral hiss bursts had the impulsive structure in a few minutes scale and they were observed in the broad frequency band (up to upper limit of our record of 39 kHz). These emissions were accompanied by bright auroral arcs, located far northward from KAN, and by Pi1 geomagnetic pulsations, too. There were also non-structured auroral hiss bursts lasting about a few minutes and observed in the limited frequency band (~5-20 kHz). These emissions were not accompanied by Pi1 pulsations and were observed simultaneously with diffuse auroras in the vicinity of KAN. A plausible phenomenological scheme is discussed.

New findings from auroral hiss

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Auroral hiss is one of the most studied VLF phenomena. However, most of the studies have been made already tens of years ago, although also some very recent papers exist. The frequency range of auroral hiss is quite wide in VLF band. The maximum intensity seems to appear around 10 kHz, which is slightly difficult due to strong sferics. When applying special digital programs, which filter out the strong impulsive sferics, we are able to find new features in the spectra of auroral hiss events.

Suppression of VLF hiss induced by whistler echo trains observed at Kannuslehto, Finland

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Whistler induced suppression of VLF noise has reported more than 30 years ago. All observations were made in the Antarctica. Same phenomenon has been observed in several ELF-VLF campaigns at Kannuslehto in Northern Finland. We are going to show more detailed properties of this phenomenon.

Banded structures observed during evening and night times

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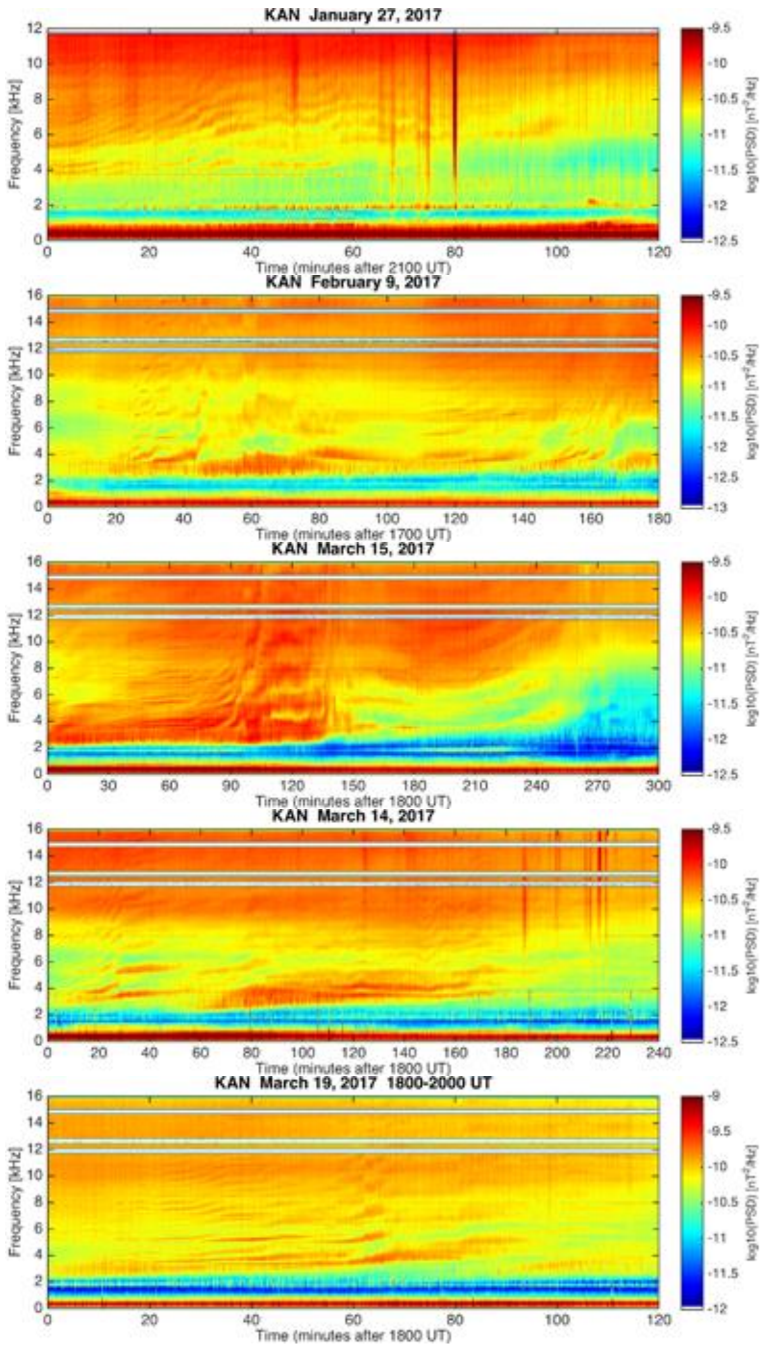
In this presentation, a new type of ELF-VLF event will be introduced.



Quasiperiodic modulation of magnetospheric plasma waves

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Whistler mode electromagnetic waves observed in the inner magnetosphere sometimes exhibit a nearly periodic time modulation of the wave intensity, with typical modulation periods on the order of minutes. Such a quasiperiodic modulation can occur both for waves propagating nearly parallel to the ambient magnetic field at frequencies between about 0.5 and 4 kHz ("VLF QP emissions"), and for waves with wave vectors nearly perpendicular to the ambient magnetic field at frequencies below the lower hybrid frequency ("equatorial noise"). We use electromagnetic wave measurements performed by the Cluster and Van Allen Probes spacecraft to systematically investigate properties and spatiotemporal variability of these emissions. We show that the events with shorter modulation periods are typically more intense, and they tend to have larger frequency drifts. These relations are remarkably similar for the two types of emissions, suggesting that their generation mechanisms might be alike. Equatorial noise events occur primarily outside the plasmasphere, and they often cease to exist just at the plasmapause. The fine harmonic structure of equatorial noise events observed in the high resolution data can be used to estimate the source radial distances. These are typically close to the radial distances where the events are observed, in agreement with rather small spatial dimensions of the events estimated using multispacecraft observations.

Long-term study of ducted VLF transmitter pulses observed in space

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We present the results of our satellite observation campaigns of ground-based VLF transmitter signals, carried out on the Van Allen Probes satellites. We automate the detection of such signals, analyse their propagation with regards to ductedness and directionality, and identify periods of ducted propagation, anomalous propagation and no propagation. We also present their analysis and inversion leading to an extended set of plasmaspheric density measurements.

On solar wind - magnetosphere interactions: a statistical survey of lion roars observed at the terrestrial bow shock

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The terrestrial bow shock is formed by a continuous interaction between the supersonic solar wind and Earth’s magnetic field. Lion roars are intense narrow-band whistler-mode emissions which frequently occur in the Earth's magnetosheath. Here, we report a statistical study of lion roars detected in a vicinity of 529 bow shock crossings observed between years 2001 and 2015 by the four Cluster spacecraft. By applying a simple timing method to multipoint measurements, we are able to retrieve bow shock normals and speed along these normals. It allows us to estimate distances of lion roars from bow shock crossings. We investigate lion roar's spatial, frequency and wave power distributions with a focus to characterize their source regions.

Characteristics of QP emissions: conjugate event between Arase (ERG) and Kannuslehto, Finland

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The dynamics that regulate the radiation belts depend on the equilibrium between the influx and loss of particles. Through wave-particle interactions, whistler-mode waves play a fundamental role in the acceleration and scattering of these particles. Quasi-periodic (QP) emissions in the ELF/VLF range (3 Hz to 30 kHz) are thought to be generated by similar processes as chorus emissions, however, the specific mechanisms behind their periodicity is still subject to debate. We use simultaneous multi-point ground-based and satellite measurements to report the physical characteristics of QP emissions at subauroral latitudes and the properties of their source region. We present a conjugate event between the Arase satellite (ERG) and the VLF receiver at Kannuslehto (KAN, MLAT=64.4°N, L=5.3) from 22:30 to 06:00 UT on March 28 and 29, 2017. The footprint of ERG was located within ~1200 km of KAN, both locations observing VLF waves for ~ 6 hours, while the conjugate QP observation lasted ~ 40 min. We study the changes in the spectral features of the QP simultaneously observed at both locations, and their evolution afterwards, to discuss the size of the active source region and the coherence scale of the waves. Using wave analysis, we discuss the propagation features during the conjunction. During the time of this event, Van Allen Probes (RBSP-A and B) were located between KAN and the ground stations of Kapuskasing (MLAT=58.7N, L=3.7) and Athabasca (MLAT=61.2N, L=4.3) longitudinally separated by 3 and 11 MLT, respectively to KAN. We use the occurrence of QP emissions at these locations, before and during the conjugate event, to discuss the mechanisms behind the periodicity and the longitudinal variations on wave generation and propagation.

Evaluation of latitude dependent time of trans-ionospheric ELF/VLF impulse propagation and LEO incident directions

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Traditional plasmasphere investigations, using natural and man-made ELF/VLF waves as tools to obtain medium characteristics involve the simplest ionosphere correction in the propagation time delay based solely on local f_0F2 values. Recent approaches, however, highlight the need of more realistic descriptions reflecting the known latitude dependence of the oblique paths within the lower plasma environment.

Real UWB oblique impulse propagation model was applied ensuring single, common path for the whole impulse in the analysed ELF/VLF band. The minimum propagation time has been the condition of the most probable 3D trajectory of the whistler-mode propagation among the possible paths in a stratified, spherical model ionosphere - determined by IGRF and IRI characteristics. Wave directions of the modelled paths at LEO altitudes are compared to measured incident angles, obtained from multi-component satellite records.

Generation mechanism of whistler-mode hiss emissions

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Recent observations of plasmaspheric hiss emissions by the Van Allen Probes show that broadband hiss emissions in the plasmasphere comprise short-time coherent elements with rising and falling tone frequencies [1]. Based on nonlinear wave growth theory of whistler mode chorus emissions, we have examined the applicability of the nonlinear theory to the coherent hiss emissions [2]. We have generalized the derivation of the optimum wave amplitude for triggering rising tone chorus emissions to the cases of both rising and falling tone hiss elements. The amplitude profiles of the hiss emissions are well approximated by the optimum wave amplitudes for triggering rising or falling tones. Through the formation of electron holes for rising tones and electron hills for falling tones, the coherent waves evolve to attain the optimum amplitudes. An electromagnetic particle simulation confirms the nonlinear wave growth mechanism as the initial phase of the hiss generation process. We find very good agreement between the theoretical optimum amplitudes and the observed amplitudes as a function of instantaneous frequency. We calculate nonlinear growth rates at the equator and find that nonlinear growth rates for rising tone emissions are much larger than the linear growth rates. From the phase variation of the waveforms processed by bandpass filters, we calculate the instantaneous frequencies and wave amplitudes. We obtain the theoretical relation between the wave amplitude and frequency sweep rates at the observation point by applying the convective growth rates and dispersion factors to the known relation at the equator [3]. By plotting the theoretical relation over scatterplots of the wave amplitudes and the frequency sweep rates for rising tone elements, we find good agreement between the hiss observations and the nonlinear theory. We also find that the duration periods of the hiss elements are in good agreement with the nonlinear transition time necessary for the formation of a resonant current through coherent nonlinear wave-particle interactions.

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Characteristics of the electron fluxes causing the pulsating auroras associated with VLF waves

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Characteristics of the electron fluxes causing pulsating auroras have been obtained by triangulation techniques using data of Multiscale Aurora Imaging Network (MAIN) in Apatity. Two cameras with diagonal field of view 18 degrees are separated by 4 km distance that gives a possibility to deduce the altitude of auroral structures near local magnetic zenith. The time resolution was 1 second. The cameras are equipped by optical filters that separate the blue-green part of the spectrum to exclude the influence of long-lived red emission line. The typical altitude of pulsating aurora forms was found to be in the range of 85-100 km. Simultaneous observations of VLF waves at the Kola Peninsula have been analyzed to find correlations with pulsating aurora patches observed by cameras of MAIN system. The estimated altitudes of pulsating auroras is in good agreement with the predicted energies of electrons that are in cyclotron resonance with the observed VLF waves.

Equatorward drifting electron/proton auroras related with spectral characteristics of chorus/EMIC waves observed at subauroral latitudes

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Energetic electrons and protons precipitate from the inner magnetosphere via wave-particle interaction, then pulsating electron and proton auroras are seen. Chorus and electromagnetic ion cyclotron (EMIC) waves are thought to be important drivers of the energetic particle precipitation into the ionosphere. Simulation studies show that geomagnetic field gradient along a field line near the equator plays an important role in the generation of chorus and EMIC waves (*Katoh & Omura*, 2013; *Shoji & Omura*, 2014). When the geomagnetic field gradient varies to more gradual one, a threshold amplitude for triggering wave emissions becomes smaller in the nonlinear wave growth theory. Then, multiple wave emissions are frequently generated, and hiss-like emissions and broadband EMIC waves are produced by merging these wave emissions in frequency spectra.

In this study, we present equatorward drifting electron and proton auroras related with the spectral characteristics of chorus and EMIC waves observed at Athabasca, Canada (L=4.3). In the ground-based observations of VLF and ULF waves, and optical images, discrete chorus and EMIC waves gradually changed to hiss-like emissions and broadband EMIC waves with the equatorward drifting electron and proton auroras. The correlation between the luminosity and wave intensity variations showed a high value, so the equatorward drifting auroras can indicate that the wave-particle interaction regions moved to near the earth side. The variations of the geomagnetic field gradient near the equator were estimated using the Tsyganenko model. The estimated geomagnetic field gradient became more gradual one when the hiss-like emissions and broadband EMIC waves were observed. These observations support the generation process of hiss-like emissions and broadband EMIC waves in the nonlinear wave growth theory.

In this presentation, we will discuss the importance of the geomagnetic field gradient on the chorus and EMIC wave generations.

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Electron hybrid simulation of the whistler-mode chorus generation in the Earth's inner magnetosphere

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We study dependencies of the chorus generation process on properties of energetic electrons, the background magnetic field, and the thermal plasma condition. Whistler-mode chorus emissions play curial roles in the evolution of radiation belt electrons. Chorus emissions are coherent waves with varying frequencies in the typical frequency range of 0.2 to 0.8 f_{ce0}, where f_{ce0} is the electron gyrofrequency at the magnetic equator. They often have a gap at half the local cyclotron frequency. The generation process of chorus has been explained by the nonlinear wave growth theory [see review by Omura et al., in AGU Monograph "Dynamics of the Earth's Radiation Belts and Inner Magnetosphere, 2012] and has been reproduced by self-consistent numerical experiments [e.g., Katoh and Omura, GRL 2007, JGR 2011, 2013, EPS 2016].

First, we conduct a series of electron hybrid simulations for different temperature anisotropy (A_T) of the initial velocity distribution function of energetic electrons. We vary A_T in the range from 3 to 9 with changing the number density of energetic electrons (N_h) so as to study whether distinct rising-tone chorus emissions are reproduced or not in the assumed initial condition. Simulation results reveal that the number density of energetic electrons (N_h) required for the chorus generation decreases as the temperature anisotropy of energetic electrons increases. We also find that reproduced spectra become hiss-like for large N_h cases. Next, we carry out simulations by changing the gradient of the background magnetic field intensity along a field line. Simulation results clarify that the small magnetic field gradient lowers the threshold amplitude for the chorus generation. These simulation results demonstrate the validity of the nonlinear wave growth theory and suggest that the coherent nonlinear wave-particle interaction is essential for generation of whistler-mode chorus emissions in the magnetosphere.

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Conjugate ground and Van Allen Probes observations of narrow-band VLF emissions

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We present the results of simultaneous observations of narrowband (Δf =1-3 kHz) hiss-like VLF emissions at the ground-based station Kannuslehto (KAN) in northern Finland and by the Van Allen Probes spacecraft (VAP) in the equatorial region of the magnetosphere. Several cases of such emissions were found for which the projection of satellite trajectory was at a distance of no more than 2-3 thousand km from KAN. The VAP spacecraft detected relatively narrow band (with a bandwidth of about 20%) VLF signals whose frequency varied in proportion to the equatorial electron gyrofrequency for the spacecraft L-shell. During certain short time intervals (Δt < 5 min), the spectral and temporal characteristics of the VLF emissions detected on the ground and on board the spacecraft showed one-to-one correspondence with each other in localized areas (ΔL <0.5). In these cases, the VLF emissions at lower frequencies show good correlation during the spacecraft location at higher L shells. The results of multicomponent measurements on board VAP showed that the wave normal directions of VLF emissions which were correlated with ground-based data, were usually close (within 20°) to the magnetic field, and their Poynting vector was directed away from the geomagnetic equator.

A good correlation between the signals detected at Kannuslehto and by the VAP spacecraft was often observed near the plasmapause and in the presence of large-scale irregularities of cold plasma density with transverse dimensions of about 700 – 900 km. These inhomogeneities can guide whistler mode waves to the ground. The results of ray tracing of VLF waves using the measured distributions of the plasma density show the possibility of wave trapping in the density ducts at frequencies below one half of the equatorial gyrofrequency of electrons. The wave normal angles for these waves remain small inside the duct which enables them to reach the ground. Therefore, we conclude that the exit of narrow-band VLF emissions to the ground was possible due to their guiding in the observed enhanced density ducts.

Influence of artificial large scale inhomogeneity on the amplitude variation of VLF waves during their propagation in the Earth's ionosphere and magnetosphere

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We study specific features of VLF wave propagation in the Earth's ionosphere and magnetosphere in the presence of large-scale field-aligned plasma inhomogeneities (ducts). These inhomogeneities can, e.g., be formed during the ionosphere heating by high-power HF facilities such as HAARP and “Sura”. They can extend up to altitudes of several thousand km along geomagnetic field lines and have transverse scales of about 1 degree determined by the heated region scale.

We analyze ray trajectories of VLF waves with frequencies of 1 to 15 kHz starting from about 100 km altitude, and use the plasma parameters obtained within the framework of the SAMI2 simulation model. This model employs MHD equations for thermal plasma and allows one to obtain the plasma parameters along the entire magnetic flux tube in a fixed magnetic meridional plane. Plasma profiles for HAARP facility location are considered for different heating parameters. By knowing the ray trajectories we calculate and compare the amplitude variation along the ray paths for the cases of unperturbed and heated ionosphere.

We show that the presence of a large-scale density disturbance produced by the HF heating can lead to significant changes of wave propagation trajectories. In particular, efficient guiding of VLF waves in this region can take place, which in turn can result in the appearance of several wave focusing regions and a drastic local increase of the VLF wave amplitude in these regions as compared to the case of unperturbed plasma. We discuss the dependence of the perturbations of the ray trajectories, the efficiency of wave guiding, and the corresponding amplitude variations on the heating parameters.

Scattering of quasi-electrostatic waves on spacecraft-borne antennas in the near-Earth plasma

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In this work, a problem of scattering of quasi-electrostatic waves on spacecraft-borne electric antennas in the near-Earth plasma is considered. As it is known, the quasi-electrostatic waves propagate close to the so-called resonance cone direction in magnetoplasmas and have large (as compared to an electromagnetic mode) wave numbers. Therefore, the scattering properties of these waves are quite distinctive.

Antennas analyzed here are short as compared to the electromagnetic wave length. They can be both transmitting and receiving ones. Indeed, the distinction between them is primarily that of the source location. For a transmitting antenna, a source is on it; and for a receiving antenna, a source is distant from it.

The approach to the scattering study is based on the mathematical physics methods, or, to be more precise, on the Green's function analysis. This function corresponds to a partial differential equation for the quasi-electrostatic potential. In the resonance conditions (i.e., when the resonance cone exists), this equation is hyperbolic, and its Green's function is singular on the resonance cone.

The antennas used for calculations in this work are a receiving monopole and a transmitting dipole. Their scattering properties (such as the scattering cross section and the input impedance) are found and analyzed. They are very different from the ones in vacuum and other isotropic media.

The results can be applied, in particular, for design of the antenna experiments in the near-Earth plasma and analysis of its results when the VLF quasi-electrostatic waves are being transmitted or received.

Results of two lastest ELF-VLF campaigns at Kannuslehto, Finland

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Although more than 50 years have passed since the classical work by Helliwell (1965), and despite significant successes of many different ground-based and satellite observations, the full nature and behaviour of different VLF waves is still not fully understood. Many naturally occurring VLF waves at higher frequencies (above 4-6 kHz) could not be studied because strong atmospherics (sferics) hide all such waves. To study these waves, we have to apply special digital programs which filter out the strong impulsive sferics.

Our results are based on the VLF observations made in Northern Finland at Kannuslehto, with the geographic coordinates (67.74°N, 26.27°E), and L~ 5.5. Several wintertime VLF campaigns (2006-2018) have been carried out at this remote, low noise field site some 35 km North of the Sodankylä Geophysical Observatory, in the auroral zone. The VLF emissions were recorded digitally in the frequency band of 0.2–39 kHz by two orthogonal magnetic loop antennas oriented in the North-South and East-West directions. The threshold of the receiver sensitivity is about 0.1 fT, (i.e. ~ 10^{-14} nT^2 Hz^{-1}), which equals to 0 dB in our colour bars.

In this presentation, we will show several new events, and most of them could not be observed without sferics filtering. We have discovered many new and unexpected natural electromagnetic emissions of magnetospheric origin at frequencies higher than 4 kHz. Only after filtering these sferics out were the peculiar VLF emissions discovered.

Precisely synchronized high-latitude network of ELF/VLF 3-component receivers

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Polar Geophysical Institute had been designing, building and running ELF/VLF data loggers since the early seventies. Many pioneer investigations on physical processes in ionosphere and magnetosphere has been made using these instruments. In recent years, a progress in microelectronics and synchronizers based on GPS/GLONASS makes possible to build a data logger precisely synchronized to UTC. We present a 3-component ELF/VLF receiver that assigns the exact time to each sample of data with an accuracy of fractions of a microsecond. It measures the vertical electric component by a monopole antenna and horizontal magnetic components using two orthogonal air core loop antennas. The vertical electric antenna is informative in several situations, especially when one needs to discriminate between wave propagation directions that differ by 180 degrees that could not be performed using only magnetic measurements. The system was calibrated by injecting a known current into a toroidal coil wound in a single layer. Both air core loops were threaded through the toroidal coil. Taking into account that the magnetic field was entirely confined to the space enclosed by windings, we calculated the amplitude and the phase calibration constants for magnetic channels. The vertical electric channel was calibrated by a dummy antenna. The first receiver was installed in November 2012 near the small village of Lovozero, which is located in the middle of the Kola Peninsula in the Russian Federation. Next year similar instruments were placed in Verkhnetulomsky (Kola Peninsula) about 150 km North-West of Lovozero and at Barentsburg (Spitsbergen archipelago). In addition, we have built two mobile receivers that are used occasionally in geophysical experiments forming a network together with stationary receivers. The network has already been used in studies of the variations of phases in signals from Russian navigational VLF transmitters during the solar eclipse in March 2015 and to estimate phase velocities in ionosphere heating experiments in 2014 and 2016 years conducted at EISCAT/heating facilities. The data from Lovozero has been frequently used in investigations of natural VLF emissions.

First results on reprocessing of AWDANet data

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In the PLASMON FP7-Space project (*http://plasmon.elte.hu*, Lichtenberger et al., 2013, SWSC], a new whistler inversion algorithm [Lichtenberger, 2009, JGR] was implemented using Virtual Trace Transformation [Lichtenberger et al., 2010, JGR]. The Virtual Trace Transformation used in the Automatic Whistler Analyzer algorithm is applied to a cleaned reassigned spectrogram and its applicability highly depends on the effectivity of the spectrogram cleaning step.

Thus the whistler inversion algorithm used to process AWDANet data has been changed from Virtual Trace Transformation to Reduction to Sferic algorithm. The main reason was to overcome the problem of so called 'outlier' points on spectrograms. A new approach has been developed for ground based whistlers based on 'de-chirping' (originally developed to low altitude satellite data [Jacobson et al., 2011, AnnGeo] or 'reduction-tosferic' method that compensates the signal phase from the time of the recording back to the sferic. The phase calculated for a frequency is based on the whistler inversion algorithm mentioned above. This algorithm works well on data recorded by satellites, but the ground based data recorded by the AWDANet are always contaminated by sferics. There are promising efforts to remove sferics from the raw signal, but they are not yet (and probably never will be) perfect.

Therefore we have swapped back to frequency domain and the Reduction to Sferic algorithm works now on spectrograms. The inversion algorithm has also been enhanced by using IRI 2016 model and be further enhanced with real-time IRTAM data soon to calculate foF2 frequency needed for correction of ionospheric propagation. We have started to reprocess all archive whistler data collected by AWDANet stations since 2002. It it will take long time to complete, thus here we present the first results on reprocessing of whistlers recorded by AWDANet.

VLF observations of transformer saturation observed in New Zealand during the 7-8 September 2017 geomagnetic storm period

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Several periods of geomagnetically induced currents (GIC) were detected in the Halfway Bush substation in Dunedin, South Island, New Zealand, as a result of intense geomagnetic storm activity during 06 to 09 September 2017. We present very low frequency (VLF) wideband measurements made next to the substation itself. Two solar wind shocks occurred within 25 hours, generating four distinct periods of GIC. Two of the GIC events were associated with the arrival of the shocks themselves. These generated large but short-lived GIC effects which resulted in no observable harmonic generation. However, two subsequent longer-lasting GIC periods caused by substorms, lasting up to 30 minutes in duration, generated harmonics through half-wave saturation detected by the VLF receiver systems. VLF receiver systems picked up radiated harmonics from the substation, up to the 30th harmonic, consistent with observed high voltage increases in Even harmonic distortion.

Sensor network for the VLF-range electromagnetic radiation monitoring

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In the vast territory of Siberia and the Far East of the Russian Federation there is no system of synchronous measurements of electromagnetic radiation in the VLF range, designed to study various geophysical characteristics. In separate observation stations that do not have a common time synchronization, and different hardware is used. We are supposing to develop and to install at the observation stations the uniform hardware and software [1] for remote monitoring of electromagnetic radiation (EMR) in the VLF range.

In November 2017, synchronous registration of atmospherics and whistlers in the radio physical observation stations in Paratunka and in Yakutsk began in the operational mode. In the test mode, registration is carry out in Vladivostok and Neryungri. In the future it is planned to increase the number of the observation stations for synchronous registration of EMR.

At present, a database of atmospherics and whistlers observed in the Russian Far East, supported by the VarSITI grant, has been created. Registration data by the uniform mini-computer software and hardware complexes are saved on IKIR FEB RAS data storage system and are available at the following address [2]. The nodes of the sensor network allow you to run user-defined signal analysis programs and create archives of recognized events, source signals and their spectrograms.

Many years of experience in IKIR FEB RAS and SHICRA SB RAS [3] allows in the future on the basis of synchronous registration of EMR, with the help of the created sensor network, to conduct remote monitoring of EMR, the source of which are not only lightning but also signals of VLF-transmitters, magnetospheric sources in the ELF range and much more.

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3. Mullayarov V.A., Kozlov V.I., Toropov A.A., Karimov R.R. Some Results of Observations of Positive Lightning Discharges and Relative Phenomena in the East of Siberia // Journal of Atmospheric and Solar-Terrestrial Physics. 2010. Vol. 72. Issue 5-6. P. 409-418. doi:10.1016/j.jastp.2009.12.008.

The database of registered whistlers detected in the Russian Far East

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Continuous record of natural electromagnetic Very Low Frequency (VLF) radiation is carried out in IKIR FEB RAS by a multichannel VLF detector. The receiving site is located far from industrial noises. The measurement station consists of a receiving part and a data acquisition module. The receiving part includes antennas, amplifiers and filters. The data acquisition module includes a repeater unit, an analog-digital converter (ADC), a digital detector, and a digital filter. Two frame antennas oriented according to the cardinal points (north-south and east-west) are used in the complex. They receive the magnetic component of natural electromagnetic field in VLF range. The electric antenna is a 6-meter pin installed on a 3-meter foundation. The magnetic antenna consists of similar vertically arranged frames with the dimensions of 7.5x15 m. Their planes are oriented in the directions of north-south and east-west. 89 coils of a copper wire are wound around each frame.

To collect a historical sampling of whistler events and to plot their diurnal and seasonal distributions, an algorithm was applied to detect whistlers in WAV files obtained by VLF radio signal recording from electric and magnetic antennas of IKIR FEB RAS. The influence of various geophysical factors on the activity of whistlers coming to Kamchatka is considered.

The VarSITI have decided to support IKIR FEB RAS database construction entitled "Creation of a database for atmospheric and whistler events detected in the Russian Far East". The history database of registered whistlers with magnetic East-West and vertical electric antenna is available at the folowing address [1]. Whistlers were registered in Karymshina Geophysical Observatory of IKIR FEB RAS in Kamchatka. The database is divided into folders according to the location of the monitoring station and the used algorithm for whistlers detection.The database stores files both in text format (the extension of file is wsf1.txt) and in Java-serialized (the extension of file is wsf1). Each Java-serialized final file with the .wsf1 extension contains entries for a particular day. Each record stores the start time of the analyzed interval T (UTC) (the storage format of T is the same to clause 2), the length in milliseconds of the analyzed interval millisDiffer (type int), the number of detected whistlers numWhistlers (type int) and array M, consisting of numWhistlers elements. Each element of array M stores the time (int type) of whistler registration in milliseconds that have elapsed from the time T.

1. http://www.ikir.ru/en/Departments/Paratunka/lre/Events/varsiti-2017.html .

Sudden enhancements of PLHRs observed at Kannuslehto, Finland

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During last 12 years a new type of power line harmonic radiation event has appeared. Sudden enhancement starts simultaneously from 50 Hz up to 5 kHz, but it decays usually exponentially with diminishing frequency. In the beginning all 50 Hz harmonics are enhanced contrary to constant PLHRs, which appear in certain pairs. For the first time, such event was observed in September 2005. After that the number of events has been increased year by year. They seemed to occur in the morning and evening hours, not on daytime. They have not been observed during quiet nor storm time.

On the balance between radial diffusion and wave particle interaction in driving the electron radiation belts dynamics

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The dynamics of the electron radiation belts are driven by a perpetual competition between radial diffusion and wave-particle interactions. While radial diffusion mainly pushes particles Earth-ward from the plasmasheet, wave-particle interactions induce losses as well as local energization in the trapped electrons population. These competing processes are function of many parameters such as on-going electromagnetic disturbances, characteristics of the ambient cold plasma, wave intensities. The main questions radiation belts modelers would like to answer to are: how can we accurately quantify this balance? How can we know we have reached the most accurate modelling of radial diffusion or wave-particle interaction?

To do that, one has to separate times during which (resp. regions where) one of the above processes significantly overwhelms the other one. With the support of the Van Allen Probes data as illustrated in the picture below, this becomes feasible, especially due to the long term survey of the "Slot" region.

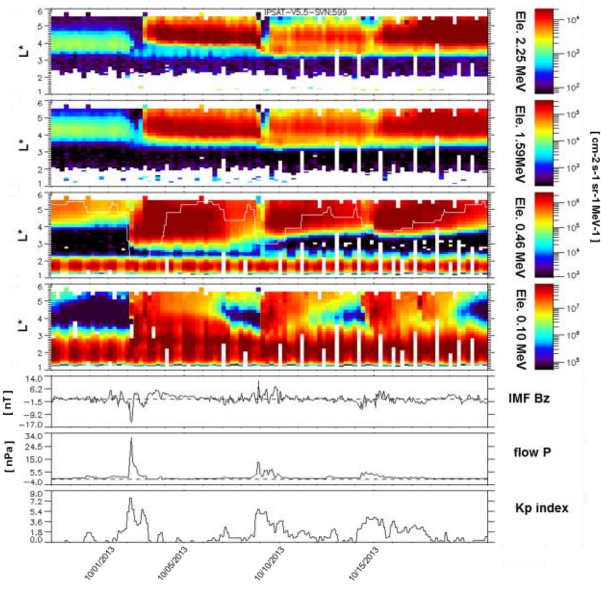

Illustration of the electron radiation belts dynamics as observed by the Van Allen Probes / MAGEIS instrument during October 2013.

In this presentation we aim at discussing our on-going effort in modeling the dynamics of the radiation belts, focusing especially on the challenges to accurately simulate the strong gradients in the "Slot" region. A particular concern will be put forward regarding the best way to drive physical processes in the radiation belts.

The global distribution of sub-relativistic electron fluxes and VLF EM waves in the near-Earth space as measured in Vernov mission

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The global distribution of sub-relativistic electron fluxes was measured in the RELEC experiment on-board Vernov space mission. The Vernov satellite was launched on July 8, 2014, to a solar-synchronous circum-circular orbit with an altitude of apocenter of 830 km. The RELEC Vernov payload included a hard X-ray, gamma-ray and electron DRGE spectrometer including four high-sensitivity NaI(Tl)/CsI (Tl) scintillator spectrometers with a total area of ~ 500 cm^2 directed to the Nadir and providing detection of gamma quanta in the range from 10 keV to 3 MeV and electrons with energies 0.05 – 15 MeV, as well as an electron spectrometer (0.2-10.0 MeV), including three mutually orthogonal detectors, each with ~2 cm^2sp geometric factor, allowed estimation of the pitch angular distribution and identified precipitating particles. A continuous recording of the counting rate of the detected particles and quanta with a time resolution 1c was provided, and a recording of the energy and detection time of each gamma-quantum (or electron) with a ~15 mcs, so called event by event mode was also realized. This allows not only to carry out a detailed analysis of the dynamics of the particle fluxes, but also to compare the time profiles with data from the other RELEC instruments, in particular detectors of very low frequency (VLF) electromagnetic waves. As the result, distribution of electron fluxes together with VLF waves were obtained at different L-shells and different areas of near-Earth space.

Short-time variations of electron fluxes and VLF EM waves in the near-Earth space from RELEC Vernov data

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There will be presented results of study of short-time variations of fluxes of electrons with energies from about hundred keV up to several MeV together with very low frequency (VLF) electromagnetic wave intensity dynamics in the RELEC experiment on-board Vernov space mission. Electron fluxes were measured with number of detectors of DRGE instrument with 1 s time resolution in monitor mode and also in the “event by event” mode, which provide the detection of short increasing of fluxes at least ~15 mcs. A few detectors with axes directed normally to each other allowed detection of trapped, quasi-trapped and precipitated particles. Electromagnetic waves were detected in the band 0.0001 – 40 kHz with different meters included magnetometers and complex wave probes. The satellite orbit was polar solar-synchronous that provided measurements in different areas of near Earth space including as equatorial as Polar Regions. During the time of satellite operation from July, 2014 to December, 2014 a various variations of fluxes of sub-relativistic and relativistic electrons were detected on different time scales from dozens microseconds to minutes. Among them were as well-known precipitation from inner and outer belts as unexpected electron flux increasing at the Slot, at low altitudes and at the Polar Cap area. The wave-particle interaction as possible reason of such variations is discussed.

Resonant interaction of relativistic electrons with electromagnetic ion-cyclotron waves in the Earth radiation belts

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We study the resonant interaction of relativistic electrons in the Earth's radiation belts with electromagnetic ion-cyclotron waves. Wave packets of finite length with varying frequency and various amplitude profiles are considered. The equations describing the interaction of test particles with a given wave packet in a dipole geomagnetic field are solved numerically. On the basis of this solution, the features of the nonlinear interaction regimes and interaction efficiency are studied for a single passage of a particle through the wave packet.

The features of the trajectories of individual particles are analyzed. The effect of the shape of the wave packet on the known regimes, such as phase bunching, leading to a nonzero mean change in the pitch angle in an inhomogeneous medium, and particle trapping by the wave field is considered. It is shown that a prolonged particle stay near the separatrix on the phase plane far from the saddle point leads to a strong decrease in the particle pitch angle without trapping. This nonlinear regime, termed “directed scattering,” is possible for not too large initial pitch angles. In this case, the decrease in the pitch angle depends on the particle initial phase. We show that the trajectories corresponding to directed scattering can be considered as a transitional type between those of the untrapped and trapped particles.

Dependence of non-linear regimes characteristics and efficiency on system parameters (particle energy, initial pitch angle, and wave packet structure) is analyzed. Quantitative estimates of the pitch angle change are obtained and it is confirmed that directed scattering and nonlinear trapping can cause the precipitation of electrons into the loss cone.

It is shown that, for a wave-packet having a Gaussian-shaped amplitude, either directed scattering or trapping can be more effective mechanism for pitch angle decrease, depending on electron energy. For a wave-packet with constant amplitude, trapping is always more effective.

Ionospheric oscillations associated with Pc5 geomagnetic pulsations and role of ELF/VLF waves

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The study is based on the data of the rapid-run ionosonde at the Sodankylä Geophysical Observatory (SGO, 67° 22' N, 26° 38' E, Finland), which routinely performs one-minute sounding since 2007. This dataset allows a unique opportunity for investigating effects of magnetospheric ULF waves in the auroral ionosphere. Suitable observations were made during moderately disturbed geomagnetic conditions typically at recovery of the geomagnetic storms caused by solar wind high-speed streams, in the daytime between 9 and 16 MLT. The oscillations corresponding to Pc5 geomagnetic pulsations were found in variations of the virtual height of the ionospheric F layer and the intensity of ionosonde reflections from E and F layers. The latter are most probably caused by modulation of electron precipitation, which is also manifested in weak variations of cosmic noise absorption.

The most important and novel result is that the pulsations of intensity of reflection from E and F layers typically contain essential second harmonic, whereas the second harmonic was negligible in the Pc5 geomagnetic pulsations. A significant second harmonic was also found in the amplitude variations of VLF waves recorded simultaneously on ground in a vicinity of SGO.

Acceleration of the electrons to the relativistic energies during the geomagnetic storms and without it

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It is considered that the electron acceleration up to the relativistic energies at the outer radiation belt can occurs due to electron interaction with ULF waves in the Pc5 frequency range and (or) with VLF chorus waves. Here we estimate the contribution of these different mechanisms to the electron acceleration for the periods during geomagnetic storm and without it. To characterize the magnetospheric wave activity in the Pc5 frequency range (1-7 mHz) the ULF index (ground and geostationary) is used. For describing the VLF wave activity in the magnetosphere the Van Allen Probes and Halley Bay station data are used. Using charged particle data from the GOES geostationary satellites the acceleration of the electrons with energies from 40 keV to > 2 MeV in the outer radiation belt is investigated. The electron fluxes with lower energies start to grow earlier than fluxes of sub-relativistic and relativistic electrons. The necessary conditions of the electron acceleration to the relativistic energies are found to be a prolong substorm activity which is accompanied by the injection of seed electrons (50-100 keV) and generation of VLF waves, and the occurrence of the high speed solar wind streams promoting the Pc5 wave generation. A good correspondence between the periods with the high solar wind speed and growth of the relativistic electron fluxes with a 1-2 days delay confirms the idea about the important role of the drift resonance of the magnetospheric electrons with MHD waves in the Pc5 frequency range. The elevated ULF wave activity causes a resonant diffusion of injected electrons into the inner magnetosphere and their preliminary acceleration, whereas VLF waves can energize pre-accelerated electrons to the relativistic energies.

Excitation and analysis of whistler waves in a laboratory plasma and comparison to observations in space

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Whistler-mode chorus waves are known to play a fundamental role in magnetospheric physics, including driving radiation belt acceleration and loss processes, as well as creating the pulsating, and the diffuse auroras. In this talk, we describe the excitation of chorus-like whistler-mode waves in UCLA's Large Plasma Device by the injection of a helical electron beam into a cold plasma. Volumetric imaging of the wave is presented at a variety of frequencies, and the mode structure of the excited whistler wave is identified using a phase correlation technique showing that the waves are excited through a combination of Landau resonance, cyclotron resonance, and anomalous cyclotron resonance. We show the results of a parametric scan of the major dependencies and compare the results against linear theory predictions. We discuss the implications of these results for the Earth's inner magnetosphere and show comparisons to in situ satellite observations.

Simulation of low-frequency space plasma physics phenomena on large KROT magnetoplasma device

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KROT device represents a stainless steel vacuum vessel 3 m in diameter and full volume of 180 m^3, a half of which can be filled with rf inductively coupled plasma. 4 MW plasma generators are used at operation frequency of 5 MHz. Magnetic system of the device produces an axial field up to 1000 G. Maximum isotropic plasma density in a volume of about 80 m^3 is 10^{11} cm^{-3}, magnetized plasma density reaches 10^{13} cm^{-3} in a volume of 10 m^3. The device is operated in a pulsed mode, so quiescent and highly uniform afterglow plasma with the decay time of about several milliseconds can be controlled down to densities of 10^5 – 10^6 cm^{-3}, corresponding to actual ionospheric quantities. The unique set of the KROT device parameters gives a possibility of space plasma physics phenomena scale modelling, as well as direct plasma tests of space-based equipment for ionospheric and magnetospheric satellite missions.

The talk mainly concerns the scale modeling of ELF-VLF antenna systems for RESONANCE and other space projects. Future plasma tests of electric antennas for STRANNIK spacecraft are discussed, both on smaller models, and on full-scale elements of scientific equipment. Considerations on model studies of VLF antennas for powerful spacecraft-based transmitters will be presented in view of future experiments on KROT device combined with numerical FDTD simulations.

Finally, upgrade of KROT device in year 2017 will be reported, which includes (i) commissioning of new power source for pulsed magnetic field, and (ii) installation of large aperture hot cathode for injection of energetic electrons into background plasma along with other systems for laboratory studies of interactions between low-frequency waves and charged particles in laboratory plasma.

Observation of multiple chirping events in electron cyclotron emission of non-equilibrium mirror-confined plasma

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The complex dynamics have been observed in the spectra of the electron cyclotron emission of a nonequilibrium plasma created by powerful microwave radiation of gyrotron (37.5 GHz, 80 kW) under electron cyclotron resonance (ECR) conditions and confined in a tabletop mirror trap [1]. The dynamic spectrum of the emission is a set of highly chirped radiation bursts with both increasing and decreasing frequencies which are repeated periodically. Such patterns are not described in the frame of a quasilinear approach which is standard for the description of a broadband plasma emission. From the other hand, the simultaneous observation of several chirping bursts in the same frequency range is typical for the formation of nonlinear phase-space structures in a proximity of the wave-particle resonances of a kinetically unstable plasma, also known as the “holes and clumps” mechanism (or Berk-Breizman model [2]).

Microwave emission is observed at a plasma decay stage with a delay of 0.1-1 ms after ECR heating switch-off. The microwave emission is observed only in a few frequency bands which are independent of the experimental conditions and the emission frequency is always less than electron cyclotron frequency in the trap center. Within every frequency band the emission spectrum is a set of fast narrowband chirping bursts ($df/dt \approx 30$ MHz/sec, $\Delta f \approx 2\times10^{-3} f_{ce}$) with a duration up to 10 us, while the duration of a burst series can be up to 1 ms. Following the model [2], the frequency drift within each wave packet is proportional to the instability growth rate and has a predetermined time dependence. Resulting from the analysis of the microwave emission spectrum, the value of the growth rate is consistent with previous studies of excitation of extraordinary waves at the stage of plasma decay [3], which confirms the applicability of the discussed model.

Our data provide the first experimental evidence for spontaneous formation of self-consistent structures such as the Bernstein-Green-Kruskal waves near the wave-particle resonances in the ultra-high frequency domain in a laboratory mirror-confined plasma.

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Observation of whistler waves frequency modulation in a mirror-confined laboratory plasma

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We investigate the nonequilibrium mirror-confined plasma created and sustained by high-power microwave radiation of a gyrotron under the electron cyclotron resonance condition (ECR discharge). Resonant plasma heating results in the formation of at least two electron components, one of which, more dense and cold, determines the dispersion properties of the high-frequency waves, and the second, a small group of energetic electrons with a highly anisotropic velocity distribution, is responsible for the excitation of unstable waves. Dynamic spectra and the intensity of stimulated electromagnetic emission are studied with high temporal resolution. Interpretation of observed data is based on the cyclotron maser paradigm. In this context, a laboratory modeling of non-stationary wave-particle interaction processes have much in common with similar processes occurring in the magnetosphere of the Earth, planets, and in solar coronal loops.

During the developed discharge phase, we registered microwave emission in a direction along the ambient magnetic field at frequencies about a half of electron cyclotron frequency. Every radiation pulse is strongly correlated with precipitations of energetic electrons. At a large density of the background plasma during the stationary ECR discharge stage cyclotron instabilities of the extraordinary waves are suppressed, because their dispersive properties are strongly modified by the background plasma. Emission of dense plasma at frequencies below electron cyclotron frequency is most naturally related to the whistler mode instability.

The distinctive feature of this type of instability is the presence of the selected frequencies (more than ten) in the spectrum, which are arranged equidistantly relatively to each other. These frequencies of spectral components are slightly changing in time while the distance between them remains constant. In the present work, we study features of the observed whistler waves with such a frequency modulation and discuss the origin of this modulation.

Abstracts of cancelled reports

Diurnal, seasonal and solar cycle dependence of effect of X-class solar flares on the D-region of ionosphere at low latitude

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Solar flares are the important component of space weather phenomenon. The flares perturbed entire daytime of ionosphere but their effect is more pronounced in the D-region of ionosphere. The X class solar flares are relatively less in number, and causes most significant effect on the D-region. The Very low frequency waves (3-30 kHz) are found to be a cost-effective tool for continuous monitoring of D-region ionosphere perturbed by the solar flares. Although, there have been several work on the correlation between solar flares and VLF signal anomaly, but effect of X class flares not and well understood. Further, as the solar activity have diurnal, seasonal and solar cycle variations, hence is the X-class flares. Therefore, in this work, we have analysed X class solar flares occurred during 24th solar cycle (2008-2016). For this work, we have chosen NWC signal recorded at Allahabad during the above period. The X class flares, that happened on the day time of Allahabad-NWC TRGCP are selected and classified based on diurnal, seasonal and solar cycle. The detailed analysis results will be discussed during the conference.

Numerical study of ionospheric response to SGR X-ray bursts observed with very low frequency signal modulation

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Sudden modification of plasma properties in earth's lower ionosphere and middle atmosphere can be imposed by the ionizing radiation from X-ray and γ-ray from astrophysical transient sources, such as, X-ray bursts from Soft gamma repeaters (SGR), Gamma-ray bursts (GRB) etc. Some of the Very Low Frequency (VLF) receivers in South America VLF Network (SAVNET), detected one such series of bursts from SGR J1550-5418 on 22 January 2009. We present here the results of our sincere effort to reconstruct the observed VLF signal modulation during some of the bursts with numerical modeling. The model comprises of Monte Carlo simulation for estimating X-ray ionization in the atmosphere, an ion-chemical evolution scheme and the Long wave propagation capability (LWPC) code calculations to determine VLF signal with the estimated atmospheric modulation. In the process we gain some valuable insight on the chemical and dynamic evolution of lower ionosphere and part of the atmosphere below it under the ionizing influence of such extra-galactic transient sources.

Effects of lightning and its energetic radiation on the upper atmosphere, ionosphere, and radiation belts

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Recent decades have shown dramatic effects of lightning in the upper atmosphere and throughout near-Earth space, driven by different aspects of the lightning discharge. The reconfiguration of the electrostatic field following an intense positive cloud-to-ground discharge triggers the impressive discharges in the mesosphere known as sprites. The electromagnetic pulse from the lightning return stroke induces elves in the D-region ionosphere, propagates into the magnetosphere as whistler-mode waves, and interacts with radiation belt particles, resulting in lightning-induced electron precipitation (LEP) in the upper atmosphere. Most recently, energetic radiation from lightning in the form of X-rays and gamma-rays has been discovered. Terrestrial gamma-ray flashes (TGFs) associated with lightning transport energy to the stratosphere and mesosphere; it has recently been shown that the transport of energy by TGFs induces ionization in these regions as well as detectable optical emissions. The specific causes of TGFs, in terms of the types of discharges that produce TGFs, and the energy deposition and atmospheric effects of TGFs, remain to be investigated.

In this paper we focus on recent modeling predictions related to lightning and its upper atmospheric effects. Lightning-induced X- and gamma-ray emissions are modeled using our Monte Carlo model for Photons (MCP). We present modeling results showing the optical emissions triggered by TGFs in the stratosphere and mesosphere, as well as the predicted optical signatures. We then transition to modeling of the X-ray emissions produced by LEP. As energetic electrons precipitate in the upper atmosphere, X-rays are emitted by bremsstrahlung, and this X-ray radiation transports energy further down into the mesosphere and stratosphere. We show that this X-ray flux may be detectable on high-altitude balloons, similar to balloon observations of radiation belt precipitation-induced X-rays, or on low Earth orbiting satellites. Observation of these LEP X-rays may provide improved quantification of the precipitating fluxes induced by lightning.

Reflection from and transmission through the ionosphere of VLF electromagnetic waves incident from the mid-latitude magnetosphere

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Trans-ionospheric propagation of the VLF electromagnetic wave from an altitude of 800 km to the Earth's surface is considered using the model of stratified media. The numerical solution of the wave equations for the mid-latitude ionosphere model conditions is found. The wave field in the lower ionosphere is calculated using the full-wave approach. The wave field in the upper ionosphere is calculated using the matrix method of perturbations for a slightly inhomogeneous plasma. Energy reflection coefficient and the horizontal magnetic field amplitude of the wave on the ground surface are calculated. Peculiarities of the wave reflection and transmission at different times of the day are analyzed. The nighttime value of is of energy reflection coefficient the order of a few tenths, the daytime value of energy reflection coefficient is of the order of a few thousandths. The dominant electromagnetic wave polarization near the ground surface is right-hand (typical of whistler waves), if the wave incidence is normal or close to normal, and is left-hand if the angle of wave incidence is relatively large. The obtained results are important for studying the ELF/VLF emission phenomena observed both onboard the satellites and in ground-based observatories.

Recent results from the Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) on the Van Allen Probes

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1. Introduction

The physics of the creation, loss, and transport of radiation belt particles is intimately connected to the electric and magnetic fields which mediate these processes. A large range of field and particle interactions are involved in this physics from large-scale ring current ion and magnetic field dynamics to microscopic kinetic interactions of whistler-mode chorus waves with energetic electrons. To measure these kinds of radiation belt interactions, NASA implemented the two-satellite Van Allen Probes mission.

2. Instrumentation

As part of the mission, the Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) investigation is an integrated set of instruments consisting of a tri-axial fluxgate magnetometer (MAG) and a Waves instrument which includes a tri-axial search coil magnetometer (MSC). These wave measurements include AC electric and magnetic fields from 10Hz to 400 kHz. Details of the instrumentation are given in the suite's instrument paper [1].

3. Recent Results

We show examples of plasmaspheric wave-particle interactions, specifically wave heating of the plasmasphere by whistler –mode waves, low frequency wave features including EMIC waves and their statistical properties, magnetosonic wave statistics with respect to location in magnetic local time, and properties of whistler mode waves including upper and lower band chorus and plasmaspheric hiss. These data are compared with particle measurements to show relationships between wave activity and particle energization.

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Two dimensional PIC simulation of generation of oblique whistler waves

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The generation of very oblique whistler waves has been suggested to be caused by an electron beam or a plateau in phase space density which suppresses Landau damping. This topic has been studied using linear theory and observation. In this work, I will use 2D PIC simulation to investigate the detailed evolution of the electron distribution in the generation of the oblique whistler wave. Another motivation of this work is to re-visit a previous study by Omura and Matsumoto about a 1D simulation of beam generated electrostatic and whistler waves. The authors concluded that the growth rate of electrostatic waves is always larger than that of whistler waves. We use 2D simulation, aided by linear theory, to systematically investigate the parameter range where electrostatic (or whistler) waves dominate, and the competition for the free energy between these two wave modes in 2D.

Plasma wave diagnostics of ELF-VLF emission in the ionosphere. The main results of the experiments on the microsatellite "Chibis-M", ISS RS "Obstanovka (1 stage)" and the RELEC/Vernov satellite and prospects 2019-2021

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The actual task space experiments in the ionosphere is the study of dynamic processes using diagnostic ELF-VLF emission, ensuring understanding of the circulation of matter in near-earth space and connection of the dynamic structure of the ionosphere with solar and magnetosphere activity, the morphological structure of the ionosphere wave fields and their interaction with the space and terrestrial sources.

One of the important applied aspects of the research consists in carrying out diagnostics of the ionosphere manifestations of space weather. Traditionally, the main purpose of the creation of systems for monitoring space weather was warning about the possible impacts on spacecraft in orbit and ground facilities (e.g., power lines). An important yet insufficiently studied problem of the effect of space weather on the health and human performance.

Another important aspect of practical relevance, is the study of the ionospheric response to powerful near-surface energy sources. The complex of such studies seems to be promising to search for the ionosphere precursors of anthropogenic and natural (such as earthquakes) events. You must include the scientific information in the global database of geo-information systems; the creation of a virtual observatory to study the dynamics of the ionosphere a wide range of scientists, teachers, students, and other interested persons; introduction of results in educational process, promotion of space research.

The most informative are measurements of ionosphere parameters in situ using the run "inside the ionosphere" spacecrafts. Convenient platform for such observations, it would seem, can serve as the ISS with orbital altitude of about 350 km, but the high level of natural electromagnetic noise and strong aerodynamic effect of the ISS moduls on the surrounding environment make it difficult to record natural atmosphere and ionosphere variations.

The paper discusses the results of studies and prospects for the use of the infrastructure of the Russian segment of the ISS for micro-satellite "Kolibri-2000" (2002). [1], "Chibis-M" (2012-2014) [2], "Chibis-AI" and "Trabant" (2020-2022) for the study of electromagnetic parameters of space weather.

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Acceleration, transport, and trapping of ultra-heavy ions in the inner zone

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We report, here, on the discovery of a population of trapped, energetic (10-50 keV), ultra-heavy (>30 AMU) ions in the inner zone of the Earth's radiation belts (L < 3). The ions are observed using the Van Allen Probes Helium, Oxygen, Proton, Electron (HOPE) plasma spectrometer [Funsten et al., 2013]. HOPE measures the energy of incoming ions using a standard electrostatic analyzer and measures the mass per charge by measuring the time of flight (TOF) of the ions at each spectrometer energy step (E). Each ion species (and charge state) falls in a specific domain of E vs TOF. The primary singly-charged ion species (Helium, Oxygen, and Protons) are reported by rate counters but HOPE also reports full E x TOF matrices at lower cadence to monitor instrument performance and identify minor ion species.

By analyzing energy vs time-of-flight (E x TOF) data over the >5 years of the Van Allen Probes mission we have identified a population of trapped ions with a most probable mass per charge of ~ 40 which would correspond to Argon; the third most abundant gas in Earth's atmosphere but not previously seen in the magnetosphere. We also consider the possibility that this new ion population corresponds to molecular species; O2 (m=32); NO (m=30); or N2O (m=44). While molecular ions have previously been observed in the magnetotail they have been no previous reports of a trapped, energetic population at L < 3.

We will consider the temporal, spatial, energy, and pitch angle distributions of this unexpected and unlikely population of ions. Important questions include: What are they? If they come from the ionosphere how are they transported to the inner zone? How are they energized to >10 keV? What are the expected lifetimes once they are trapped? and What can they tell us about other radiation belt trapping and energization processes?

Estimating daytime equatorial vertical E×B drift velocities from magnetic field variations

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Previous work done in the Peruvian longitude sector has demonstrated that the daytime vertical ***E x B*** drift velocities in the equatorial F region can be estimated using a pair of magnetometer. They have established an empirical drift velocity formula between (ΔH) and ***E x B*** drift velocity for 270 days of observations. This paper investigates whether the same drift velocity formula can be applicable to the west African longitude sector. We used magnetic field data of Conakry (Guinea) and Abidjan (Côte d'Ivoire) provided by the African Meridian B-field Education and Research (AMBER) network, whose geomagnetic coordinates are respectively (-0.5°, 60.40°) (- 6°, 65.80°). On the basis of data availability, we have chosen 9 magnetically quiet days (A_p<10) in the year 2013. Our results have shown that the Peruvian ΔH versus ***E x B*** relationships is applicable to the west African longitude sector. We found a good correlation between the inferred ***E x B*** drifts and ΔH (R=0.96). The aim of this study is to predict the vertical drift velocity at locations close to the magnetic equator where measurements are not carried out on a continuous basis.

Effect of solar and geomagnetic activity on plasma bubbles over low latitude regions

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The ionosphere is a part of the upper atmosphere and formed by photoionization process from Sun, play an important role in radio wave propagation. The occurrence of the ionospheric irregularities such as equatorial plasma bubbles can impact on communications and satellite systems. Observation and analysis of the ionospheric irregularities are important task for both scientific point of view and satellite system applications. In this study we observed ionospheric irregularities (plasma density depletion/plasma bubbles) by using Equatorial Atmosphere Radar (EAR), Ionosonde and GISTM receiver operated at Kototabang and Pontianak. Data during 2011-2012 analyzed to obtain seasonal variation of plasma irregularities and dependence of evening plasma bubble occurrence with solar and geomagnetic activity. The results show that most of plasma bubbles develop during hours after sunset (postsunset) and occured around equinox period (March/April and September/October). These clearly confirm dependency of ionosphere plasma irregularities to solar activity and also relationship between scintillation events and ionospheric irregularities as well. Some parameters of geomagnetic activity also show impact of geomagnetic storm on plasma irregularities.